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Remarks and Instructions

The complete manual, revision packages, and individual chapters can be accessed at [www.wsdot.wa.gov/publications/manuals/m46-01.htm](http://www.wsdot.wa.gov/publications/manuals/m46-01.htm).

Please contact Linda Hughes at 360-709-5412 or [hughel@wsdot.wa.gov](mailto:hughel@wsdot.wa.gov) with comments, questions, or suggestions for improvement to the manual.

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Tom Baker /s/
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Introduction

The 2012 edition of the Materials Manual has been revised. It continues to use AASHTO, ASTM, WAQTC, and WSDOT test methods. The strategic directions for the Materials Laboratory is to continue to expand the use of AASHTO and ASTM standards whenever possible.

The manual has retained its dual unit format. However, English units predominate with metric units in parenthesis. WSDOT is using English units.

The manual reflects the Quality System concerns of an AASHTO accredited organization. The manual is organized by numerical test order. It also features two contents and an index.

The manual reflects a continuing policy of adopting “consensus” standards wherever practical. Adoption of these, in the form of AASHTO, ASTM, WAQTC, or other nationally recognized standards eliminates much of the previous text, which merely recopied the national documents. By adopting these standards, we provide a common standard that can be used by neighboring states and other laboratories or organizations. Contractors who work in more than one state also benefit by having to conform with fewer unique tests.

The concept of Field Operating Procedures (FOP) is continued to support the work of Materials Testers at the Field or Project level. Full procedures are provided when WSDOT Test Methods apply, or when a consensus standard (AASHTO, ASTM, or WAQTC) has been adapted to an FOP. The FOP provides the essential performance elements for the field technician.

When not specified by the test procedure, test reports will be generated through the Materials Testing System (MATS) or by the use of forms approved by the State Materials Engineer.

The WSDOT Materials Laboratory is responsible for establishing and managing all test procedures. For technical information or suggested changes to test methods or procedures, contact the WSDOT Materials Laboratory Quality Systems Manager through the departmental mail system at MS 47365; by mail at PO Box 47365, Olympia, WA 98504-7365; by telephone at 360-709-5412; or by fax at 360-709-5588, physically located at 1655 South Second Avenue, Tumwater, WA 98512. Please use this physical address for all communications other than US Postal Service mail.

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/s/

Thomas E. Baker
State Materials Engineer
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- T 106 AASHTO Compressive Strength of Mortars (Using 0 mm or 2 in) Cube Specimens
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- T 107 AASHTO Autoclave Expansion of Portland Cement
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### Geotextile and Steel

### Paint
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**Pavement Soils**

| T 242            | AASHTO |           |           | Frictional Properties of Paved Surfaces Using a Full-Size Tire |
| T 272            | AASHTO |           | ✔         | Family of Curves — One Point Method |
| T 272 WSDOT      | ✔ ✔    | ✔ ✔       |           | FOP for AASHTO for Family of Curves — One Point Method |
| T 307            | AASHTO | ✔ ✔       |           | Resilient Modulus of Subgrade Soils and Untreated Base/Subbase Materials |
| T 310 WSDOT      | ✔ ✔    |           |           | FOP for AASHTO for In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth) |
| T 606 WSDOT      | ✔ ✔    |           |           | Method of Test for Compaction Control of Granular Materials |
| T 610 WSDOT      | ✔ ✔    |           |           | Method of Test for the Capillary Rise of Soils |
| SOP 615 WSDOT    | ✔ ✔    |           |           | Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge |
| T 807 WSDOT      | ✔ ✔    |           |           | Method of Operation of California Profilograph and Evaluation Profile |
| D 4694           | ASTM  |           |           | Test Method for Deflections With Falling-eight Type Impulse Load Device |

**Standard Practice**

<p>| QC 1             | WSDOT  | ✔ ✔       |           | Standard Practice for Cement Producers That Certify Portland Cement |
| QC 2             | WSDOT  | ✔ ✔       |           | Standard Practice for Asphalt Suppliers That Certify Performance Graded Asphalts |
| QC 3             | WSDOT  | ✔ ✔       |           | Quality System Laboratory Review |
| QC 4             | WSDOT  | ✔ ✔       |           | Standard Practice for Fly Ash Producers/Importers/Distributors That Certify Fly Ash |
| QC 5             | WSDOT  | ✔ ✔       |           | Standard Practice for Ground Granulated Blast-Furnace Slag Producers/Importers/Distributors That Certify Ground Granulated Blast-Furnace Slag |
| QC 6             | WSDOT  | ✔ ✔       |           | Standard Practice for Annual Prestressed Plant Review and Approval Process |</p>
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<td>Viscosity Determination of Asphalt Binder Using Rotational Viscometer</td>
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<td>Method for Coatings (Pigmented Sealers) Used on Concrete Structures</td>
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<td>Determining the Percentage of Fracture in Coarse Aggregate</td>
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<td>Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets</td>
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<td>Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders</td>
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<td>Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements (Checklist Only)</td>
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<td>Test Method</td>
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<tr>
<td>D 4355</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Method for Deterioration of Geotextiles From Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)</td>
</tr>
<tr>
<td>D 4491</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Methods for Water Permeability of Geotextiles by Permittivity</td>
</tr>
<tr>
<td>D 4505</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Specification for Preformed Plastic Pavement Marking Tape for Extended Service Life</td>
</tr>
<tr>
<td>D 4533</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Method for Trapezoid Tearing Strength of Geotextiles</td>
</tr>
<tr>
<td>D 4632</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Method for Grab Breaking Load and Elongation of Geotextiles</td>
</tr>
<tr>
<td>D 4644</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Method for Slake Durability of Shales and Similar Weak Rocks</td>
</tr>
<tr>
<td>D 4694</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Test Method for Deflections With Falling-Eight Type Impulse Load Device</td>
</tr>
<tr>
<td>D 4751</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Test Method for Determining Apparent Opening Size of a Geotextile</td>
</tr>
<tr>
<td>D 4791</td>
<td>WSDOT</td>
<td></td>
<td></td>
<td>FOP for ASTM for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate</td>
</tr>
<tr>
<td>D 4833</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Test Method for Index Puncture Resistance of Geomembranes and Related Products</td>
</tr>
<tr>
<td>D 4956</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Specification for Retroreflective Sheeting for Traffic Control</td>
</tr>
<tr>
<td>D 5311</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Method for Load Controlled Cyclic Triaxial Strength of Soil</td>
</tr>
<tr>
<td>D 5329</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Methods for Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements</td>
</tr>
<tr>
<td>D 5731</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications</td>
</tr>
<tr>
<td>Procedure Number</td>
<td>Owner</td>
<td>Field Use</td>
<td>In Manual</td>
<td>Test Method</td>
</tr>
<tr>
<td>------------------</td>
<td>-------</td>
<td>-----------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>D 6467</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils</td>
</tr>
<tr>
<td>D 7012</td>
<td>ASTM</td>
<td>✔</td>
<td>✔</td>
<td>Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures</td>
</tr>
<tr>
<td>D 7091</td>
<td>ASTM</td>
<td>✔</td>
<td>✔</td>
<td>Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals (Checklist Only)</td>
</tr>
<tr>
<td>D 7585</td>
<td>ASTM</td>
<td></td>
<td></td>
<td>Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments</td>
</tr>
</tbody>
</table>
WSDOT Standard Practice QC 3
Quality System Laboratory Review

1. Scope

This standard specifies requirements and procedures for the review of WSDOT Regional Materials Laboratory and for Private Laboratories by the Quality Systems Laboratory Review Team. The on-site laboratory review shall include the following elements:

• Review of the testing facility.
• Review of the equipment calibration/verification records.
• Review of the testing technician’s training records.
• Physical inspection of the equipment used to perform tests.
• Observation of technician performing the test procedure.
• Review of Test Reports and Calculations.

2. Referenced Documents

2.1 AASHTO Standards

R 18 – Establishing and Implementing a Quality System for Construction Materials Testing Laboratories

PP 57 – Establishing Requirements for and Performing Equipment Calibrations, Standardizations, and Checks

2.2 WSDOT Standards

WSDOT Materials Manual
WSDOT Construction Manual
WSDOT Standard Specifications

3. Terminology

3.1 AASHTO – American Association of State Highway and Transportation Officials

3.2 ASTM – American Society for Testing and Materials

3.3 Calibration – A process that establishes the relationship (traceability) between the results of a measurement instrument, measurement system, or material measure and the corresponding values assigned to a reference standard (Note 1).

Note 1: The definition for calibration and the following definitions for check, standardization, traceability, uncertainty, and verification of calibration are based on the definitions in PP 57.

3.4 Check – A specific type of inspection and/or measurement performed on equipment and materials to indicate compliance or otherwise with stated criteria.
3.5 Standardization – A process that determines (1) the correction to be applied to the result of a measuring instrument, measuring system, material measure or reference material when its values are compared to the values realized by standards; or (2) the adjustment to be applied to a piece of equipment when its performance is compared with that of an accepted standard or process.

3.6 WSDOT – Washington State Department of Transportation

4. Significance and Use

4.1 This standard specifies procedures for reviewing laboratories for the purpose of determining the capability of the facility and its personnel to perform the necessary acceptance testing for WSDOT.

5. Laboratory Requirements

5.1 Facility and Equipment

5.1.1 Laboratory facilities shall adequately house and allow proper operation of all required equipment in accordance with the applicable test procedures.

5.1.2 The temperature and humidity of the laboratory shall meet the requirements of all test procedures performed in the laboratory.

5.1.3 The testing areas shall be clean and free of clutter.

5.1.4 The laboratory shall use testing equipment that meets the requirements of each test procedure.

5.1.5 Testing equipment for private laboratories and the State Materials Laboratory shall be calibrated/standardized/checked in accordance with the test procedure, appropriate sections of AASHTO R 18 and AASHTO PP 57. WSDOT Region and Field laboratories testing equipment shall be calibrated/standardized/checked in accordance with the test procedure and Section 9-5 of the Construction Manual M 41-01.

5.1.6 Documentation of equipment calibration/standardization/check shall be maintained and available onsite during laboratory review.

5.1.7 Safety equipment will be available and maintained in proper working order.

5.2 Tester Training and Records

5.2.1 The laboratory shall use personnel qualified in accordance with the appropriate sections of AASHTO R 18. WSDOT Region and Field laboratory personnel shall be qualified in accordance with Section 9-5 of the Construction Manual M 41-01.

5.2.2 The laboratory shall maintain records of training for each tester.

5.2.3 A tester’s competency for performing a test procedure shall be evaluated using a checklist relating to the test procedure. The checklist shall be filed in the tester’s training record.
Note: Private laboratories may use test procedure checklists from the WSDOT Materials Manual, or may develop their own checklists similar to those found in the Materials Manual.

5.2.4 Testers for private laboratories shall be reviewed for qualification at the frequency stated in the laboratory’s Quality Systems Manual.

5.3 Manuals and Records

5.3.1 Private laboratories shall have an up-to-date Laboratory Quality Systems Manual (LQSM) meeting the requirements of AASHTO R 18 and approved by the State Materials Engineer.

5.3.2 All private laboratories shall have an up-to-date copy of the LQSM on site and available to all testers.

5.3.3 Each tester must have access to the most current copy of the AASHTO, ASTM and the WSDOT Materials Manual. WSDOT testers must have access to the most current copy of the WSDOT Construction Manual.

5.3.4 If an earlier version of the WSDOT Materials Manual or Construction Manual is required by contract, the laboratory shall maintain an unaltered version of the required manual.

5.3.5 A file of MSDS sheets must be maintained in the laboratory and must be available to all testers.

5.3.6 Test records are required to contain sufficient information to permit verification of any test report (original observations, calculations, derived data and identification of personnel involved in the sampling and testing).

5.3.7 Amendments to reports must be made in the manner stated in the LQSM.

5.3.8 The laboratory shall define the process used to insure testers are performing the correct testing procedure according to the clients’ contractual requirements (i.e., AASHTO, ASTM or WSDOT test procedure as required by the contract).

5.3.9 Test reports are required to contain the following information:

- Name and address of the testing laboratory.
- Name and address of the client or identification of the project.
- Date of receipt of the test sample.
- Date of test performance.
- Identification of the standard test method used and notation of all known deviations from the test method.
- Test results and specification of the material.
- Name of tester performing the test.
- Date report was issued.
- Name of person accepting technical responsibility for test report.
6. Sampling

6.1 Test samples required for observation of test procedures shall be obtained by:

- T 2 – WSDOT FOP for AASHTO for Soils and Aggregate
- T 168 – WSDOT FOP for WAQTC for Hot Mix Asphalt
- TM 2 – WSDOT FOP for WAQTC for Concrete

7. Sample Preparation Requirements

7.1 Prior to the performance portion of the laboratory review, for the testing being performed, samples are required to be prepared as shown in Table 1.

<table>
<thead>
<tr>
<th>Test Procedure</th>
<th>Test</th>
<th>Required Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate Tests</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOP for AASHTO T 335</td>
<td>Fracture</td>
<td>Material washed, graded, and ready for counting fracture.</td>
</tr>
<tr>
<td>FOP for WAQTC T 27/11</td>
<td>Sieve Analysis of Fine and Coarse Aggregates</td>
<td>Split or quarter proper amount of the original sample and dry to constant weight. Have a duplicate sample that has been washed and dried, ready for sieving. Retain all weights in order to do calculations.</td>
</tr>
<tr>
<td>FOP for AASHTO T 176</td>
<td>Sand Equivalent Test</td>
<td>Split or quarter enough of the original sample to yield approx. 1000 g of #4 minus. Do not sieve over the #4. Have 2 tins that have been properly prepared ready for introduction into the SE tube.</td>
</tr>
<tr>
<td>FOP for AASHTO T 248</td>
<td>Reducing Sample</td>
<td>30 lbs dry material</td>
</tr>
<tr>
<td><strong>Concrete Tests</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOP for AASHTO T 106</td>
<td>Compressive strength</td>
<td>3 mortar cubes</td>
</tr>
<tr>
<td>FOP for AASHTO T 22</td>
<td>Compressive strength</td>
<td>2 cylinders</td>
</tr>
<tr>
<td>FOP for AASHTO T 231</td>
<td>Capping cylinder</td>
<td>Capping compound ready to perform capping. Have 2 cylinders available for capping (can be the cylinders for T 22)</td>
</tr>
<tr>
<td>WSDOT T 810</td>
<td>Density of Pavement Core</td>
<td>Have a drilled pavement core available</td>
</tr>
<tr>
<td>WSDOT T 812</td>
<td>Length of drilled PCC Core</td>
<td>May use the core from T 810</td>
</tr>
<tr>
<td><strong>Soils Tests</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WSDOT T 417</td>
<td>Resistivity and pH</td>
<td>1500 g of #8 minus soil</td>
</tr>
<tr>
<td>AASHTO T 84</td>
<td>Specific gravity and absorption Fine Agg.</td>
<td>Prepare sample to step 6.1.2 of the procedure</td>
</tr>
<tr>
<td>AASHTO T 85</td>
<td>Specific gravity and absorption Coarse Agg.</td>
<td>Prepare sample to step 8.2 of the procedure</td>
</tr>
<tr>
<td>AASHTO T 87</td>
<td>Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test</td>
<td>500 g of soil aggregate air dried</td>
</tr>
<tr>
<td>AASHTO T 88</td>
<td>Particle Size Analysis</td>
<td>No preparation</td>
</tr>
<tr>
<td>AASHTO T 100</td>
<td>Specific gravity soils</td>
<td>No preparation</td>
</tr>
<tr>
<td>AASHTO T 255</td>
<td>Moisture Content</td>
<td>No preparation</td>
</tr>
</tbody>
</table>

Sample Preparation Requirements

*Table 1*
<table>
<thead>
<tr>
<th>Test Procedure</th>
<th>Test</th>
<th>Required Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO T 265</td>
<td>Moisture Content</td>
<td>No preparation</td>
</tr>
<tr>
<td>FOP for AASHTO T 99/T 180</td>
<td>Proctor</td>
<td>Enough #4 or ¾” material prepared for a five point proctor determination. Prepare five representative samples with approximately 2% moisture already added to each sample and starting at approximately 4% below optimum moisture of the material. Store in sealed containers.</td>
</tr>
<tr>
<td>WSDOT T 606</td>
<td>Maximum Density Curve</td>
<td>Split a sample of material into coarse and fine material. Prepare material to step 1.3e of Test No. 1. Also, prepare material to either 2.3a of Test 2, Procedure 1 or step 2.5b of Test 2, Procedure 2.</td>
</tr>
</tbody>
</table>

**Hot Mix Asphalt Tests**

| WSDOT T 712                    | Reducing Sample             | An adequate amount of HMA to perform all the testing required. Heat sample and have it ready to reduce. Required to split material from sample for T 308, T 312, T 329, T 209 |
| FOP for AASHTO T 166           | Bulk Specific Gravity       | A room temperature compacted sample must be provided for this test. A gyratory sample or a core sample will suffice |
| WSDOT SOP 724                  | Preparation of Aggregates   | Representative aggregate from stockpiles used in JMF, dried to a constant weight |
| WSDOT SOP 726                  | Mixing Procedure HMA        | Binder used in JMF mix design heated to mixing temperature as recommended by binder supplier (typically one quart container). Aggregate representative of JMF sample size based on class of HMA heated to mixing temperature as recommended by binder supplier |

**Sample Preparation Requirements**

*Table 1 (continued)*

8. Performance of Test Procedure

8.1 All technicians must be current in their qualifications.

8.2 The laboratory review team will evaluate the technician’s testing proficiency using an approved WSDOT checklist.

8.3 All equipment, used during the evaluation of the technician’s proficiency, must be operational and have a current calibration sticker on the equipment.

8.4 When the test is complete the reviewer will go over the checklist with the tester and point out any deficiencies that occurred during the performance of the test procedure.

9. Termination of Review

9.1 A laboratory review team member may choose to terminate the review of a procedure for the following reasons:

9.1.1 Equipment is non-operational or the wrong equipment is being used.

9.1.2 Tester is not qualified in the test procedure being reviewed.

9.1.3 Tester makes multiple major errors in the performance of the test
9.2 The review of the laboratory may be terminated by the WSDOT Quality Systems Manager for the following reasons:

9.2.1 Facility is not adequate for the test procedures being reviewed

9.2.2 Two or more testers fail during the proficiency portion of the review.

9.2.3 Documentation of qualification of testers or calibration of equipment is not available for review when team arrives.

10. Failure of Review

10.1 Rescheduling a review will require the following wait periods:

   First Failure – Minimum of one week wait to reschedule.

   Second Failure – Minimum of one month wait to reschedule.

   Third Failure – Minimum of one month wait and submittal of corrective action documentation. The documents submitted must state the concerns of the review team and the corrective action taken to solve the problem.

11. Laboratory Review Team Report

11.1 The Laboratory review team will review the facility, equipment, records and testers compliance with the established requirements.

11.2 The evaluation report will be prepared and sent to the laboratory within 30 days of the completion of the review.

11.3 Any items that did not meet the requirements of Section 5 will be written up as “Issues.”

   11.3.1 Issues resolved during the review shall be noted as “Issue Resolved No Response” necessary. If a “Resolved No Response Required” issue reoccurs in subsequent evaluations the issue will be escalated to a “Response Required Issue.”

   11.3.2 Issues that were not able to be resolved during the review will be noted as “Response Required Issue.”

11.4 During the review members of the team may make suggestions for improvements to the performance of the test procedure or operation of equipment. These are suggestions only and will be noted in the report as “Observations.” These do not require a response.

12. Response to Report

12.1 Once the evaluation report has been received the laboratory will have 90 days to respond in writing to all “Issues” which labeled “Response Required.”

12.2 The response must be a detailed explanation stating how the laboratory has resolved the issue and what measures they have taken to prevent this issue from reoccurring in the future.
13. Approval of Laboratory

13.1 If the laboratory review report had no issues or the issues are minor and resolved at the time of the review the laboratory may be approved to perform acceptance, Independent Assurance or dispute resolution testing.

13.2 If the laboratory review contained Response Required Issues the laboratory may receive a conditional approval until the deficiencies are corrected or the review team may recommend that the laboratory be disapproved for all testing until the deficiencies are corrected to the satisfaction of the WSDOT Quality System Manager.
WSDOT Standard Practice QC 4
Standard Practice for Fly Ash Producers/Importers/Distributors That Certify Fly Ash

1. Scope

This standard specifies requirements and procedures for a certification system that shall be applicable to all Producers/Importers/Distributors of Fly Ash.

This standard may involve hazardous materials, operations and equipment. It does not address all of the safety problems associated with their use. It is the responsibility of those using this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 AASHTO Standards

2.1.1 M 295 – Standard Specifications for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

2.1.2 R 18 – Establishing and Implementing a Quality System for Construction Materials Testing Laboratories

2.2 ASTM Standards

2.2.1 C 618 – Standard Specifications for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

2.3 Agency’s Standard Specifications

3. Terminology

3.1 AASHTO – American Association of State Highway and Transportation Officials

3.2 ASTM – American Society of Testing and Materials

3.3 CCRL – Cement and Concrete Reference Laboratory

3.4 NIST – National Institute of Standards and Technology

3.5 Import/Distribution Facility – A facility that receives finished fly ash products for distribution.

3.6 Production Facility – A facility that has the capacity for producing fly ash.

3.7 Supplier – A supplier stores and then delivers fly ash produced by another entity to a concrete plant or another supplier.
3.8 Supplier Certification – Certification of fly ash provided by the supplier or importer using representative test results obtained in accordance with an agency approved QC plan and approved testing lab.

3.9 Agency – State highway agency or other agency responsible for the final acceptance of fly ash. Samples and documentation shall be sent to:

WSDOT State Materials Laboratory
Attn: Cement Acceptance Program Director
PO Box 47365
Olympia, WA 98504-47365

3.10 Specification Compliance Testing – Complete testing in accordance with the specification requirements.

3.11 Quality Control Testing – The quality control testing shall be described in the Production/Import/Distribution Facility’s quality control plan. The Production/Import/Distribution Facility’s quality control plan must be approved by the Agency.

3.12 CAP – Cement Acceptance Program

3.13 Mill Test Report – A document provided to the Agency on a monthly basis by a fly ash producer for fly ash that is actually produced at a U.S. or Canadian production facility. This document will list the actual chemical and physical test results of the product sample along with the appropriate AASHTO or ASTM specification limits.

3.14 Certificate of Analysis – A document provided to the Agency on a per shipload basis by a fly ash importer/distributor. This document shall represent a specific shipload of imported fly ash. This document will list the actual chemical and physical test results of the product sample along with the appropriate AASHTO or ASTM specification limits.

4. Significance and Use

4.1 This standard specifies procedures for accepting fly ash. This is accomplished by a certification system that evaluates quality control and specification compliance tests performed by the Production/Import/Distribution Facility according to their quality control plan.

5. Laboratory and Tester Requirements

5.1 Laboratories shall be AASHTO accredited in all tests required by specification compliance testing or meet the following requirements:

5.1.1 Laboratory facilities shall adequately house and allow proper operation of all required equipment in accordance with the applicable test procedures.

5.1.2 The laboratory shall use personnel qualified in accordance with the appropriate sections of AASHTO R 18.

5.1.3 The laboratory shall use testing equipment that has been calibrated/standardized/checked to meet the requirements of each test procedure in accordance with the appropriate sections of AASHTO R 18.
5.1.4 Documentation of personnel qualifications and the equipment certification/standardization/checked records shall be maintained.

5.1.5 The agency at their discretion may review the laboratory in accordance with WSDOT QC 3.

5.1.6 The laboratory must participate in the NIST’s CCRL proficiency sample program.

6. Production/Import/Distribution Facility Qualification

6.1 The Production/Import/Distribution Facility shall submit a written request for acceptance into the Cement Acceptance Program to the Agency along with a copy of the Production/Import/Distribution Facility’s Quality Control Plan.

6.2 The Production/Import/Distribution Facility shall submit one sample with its “Mill Test Report” or “Certificate of Analysis” for the initial lot for each class of fly ash it intends to provide to the Agency.

6.3 Initial lots shall be tested for conformance to Agency Standard Specifications and both physical and chemical requirements of either AASHTO M 295 or ASTM C 618.

6.4 The Production/Import/Distribution Facility shall allow the Agency to visit and observe the quality control activities and obtain samples for testing.

7. Production/Import/Distribution Facility Quality Control Plan

7.1 The quality control plan, as a minimum, shall identify the following:

7.1.1 Facility type.

7.1.2 Facility location.

7.1.3 Name and telephone number of the contact person responsible for the quality control of the facility.

7.1.4 The quality control tests to be performed on each class of fly ash.

7.1.5 Name of the laboratory performing quality control tests on the fly ash if independent of the Production/Import/Distribution Facility.

7.1.6 Declaration stating that if a test result indicates that a lot of fly ash is not in compliance with the specifications, the facility shall immediately notify the Agency of the lot in question.

7.1.7 Description of the method and frequency for sampling, quality control testing, and specification compliance testing.

7.1.8 Class of fly ash the Production/Import/Distribution Facility intends to provide to the Agency.

7.1.9 Show compliance with Section 5.

7.2 The Quality Control Plan shall be submitted to the Agency annually for review.
8. Documentation Requirements

8.1 Each Production/Import/Distribution Facility shall document its conformance to the Agency’s Standard Specifications and both physical and chemical requirements of AASHTO M 295 or ASTM C 618 by means of either a “Mill Test Report” or “Certificate of Analysis” that certifies the sample test results.

8.2 “Mill Test Reports” of all fly ash shall be submitted by the producer on a monthly basis to the Agency. Negative reports (i.e., reports indicating no production for the month) are required to insure that a continuous flow of documentation is maintained.

8.3 “Certificates of Analysis” shall be provided by the importer/distributor to the Agency whenever a new shipment of imported fly ash is received for distribution.

8.4 Separate sequences of “Mill Test Reports” shall be provided for each individual production facility and a unique lot number traceable to a production run shall be included in each report.

8.5 “Mill Test Reports” and “Certificates of Analysis” shall show the applicable test results and the applicable specifications for each component or property tested and shall show the test requirements specified by the Agency.

9. Agency Requirements

9.1 The Agency will review the Production/Import/Distribution Facility’s quality control plan listed in Section 6 and respond to the Production Facility within 30 days.

9.2 The Agency may perform quality assurance or acceptance sampling and testing in accordance with the agency standards.

10. Requirements for Shipping Fly Ash to Projects

10.1 The Production/Import/Distribution Facility’s quality control plan as approved by the Agency (see Section 9) shall be implemented.

10.2 Each shipment shall identify the applicable “Mill Test Report” or “Certificate of Analysis.” This may be included on the Bill of Lading for the shipment, or provided by other means as long as each shipment can be traced to the applicable “Mill Test Report” or “Certificate of Analysis.”

11. Quarterly Split Sample Testing

11.1 Production/Import/Distribution Facilities, on a quarterly basis, shall split a production sample into two portions (10 pounds each) for each class of fly ash being produced.

11.2 For the purpose of this standard, quarters are defined as January through March, April through June, July through September, and October through December.

11.3 All fly ash test samples required by this standard shall be obtained as provided in the applicable standard specification or the Production Facility’s quality control plan.

11.4 The Production/Import/Distribution Facility or an independent test facility meeting the requirements specified in Section 5 shall conduct chemical and physical testing on one portion.
11.5 The other portion, along with accompanying chemical and physical analysis, shall be submitted to the Agency. The sample will include the “Mill Test Report” or “Certificate of Analysis” for the lot number that is traceable to the production run of fly ash.

11.6 The Production/Import/Distribution Facility shall submit a letter in lieu of split sample(s) indicating the class(es) of fly ash (if any) for which they were accepted under this program that were not produced during the quarter.

12. Comparison of Split Sample Test Results

12.1 The Agency may elect not to test their portion, but when the Agency does elect to test, the Agency may conduct chemical and/or physical tests.

12.2 The results of split sample tests must conform to the applicable AASHTO or ASTM specification requirements.

12.3 If any discrepancies or problems are identified between the Production/Import/Distribution Facility’s test results and the Agency’s test results the Production/Import/Distribution Facility shall respond to the Agency within 30 days and address the following points concerning their results:

a. Did the results reported accurately reflect the results obtained?

b. Were the test results properly transferred to the report?

c. Were the calculations leading to the test result correct?

d. Did the equipment used to perform the test meet specification requirements?

e. Did the test procedures conform to specification requirements?

f. Was corrective action taken to repair or replace defective equipment?

g. Was the technician instructed of the correct procedure?

12.4 The Production/Import/Distribution Facility shall prepare a response to the Agency, summarizing the results of the investigation, identifying the cause, if determined, and describing any corrective action taken. Comments may include the test facility’s data from CCRL Proficiency Tests.

13. Revocation of Certification Status

13.1 A Production/Import/Distribution Facility may have its certification status with the Agency revoked if found in nonconformance with the Standard Specifications or this Standard Practice.

13.2 The following criteria will be used to judge the conditions of nonconformance:

13.2.1 Failure to follow the Production/Import/Distribution Facility’s approved quality control plan as required in Section 8.

13.2.2 Failure to declare that test results indicated that a lot of fly ash was not in compliance with the specifications as required under Section 8.1.
13.2.3 When a test report shows nonconformance to the applicable specification, the results will be referred for comment and action to the Production/Import/Distribution Facility.

13.2.3.1 The Production Facility shall submit one sample for retest from the next two available production runs.

13.2.3.2 The Import/Distribution Facility shall submit two random samples for retest.

13.2.3.3 If two of three successive samples show nonconformance, the Agency will revoke certification status.

13.3 A Production/Import/Distribution Facility that has had its certification status revoked may seek reinstatement by demonstrating conformance to the qualification criteria shown in Section 7.
WSDOT Standard Practice QC 5
Standard Practice for Ground Granulated Blast-Furnace Slag Producers/Importers/Distributors That Certify Ground Granulated Blast-Furnace Slag

1. Scope

This standard specifies requirements and procedures for a certification system that shall be applicable to all Producers/Importers/Distributors of Ground Granulated Blast-Furnace Slag.

This standard may involve hazardous materials, operations and equipment. It does not address all of the safety problems associated with their use. It is the responsibility of those using this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 AASHTO Standards
   2.1.1 M 302 – Standard Specifications for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
   2.1.2 R 18 – Establishing and Implementing a Quality System for Construction Materials Testing Laboratories

2.2 ASTM Standards
   2.2.1 C 989 – Standard Specifications for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

2.3 Agency’s Standard Specifications

3. Terminology

3.1 AASHTO – American Association of State Highway and Transportation Officials
3.2 ASTM – American Society of Testing and Materials
3.3 CCRL – Cement and Concrete Reference Laboratory
3.4 NIST – National Institute of Standards and Technology
3.5 Import/Distribution Facility – A facility that receives finished ground granulated blast-furnace slag for distribution.
3.6 Production Facility – A facility that has the capacity for producing and/or grinding ground granulated blast-furnace slag.
3.7 Supplier – A supplier stores and then delivers ground granulated blast-furnace slag produced by another entity to a concrete plant or another supplier.
3.8 Supplier Certification – Certification of ground granulated blast-furnace slag provided by the supplier or importer using representative test results obtained in accordance with an agency approved QC plan and approved testing lab.

3.9 Agency – State highway agency or other agency responsible for the final acceptance of ground granulated blast-furnace slag. Samples and documentation shall be sent to:

WSDOT State Materials Laboratory
Attn: Cement Acceptance Program Director
PO Box 47365
Olympia, WA 98504-47365

3.10 Specification Compliance Testing – Complete testing in accordance with the specification requirements.

3.11 Quality Control Testing – The quality control testing shall be described in the Production/Import/Distribution Facility’s quality control plan. The Production/Import/Distribution Facility’s quality control plan must be approved by the Agency.

3.12 CAP – Cement Acceptance Program

3.13 Mill Test Report – A document provided to the Agency on a monthly basis by a ground granulated blast-furnace slag producer that is actually produced at a U.S. or Canadian production facility. This document will list the actual chemical and physical test results of the product sample along with the appropriate AASHTO or ASTM specification limits.

3.14 Certificate of Analysis – A document provided to the Agency on a per shipload basis by a ground granulated blast-furnace slag importer/distributor for imported ground granulated blast-furnace slag. This document shall represent a specific shipload of imported ground granulated blast-furnace slag. This document will list the actual chemical and physical test results of the product sample along with the appropriate AASHTO or ASTM specification limits.

4. Significance and Use

4.1 This standard specifies procedures for accepting ground granulated blast-furnace slag. This is accomplished by a certification system that evaluates quality control and specification compliance tests performed by the Production/Import/Distribution Facility according to their quality control plan.

5. Laboratory and Tester Requirements

5.1 Laboratories shall be AASHTO accredited in all tests required by specification compliance testing or meet the following requirements:

5.1.1 Laboratory facilities shall adequately house and allow proper operation of all required equipment in accordance with the applicable test procedures.

5.1.2 The laboratory shall use personnel qualified in accordance with the appropriate sections of AASHTO R 18.
5.1.3 The laboratory shall use testing equipment that has been calibrated/standardized/checked to meet the requirements of each test procedure in accordance with the appropriate sections of AASHTO R 18.

5.1.4 Documentation of personnel qualifications and the equipment certification/standardization/checked records shall be maintained.

5.1.5 The agency at their discretion may review the laboratory in accordance with WSDOT QC 3.

5.1.6 The laboratory must participate in the NIST’s CCRL proficiency sample program.

6. Production/Import/Distribution Facility Qualification

6.1 The Production/Import/Distribution Facility shall submit a written request for acceptance into the Cement Acceptance Program to the Agency along with a copy of the Production/Import/Distribution Facility’s Quality Control Plan.

6.2 The Production/Import/Distribution Facility shall submit one sample with its “Mill Test Report” or “Certificate of Analysis” for the initial lot for each grade of ground granulated blast-furnace slag it intends to provide to the Agency.

6.3 Initial lots shall be tested for conformance to Agency Standard Specifications and both physical and chemical requirements of either AASHTO M 302 or ASTM C 989.

6.4 The Production/Import/Distribution Facility shall allow the Agency to visit and observe the quality control activities and obtain samples for testing.

7. Production/Import/Distribution Facility Quality Control Plan

7.1 The quality control plan, as a minimum, shall identify the following:

7.1.1 Facility type.

7.1.2 Facility location.

7.1.3 Name and telephone number of the contact person responsible for the quality control of the facility.

7.1.4 The quality control tests to be performed on each grade of ground granulated blast-furnace slag.

7.1.5 Name of the laboratory performing quality control tests on the ground granulated blast-furnace slag if independent of the Production/Import/Distribution Facility.

7.1.6 Declaration stating that if a test result indicates that a lot of ground granulated blast-furnace slag is not in compliance with the specifications, the facility shall immediately notify the Agency of the lot in question.

7.1.7 Description of the method and frequency for sampling, quality control testing, and specification compliance testing.
7.1.8 Type of ground granulated blast-furnace slag the Production/Import/Distribution Facility intends to provide to the Agency.

7.1.9 Show compliance with Section 5.

7.2 The Quality Control Plan shall be submitted to the Agency annually for review.

8. Documentation Requirements

8.1 Each Production/Import/Distribution Facility shall document its conformance to the Agency’s Standard Specifications and both physical and chemical requirements of AASHTO M 302 or ASTM C 989 by means of either, a “Mill Test Report” or “Certificate of Analysis” that certifies the sample test results.

8.2 “Mill Test Reports” of all ground granulated blast-furnace slag shall be submitted by the producer on a monthly basis to the Agency. Negative reports (i.e., reports indicating no production for the month) are required to insure that a continuous flow of documentation is maintained.

8.3 “Certificates of Analysis” shall be provided by the importer/distributor to the Agency whenever a new shipment of imported ground granulated blast-furnace slag is received for distribution.

8.4 Separate sequences of “Mill Test Reports” shall be provided for each individual production facility and a unique lot number traceable to a production run shall be included in each report.

8.5 “Mill Test Reports” and “Certificates of Analysis” shall show the applicable test results and the applicable specifications of AASHTO M 302 or ASTM C 989 for each component or property tested and shall show the test requirements specified by the Agency.

9. Agency Requirements

9.1 The Agency will review the Production/Import/Distribution Facility’s quality control plan listed in Section 6 and respond to the Production Facility within 30 days.

9.2 The Agency may perform quality assurance or acceptance sampling and testing in accordance with the agency standards.

10. Requirements for Shipping Ground Granulated Blast-Furnace Slag to Projects

10.1 The Production/Import/Distribution Facility’s quality control plan as approved by the Agency (see Section 9) shall be implemented.

10.2 Each shipment shall identify the applicable “Mill Test Report” or “Certificate of Analysis.” This may be included on the Bill of Lading for the shipment, or provided by other means as long as each shipment can be traced to the applicable “Mill Test Report” or “Certificate of Analysis.”

11. Quarterly Split Sample Testing

11.1 Production/Import/Distribution Facilities, on a quarterly basis, shall split a production sample into two portions (10 pounds each) for each type of ground granulated blast-furnace slag being produced.
11.2 For the purpose of this standard, quarters are defined as January through March, April through June, July through September, and October through December.

11.3 All ground granulated blast-furnace slag test samples required by this standard shall be obtained as provided in the applicable standard specification or the Production Facility’s quality control plan.

11.4 The Production/Import/Distribution Facility or an independent test facility meeting the requirements specified in Section 5 shall conduct chemical and physical testing on one portion.

11.5 The other portion, along with accompanying chemical and physical analysis, shall be submitted to the Agency. The sample will include the “Mill Test Report” or “Certificate of Analysis” for the lot number that is traceable to the production run of ground granulated blast-furnace slag.

11.6 The Production/Import/Distribution Facility shall submit a letter in lieu of split sample(s) indicating the grade(s) of ground granulated blast-furnace slag (if any) for which they were accepted under this program that were not produced during the quarter.

12. Comparison of Split Sample Test Results

12.1 The Agency may elect not to test their portion, but when the Agency does elect to test, the Agency may conduct chemical and/or physical tests.

12.2 The results of split sample tests must conform to the applicable AASHTO or ASTM specification requirements.

12.3 If any discrepancies or problems are identified between the Production/Import/Distribution Facility’s test results and the Agency’s test results the Production/Import/Distribution Facility shall respond to the Agency within 30 days and address the following points concerning their results:

a. Did the results reported accurately reflect the results obtained?

b. Were the test results properly transferred to the report?

c. Were the calculations leading to the test result correct?

d. Did the equipment used to perform the test meet specification requirements?

e. Did the test procedures conform to specification requirements?

f. Was corrective action taken to repair or replace defective equipment?

g. Was the technician instructed of the correct procedure?

12.4 The Production/Import/Distribution Facility shall prepare a response to the Agency, summarizing the results of the investigation, identifying the cause, if determined, and describing any corrective action taken. Comments may include the test facility’s data from CCRL Proficiency Tests.
13. Revocation of Certification Status

13.1 A Production/Import/Distribution Facility may have its certification status with the Agency revoked if found in nonconformance with the Standard Specifications or this Standard Practice.

13.2 The following criteria will be used to judge the conditions of nonconformance:

13.2.1 Failure to follow the Production/Import/Distribution Facility’s approved quality control plan as required in Section 8.

13.2.2 Failure to declare that test results indicated that a lot of ground granulated blast-furnace slag was not in compliance with the specifications as required under Section 8.1.

13.2.3 When a test report shows nonconformance to the applicable specification, the results will be referred for comment and action to the Production/Import/Distribution Facility.

   13.2.3.1 The Production Facility shall submit one sample for retest from the next two available production runs.

   13.2.3.2 The Import/Distribution Facility shall submit two random samples for retest.

   13.2.3.3 If two of three successive samples show nonconformance, the Agency will revoke certification status.

13.3 A Production/Import/Distribution Facility that has had its certification status revoked may seek reinstatement by demonstrating conformance to the qualification criteria shown in Section 7.
In-Place Density of Bituminous Mixes Using the Nuclear Moisture-Density Gauge

Scope

This test method describes a test procedure for determining the density of Hot Mix Asphalt (HMA) by means of a nuclear density gauge employing either direct transmission or backscatter (thin layer only) methods. Correlation with densities determined under SOP 730 is required.

Apparatus

- Nuclear density gauge with the factory matched standard reference block.
- Drive pin, guide, scraper plate, and hammer for testing in direct transmission mode.
- Transport case for properly shipping and housing the gauge and tools.
- Instruction manual for the specific make and model of gauge.
- Radioactive materials information and calibration packet containing:
  - Daily Standard Count Log
  - Factory and Laboratory Calibration Data Sheet
  - Leak Test Certificate
  - Shippers Declaration for Dangerous Goods
  - Procedure Memo for Storing, Transporting and Handling Nuclear Testing Equipment
  - Other radioactive materials documentation as required by local regulatory requirements.

Material

WSDOT does not use filler material

Radiation Safety

This method does not purport to address the safety concerns, if any, associated with its use. This test method involves potentially hazardous materials. The gauge utilizes radioactive materials that may be hazardous to the health of the user unless proper precautions are taken. Users of this gauge must become familiar with the applicable safety procedures and governmental regulations. All operators will be trained in radiation safety prior to operating nuclear density gauges. Some agencies require the use of personal monitoring devices such as a thermoluminescent dosimeter or film badge. Effective instructions together with routine safety procedures such as source leak tests, recording and evaluation of personal monitoring device data, etc., are a recommended part of the operation and storage of this gauge.

Calibration

WSDOT performs calibrations according to the manufacturer’s Operators Manual.
Standardization

1. Turn the gauge on and allow it to stabilize (approximately 10 to 20 minutes) prior to standardization. Leave the power on during the day’s testing.

2. Standardize the gauge at the construction site at the start of each day’s work and as often as deemed necessary by the operator or agency. Daily variations in standard count shall not exceed the daily variations established by the manufacturer of the gauge. If the daily variations are exceeded after repeating the standardization procedure, the gauge should be repaired and or recalibrated.

3. Record the standard count for both density and moisture in the Daily Standard Count Log. The exact procedure for standard count is listed in the manufacturer’s Operators Manual.

Test Site Location

1. Select a test location(s) randomly and in accordance with WSDOT Test Method T 716. Test sites should be relatively smooth and flat and meet the following conditions:
   a. At least 33 ft (10 m) away from other sources of radioactivity.
   b. At least 10 ft (3 m) away from large objects (i.e., vehicles).
   c. No closer than 24 in (600 mm) to any vertical mass, or less than 6 in (152.0 mm) from a vertical pavement edge.

Overview

There are two methods for determining in-place density of HMA.

- Direct Transmission – The standard for WSDOT when the depth of Hot Mix Asphalt is 0.15 foot or greater.
- Backscatter – Optional standard for WSDOT when the depth of Hot Mix Asphalt is 0.10 foot or greater. Only gauges with two sets of photon detectors operating in “Thin Layer Mode” will be allowed.

Note: When a density lot is started in thin layer mode it must remain in thin layer mode until the lot is completed. If a density lot is started in direct transmission the lot must be completed in direct transmission unless the pavement depth falls below 0.15 feet.

Procedure

Direct Transmission

1. Maintaining maximum contact between the base of the gauge and the surface of the material under test is critical.

2. Use the guide and scraper plate as a template and drill a hole to a depth of at least ¼ in (7 mm) deeper than the measurement depth required for the gauge.

3. Place the gauge on the prepared surface so the source rod can enter the hole. Insert the probe in the hole and lower the source rod to the desired test depth using the handle and trigger mechanism. Position the gauge with the long axis of the gauge parallel to the direction of paving. Pull the gauge so that the probe is firmly against the side of the hole.
**WSDOT Note:** For alignment purposes, the user may expose the source rod for a maximum of 10 seconds.

4. Take one 4-minute test and record the wet density (WD) reading.

**Thin Layer Gauge or Mode**

1. A thin layer gauge (i.e., Troxler 4640) or a moisture density & thin layer gauge that has a thin layer mode setting (i.e., Troxler 3450) is required to perform this testing.

2. Take tests in accordance with manufacturer’s recommendation.

3. Take one 4-minute test and record the wet density (WD) reading.

**Calculation of Percent of Compaction**

The percent compaction is determined by comparing the in-place wet density, as determined by this method, to the Average Theoretical Maximum Density of the HMA as determined by the WSDOT SOP 729.

The density gauge operator will receive a new average Theoretical Maximum Density from the tester at the HMA plant each day that production requires a mix test. The density gauge operator will continue to use the previous moving average until a new moving average is received from the tester at the HMA plant.

Each gauge shall be correlated in accordance with WSDOT SOP 730. A correlation factor will be provided to the density gauge operator for each gauge.

Use the following equations to calculate the percent of compaction:

1. Calculate the corrected gauge reading to the nearest tenth of a percent as follows:
   
   
   \[
   \text{Corrected Gauge Reading} = \text{WD} \times \text{CF}
   \]

   \(\text{WD} = \) moisture density gauge wet density reading

   \(\text{CF} = \) gauge correlation factor (WSDOT SOP 730)

2. Calculate the percent compaction as follows.

   \[
   \text{Percent Compaction} = \frac{\text{Corrected Gauge Reading}}{\text{Average Theoretical Maximum Density}} \times 100
   \]

**Correlation With Cores**

WSDOT has deleted this section, refer to WSDOT SOP 730.

**Report**

Report the results using one of the following:

- Materials Testing System (MATS)
- WDOT Form 350-092 and 350-157
- Form approved in writing by the State Materials Engineer

Report the percent compaction to the nearest tenth of a percent (0.1 percent)
## Tester Qualification Practical Exam Checklist

**In-place Density of Hot Mix Asphalt (HMA) Using the Nuclear Moisture-Density Gauge**

**FOP for WAQTC TM 8**

<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, and if required, has the current calibration/verification tags present?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Gauge turned on?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Gauge standardized and standard count recorded?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Test location selected appropriately?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Direct Transmission Mode:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Hole made a minimum of ¼ inch deeper than measurement depth?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>b. Gauge placed parallel to direction of paving, probe extended, gauge pulled back so probe against hole?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>c. For alignment purposes did not expose the source rod for more than 10 seconds.</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>d. One four-minute test made?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>e. Wet density recorded?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Thin Layer Gauge or Gauge in Thin Layer Mode:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Gauge placed, probe extended to backscatter position?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>b. One four-minute test made; gauge placed as described in the manufacture recommendations?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>c. Wet Densities recorded?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. All calculations performed correctly?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Nuclear Gauge secured in a manner consistent with current DOH requirements?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

First Attempt:  Pass ☐   Fail ☐  
Second Attempt: Pass ☐   Fail ☐

Signature of Examiner

Comments:
WSDOT FOP for AASHTO T 22¹
Compressive Strength of Cylindrical Concrete Specimens

1. Scope

1.1 This test method covers determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a unit weight in excess of 50 lb/ft³ [800 kg/m³].

1.2 The values stated in English units are the standard.

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

Warning: Means should be provided to contain concrete fragments during sudden rupture of specimens. Tendency for sudden rupture increases with increasing concrete strength (Note 1).

Note 1: The safety precautions given in the Manual of Aggregate and Concrete Testing, located in the Related Materials section of Volume 04.02 of the Annual Book of ASTM Standards, are recommended.

1.4 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 AASHTO Standards
R 39 – Making and curing Concrete Test Specimens in the Laboratory
T 23 – Making and Curing Concrete Test Specimens in the Field
T 24 – Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
T 231 – Capping Cylindrical Concrete Specimens

2.2 ASTM Standards
C 873 – Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
C 1231 – Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders
E 74 – Practice for Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines

¹This FOP is based on AASHTO T 22-11 and has been modified per WSDOT standards. To view the redline modifications, contact WSDOT Quality Systems Manager at (360) 709-5412.
3. Summary of Test Method

3.1 This test method consists of applying a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

4. Significance and Use

4.1 Care must be exercised in the interpretation of the significance of compressive strength determinations by this test method since strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing procedures, the methods of sampling, molding, and fabrication and the age, temperature, and moisture conditions during curing.

4.2 This test method is used to determine compressive strength of cylindrical specimens prepared and cured in accordance with Methods T 23, T 24, T 231, and ASTM C873.

4.3 The results of this test method are used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specifications; control for evaluating effectiveness of admixtures and similar uses.

5. Apparatus

5.1 Testing Machine – The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading prescribed in Section 7.5. As a minimum, the machine should be capable of achieving 170 percent of the design strength.

5.1.1 Verify calibration of the testing machines in accordance with Method T 67 except that the verified loading range shall be as required in 5.3.2. Verification is required under the following conditions:

5.1.1.1 At least annually, but not to exceed 13 months;

5.1.1.2 On original installation or immediately after relocation;

5.1.1.3 Immediately after making repairs or adjustments that affect the operation of the force applying system or the values displayed on the load indicating system, except for zero adjustments that compensate for the mass (weight) of tooling, or specimen, or both; or

5.1.1.4 Whenever there is reason to suspect the accuracy of the indicated loads.

5.1.2 Design – The design of the machine must include the following features:

5.1.2.1 The machine must be power operated and must apply the load continuously rather than intermittently, and without shock. If it has only one loading rate (meeting the requirements of Section 7.5), it must be provided with a supplemental means for loading at a rate suitable for verification. This supplemental means of loading may be power or hand operated.
5.1.2.2 The space provided for test specimens shall be large enough to accommodate, in a readable position, an elastic calibration device which is of sufficient capacity to cover the potential loading range of the testing machine and which complies with the requirements of Practice E 74.

Note 2: The types of elastic calibration devices most generally available and most commonly used for this purpose are the circular proving ring or load cell.

5.1.3 Accuracy – The accuracy of the testing machine shall be in accordance with the following provisions:

5.1.3.1 The percentage of error for the loads within the proposed range of use of the testing machine shall not exceed ± 1.0 percent of the indicated load.

5.1.3.2 The accuracy of the testing machine shall be verified by applying five test loads in four approximately equal increments in ascending order. The difference between any two successive test loads shall not exceed one third of the difference between the maximum and minimum test loads.

5.1.3.3 The test load as indicated by the testing machine and the applied load computed from the readings of the verification device shall be recorded at each test point. Calculate the error, E, and the percentage of error, Ep, for each point from these data as follows:

\[ E = A - B \]
\[ Ep = 100 \frac{(A - B)}{B} \]

where:
A = load, lbf [kN] indicated by the machine being verified, and
B = applied load, lbf [kN] as determined by the calibrating device.

5.1.3.4 The report on the verification of a testing machine shall state within what loading range it was found to conform to specification requirements rather than reporting a blanket acceptance or rejection. In no case shall the loading range be stated as including loads below the value which is 100 times the smallest change of load that can be estimated on the load-indicating mechanism of the testing machine or loads within that portion of the range below 10 percent of the maximum range capacity.

5.1.3.5 In no case shall the loading range be stated as including loads outside the range of loads applied during the verification test.

5.1.3.6 The indicated load of a testing machine shall not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required permissible variation.
5.2 The testing machine shall be equipped with two steel bearing blocks with hardened faces (Note 3), one of which is a spherically seated block that will bear on the upper surface of the specimen, and the other a solid block on which the specimen shall rest. Bearing faces of the blocks shall have a minimum dimension at least 3 percent greater than the diameter of the specimen to be tested. Except for the concentric circles described below, the bearing faces shall not depart from a plane by more than 0.001 in \([0.025 \text{ mm}]\) in any 6 in \([150 \text{ mm}]\) of blocks 6 in \([150 \text{ mm}]\) in diameter or larger, or by more than 0.001 in \([0.025 \text{ mm}]\) in the diameter of any smaller block; and new blocks shall be manufactured within one half of this tolerance. When the diameter of the bearing face of the spherically seated block exceeds the diameter of the specimen by more than 0.5 in \([13 \text{ mm}]\), concentric circles not more than 0.031 in \([0.8 \text{ mm}]\) deep and not more than 0.047 in \([1 \text{ mm}]\) wide shall be inscribed to facilitate proper centering.

**Note 3:** It is desirable that the bearing faces of blocks used for compression testing of concrete have a Rockwell hardness of not less than 55 HRC.

5.2.1 Bottom bearing blocks shall conform to the following requirements:

5.2.1.1 The bottom bearing block is specified for the purpose of providing a readily machinable surface for maintenance of the specified surface conditions (Note 4). The top and bottom surfaces shall be parallel to each other. Its least horizontal dimension shall be at least 3 percent greater than the diameter of the specimen to be tested. Concentric circles as described in Section 5.2 are optional on the bottom block.

**Note 4:** The block may be fastened to the platen of the testing machine.

5.2.1.2 Final centering must be made with reference to the upper spherical block when the lower bearing block is used to assist in centering the specimen. The center of the concentric rings, when provided, or the center of the block itself must be directly below the center of the spherical head. Provision shall be made on the platen of the machine to assure such a position.

5.2.1.3 The bottom bearing block shall be at least 1 in \([25 \text{ mm}]\) thick when new, and at least 0.9 in \([22.5 \text{ mm}]\) thick after any resurfacing operations, except when the block is in full and intimate contact with the lower platen of the testing machine, the thickness may be reduced to 0.38 in \((10 \text{ mm})\).

**Note 5:** If the testing machine is so designed that the platen itself can be readily maintained in the specified surface condition, a bottom block is not required.

5.2.2 The spherically seated bearing block shall conform to the following requirements:

5.2.2.1 The maximum diameter of the bearing face of the suspended spherically seated block shall not exceed the values given below:
### Diameter of Test Specimens in (mm)  |  Maximum Diameter of Bearing Face in [mm]
---|---
2 (50) | 4 (105)
3 (75) | 5 (130)
4 (100) | 6.5 (165)
6 (150) | 10 (255)
8 (200) | 11 (280)

**Note 6:** Square bearing faces are permissible, provided the diameter of the largest possible inscribed circle does not exceed the above diameter.

5.2.2.2 The center of the sphere shall coincide with the surface of the bearing face within a tolerance of ± 5 percent of the radius of the sphere. The diameter of the sphere shall be at least 75 percent of the diameter of the specimen to be tested.

5.2.2.3 The ball and the socket shall be designed so that the steel in the contact area does not permanently deform when loaded to the capacity of the test machine. (Note 7).

**Note 7:** The preferred contact area is in the form of a ring (described as preferred “bearing” area) as shown on Figure 1.

5.2.2.4 The curved surfaces of the socket and of the spherical portion shall be kept clean and shall be lubricated with a petroleum-type oil such as conventional motor oil, not with a pressure type grease. After contacting the specimen and application of small initial load, further tilting of the spherically seated block is not intended and is undesirable.

5.2.2.5 If the radius of the sphere is smaller than the radius of the largest specimen to be tested, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen. The least dimension of the bearing face shall be at least as great as the diameter of the sphere (see Figure 1).

5.2.2.6 The movable portion of the bearing block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted at least 4 degrees in any direction.

5.2.2.7 If the ball portion of the upper bearing block is a two-piece design composed of a spherical portion and a bearing plate, a mechanical means shall be provided to ensure that the spherical portion is fixed and centered on the bearing plate.
5.3 Load Indication

5.3.1 If the load of a compression machine used in concrete testing is registered on a dial, the dial shall be provided with a graduated scale that is readable to at least the nearest 0.1 percent of the full scale load (Note 8). The dial shall be readable within 1 percent of the indicated load at any given load level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value that is 100 times the smallest change of load that can be read on the scale. The scale shall be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the end of the pointer shall not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment which is easily accessible from the outside of the dial case, while observing the zero mark and dial pointer, and with a suitable device that at all times until reset will indicate to within one percent accuracy the maximum load applied to the specimen.

Note 8: As close as can reasonably be read is considered to be 0.02 in (0.5 mm) along the arc described by the end of the pointer. Also, one half of a scale interval is close as can reasonably be read when the spacing on the load indicating mechanism is between 0.04 in (1 mm) and 0.06 in (2 mm). When the spacing is between 0.06 and 0.12 in (2 and 3 mm), one third of a scale interval can be read with reasonable certainty. When the spacing is 0.12 in (3 mm) or more, one fourth of a scale interval can be read with reasonable certainty.
5.3.2 If the testing machine load is indicated in digital form, the numerical display must be large enough to be easily read. The numerical increment must be equal to or less than 0.10 percent of the full scale load of a given loading range. In no case shall the verified loading range include loads less than the minimum numerical increment multiplied by 100. The accuracy of the indicated load must be within 1.0 percent for any value displayed within the verified loading range. Provision must be made for adjusting to indicate true zero at zero load. There shall be provided a maximum load indicator that at all times until reset will indicate within 1.0 percent system accuracy the maximum load applied to the specimen.

5.4 Provide a means for containing fragments in the event of explosive rupture of the cylinders during testing.

6. Specimens

6.1 Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 percent. (Note 9).

**Note 9:** This may occur when single use molds are damaged or deformed during shipment, when flexible single use molds are deformed during molding or when a core drill deflects or shifts during drilling.

6.2 Neither end of compressive test specimens when tested shall depart from perpendicularity to the axis by more than 0.5 degrees (approximately equivalent to 0.12 in in 12 in (3 mm in 300 mm). The ends of compression test specimens that are not plane within 0.002 in [0.050 mm] shall be sawed, ground or capped in accordance with T 231 to meet that tolerance or if the ends meet the requirements of A6, then neoprene caps with steel controllers may be used instead of capping. The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.01 in (0.25 mm) by averaging two diameters measured at right angles to each other at about mid-height of the specimen.

6.3 The height of the cylinder shall be determined to 0.01 in. The mass of the cylinder shall be determined to the nearest 0.1 lb or better.

7. Procedure

7.1 Compression tests of moist-cured specimens shall be made as soon as practicable after removal from moist storage.

7.2 Test specimens shall be kept moist by any convenient method during the period between removal from moist storage and testing. They shall be tested in the moist condition.

7.3 All test specimens for a given test age shall be broken within the permissible time tolerances prescribed as follows:
### Table: Test Age and Permissible Tolerance

<table>
<thead>
<tr>
<th>Test Age</th>
<th>Permissible Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 h</td>
<td>± 0.25 h or 2.1%</td>
</tr>
<tr>
<td>24 h</td>
<td>± 0.5 h or 2.1%</td>
</tr>
<tr>
<td>3 days</td>
<td>+ 2 h or 2.8%</td>
</tr>
<tr>
<td>7 days</td>
<td>+ 6 h or 3.6%</td>
</tr>
<tr>
<td>28 days</td>
<td>+ 20 h or 3.0%</td>
</tr>
<tr>
<td>56 days</td>
<td>+ 40 h or 3.0%</td>
</tr>
<tr>
<td>90 days</td>
<td>+ 2 days 2.2%</td>
</tr>
</tbody>
</table>

**Note:** The 28 day compressive break may be extended by up to 48 hours if the scheduled 28 day break falls on a Saturday, Sunday, or Holiday. The Regional Materials Engineer must authorize the time extension in writing.

7.4 Placing the Specimen

Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen and place the test specimen on the lower bearing block.

7.4.1 Zero Verification and Block Seating – Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator (Note 10). Prior to the spherically-seated block is being brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

**Note 10:** The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner’s manual or compression machine calibrator for the proper technique.

7.5 Rate of Loading – Apply the load continuously and without shock.

7.5.1 The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of $35 \pm 7 \text{ psi/s}$ ($0.25 \pm 0.05 \text{ MPa/s}$) (Note 11). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

**Note 11:** For a screw driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

7.5.2 During application of the first half of the anticipated Loading phase a higher rate of loading shall be permitted. The higher loading rate shall be applied in a controlled manner so that the specimen is not subjected to shock loading.

7.5.3 Make no adjustment in the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.
7.6 Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (Figure 2). For a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95 percent of the peak load. When testing with unbonded caps, a corner fracture may occur before the ultimate capacity of the specimen has been attained. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern according to Figure 2. If the fracture pattern is not one of the typical patterns shown in Figure 2, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with Practice T 231 or Practice C1231.

8. Calculation

8.1 Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area determined as described in Section 6 and express the result to the nearest 10 psi [0.1 MPa].

8.2 If the specimen length to diameter ratio is 1.75 or less, correct the result obtained in Section 8.1 by multiplying by the appropriate correction factor shown in the following table Note 11:

<table>
<thead>
<tr>
<th>L/D:</th>
<th>1.75</th>
<th>1.50</th>
<th>1.25</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
<td>0.98</td>
<td>0.96</td>
<td>0.93</td>
<td>0.87</td>
</tr>
</tbody>
</table>

(Note 11) Use interpolation to determine correction factors for L/D values between those given in the table.

*Note 11:* Correction factors depend on various conditions such as moisture condition, strength level, and elastic modulus. Average values are given in the table. These correction factors apply to lightweight concrete weighing between 100 and 120 lb/ft\(^3\) (1,600 and 1,920 kg/m\(^3\)) and to normal weight concrete. They are applicable to concrete dry or soaked at the time of loading and for nominal concrete strengths from 2,000 to 6,000 psi (15 to 45 MPa). For strengths higher than 6,000 psi (45 MPa) correction factors may be larger than the values listed above x.

8.3 Calculate the density of the specimen to the nearest 1 lb/ft\(^3\) (10 kg/m\(^3\)) as follows:

\[
\text{Density} = \frac{W}{V}
\]

where:

- \(W\) = mass of specimen, lb (kg)
- \(V\) = volume of specimen computed from the average diameter and average length or from weighing the cylinder in air and submerged, ft\(^3\) (m\(^3\))
9. Report

9.1 Report the following information:

9.1.1 Identification number.

9.1.2 Diameter (and length, if outside the range of 1.8D to 2.2D), in inches or millimeters.

9.1.3 Cross-sectional area, in square inches or centimeters.

9.1.4 Maximum load, in pounds-force or Newton.

9.1.5 Compressive strength calculated to the nearest 10 psi or 0.1MPa.

9.1.6 Type of fracture, if other than the usual cone (see Figure 2).

9.1.7 Defects in either specimen or caps.

9.1.8 Age of specimen.

9.1.9 Report the density to the nearest 10 kg/m$^3$ (1 lb/ft$^3$).

10. Precision And Bias

See AASHTO T 22 for Precision and bias.

WSDOT has added Appendix A and it is an excerpt of ASTM C1231-00 sections 1 through 7.
Appendix A

A1. Scope

A1.1 This practice covers requirements for a capping system using unbonded caps for testing concrete cylinders molded in accordance with Practice C 31/C 31M or C 192/C 192M. Unbonded neoprene caps of a defined hardness are permitted to be used for testing for a specified maximum number of reuses without qualification testing up to a certain concrete compressive strength level. Above that strength, level neoprene caps will require qualification testing. Qualification testing is required for all elastomeric materials other than neoprene regardless of the concrete strength.

A1.2 Unbonded caps are not to be used for acceptance testing of concrete with compressive strength below 1500 psi [10 MPa] or above 12,000 psi [85 MPa].

A1.3 The values stated in either inch-pound or SI units shall be regarded as standard. SI units are shown in brackets. That values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining the values in any way.

A1.4 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. For a specific hazard statement, see Note 4.

A2. Referenced Documents

A2.1 ASTM Standards

C 31/C 31M – Practice for Making and Curing Concrete Test Specimens in the Field
C 39 – Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 192/C 192M – Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 617 – Practice for Capping Cylindrical Concrete Specimens
D 2000 – Classification System for Rubber products in Automotive Applications
D 2240 – Test Method for Rubber Property—Durometer Hardness

A3. Terminology

A3.1 Definitions of Terms Specific to This Standard:

A3.1.1 pad, n – An unbonded elastomeric pad.

A3.1.2 unbonded cap, n – A metal retainer and an elastomeric pad.

A4. Significance and Use

A4.1 This practice provides for using an unbonded capping system in testing hardened concrete cylinders made in accordance with Practices C 31/C 31M or C 192/C 192M in lieu of the capping systems described in Practice C 617.
A4.2 The elastomeric pads deform in initial loading to conform to the contour of the ends of the cylinder and are restrained from excessive lateral spreading by plates and metal rings to provide a uniform distribution of load from the bearing blocks of the testing machine to the ends of the concrete or mortar cylinders.

A5. Materials and Apparatus

A5.1 Materials and equipment necessary to produce ends of the reference cylinders that conform to planeness requirements of Test Method C 39 and the requirements of Practice C 617. This may include grinding equipment or capping materials and equipment to produce neat cement paste, high strength gypsum plaster, or sulfur mortar caps.

A5.2 Elastomeric Pads:

A5.2.1 Pads shall be ½ ± ¼ in [13± 2 mm] thick and the diameter shall not be more than ¼ in [2 mm] smaller than the inside diameter of the retaining ring.

1This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregate sand is the direct responsibility of Subcommittee C09.61 on Testing Concrete for Strength. Current edition approved Jan. 10, 2000. Published April 2000. Originally published as C 1231–93. Last previous edition C 1231–99.


3Annual Book of ASTM Standards, Vol 09.02.

4Annual Book of ASTM Standards, Vol 09.01.

A5.2.2 Pads shall be made from polychloroprene (neoprene) meeting the requirements of Classification D 2000 as follows:

<table>
<thead>
<tr>
<th>Shore A Durometer</th>
<th>Classification D 2000 Line Call-Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>M2BC514</td>
</tr>
<tr>
<td>60</td>
<td>M2BC614</td>
</tr>
<tr>
<td>70</td>
<td>M2BC714</td>
</tr>
</tbody>
</table>

The tolerance on Shore A durometer hardness is ± 5. Table 1 provides requirements for use of caps made from material meeting the requirements of Classification D 2000, above.

A5.2.3 Other elastomeric materials that meet the performance requirements of qualification tests in Section 8 are permitted.

A5.2.4 Elastomeric pads shall be supplied with the following information:

A5.2.4.1 The manufacturer’s or supplier’s name,

A5.2.4.2 The Shore A hardness, and

A5.2.4.3 The applicable range of concrete compressive strength from Table 1 or from qualification testing.
A5.2.5 The user shall maintain a record indicating the date the pads are placed in service, the pad durometer, and the number of uses to which they have been subjected.

A5.3 Retainers, shall be made of metal that will prove durable in repeated use (Note 1). The cavity in the metal retainers shall have a depth at least twice the thickness of the pad. The inside diameter of the retaining rings shall not be less than 102 percent or greater than 107 percent of the diameter of the cylinder. The surfaces of the metal retainer which contact the bearing blocks of the testing machine shall be plane to within 0.002 in (0.05 mm).

The bearing surfaces of the retainers shall not have gouges, grooves, or indentations greater than 0.010 in (0.25 mm) deep or greater than 0.05 in² (32 mm²) in surface area.

Note 1: Retainers made from steel and some aluminum alloys have been found acceptable. Steel retaining rings that have been used successfully with ½ in (13 mm) neoprene pads are shown in Figure 1. Retainer design and metals used are subject to the performance and acceptance requirements of Section 8.

A6. Test Specimens

A6.1 The specimens shall be either 6 by 12 in (150 by 300 mm) or 4 by 8 in (100 by 200 mm) cylinders made in accordance with Practices C 31/C 31M or C 192/C 192M.

Neither end of a cylinder shall depart from perpendicularity to the axis by more than 0.5° (approximately equivalent to ⅛ in in 12 in [3 mm in 300 mm]). No individual diameter of a cylinder may differ from any other diameter by more than 2 percent.

Note 2: One method of measuring the perpendicularly of ends of cylinders is to place a try square across any diameter and measure the departure of the longer blade from an element of the cylindrical surface. An alternative method is to place the end of the cylinder on a plane surface and support the try square on that surface.

A6.2 Depressions under a straight edge measured with a round wire gage across any diameter shall not exceed 0.20 in (5 mm). If cylinder ends do not meet this tolerance, the cylinder shall not be tested unless irregularities are corrected by sawing or grinding.

<table>
<thead>
<tr>
<th>Cylinder Compressive Strength, psi [MPa]</th>
<th>Shore A Durometer Hardness</th>
<th>Qualification Tests Required</th>
<th>Maximum Reuses$^A$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500 to 6000 [10 to 40]</td>
<td>50</td>
<td>none</td>
<td>100</td>
</tr>
<tr>
<td>2500 to 7000 [17 to 50]</td>
<td>60</td>
<td>none</td>
<td>100</td>
</tr>
<tr>
<td>4000 to 7000 [28 to 50]</td>
<td>70</td>
<td>None</td>
<td>100</td>
</tr>
<tr>
<td>7000 to 12000 [50 to 80]</td>
<td>70</td>
<td>Required</td>
<td>50</td>
</tr>
<tr>
<td>Greater than 12000 [80]</td>
<td></td>
<td>not permitted</td>
<td></td>
</tr>
</tbody>
</table>

$^A$ Maximum number of reuses. Will be less if pads wear, crack or split. See Note 6.

Requirements for Use of Polychloroprene (Neoprene) Pads

Table 1
A7 Procedure

A7.1 Unbonded caps are permitted to be used on one or both ends of a cylinder in lieu of a cap or caps meeting Practice C 617, provided they meet the requirements of Section 5.

A7.2 Examine the pads for excessive wear or damage (Note 6). Replace pads which have cracks or splits exceeding \( \frac{3}{8} \) in (10 mm) in length regardless of depth. Insert the pads in the retainers before they are placed on the cylinder (Note 3).

**Note 3:** Some manufacturers recommend dusting the pads and the ends of the cylinders with corn starch or talcum powder prior to testing.

**Note 4:** Caution: Concrete cylinders tested with unbonded caps rupture more violently than comparable cylinders tested with bonded caps. As a safety precaution the cylinder testing machine must be equipped with a protective cage. In addition, some users have reported damage to testing machines from the sudden release of energy stored in the elastomeric pads.
A7.3 Center the unbonded cap or caps on the cylinder and place the cylinder on the lower bearing block of the testing machine. Carefully align the axis of the cylinder with the center of thrust of the testing machine by centering the upper retaining ring on the spherically seated bearing block. As the spherically seated block is brought to bear on the upper retaining ring, rotate its movable portion gently by hand so that uniform seating is obtained. After application of load, but before reaching 10 percent of the anticipated specimen strength, check to see that the axis of the cylinder is vertical within a tolerance of ⅛ in in 12 in [3.2 mm in 300 mm] and that the ends of the cylinder are centered within the retaining rings. If the cylinder alignment does not meet these requirements, release the load, check compliance with 6.1, and carefully recenter the specimen. Reapply load and recheck specimen centering and alignment. A pause in load application to check cylinder alignment is permissible.

A7.4 Complete the load application, testing, calculation, and reporting of results in accordance with Test Method C 39.

Note 5: Because of the violent release of energy stored in pads, the broken cylinder rarely exhibits conical fracture typical of capped cylinders and the sketches of types of fracture in Test Method C 39 are not descriptive. Occasionally, unbonded capped cylinders may develop early cracking, but continue to carry increasing load. For this reason cylinders must be tested to complete failure.
# Performance Exam Checklist

**Compressive Strength of Cylindrical Concrete Specimens**  
**FOP for AASHTO T 22**

**Participant Name ________________________________**    **Exam Date ________________**

<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, and if required, has the current calibration/verification tags present?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Is the diameter of the cylinder reported to the nearest 0.01 inch by averaging two diameters taken at about mid-height?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Is the length of the cylinder reported to the nearest 0.01 inches?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Is the mass of the cylinder reported to the nearest 0.1 lbs or better?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Ends of cylinders checked for perpendicularity to axis?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Ends of cylinders checked for depressions greater than 0.2 inch?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Ends of cylinders checked for plane?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. If ends did not meet plane was correct method chosen to correct plane?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. Are lower and upper bearing surface wiped clean?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>11. Is the axis of the cylinder aligned with center of the spherical block?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12. Is the spherical block rotated prior to it contacts with the cylinder?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13. Is the load applied continuously and without shock?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>14. Is the load applied at the specified rate and maintain for the latter half of the anticipated load.</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>15. Is no rate adjustment made while the cylinder is yielding?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>16. Is the maximum load recorded?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>17. Are cylinders tested to failure and the type of fracture recorded?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>18. Breaking Cylinders at 28 days + 20 hours?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>19. All calculations performed correctly?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Unbonded Caps – AASHTO-22 Appendix A**

<table>
<thead>
<tr>
<th>Unbonded Caps Element</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pads examined for splits or cracks?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Cylinders centered in retaining rings?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Is cylinders checked for alignment with a small load applied?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

First Attempt: Pass ☐ Fail ☐  
Second Attempt: Pass ☐ Fail ☐

Signature of Examiner ____________________________________________
Comments:
WSDOT FOP for AASHTO T 23
Making and Curing Concrete Test Specimens in the Field

1. Scope

1.1 This method covers procedures for making and curing cylinder specimens from representative samples of fresh concrete for a construction project.

1.2 The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures, except as modified in Section 5.1. This practice is not satisfactory for making specimens from concrete not having measurable slump or requiring other sizes or shapes of specimens.

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

1.4 This standard does not purport to address the safety problems 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. (Warning – Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.)

2. Referenced Documents

2.1 AASHTO Standards
   T 23 – Making and Curing Concrete Test Specimens in the Field
   M 201 – Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
   M 205 – Molds for Forming Concrete Test Cylinders Vertically
   R 39 – Making and Curing Concrete Test Specimens in the Laboratory
   T 231 – Capping Cylindrical Concrete Specimens

2.2 ASTM Standards
   C 125 – Terminology Related to Concrete and Concrete Aggregates

2.3 ACI Standards
   309 R – Guide for Consolidation of Concrete

2.4 WSDOT
   FOP for WAQTC TM 2 Sampling Freshly Mixed Concrete

3. Terminology

For definitions of terms used in this practice, refer to Terminology ASTM C 125.

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This FOP is based on AASHTO T 23-08
4. Significance and Use

4.1 This practice provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.

4.2 If the specimens are made and standard cured, as stipulated herein, the resulting strength test data where the specimens are tested are able to be used for the following purposes:

4.2.1 Acceptance testing for specified strength,
4.2.2 Checking the adequacy of mixture proportions for strength,
4.2.3 Quality control.

4.3 If the specimens are made and field cured, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:

4.3.1 Determination of whether a structure is capable of being put in service.
4.3.2 Comparison with test results of standard cured specimens or with test results from various in-place test methods,
4.3.3 Adequacy of curing and protection of concrete in the structure.
4.3.5 Form or shoring removal time requirements.

5. Apparatus

5.1 Molds, General – Refer to AASHTO T 23.

5.2 Cylinder – Molds for casting concrete test specimens shall conform to the requirements of M 205, and shall come from an approved shipment as verified by the WSDOT Quality Systems Manual Verification Procedure No. 2.

5.3 Beam Molds – Refer to WSDOT Test Method T 808.

5.4 Tamping Rod – Two sizes are specified as indicated in Table 1. Each shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod. Both ends may be rounded if preferred.

<table>
<thead>
<tr>
<th>Diameter of Cylinder, in (mm)</th>
<th>Rod Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diameter, in (mm)</td>
</tr>
<tr>
<td>4 (100)</td>
<td>⅜ (10)</td>
</tr>
<tr>
<td>6 (150)</td>
<td>⅝ (16)</td>
</tr>
</tbody>
</table>

a. Rod tolerances length ± 4 in (100 mm) and diameter ± ⅛ in (2 mm).

5.5 Vibrators – Internal vibrators shall be used. The vibrator frequency shall be at least 7,000 vibrations per minute at 150 Hz while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one-fourth the diameter of the
cylinder mold or one-fourth the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in (75 mm). The vibrator frequency shall be checked periodically.

Note 1: For information on size and frequency of various vibrators and a method to periodically check vibrator frequency, see ACI 309R.

5.6 Mallet – A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb (0.57 ± 0.23 kg) shall be used.

5.7 Small Tools – Tools and items that may be required are shovels, pails, trowels, wood float, metal float, blunted trowels, straightedge, feeler gauge, scoops, and rules.

5.8 Sampling and Mixing Receptacle – The receptacle shall be a suitable heavy gage metal pan, wheelbarrow, or flat, clean non-absorbent mixing board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

5.9 Cure Box – The cure box shall be capable of maintaining temperatures between 60°F and 80°F. The box shall also be capable of maintaining an environment that does not allow moisture loss from the concrete cylinders.

5.10 Temperature Measuring Device – The temperature measuring device shall be capable of recording the minimum and maximum temperature within a 24 hr period. The thermometer shall be capable of reading from 32°F to 150°F (0°C to 65°C) with an accuracy of 1.8°F (1.0°C).

6. Testing Requirements

Testing for determining the compressive strength at 28 days shall require a set of two specimens made from the same sample.

6.1 Compressive Strength Specimens – Compressive strength specimens shall be cylinders cast and allowed to set in an upright position. The length shall be twice the diameter. The cylinder diameter shall be at least three times the nominal maximum size of the coarse aggregate. The standard specimen shall be the 4 by 8 in (100 by 200 mm) cylinder when the nominal maximum size of the coarse aggregate does not exceed 1 in (25 mm). When the nominal maximum size of the coarse aggregate exceeds 1 in (25 mm) the specimens shall be made with 6 by 12 in (150 by 300 mm) cylinders. Mixing of cylinder sizes for a particular concrete mix design is not permitted on a project. When the nominal maximum size of the coarse aggregate exceeds 2 in (50 mm) the concrete sample shall be treated by wet sieving through a 2 in (50 mm) sieve as described in FOP for WAQTC TM 2. Contact the Materials Laboratory for directions.

Note 2: The nominal maximum size is the smallest standard sieve opening through which the entire amount of aggregate is permitted to pass.

Note 3: When molds in SI units are required and not available, equivalent inch-pound unit size molds should be permitted.
6.2 Flexural Strength Specimens

Refer to WSDOT Test Method T 808.

7. Sampling Concrete

7.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with FOP for WAQTC TM 2 unless an alternative procedure has been approved.

7.2 Record the identification of the sample with respect to the location of the concrete represented and the time of casting.

7.3 Cylinders shall be made using fresh concrete from the same sample as the slump, air content and temperature tests. Material from the slump, air content, and unit weight tests cannot be reused to construct cylinders.

8. Slump, Air Content, and Temperature

As required, perform the following tests prior to making cylinders:

8.1 Slump – FOP for AASHTO T 119

8.2 Air Content – FOP for WAQTC T 152 or FOP for AASHTO T 196

8.3 Temperature – FOP for AASHTO T 309

8.4 Unit Weight – AASHTO T 121

9. Molding Cylinders

9.1 Place of Molding – Mold cylinders on a level, rigid horizontal surface, free of vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

9.2 Casting the Concrete – Place the concrete in the mold using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of concrete from the mixing pan to ensure that it is representative of the batch. Remix the concrete in the mixing pan with a shovel or trowel to prevent segregation during the molding of specimens. Move the scoop, trowel, or shovel around the perimeter of the mold opening when adding concrete so the concrete is uniformly distributed within each layer with a minimum of segregation. Further distribute the concrete by use of the tamping rod prior to the start of consolidation. In placing the final layer, the operator shall attempt to add an amount of concrete that will exactly fill the mold after consolidation. Underfilled molds shall be adjusted with representative concrete during consolidation of the top layer. Overfilled molds shall have excess concrete removed.
9.2.1 Number of Layers – Make specimens in layers as indicated in Table 2 or 3.

<table>
<thead>
<tr>
<th>Cylinders: Diameter, in (mm)</th>
<th>Number of Layers of Approximately Equal Depth</th>
<th>Number of Roddings per Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders: Diameter, in (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (100)</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>6 (150)</td>
<td>3</td>
<td>25</td>
</tr>
</tbody>
</table>

Molding Requirements by Rodding  
*Table 2*

<table>
<thead>
<tr>
<th>Cylinders: Diameter, in (mm)</th>
<th>Number of Layers</th>
<th>Number of Vibrator Insertions per Layer</th>
<th>Approximate Depth of Layer, in (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders: Diameter, in (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (100)</td>
<td>2</td>
<td>1</td>
<td>one-half depth of specimen</td>
</tr>
<tr>
<td>6 (150)</td>
<td>2</td>
<td>2</td>
<td>one-half depth of specimen</td>
</tr>
</tbody>
</table>

Molding Requirements by Vibration  
*Table 3*

9.2.2 Select the proper tamping rod from 5.4 and Table 1 or the proper vibrator from 5.5. If the method of consolidation is rodding, determine molding requirements from Table 2. If the method of consolidation is vibration, determine molding requirements from Table 3.

9.3 Consolidation

9.3.1 Method of Consolidation – Preparation of satisfactory cylinders require different methods of consolidation. The methods of consolidation are rodding and vibration. Base the selection of the method of consolidation on slump, unless the method is stated in the specifications under which the work is being performed. Rod or vibrate concretes with slumps greater than 1 in (25 mm). Vibrate concretes with slumps less than or equal to 1 in (25 mm). Concretes of such low water content that they cannot be properly consolidated by the method herein, or requiring other sizes and shapes of specimens to represent the product or structure, are not covered by this method. Specimens for such concretes shall be made in accordance with the requirements of R 39 with regards to specimen size and shape and method of consolidation.

9.3.2 Rodding – Place the concrete in the mold, in the required number of layers of approximately equal volume. Rod each layer with the rounded end of the rod using the required number of roddings specified in Table 2. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold. For each layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in (25 mm). After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the open hand, mallet, or rod, to close any holes left by rodding and to release any large air bubbles that may have been trapped.
9.3.3 Vibration – Maintain a uniform time period for duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied as soon as the surface of the concrete has become relatively flat and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete. (See Note 4.) Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. Compacting the specimen, insert the vibrator slowly and do not allow it to rest on the bottom or sides of the mold. Slowly withdraw the vibrator so that no large air pockets are left in the specimen. When placing the final layer, avoid overfilling by more than ¼ in (6 mm).

Note 4: Generally, no more than 5 s of vibration should be required for each insertion to adequately consolidate concrete with a slump greater than 3 in (75 mm). Longer times may be required for lower slump concrete, but the vibration time should rarely have to exceed 10 s per insertion.

9.3.3.1 Cylinders – The number of insertions of a vibrator per layer is given in Table 3. When more than one insertion per layer is required, distribute the insertion uniformly within each layer. Allow the vibration to penetrate through the layer being vibrated, and into the layer below, approximately 1 in (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the open hand, mallet, or rod, to close any holes left by rodding and to release any large air bubbles that may have been trapped.

9.3.3.2 Beam – Refer to WSDOT Test Method T 808.

9.4 Finishing – After consolidation, strike off excess concrete from the surface. Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and that has no depressions or projections larger than ⅛ in (3.2 mm). Place lid on cylinder.

10. Curing

10.1 Standard Curing – Standard curing is the curing method used when the specimens are made and cured for the purposes stated in 4.2.

10.1.1 Storage – If specimens cannot be molded at the place where they will receive initial curing, immediately after finishing, move the specimens to an initial curing place for storage. The supporting surface on which specimens are stored shall be level to within ¼ in per ft (20 mm per m). If cylinders in the single-use molds are moved, lift and support the cylinders from the bottom of the molds with a large trowel or similar device. If the top surface is marred during movement to place of initial storage, immediately refinish.
10.1.2 Initial Curing – Immediately after molding and finishing, the specimens shall be stored in a cure box for a period 24 ± 8 hours, unless Contractor provides initial curing information for final set.

For concrete with a specified strength less than 6,000 psi the cure temperature shall be between 60°F and 80°F and for concrete with specified strengths of 6,000 psi and higher the cure temperature shall be between 68°F and 78°F.

A minimum/maximum thermometer shall be mounted on the cure box such that the thermometer reads the internal temperature of the box but is visible from the outside. Keep a record of the minimum and maximum temperatures at intervals of 24 hours during the initial curing time.

Do not exceed the capacity of the cure box. When concrete is placed at more than one location simultaneously, each location must have its own cure box.

Once concrete cylinders are placed in the cure box, the cure box shall not be moved until the cylinders are ready to be transported to the final cure location (See 10.1.3).

10.1.3 Transportation of Specimens to Final Cure Location – Prior to transporting, cure and protect specimens as required in Section 10. Specimens shall not be transported until at least 8 h after final set. (See Note 5) During transporting, protect the specimen with suitable cushioning material to prevent damage from jarring and transport in an upright position. During cold weather, protect the specimens from freezing by transporting in an insulated container. Prevent moisture loss during transportation by use of tight-fitting plastic caps on plastic molds. Transportation time shall not exceed 4 h.

*Note 5:* If a specimen does not attain final set within 32 hours, it is to remain in place until final set is reached. The time of final set shall be provided by the concrete producer. After final set is reached, it can then be transported.

10.1.4 Final Curing

10.1.4.1 Cylinders – Upon completion of initial curing and within 30 minutes after removing the molds, cure specimens with free water maintained on their surfaces at all times at a temperature of 73 ± 3°F (23 ± 2°C) using water storage tanks or moist rooms complying with the requirements of Specification M 201, except when capping with sulfur mortar capping compound and immediately before testing. When capping with sulfur mortar capping compounds, the ends of the cylinder shall be dry enough to preclude the formation of steam or foam pockets under or in cap larger than ¼ in (6 mm) as described in T 231. For a period not to exceed 3 h immediately prior to test, standard curing temperature is not required provided free moisture is maintained on the cylinders and ambient temperature is between 68 to 80°F (20 and 30°C).

10.1.4.2 Beams – Refer to WSDOT Test Method T 808.
10.2 Field Curing – Field curing is the curing method used for the specimens made for the purposes stated in 4.3.

10.2.1 Cylinders – Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified curing treatment. To meet these conditions, specimens made for the purpose of determining when a structure is capable of being put in service shall be removed from the molds at the time of removal of form work.

10.2.2 Beams – Refer to WSDOT Test Method T 808.

11. Transportation of Specimens to Laboratory

See Section 10.1.3

12. Report

12.1 Report the following information to the laboratory that will test the specimens:

12.1.1 Identification number.

12.1.2 Location of concrete represented by the samples.

12.1.3 Date, time, and name of individual molding specimens.

12.1.4 Slump, air content, and concrete temperature, test results and results of any other tests on the fresh concrete and any deviations from referenced standard test methods.

12.1.5 Record all information required using the Materials Testing System (MATS) electronic Concrete Transmittal.

Note: Agencies that do not have access to MATS may use WSDOT Form 350-009 Concrete Cylinder Transmittal.
Performance Exam Checklist

Making and Curing Concrete Test Specimens in the Field
FOP for AASHTO T 23

Participant Name ________________________________  Exam Date __________________

Procedure Element

1. The tester has a copy of the current procedure on hand? ☐ ☐
2. Molds placed on a level, rigid, horizontal surface free of vibration? ☐ ☐
3. Making of specimens begun within 15 minutes of sampling? ☐ ☐
4. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged? ☐ ☐
5. Mold filled in correct number of layers, attempting to exactly fill the mold on the last layer? ☐ ☐
6. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes? ☐ ☐
7. Bottom layer rodded throughout its depth? ☐ ☐
8. Middle and top layers rodded, each throughout their depths, and penetrate into the underlying layer? ☐ ☐
9. Sides of the mold tapped 10-15 times after rodding each layer? ☐ ☐
10. Strike off excess concrete, and finished the surface with a minimum of manipulation? ☐ ☐
11. Specimens covered with non-absorbent, nonreactive cap or plate? ☐ ☐

First Attempt:  Pass ☐  Fail ☐  Second Attempt:  Pass ☐  Fail ☐

Signature of Examiner ________________________________

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Comments:
Sieve Analysis of Fine and Coarse Aggregates

Significance

Sieve analyses are performed on aggregates used in roadway bases and in portland cement and asphalt cement concretes. Sieve analyses reveal the size makeup of aggregate particles – from the largest to the smallest. A gradation curve or chart showing how evenly or unevenly the sizes are distributed between largest and smallest is created in this test. How an aggregate is graded has a major impact on the strength of the base or on the properties and performance of concrete. In portland cement concrete (PCC), for example, gradation influences shrinkage and shrinkage cracking, pumpability, finishability, permeability, and other characteristics.

Scope

This procedure covers sieve analysis in accordance with AASHTO T 27 and materials finer than No. 200 (75 µm) in accordance with AASHTO T 11. The procedure combines the two test methods.

Sieve analyses determines the gradation or distribution of aggregate particles within a given sample in order to determine compliance with design and production standards.

Accurate determination of material smaller than No. 200 (75 µm) cannot be made with AASHTO T 27 alone. If quantifying this material is required, it is recommended that AASHTO T 27 be used in conjunction with AASHTO T 11. Following AASHTO T 11, the sample is washed through a No. 200 (75 µm) sieve. The amount of material passing this sieve is determined by comparing dry sample masses before and after the washing process.

This procedure covers sieve analysis in accordance with AASHTO T 27 and materials finer than No. 200 (75 µm) in accordance with AASHTO T 11. The procedure includes two method choices, A and B.

Note: All Field Operating Procedures (FOPs) referred to in this procedure are WSDOT FOPs.

Apparatus

- Balance or scale – Capacity sufficient for the masses shown in Table 2, accurate to 0.1 percent of the sample mass or better and conform to the requirements of AASHTO M 231.
- Sieves – Meeting the requirements of AASHTO M 92.
- Mechanical sieve shaker – Meeting the requirements of AASHTO T 27.
- Suitable drying equipment (see FOP for AASHTO T 255).
- Containers and utensils – A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.
- Optional Mechanical washing device.
Sample Sieving

In all procedures it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification. The sieves are nested in order of decreasing size from the top to the bottom and the sample, or a portion of the sample, is placed on the top sieve. The sample may also be sieved in increments.

Sieves are shaken in a mechanical shaker for the minimum time determined to provide complete separation for the sieve shaker being used.

Time Evaluation

WSDOT has deleted this section.

Overload Determination

Additional sieves may be necessary to provide other information, such as fineness modulus, or to keep from overloading sieves. The sample may also be sieved in increments.

For sieves with openings smaller than No. 4 (4.75 mm), the mass retained on any sieve shall not exceed 4 g/in² (7 kg/m²) of sieving surface. For sieves with openings No. 4 (4.75 mm) and larger, the mass, in grams shall not exceed the product of 2.5 × (sieve opening in mm) × (effective sieving area). See Table 1.

<table>
<thead>
<tr>
<th>Sieve Size US inches (mm)</th>
<th>8 φ (203)</th>
<th>12 φ (305)</th>
<th>12 × 12 (305 × 305)</th>
<th>14 × 14 (350 × 350)</th>
<th>16 × 24 (372 × 580)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sieving Area m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0285</td>
<td>0.0670</td>
<td>0.0929</td>
<td>0.1225</td>
<td>0.2158</td>
</tr>
<tr>
<td>3½ (90)</td>
<td>*</td>
<td>15.1</td>
<td>20.9</td>
<td>27.6</td>
<td>48.5</td>
</tr>
<tr>
<td>3 (75)</td>
<td>*</td>
<td>12.6</td>
<td>17.4</td>
<td>23.0</td>
<td>40.5</td>
</tr>
<tr>
<td>2½ (63)</td>
<td>*</td>
<td>10.6</td>
<td>14.6</td>
<td>19.3</td>
<td>34.0</td>
</tr>
<tr>
<td>2 (50)</td>
<td>3.6</td>
<td>8.4</td>
<td>11.6</td>
<td>15.3</td>
<td>27.0</td>
</tr>
<tr>
<td>1½ (37.5)</td>
<td>2.7</td>
<td>6.3</td>
<td>8.7</td>
<td>11.5</td>
<td>20.2</td>
</tr>
<tr>
<td>1 (25.0)</td>
<td>1.8</td>
<td>4.2</td>
<td>5.8</td>
<td>7.7</td>
<td>13.5</td>
</tr>
<tr>
<td>¾ (19.0)</td>
<td>1.4</td>
<td>3.2</td>
<td>4.4</td>
<td>5.8</td>
<td>10.2</td>
</tr>
<tr>
<td>¾ (16.0)</td>
<td>1.1</td>
<td>2.7</td>
<td>3.7</td>
<td>4.9</td>
<td>8.6</td>
</tr>
<tr>
<td>½ (12.5)</td>
<td>0.89</td>
<td>2.1</td>
<td>2.9</td>
<td>3.8</td>
<td>6.7</td>
</tr>
<tr>
<td>¾ (9.5)</td>
<td>0.67</td>
<td>1.6</td>
<td>2.2</td>
<td>2.9</td>
<td>5.1</td>
</tr>
<tr>
<td>¼ (6.3)</td>
<td>0.44</td>
<td>1.1</td>
<td>1.5</td>
<td>1.9</td>
<td>3.4</td>
</tr>
<tr>
<td>No. 4 (4.75)</td>
<td>0.33</td>
<td>0.80</td>
<td>1.1</td>
<td>1.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Less than No. 4</td>
<td>0.20</td>
<td>0.47</td>
<td>0.65</td>
<td>0.86</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Sample sizes above are in kilograms to covert: to grams multiple by 1,000. To convert to pounds multiple by 2.2.

Maximum Allowable Mass of Material Retained on a Sieve, kg

Table 1
Sample Preparation

Obtain samples in accordance with the FOP for AASHTO T 2 and reduce to the size shown in Table 2 in accordance with the FOP for AASHTO T 248.

If the gradation sample is obtained from FOP for AASHTO T-308, the Ignition Furnace, proceed to Procedure Method A, Step 2.

<table>
<thead>
<tr>
<th>Nominal Maximum</th>
<th>Minimum Dry Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size* in</td>
<td>(mm)</td>
</tr>
<tr>
<td>US No. 4</td>
<td>(4.75)</td>
</tr>
<tr>
<td>¼</td>
<td>(6.3)</td>
</tr>
<tr>
<td>½</td>
<td>(9.5)</td>
</tr>
<tr>
<td>⅔</td>
<td>(12.5)</td>
</tr>
<tr>
<td>⅞</td>
<td>(16.0)</td>
</tr>
<tr>
<td>¾</td>
<td>(19.0)</td>
</tr>
<tr>
<td>1</td>
<td>(25.0)</td>
</tr>
<tr>
<td>1¼</td>
<td>(31.5)</td>
</tr>
<tr>
<td>1½</td>
<td>(37.5)</td>
</tr>
<tr>
<td>2</td>
<td>(50)</td>
</tr>
<tr>
<td>2¼</td>
<td>(63)</td>
</tr>
<tr>
<td>3</td>
<td>(75)</td>
</tr>
<tr>
<td>3½</td>
<td>(90)</td>
</tr>
</tbody>
</table>

*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.

Sample Sizes for Aggregate Gradation Test

Table 2

Note: For an aggregate specification having a generally unrestrictive 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.

WSDOT Note 1: These sample sizes are standard for aggregate testing but, due to equipment restraints, samples may need to be partitioned into several “subsamples.” See Method A.

Overview

Method A – This method is the preferred method of sieve analysis for HMA aggregate.

- Determine dry mass of original sample
- Wash through a No. 200 (75 µm) sieve
- Determine dry mass of washed sample
- Sieve material

Method B

- Determine dry mass of original sample
- Wash through a No. 200 (75 µm) sieve
- Determine dry mass of washed sample
- Sieve coarse material
- Determine mass of fine material
- Reduce fine portion
- Determine mass of reduced portion
- Sieve fine portion
**Procedure Method A**

1. Dry the sample in accordance with the FOP for AASHTO T 255, and record to the nearest 0.1 percent of total mass or better.

2. When the specification requires that the amount of material finer than No. 200 (75 µm) be determined, do Step 3 through Step 9 – otherwise, skip to Step 10.

   **WSDOT Note 2:** If the applicable specification requires that the amount passing the No. 200 (75 µm) sieve be determined on a portion of the sample passing a sieve smaller than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing that sieve to 0.1 percent of the mass of this portion of the test sample. Use the mass as the original dry mass of the test sample.

3. Nest a sieve, any sieve ranging from a No. 8 (2.36 mm) to a No.16 (1.18 mm) may be used, above the No. 200 (75 µm) sieve.

4. Place the test sample in a container and add sufficient water to cover it.

   WSDOT requires the use of a detergent, dispersing agent, or other wetting solution when washing a sample from FOP for AASHTO T 308, an ignition furnace sample.

   **WSDOT Note 3:** A detergent, dispensing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the No. 200 (75 µm) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

5. Agitate vigorously to ensure complete separation of the material finer than No. 200 (75 µm) from coarser particles and bring the fine material into suspension above the coarser material. When using a mechanical washing device, exercise caution to not degrade the sample.

6. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, being careful not to pour out the coarser particles.

7. Add a second change of water to the sample remaining in the container, agitate, and repeat Step 6. Repeat the operation until the wash water is reasonably clear.

8. Return all material retained on the nested sieves to the container by flushing into the washed sample.

   **WSDOT Note 4:** A suction device may be used to extract excess water from the washed sample container. Caution will be used to avoid removing any material greater than the No. 200.

9. Dry the washed aggregate in accordance with the FOP for AASHTO T 255, and then cool prior to sieving. Record the cooled dry mass.

10. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom and place the sample, or a portion of the sample, on the top sieve.

11. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.
12. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g.

**WSDOT Note 5:** Use coarse wire brushes to clean the No. 40 (425 µm) and larger sieves, and soft bristle brushes for smaller sieves.

**Calculations**

The total mass of material after sieving should be verified with the mass before sieving. If performing T 11 with T 27 this would be the dry mass after wash. If performing just T 27 this would be the original dry mass. When the masses before and after sieving differ by more than 0.3 percent do not use the results for acceptance purposes. When performing the gradation from HMA using T 308, the masses before and after sieving shall not differ by more than 0.2 percent.

Calculate the total percentages passing, individual or cumulative percentages retained, or percentages in various size fractions to the nearest 0.1 percent by dividing the masses for Method A, or adjusted masses for Methods B and C, on the individual sieves by the total mass of the initial dry sample. If the same test sample was first tested by T 11, use the total dry sample mass prior to washing in T 11 as the basis for calculating all percentages. Report percent passing as indicated in the “Report” section at the end of this FOP.

Percent Retained:

\[
IPR = \frac{IMR}{M} \times 100 \quad \text{or} \quad CPR = \frac{CMR}{M} \times 100
\]

Where:
- \(IPR\) = Individual Percent Retained
- \(CPR\) = Cumulative Percent Retained
- \(M\) = Total Dry Sample mass before washing
- \(IMR\) = Individual Mass Retained OR Adjusted Individual mass from Methods B or C
- \(CMR\) = Cumulative Mass Retained OR Adjusted Individual mass from Methods B or C

OR

Percent Passing (Calculated):

\[
PP = PPP - IPR \quad \text{or} \quad PP = 100 - CPR
\]

Where:
- \(PP\) = Percent Passing
- \(PPP\) = Previous Percent Passing

Calculate cumulative percent retained on and passing each sieve on the basis of the dry mass of total sample, before washing. This will include any material finer than No. 200 (75 µm) that was washed out.

Divide the cumulative masses, or the corrected masses, on the individual sieves by the total mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the “Report” section at the end of this FOP.
Example

Dry mass of total sample, before washing: 3214.0 g
Dry mass of sample, after washing out the No. 200 (75 μm) minus: 3085.1 g

For the ½ sieve:

Cumulative Mass retained on ½" sieve = 161.0 g

Cumulative % retained = \( \frac{161.0}{3214.0} \times 100 = 5.0\% \) retained

% passing = 100 - 5.0 = 95% passing ½" sieve

<table>
<thead>
<tr>
<th>Sieve Size in (mm)</th>
<th>Cumulative Mass Retained g</th>
<th>Cumulative Percent Retained</th>
<th>Reported Percent Passing*</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾ (19.0)</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>½ (12.5)</td>
<td>161.0</td>
<td>5.0</td>
<td>95</td>
</tr>
<tr>
<td>⅜ (9.5)</td>
<td>642.0</td>
<td>20.0</td>
<td>80</td>
</tr>
<tr>
<td>No. 4 (4.75)</td>
<td>1118.3</td>
<td>34.8</td>
<td>65</td>
</tr>
<tr>
<td>**No. 6 (3.35)</td>
<td>1515.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 10 (2.0)</td>
<td>1914.7</td>
<td>59.6</td>
<td>40</td>
</tr>
<tr>
<td>No. 40 (0.425)</td>
<td>2631.6</td>
<td>81.9</td>
<td>18</td>
</tr>
<tr>
<td>No. 80 (0.210)</td>
<td>2862.7</td>
<td>89.1</td>
<td>11</td>
</tr>
<tr>
<td>No. 200 (0.075)</td>
<td>3051.1</td>
<td>94.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Pan</td>
<td>3086.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Report No. 200 (75 μm) sieve to 0.1 percent. Report all others to 1 percent.

**Intermediate sieve used to prevent overloading the U. S. No. 10 sieve.

Gradation on All Screens

Test Validation: 3086.4 – 3085.1/3085.1 x 100 = 0.04% which is within the 0.3 percent requirement and the results can be used for acceptance purposes.
**Procedure Method B**

1. Perform steps 1 thru 9 from the Procedure Method A then continue as follows:

2. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the No. 4 (4.75 mm) with a pan at the bottom to retain the minus No. 4 (4.75 mm). (See Table 1.)

3. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.

4. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in the openings of the sieve are cleaned out and included in the mass retained. (See Note 5)

5. Determine the mass retained on each sieve to the nearest 0.1 percent of the total mass or better.

6. Determine the mass of the material in the pan (minus No. 4 (4.75 mm)).

7. Reduce the minus No. 4 (4.75 mm) using a mechanical splitter in accordance with the FOP for AASHTO T 248 to produce a sample with a mass of 500 g minimum. Determine and record the mass of the minus No. 4 (4.75 mm) split.

8. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the No. 200 (75 µm) with a pan at the bottom to retain the minus No. 200 (75 µm).

9. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.

10. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in the openings of the sieve are cleaned out and included in the mass retained. (See Note 5)

**Calculations**

Compute the “Adjusted Cumulative Mass Retained” of the size increment of the original sample as follows when determining “Cumulative Mass Retained”:

Divide the cumulative masses, or the corrected masses, on the individual sieves by the total mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the “Report” section at the end of this FOP.

When material passing the No. 4 (4.75 mm) sieve is split and only a portion of that is tested, the proportionate share of the amount passing the No. 200 (75 µm) sieve must be added to the sample mass to obtain a corrected test mass. This corrected test mass is used to calculate the gradation of the material passing the No. 4 (4.75 mm) sieve.
C = \left( \frac{M_1}{M_2} \times B \right) + D

Where:

\begin{align*}
C &= \text{Total cumulative mass retained of the size increment based on a total sample} \\
M_1 &= \text{Mass of fraction finer than No. 4 (4.75 mm) sieve in total sample} \\
M_2 &= \text{Mass of reduced portion of material finer than No. 4 (4.75 mm) sieve actually sieved} \\
B &= \text{Cumulative mass of the size increment in the reduced portion sieved} \\
D &= \text{Cumulative mass of plus No. 4 (4.75 mm) portion of sample}
\end{align*}

Example:

Dry mass of total sample, before washing: 3214.0 g

Dry mass of sample, after washing out the No. 200 (75 µm) minus: 3085.1 g

Gradation on Coarse Screens

<table>
<thead>
<tr>
<th>Sieve Size in (mm)</th>
<th>Cumulative Mass Retained (g)</th>
<th>Cumulative Percent Retained</th>
<th>Reported Percent Passing*</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾ (19.0)</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>½ (12.5)</td>
<td>161.0</td>
<td>5.0</td>
<td>95</td>
</tr>
<tr>
<td>⅜ (9.50)</td>
<td>642.0</td>
<td>20.0</td>
<td>80</td>
</tr>
<tr>
<td>No. 4 (4.75)</td>
<td>1118.3</td>
<td>34.8</td>
<td>65</td>
</tr>
</tbody>
</table>

Pan = 1968.0

Test Validation: 1118.3 + 1968.0 – 3085.1/3085.1 x 100 = 0.04% which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

The actual mass of material passing the No. 4 (4.75 mm) sieve and retained in the pan is 1968.0 g. This is M_1.

The pan (1968.0 grams) was reduced in accordance with the FOP for AASHTO T 248, so that at least 500 g are available. In this case, the mass determined was 512.8 g. This is M_2.

Gradation on Fine Screens

<table>
<thead>
<tr>
<th>Sieve Size in (mm)</th>
<th>Cumulative Mass Retained (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4 (4.75)</td>
<td>0</td>
</tr>
<tr>
<td>No. 10 (2.00)</td>
<td>207.5</td>
</tr>
<tr>
<td>No. 40 (0.425)</td>
<td>394.3</td>
</tr>
<tr>
<td>No. 80 (0.210)</td>
<td>454.5</td>
</tr>
<tr>
<td>No. 200 (0.075)</td>
<td>503.6</td>
</tr>
<tr>
<td>Pan</td>
<td>512.8</td>
</tr>
</tbody>
</table>

Test Validation: 512.8 - 512.8/512.8 = 0.0 % which is within the 0.3 percent requirement and the results can be used for acceptance purposes.
For the No. 10 sieve:

\[
\begin{align*}
M_1 &= 1968.0 \text{ g} \\
M_2 &= 512.8 \text{ g} \\
B &= 207.5 \text{ g} \\
D &= 1118.3 \text{ g} \\
C &= \frac{M_1}{M_2} \times B + D = \frac{1968.0 \text{ g}}{512.8 \text{ g}} \times 207.5 \text{ g} + 1118.3 \text{ g} = 1914.7 \text{ g} \\
\% \text{ retained} &= \frac{1914.7 \text{ g}}{3214.0 \text{ g}} = 59.6\% \\
\% \text{ passing} &= 100 - 59.6 = 40.4\%, \text{ reported as 40%}
\end{align*}
\]

### Final Gradation on All Screens

<table>
<thead>
<tr>
<th>Sieve Size in (mm)</th>
<th>Cumulative Mass Retained g</th>
<th>Adjusted Cumulative Mass Retained g</th>
<th>Cum. Percent Retained</th>
<th>Reported Percent Passing*</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾ (19.0)</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
<td>95</td>
</tr>
<tr>
<td>½ (12.5)</td>
<td>161.1</td>
<td>161.1</td>
<td>5.0</td>
<td>80</td>
</tr>
<tr>
<td>⅜ (9.5)</td>
<td>642.5</td>
<td>642.5</td>
<td>20.0</td>
<td>65</td>
</tr>
<tr>
<td>No. 4 (4.75)</td>
<td>1118.3</td>
<td>1118.3</td>
<td>34.8</td>
<td>65</td>
</tr>
<tr>
<td>No. 10 (2.0)</td>
<td>207.5 \times 3.838 + 1118.3</td>
<td>1914.7</td>
<td>59.6</td>
<td>40</td>
</tr>
<tr>
<td>No. 40 (0.425)</td>
<td>394.3 \times 3.838 + 1118.3</td>
<td>2631.6</td>
<td>81.6</td>
<td>18</td>
</tr>
<tr>
<td>No. 80 (0.210)</td>
<td>454.5 \times 3.838 + 1118.3</td>
<td>2862.7</td>
<td>89.1</td>
<td>11</td>
</tr>
<tr>
<td>No. 200 (0.075)</td>
<td>503.6 \times 3.838 + 1118.3</td>
<td>3051.1</td>
<td>94.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Pan</td>
<td>512.8 \times 3.838 + 1118.3</td>
<td>3086.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Report No. 200 (75 µm) sieve to 0.1 percent. Report all others to 1 percent.

### Alternative Method B

As an alternate method to account for the fact that only a portion of the minus No. 4 (4.75 mm) material was sieved, multiply the fine screen “Percent Passing” values by the percent passing the No. 4 (4.75 mm) sieve obtained in the coarse screen procedure, 65 percent in this case.

The mass retained in the pan must be corrected to include the proper percent of No. 200 (.075 mm) minus material washed out.

Divide the cumulative masses, or the corrected masses, on the individual sieves by the corrected pan mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the “Report” section at the end of this FOP.

Dry mass of total sample, before washing: 3214.0 g
Dry mass of sample, after washing out the No. 200 (75 µm) minus: 3085.1 g
Amount of No. 200 (75 µm) minus washed out: 3214.0 g – 3085.1 g = 128.9 g
Gradation on Coarse Screens

Pan = 1968.0

Test validation: \[
\frac{1118.3 + 1968.0 - 3085.1}{3085.1} \times 100 = 0.04\%
\]

which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

The actual mass of material passing the No. 4 (4.75 mm) sieve and retained in the pan is 1968.0 g. This is \(M_3\).

The pan (1968.0 grams) was reduced in accordance with the FOP for AASHTO T 248, so that at least 500 g are available. In this case, the mass determined was 512.8 g. This is \(M_4\).

\[
\text{Corrected pan mass} = M_4 + \frac{(M_4)(C_1)}{M_3}
\]

Where:
- \(M_4\) = Mass retained in the pan from the split of the No. 4 (4.75 mm) minus
- \(M_3\) = Mass of the No. 4 (4.75 mm) minus of entire sample, not including No. 200 (.075 mm) minus washed out
- \(C_1\) = Mass of No. 200 (.075 mm) minus washed out

The corrected pan mass is the mass used to calculate the percent retained for the fine grading.
Example:

\[ M_4 = 512.8g \]
\[ M_3 = 1968.0g \]
\[ C_1 = 128.9g \]

Corrected pan mass = \[ \frac{512.8g(128.9g)}{1968.0g} = 546.4g \]

For the No. 10 sieve:

Mass of No. 10 sieve = 207.5g
Corrected Pan Mass = 546.4g
Cumulative % retained = \[ \frac{207.5g}{546.4g} = 38\% \]

% passing = 100-38.0 = 62.0%

Adjusted % passing No. 10 = % passing No. 10 \times \% No. 4 = 62.0 \times 0.65 = 40%

<table>
<thead>
<tr>
<th>Sieve Size in (mm)</th>
<th>Adjustment</th>
<th>Reported Percent Passing*</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾ (19.0)</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>½ (12.5)</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>⅜ (9.5)</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>No. 4 (4.75)</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>No. 10 (2.00)</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>No. 40 (0.425)</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>No. 80 (0.210)</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>No. 200 (0.075)</td>
<td>5.1</td>
<td></td>
</tr>
</tbody>
</table>

*Report No. 200 (75 µm) sieve to 0.1 percent. Report all others to 1 percent

**Final Gradation on All Screens**
Sample Calculation for Fineness Modulus

Fineness Modulus (FM) is used in determining the degree of uniformity of aggregate gradation in PCC mix designs. It is an empirical number relating to the fineness of the aggregate. The higher the FM, the coarser the aggregate. Values of 2.40 to 3.00 are common for FA in PCC.

The FM is the sum of the percentages retained on specified sieves, for PCC fine aggregate they are: No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (0.60 mm), No. 50 (0.30 mm), and No. 100 0.15 mm) divided by 100 gives the FM.

The following example is for WSDOT Class 2 Sand:

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Size</th>
<th>% Passing</th>
<th>% Retained</th>
<th>% Retained on Specified Sieves</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>4.75 mm</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. 8</td>
<td>2.36 mm</td>
<td>87</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>No. 16</td>
<td>1.18 mm</td>
<td>69</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>No. 30</td>
<td>0.60 mm</td>
<td>44</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>No. 50</td>
<td>0.30 mm</td>
<td>18</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>No. 100</td>
<td>0.15 mm</td>
<td>4</td>
<td>96</td>
<td>96</td>
</tr>
</tbody>
</table>

= 278

**FM = 2.78**

Report

Results shall be reported on standard forms approved for use by the agency. Depending on the agency, this may include:

- Cumulative mass retained on each sieve.
- Cumulative percent retained on each sieve.
- Percent passing and retained on each sieve shall be reported to the nearest 1 percent except for the percent passing the U.S. No. 200 (75 µm) sieve, which shall be reported to the nearest 0.1 percent.
- FM to the nearest 0.01 percent for WSDOT Class 2 Sand.

Report the results using one or more of the following:

- Materials Testing System (MATS)
- WSDOT Form 422-020, 422-020A, or 422-020B
- Form approved in writing by the State Materials Engineer
Performance Exam Checklist
WAQTC FOP for AASHTO T 27/T 11
Sieve Analysis of Fine And Coarse Aggregates

Participant Name ________________________________ Exam Date __________________

<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, and if required, has the current calibration/verification tags present?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Minimum sample mass meets requirement of Table 1 or from FOP for AASHTO T 308?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Test sample dried to a constant mass by FOP for AASHTO T 255?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Test sample cooled and mass determined to nearest 0.1 percent of mass?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Sample placed in container and covered with water? (If specification requires that the amount of material finer than the No. 200 sieve is to be determined.)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Dispersing Agent used for HMA?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Contents of the container vigorously agitated?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Complete separation of coarse and fine particles achieved?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. Wash water poured through required nested sieves?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>11. Operation continued until wash water is reasonably clear?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12. Material retained on sieves returned to washed sample?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13. Washed aggregate dried to a constant mass by FOP for AASHTO T 255?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>14. Washed aggregate cooled and mass determined to nearest 0.1 percent of mass?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>15. Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>16. Material sieved in verified mechanical shaker for minimum of 10 minutes or for the minimum verified time whichever is longer?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>17. Mass of residue on each sieve determined to 0.1 percent of mass?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>18. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent, or 0.2 percent for HMA (per FOP for AASHTO T 308)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>19. Percentages calculated to the nearest 0.1 percent and reported to the nearest whole number, except No. 200 - reported to the nearest 0.1 percent?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>20. Percentage calculations based on original dry sample mass?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>21. Calculations performed properly? If material passing No. 4 sieve is split and only a portion is tested, calculation as noted in FOP performed properly?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

First Attempt: Pass ☐ Fail ☐ Second Attempt: Pass ☐ Fail ☐

Signature of Examiner ____________________________________________
Comments:
AASHTO T 99
Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop

AASHTO T 99, Method A, has been adopted by WSDOT.
Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop
### Tester Qualification Practical Exam Checklist

**Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop**

**FOP for AASHTO T 99**

- Participant Name ________________________________
- Exam Date ____________________

<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, and if required, has the current calibration/verification tags present?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

### Sample Preparation

1. If damp, sample dried in air or drying apparatus, not exceeding 140°F (60°C)?
   - Yes ☐ No ☐
2. Sample pulverized and adequate amount sieved over the No. 4 (4.75 mm) sieve?
   - Yes ☐ No ☐
3. Material retained on the sieve discarded?
   - Yes ☐ No ☐
4. Sample passing the sieve has appropriate mass?
   - Yes ☐ No ☐

### Procedure

1. Sample mixed with water to approximately 4 percent below expected optimum moisture content?
   - Yes ☐ No ☐
2. Layer of soil placed in mold with collar attached?
   - Yes ☐ No ☐
3. Mold placed on rigid and stable foundation?
   - Yes ☐ No ☐
4. Lightly tamp soil in mold?
   - Yes ☐ No ☐
5. Soil compacted with 25 blows?
   - Yes ☐ No ☐
6. Scrape sides of mold and evenly distributed on top of the layer?
   - Yes ☐ No ☐
7. Soil placed and compacted in three equal layers?
   - Yes ☐ No ☐
8. No more than ½ inch of soil above the top of the bottom portion of the mold?
   - Yes ☐ No ☐
9. Collar removed and soil trimmed to top of mold with straightedge?
   - Yes ☐ No ☐
10. Mass of mold and contents determined to appropriate precision?
    - Yes ☐ No ☐
11. Wet mass of specimen multiplied by mold factor to obtain wet density?
    - Yes ☐ No ☐
12. Soil removed from mold using sample extruder when applicable?
    - Yes ☐ No ☐
13. Soil sliced vertically through center?
    - Yes ☐ No ☐
14. Moisture sample removed from the entire face of one of the cut faces?
    - Yes ☐ No ☐
15. Sample weighed immediately and mass recorded?
    - Yes ☐ No ☐
16. Moisture sample mass per Table 1? ☐ ☐
17. Sample dried and water content determined according to AASHTO T 255 or T 265? ☐ ☐
18. Remainder of material from mold broken up to about passing sieve size and added to remainder of original test sample? ☐ ☐
19. Water added to increase moisture content in approximately 2 percent increments? ☐ ☐
20. Steps 2 through 15 repeated for each increment of water added? ☐ ☐
21. If soil is plastic (clay types):
   a. Sample mixed with water varying moisture content by approximately 2 percent, bracketing the optimum moisture content? ☐ ☐
   b. Samples placed in covered containers and allowed to stand for at least 12 hours ☐ ☐
22. Process continued until wet density either decreases or stabilizes? ☐ ☐
23. Water content and dry density calculated for each sample? ☐ ☐
24. All calculations performed correctly? ☐ ☐

First Attempt: Pass ☐ Fail ☐ Second Attempt: Pass ☐ Fail ☐

Signature of Examiner ________________________________

Comments:
WSDOT FOP for WAQTC T 152
Air Content of Freshly Mixed Concrete by the Pressure Method

Significance

Concrete is not a solid, but rather a solid with void spaces. The voids may contain gas such as air, or liquid, such as water. All concrete contains air voids, and the amount can be increased by the addition of an air entraining agent to the mix. When such an agent is used, the size of the voids drastically decreases and the number of voids greatly increases, providing a much greater dispersal of voids.

Air entrainment is necessary in concrete that will be saturated and exposed to cycles of freezing and thawing, and to deicing chemicals. The microscopic entrained air voids provide a site for relief of internal pressure that develops as water freezes and thaws inside the concrete. Without the proper entrained-air content, normal concrete that is saturated and is exposed to cycles of freezing and thawing can fail prematurely by scaling, spalling, or cracking.

Care must be taken, however, not to have too much entrained air. As the air content increases, there will be a corresponding reduction in the strength and other desirable properties of the concrete. Typically, this strength reduction will be on the order of 3 to 5 percent for each 1 percent of air content. A concrete mix design proportioned for 5 percent air, for example, will be approximately 15 to 25 percent lower in strength if the air content were to double.

Scope

This procedure covers determination of the air content in freshly mixed portland cement concrete containing dense aggregates in accordance with AASHTO T 152 (Type B meter). It is not for use with lightweight or highly porous aggregates. This procedure includes calibration of the "Type B" air meter gauge, and two methods for calibrating the gauge are presented. Concrete containing aggregate that would be retained on the 1½ in (37.5 mm) sieve must be wet sieved. Sieve a sufficient amount of the sample over the 1½ in (37.5 mm) sieve in accordance with the FOP for WAQTC TM 2.

Apparatus

- Air meter – Type B, as described in AASHTO T 152.
- Balance or scale – Accurate to 0.3 percent of the test load at any point within the range of use (for Method 1 calibration only).
- Verified external or internal calibration vessel of known volume (usually 5% ± of the volume of the meter base).
- Tamping rod – ⅝ in (16 mm) diameter and approximately 24 in (600 mm) long, having a hemispherical tip. (Hemispherical means half a sphere; the tip is rounded like half of a ball.)
- Vibrator – 7000 vibrations per minute, 0.75 to 1.50 in (19 to 38 mm) in diameter, at least 3 in (75 mm) longer than the section being vibrated for use with low slump concrete.
- Scoop.
- Container for water – rubber syringe (may also be a squeeze bottle).

---

1This FOP is based on WAQTC T 152 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
• Strike-off bar – Approximately 12 in × ¾ in × ⅛ in (300 mm × 22 mm × 3 mm).

• Strike-off Plate – A flat rectangular metal plate at least ¼ in (6 mm) thick or a glass or acrylic plate at least ½ in (12 mm) thick, with a length and width at least 2 in (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of ¼ in (1.5 mm).

Note 1: Use either the strike-off bar or strike-off plate; both are not required. Unit weight requires the use of a strike off plate.

• Mallet – With a rubber or rawhide head having a mass of 1.25 ±0.5 lb (0.57 ± 0.23 kg).

Calibration of Air Meter Gauge

Note 2: There are two methods for calibrating the air meter, mass or volume.

1. Screw the short piece of straight tubing into the threaded petcock hole on the underside of the cover. Determine the mass of the dry, empty air meter base and cover assembly (Mass Method only).

2. Fill the base nearly full with water.

3. Clamp the cover on the base with the tube extending down into the water. Mark the petcock with the tube attached for future reference.

4. Add water through the petcock having the pipe extension below until all air is forced out the other petcock. Rock the meter slightly until all air is expelled through the petcock.

5. Wipe off the air meter base and cover assembly, and determine the mass of the filled unit (Mass Method only).

6. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.

7. Close both petcocks and immediately open the main air valve exhausting air into the base. Wait a few seconds until the meter needle stabilizes. The gauge should now read 0 percent. If two or more tests show a consistent variation from 0 percent in the result, change the initial pressure line to compensate for the variation, and use the newly established initial pressure line for subsequent tests.

8. Determine which petcock has the straight tube attached to it. Attach the curved tube to external portion of the same petcock.

9. Pump air into the air chamber. Open the petcock with the curved tube attached to it. Open the main air valve for short periods of time until 5 percent of water by mass or volume has been removed from the air meter. Remember to open both petcocks to release the pressure in the base and drain the water in the curved tube back into the base. To determine the mass of the water to be removed, subtract the mass found in Step 1 from the mass found in Step 5. Multiply this value by 0.05. This is the mass of the water that must be removed. To remove 5 percent by volume, remove water until the external calibrating vessel is level full.
**Note 3:** Many air meters are supplied with a calibration vessel(s) of known volume that are used for this purpose. Calibration vessels must be protected from damage that would change their volume.

If an external or internal calibration vessel is used, confirm what percentage volume it represents for the air meter being used. Vessels commonly represent 5 percent volume, but they are for specific size meters. This should be confirmed by mass.

10. Remove the curved tube. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.

11. Close both petcocks and immediately open the main air valve exhausting air into the base. Wait a few seconds until the meter needle is stabilized. The gauge should now read 5.0 ± 0.2 percent. If the gauge is outside that range, the meter needs adjustment. (Consult the Region Materials Lab) The adjustment could involve adjusting the starting point so that the gauge reads 5.0 ± 0.2 percent when this calibration is run, or could involve moving the gauge needle to read 5.0 percent. Any adjustment should comply with the manufacturer’s recommendations.

**Note 4:** Calibration shall be performed per agency standards, prior to field use, and weekly during construction use. Record the date of the calibration, the calibration results, and the name of the technician performing the calibration in the log book kept with each air meter.

**WSDOT Note:** Air meter calibration standard for WSDOT:

- **Region Laboratory** – Required to calibrate air meter yearly
- **Project Office** – Required to calibrate air meter as follows:

  1. First Time Use Calibration: Calibrate air meter prior to first time use in the field each construction season or when the air meter has not been used for more than a month during the construction season.

  2. Construction Use Calibration: After “First Time Use Calibration,” calibrate the air meter once a week when used during construction.

12. When the gauge hand reads correctly at 5.0 percent, additional water may be withdrawn in the same manner to check the results at other values such as 10 percent or 15 percent.

**Note 5:** Remove the extension tubing from threaded petcock hole in the underside of the cover before starting the test procedure.

An internal calibration vessel of known volume, usually 5% of the volume of the bucket, may be employed as a quick method to verify the calibration of the air meter during construction use. To employ this vessel proceed as follows:

13. Fill the base nearly full with water and place the internal calibration vessel into the base. Place the cover back on the base and gently add water through the petcock until all the air has been expelled. Do not disturb the meter to such an extent as to knock the calibration vessel from an upright position. Do not install either of the threaded tubes into the petcock when using the calibration vessels.
14. Pump up the air pressure to a little beyond the predetermined initial pressure indicated in the calibration record log book. Wait a few seconds for the compressed air to cool and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.

15. Close both petcocks and immediately open the main air valve exhausting air into the base. Wait a few seconds and gently tap the back of the gauge until the meter needle stabilizes. The gauge should now read 5.0 ± 0.2 percent or ± 0.2 percent of the volume indicated in the calibration vessel. If the gauge is outside of that range follow step 1 through step 12 of the calibration procedure to re-calibrate the air meter. If further adjustment is required consult the Region Materials Lab.

16. If necessary, additional vessels may be placed into the base to verify the calibration of the air meter at 10 percent volume and 15 percent volume or the sum of the volumes indicated on the individual calibration vessels.

17. Record the date that the calibration of the air meter was verified in the calibration log book.

18. Gently release the air pressure in the base by opening one of the petcocks then remove and drain any water from within the calibration vessel and store it in a safe location. The air meter is now ready for use.

**Procedure Selection**

There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 3 in (75 mm), consolidation is by rodding. When the slump is 1 to 3 in (25 to 75 mm), internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency in order to obtain consistent, comparable results. For slumps less than 1 in (25 mm), consolidate the sample by internal vibration.

**Procedure – Rodding**

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If any aggregate larger than 1½ in (37.5 mm) is present, the larger aggregate must be removed. Sieve a sufficient amount of the sample over the 1½ in (37.5 mm), sieve in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2. Contact the Materials Laboratory for directions.

   **Note 7:** Testing shall begin within five minutes of obtaining the sample.

2. Dampen the inside of the air meter base and place on a firm, level surface.

3. Fill the base approximately ⅓ full with concrete.

4. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.

5. Tap the sides of the base smartly 10 to 15 times with the mallet to close voids and release trapped air.

6. Add the second layer, filling the base about ⅔ full.

7. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in (25 mm) into the bottom layer.
8. Tap the sides of the base 10 to 15 times with the mallet.

9. Add the final layer, slightly overfilling the base.

10. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in (25 mm) into the second layer.

11. Tap the sides of the base smartly 10 to 15 times with the mallet.

   **Note 8:** The base should be slightly over full, about ⅛ in (3 mm) above the rim. If there is a great excess of concrete, remove a portion with the trowel or scoop. If the base is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.

12. Strike off the surface of the concrete and finish it smoothly with a sawing action of the strike-off bar or plate, using great care to leave the base just full. The surface should be smooth and free of voids, as much as possible.

13. Clean the top flange of the base to ensure a proper seal.

14. Moisten the inside of the cover and check to see that both petcocks are open and the main air valve is closed.

15. Clamp the cover on the base.

16. Inject water into one petcock until water emerges from the second petcock. **(Note: Water is injected into only one petcock during the entire procedure)**

17. Rock the air meter gently until no air bubbles appear to be coming out of the second petcock. The petcock expelling water should be higher than the petcock where water is being injected. Return the air meter to a level position and verify that water is present in both petcocks.

18. Close the air bleeder valve and pump air into the air chamber until the needle goes past the initial pressure line. Allow a few seconds for the compressed air to cool.

19. Tap the gauge gently with one hand while slowly opening the air bleeder valve until the needle rests on the initial pressure line. Close the air bleeder valve.

20. Close both petcocks.

21. Open the main air chamber valve.

22. Tap the sides of the base smartly with the mallet.

23. With the main air chamber valve open, lightly tap the gauge to settle the needle, and then read the air content to the nearest 0.1 percent, while the air chamber valve is open.

24. Release or close the main air chamber valve.

25. Open both petcocks to release pressure, remove the concrete, and thoroughly clean the cover and base with clean water.

26. Open the main air valve to relieve the pressure in the air chamber.
Procedure – Internal Vibration

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If any aggregate larger than 1½ in (37.5 mm) is present, the larger aggregate must be removed. Sieve a sufficient amount of the sample over the 1½ in (37.5 mm) sieve in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2. Contact the Materials Laboratory for directions.

2. Dampen the inside of the air meter bowl and place on a firm level surface.

3. Fill the base approximately half full.

4. Insert the vibrator at three different points. Do not let the vibrator touch the bottom or sides of the base.
   
   **Note 9:** Remove the vibrator slowly, so that no air pockets are left in the material.
   
   **Note 10:** Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

5. Fill the base a bit over full.

6. Insert the vibrator as in Step 3. Do not let the vibrator touch the sides of the base, and penetrate the first layer approximately 1 in (25 mm).

7. Return to Step 12 of the rodding procedure and continue.

Report

Results shall be reported on standard forms approved for use by the agency. Record the percent of air to the nearest 0.1 percent.

Report results on concrete delivery ticket, (i.e. Certificate of Compliance).

The name of the tester who performed the field acceptance test is required on concrete delivery tickets containing test results.
Performance Exam Checklist
WSDOT FOP for WAQTC T 152
Air Content of Freshly Mixed Concrete by the Pressure Method

Participant Name ________________________________  Exam Date ________________

<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, and if required,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>has the current calibration/verification tags present?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Container filled in three equal layers, slightly overfilling the last layer?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Each layer rodded throughout its depth 25 times with hemispherical end of rod,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uniformly distributing strokes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Bottom layer rodded throughout its depth, without forcibly striking the bottom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of the container?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Middle and top layers rodded, each throughout their depths and penetrating 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in (25 mm) into the underlying layer?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Sides of the container tapped 10 to 15 times with the mallet after rodding each</td>
<td></td>
<td></td>
</tr>
<tr>
<td>layer?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Concrete struck off level with top of container using the bar and rim cleaned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>off?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Using a Type B Meter

<table>
<thead>
<tr>
<th>Using a Type B Meter</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Both petcocks open?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Air valve closed between air chamber and the bowl?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Inside of cover cleaned and moistened before clamping to base?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Water injected through petcock until it flows out the other petcock?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Water injection into the petcock continued while tipping the meter to insure all</td>
<td></td>
<td></td>
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<tr>
<td>air is expelled?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Air pumped up to initial pressure line?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. A few seconds allowed for the compressed air to stabilize?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Gauge adjusted to the initial pressure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Both petcocks closed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Air valve opened between chamber and bowl?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Sides of bowl tapped with the mallet?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Using a Type B Meter

20. With air valve open, Air percentage read after lightly tapping the gauge to stabilize the hand? [ ] Yes [ ] No

21. Air valve closed and then petcocks opened to release pressure before removing the cover? [ ] Yes [ ] No

22. Air content recorded to 0.1 percent? [ ] Yes [ ] No

23. All calculations performed correctly? [ ] Yes [ ] No

First Attempt: Pass [ ] Fail [ ]

Second Attempt: Pass [ ] Fail [ ]

Signature of Examiner ________________________________

Comments:
1. Scope

1.1 This method of test covers the determination of bulk specific gravity of specimens of compacted hot mix asphalt.

1.2 Definition:

1.3 Bulk specific gravity (of solids) – The ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The form of the expression shall be:

\[
\text{Bulk specific gravity } \frac{x}{y} ^\circ C
\]

where:

\[
x = \text{temperature of the material, and} \\
y = \text{temperature of the water}
\]

1.4 The bulk specific gravity of the compacted hot mix asphalt may be used in calculating the unit mass of the mixture.

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

Note: Method A shall be used for laboratory compacted specimens, and field specimens compacted using gyratory compactor.

Method C shall be used for asphalt pavement cores.

2. Referenced Documents

2.1 AASHTO Standards

M 231 – Weighing Devices Used in the Testing of Materials

T 275 – Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens

3. Test Specimens

3.1 Test specimens may be either laboratory-molded HMA mixtures or from HMA pavements. The mixtures may be surface, wearing, leveling or base course materials.

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

\[This Test Method is based on AASHTO T 166-10.\]
3.3 Specimens shall be taken from pavements with core drill, diamond or carborundum saw, or by other suitable means.

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

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

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

Method A

4. Apparatus

4.1 Weighing Device – The weighing device shall have sufficient capacity, be readable to 0.1 percent of the specimen mass, or better, and conform to the requirements of AASHTO M 231. The weighing device shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of scale pan of the weighing device.

4.2 Suspension Apparatus – The wire suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the specimen during weighing. Care should be exercised to ensure no trapped air bubbles exist under the specimen.

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

4.4 Thermometric Device – Liquid-in-glass thermometers or other suitable thermometric device, accurate to 1°F (0.5°C).

5. Procedure

5.1 Dry the specimen to a constant mass (Note 1). Cool the specimen to room temperature for a minimum of 15 hours and a maximum of 24 hours at 77 ± 9°F (25 ± 5°C) per SOP 731 and record the dry mass as A. Immerse each specimen in water at 77 ± 1.8°F (25 ± 1°C) for 4 ± 1 minute and record the immersed mass as C. Remove the specimen from the water, damp dry the specimen by blotting with a damp towel as quickly as possible (blotting not to exceed 10s), and determine the surface-dry mass as, B. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen (Note 1). Each specimen shall be immersed and weighed individually.

*Note 1:* Constant mass shall be defined as the mass at which further drying at 125 ± 5°F (52 ± 3°C) does not alter the mass by more than 0.05 percent. Specimen saturated with water shall initially be dried overnight at 125 ± 5°F (52 ± 3°C) and then weighed at 2-hour drying intervals. Recently molded laboratory specimens which have not been exposed to moisture do not require drying.
Note 2: If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass (C) can be taken, then the surface-dry mass (B), and finally the dry mass (A).

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

6. Transportation of Warm Specimens

It is not recommended that specimens be transported before they have cooled to room temperature. If however, a specimen must be transported prior to reaching room temperature the following guidelines should be used to transport the specimen:

a. Place the specimen in a container that has a flat bottom surface to prevent deformation of the bottom of the specimen.

Note: A flat piece of wood, rigid aluminum or reinforced cardboard may be used to create a flat surface in an HMA sample box.

b. Make sure the specimen is not deformed in handling.

c. Do not stack anything on top of the specimen container.

d. Transport the container in the cab of the vehicle or secure it in the vehicle bed to prevent movement during transit.

7. Calculation

7.1 Calculate the bulk specific gravity of the specimens as follows (round and report the value to the nearest three decimal places):

\[
\text{Bulk Specific Gravity} = \frac{A}{B - C}
\]

Where:

- \( A \) = Mass in grams of specimen in air
- \( B \) = Mass in grams of surface-dry specimen in air
- \( C \) = Mass in grams of specimen in water.

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

\[
\text{Percent Water Absorbed by Volume} = \frac{B - A}{B - C} \times 100
\]

7.3 If the percent water absorbed by the specimen in Section 5.1 exceeds 2 percent, use T 275 (Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens) to determine the bulk specific gravity.
Method B

WSDOT does not use Method B and has removed this section from the procedure.

Method C (Rapid Test)

8. Procedure

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

8.2 The testing procedure shall be the same as given in Sections 5 except for the sequence of operations. The dry mass (A) of the specimen is determined last as follows.

*Note 4:* A microwave oven can be used to speed up the process by initially heating the sample so that it can be broken into small pieces prior to placing it into the drying oven.

8.3 Place the specimen in a large flat bottom drying pan of known mass. Place the pan and specimen in a 325 ± 25º F (164 ± 14ºC) oven. Leave the specimen in the oven until it can be easily separated to the point where the particles of the fine aggregate-asphalt portion are not larger than ¼ in (6.4 mm). Place the separated specimen in the 325º F (164ºC) oven and dry to a constant mass. The test sample shall be initially dried for a minimum of 90 minutes, and its mass determined. Then, at 30 minute intervals until constant mass is achieved.

*Note:* If samples are placed in the oven overnight for a minimum of 6 hours at 230°F, then the 90 minute weighting is not necessary.

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

9. Calculations

9.1 Calculate the bulk specific gravity per Sections 7.1.

10. Report

10.1 The report shall include the following:

10.1.1 Bulk Specific Gravity reported to the nearest thousandth (0.001).

10.1.2 Absorption reported to the nearest hundredth (0.01).

11. Precision

11.1 See AASHTO T 166 for precision statement.
Performance Exam Checklist
WSDOT FOP for AASHTO T 166
Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface Dry Specimens

Participant Name ________________________________  Exam Date __________________

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?  ☐  ☐

Method A (For use with laboratory compacted specimens.)
1. Compacted specimen cooled to room temperature (refer to WSDOT SOP 731, Procedure #5g), 77 ± 9º F, and record the dry mass.  ☐  ☐
2. Immerse each specimen in water at 77 ± 1.8°F for 3 to 5 minutes and record the immersed mass to the nearest 0.1 gram?  ☐  ☐
3. Remove sample from water, surface dry with damp towel and weigh the specimen in air at 77 ± 9º F to the nearest 0.1 gram?  ☐  ☐
4. Calculated the bulk specific gravity of the specimens per Section 7.1?  ☐  ☐

Method C (For use with pavement cores and chunks.)
1. Immerse specimen in water at 77 ± 1.8º F for 3 to 5 minutes and record the immersed weight to the nearest 0.1 gram?  ☐  ☐
2. Remove sample from water, surface dry by blotting with damp towel and immediately weigh specimen in air at 77 ± 9º F to the nearest 0.1 gram?  ☐  ☐
3. Place specimen in container (noting the empty container weight), then into an oven set at 325 ± 25º F until sample can be broken into small pieces?  ☐  ☐
4. Return container to oven until it has reached a constant weight?  ☐  ☐
5. Remove container and sample from oven and allow to cool to room temperature, 77 ± 9º F?  ☐  ☐
6. Weigh pan with sample and record to nearest 0.1 gram, deducting known weight of pan to arrive at oven-dried sample weight?  ☐  ☐
7. Calculated the bulk specific gravity of the specimen per Section 6.1?  ☐  ☐

First Attempt:  Pass ☐  Fail ☐  Second Attempt:  Pass ☐  Fail ☐

Signature of Examiner ________________________________
Comments:
WSDOT FOP for AASHTO T 176¹

Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

1. Scope
   1.1 This test is intended to serve as a rapid field test to show the relative proportions of fine dust or claylike material in soils or graded aggregates.
   1.2 The following applies to all specified limits in this standard: For the purpose 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 E 29, Using Significant Digits in Test Data to Determine Conformance with Specifications.
   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. Reference Document
   2.1 AASHTO Standards
      M 92 – Wire-Cloth Sieves for Testing Purposes
      M 231 – Weighing Devices Used in the Testing of Materials
   2.2 ASTM Standards
      E 29 – Using Significant Digits in Test Data to Determine Conformance With Specifications
   2.3 WSDOT Standards
      T2 – FOP for Sampling of Aggregates
      T 248 – FOP for Reducing Samples of Aggregate to Testing Size

3. Significance and Use
   3.1 This test method is used to determine the proportion of detrimental fines in the portion passing the 4.75-mm (No. 4) sieve of soils or graded aggregates

4. Apparatus
   4.1 A graduated plastic cylinder, rubber stopper, irrigator tube, weighted foot assembly, and siphon assembly, all conforming to their respective specifications and dimensions shown in Figure 1. Fit the siphon assembly to a 1 gal (4L) bottle of working calcium chloride solution (see Section 4.9) placed on a shelf 36 ± 1 in (915 ± 25 mm) above the work surface. In lieu of the specified 1 gal (4L) bottle, a glass or plastic vat having a larger capacity may be used provided the liquid level of the working solution is maintained between 36 and 46 inches (915 and 1170 mm) above the work surface.

¹This FOP is based on AASHTO T 176-08 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
**FIGURE 1 Sand Equivalent Apparatus (continued)**

Note: all dimensions are shown in mm unless otherwise indicated.
T 176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

<table>
<thead>
<tr>
<th>Assembly</th>
<th>No. Reg.</th>
<th>Description</th>
<th>Stock size</th>
<th>Material</th>
<th>Heat Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>Siphon Assembly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Siphon Tube</td>
<td>6.4 dia. × 400</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Siphon Hose</td>
<td>4.6 I.D. × 1220</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Blow Hose</td>
<td>4.8 I.D. × 50.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Blow Tube</td>
<td>6.4 dia × 50.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Two-Hole Stopper</td>
<td>No. 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Irrigator Tube</td>
<td>6.4 O.D. 0.89 Wall × 500 Stainless Steel tube, Type 316</td>
<td>Pinchcock, Day, BKH No. 21730 or Equiv.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Clamp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>Graduate Assembly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Tube</td>
<td>38.1 Od. × 430</td>
<td>Trans. Acrylic Plastic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Base</td>
<td>12.7 × 102 × 102</td>
<td>Trans. Acrylic Plastic</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>Weighted Foot Assembly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Sand Reading Indicator</td>
<td>6.4 dia. × 14.9</td>
<td>Nylon 101 type 66 Annealed</td>
<td></td>
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<tr>
<td></td>
<td>11</td>
<td>Rod</td>
<td>6.4 dia. × 438.2</td>
<td>Brass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Weight</td>
<td>50.8 dia. × 52.78</td>
<td>C.R. SH.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Roll Pin</td>
<td>0.16 dia. × 12.7</td>
<td>Steel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Foot</td>
<td>0.16 dia. × 13.7</td>
<td>Brass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Solid Stopper</td>
<td>No. 7</td>
<td>Rubber</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. "C" Mounted Foot Assembly to weigh 1000 ± 5 g.
2. Graduations of graduate to be 2.54 mm apart and every tenth mark to be numerically designated as shown. Every fifth line should be approximately 9.5 mm long. All other lines should be approximately 5.5 mm long. Depth to be 0.4 mm. Width to be 0.8 mm across the top.
3. Accuracy of scale to be ± 0.25 mm. Error at any point on scale to be ± 0.75 mm of true distance to zero.
4. Glass or stainless steel may be substituted as a material type for the copper siphon and blow tubing.

Sand Equivalent Apparatus

![Figure 1](image_url)

**Note 1:** An older model of weighted foot assembly has a guide cap that fits over the upper end of the graduated cylinder and centers the rod in the cylinder, and the foot of the assembly has a conical upper surface and three centering screws to center it loosely in the cylinder. The older model does not have the same reading indicator affixed to the rod (Figure 1), but a slot in the centering screws of the weighted foot is used to indicate the sand reading. Apparatus with the sand reading indicator (Figure 2) is preferred for testing clayey materials.
Apparatus

Figure 2

4.2 A tinned measure, having a capacity of 3 oz (85 ± 5 mL), approximately 2.25 in (57 mm) in diameter.

4.3 A balance with sufficient capacity, readable to 0.1 percent of the sample mass, or better, and conforming to the requirements of M 231.

4.4 A wide-mouth funnel approximately 4 in (100 mm) in diameter at the mouth.

4.5 A clock or watch reading in minutes and seconds.

4.6 A mechanical shaker having a throw of 8.00 ± 0.04 in (203.2 ± 1.0 mm) and operating at 175 ± 2 cycles per minute (2.92 ± 0.03 Hz) (Note 2). Prior to use, fasten the mechanical sand equivalent shaker securely to a firm and level mount.

Note 2: The mechanical shaker shall be used when performing referee sand equivalent determinations.

4.7 A manually operated shaker capable of producing an oscillating motion at the rate of 100 complete cycles in 45 ± 5 seconds, with a hand-assisted half stroke length of 5.0 ± 0.2 in (127 ± 5 mm). The shaker shall be fastened securely to a firm and level mount by bolts or clamps.

4.8 Stock Solution – Shall meet the requirements of AASHTO T 176.

4.9 Working calcium chloride solution: Prepare the working calcium chloride by diluting one measuring tin full 3 oz. (85 ± 5 mL), or from a graduated cylinder of the stock calcium chloride solution to 1 gal (3.8 L) with water (finished product will equal 1 gallon). Use distilled or demineralized water for the normal preparation of the working solution. Record the date made on the gallon bottle. Working solutions more than 30 days old shall be discarded.

4.10 A straightedge or spatula, suitable for striking off the excess soil from the tin measure.

4.11 A thermostatically controlled drying oven.

4.12 Quartering or splitting cloth, approximately 2 ft square, nonabsorbent material such as plastic or oil cloth.

4.13 A No. 4 (4.75-mm) sieve conforming to the requirements of M 92.

4.14 Optional Handle for Irrigation Tube – A 25 mm diameter wooden dowel to aid in pushing the irrigation tube into firm materials. See Figure 1, Assembly B.
5. Temperature Control

5.1 The temperature of the working solution should be maintained at 67-77°F (22 ± 3°C) during the performance of this test. If field conditions preclude the maintenance of the temperature range, frequent reference samples should be submitted to a laboratory where proper temperature control is possible. It is also possible to establish temperature correction curves for each material being tested where proper temperature control is not possible. However, no general correction curve should be utilized for several materials even within a narrow range of sand equivalent values. Samples which meet the minimums and equivalent requirement at a working solution temperature below the recommended range need not be subject to reference testing.

6. Sampling

6.1 Obtain a sample of the material to be tested in accordance with WSDOT FOP for AASHTO T 2.

6.2 Reduce the sample in accordance with WSDOT FOP for AASHTO T 248.

6.3 Sieve the sample over No. 4 (4.75 mm) sieve using a mechanical shaker. (Make sure all large clumps of material are broken up before placing sieves in the mechanical shaker)

6.3.1 Shake the sample in the mechanical shaker for a minimum of 10 minutes or for the minimum verified shaking time whichever is greater.

6.3.2 The material shall be at Saturated Surface Dry (Saturated Surface Dry is defined herein as no visible free moisture, but material may still appear damp) or drier prior to sieving.

6.3.2.1 If the “as received” sample requires drying to achieve the required SSD or dryer condition prior to initial sieving, either air dry it or dry it in a thermostatically controlled oven at a temperature not to exceed 350°F.

6.3.3 Sieves may be nested above the No. 4 (4.75 mm) to prevent overloading, as defined in Table 1 of WSDOT FOP for WAQTC/AASHTO T 27/T 11, or the sample may be sieved in increments.

6.3.4 Break up any remaining clumps of fine-grained material and clean the fines from particles retained above the No. 4 (4.75 mm) sieve. Pass this material over the No. 4 (4.75 mm) sieve and include the material that passes in the total material passing the No. 4 (4.75 mm) sieve.

6.4 Split or quarter the material passing the No. 4 (4.75 mm), in accordance with WSDOT FOP for AASHTO T 248, to yield approximately 1,000 g to 1,500 g of material. Use extreme care to obtain a truly representative portion of the original sample (Note 3).

Note 3: Experiments show that as the amount of material being reduced by splitting or quartering is decreased, the accuracy of providing representative portions is decreased. It is imperative that the sample be split or quartered carefully. When it appears necessary, dampen the material before splitting or quartering, to avoid segregation or loss of fines.
7. Sample Preparation

7.1 Prepare two test samples by the following method:

7.1.1 The sample must be in the proper moisture condition to achieve reliable results. Condition is determined by tightly squeezing a small portion of the thoroughly mixed sample in the palm of the hand. If the cast that is formed permits careful handling without breaking, the correct moisture range has been obtained. If the material is too dry, the cast will crumble and it will be necessary to add water and remix and retest until the material forms a cast. If the material shows any free water it is too wet to test and must be drained and air-dried, mixing it frequently to insure uniformity. This overly wet material will form a good cast when checked initially, so the drying process should continue until a squeeze check on the drying material gives a cast which is more fragile and delicate to handle than the original.

Place the sample on the splitting cloth and mix by alternately lifting each corner of the cloth and pulling it over the sample toward the diagonally opposite corner, causing the material to be rolled. When the material appears homogeneous, finish the mixing with the sample in a pile near the center of the cloth.

7.1.2 Fill the 3 oz (85 mL) tin measure by pushing it through the base of the pile while exerting pressure with the hand against the pile on the side opposite the measure. As the tin is moved through the pile, hold enough pressure with the hand to cause the material to fill the tin to overflowing. Press firmly with the palm of the hand, compacting the material and allowing the maximum amount to be placed in the tin. Strike off the tin measure level full with a spatula or straightedge. For the second determination, remix the sample and fill the tin again.

Dry the test sample in an oven to constant mass in accordance with FOP for AASHTO T 255. The oven temperature shall not exceed 350°F (177°C). Cool to room temperature before testing. It is acceptable to place the test sample in a larger container to aid drying.

8. Procedure

8.1 Start the siphon by forcing air into the top of the solution bottle through the bent copper, glass, or stainless steel blow tube while the pinch clamp is open. The apparatus is now ready for use.

8.2 Siphon 4.0 ± 0.1 in (101.6 ± 2.5 mm) of working calcium chloride solution into the plastic cylinder. Pour the prepared test sample into the plastic cylinder using the funnel to avoid spillage (see Figure 3). Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the sample.
8.3 Allow the wetted sample to stand undisturbed for 10 ± 1 minute. At the end of the 10-minute soaking period, stopper the cylinder, then loosen the material from the bottom by partially inverting the cylinder and shaking it simultaneously.

8.4 After loosening the material from the bottom of the cylinder, shake the cylinder and contents by any one of the following methods:

8.4.1 Mechanical Shaker Method – Place the stoppered cylinder in the mechanical sand equivalent shaker, set the timer, and allow the machine to shake the cylinder and contents for 45 ± 1 second.

8.4.2 Manual Shaker Method – Secure the stoppered cylinder in the three spring clamps on the carriage of the hand-operated sand equivalent shaker and reset the stroke counter to zero. Stand directly in front of the shaker and force the pointer to the stroke limit marker painted on the backboard by applying an abrupt horizontal thrust to the upper portion of the right hand spring steel strap. Then remove the hand from the strap and allow the spring action of the straps to move the carriage and cylinder in the opposite direction without assistance or hindrance. Apply enough force to the right hand spring steel strap during the thrust portion of each stroke to move the pointer to the stroke limit marker by pushing against the strap with the ends of the fingers to maintain a smooth oscillating motion. The center of the stroke limit marker is positioned to provide the proper stroke length and its width provides the maximum allowable limits of variation. The proper shaking action is accomplished only when the tip of the point reverses direction within the marker limits. Proper shaking action can best be maintained by using only the forearm and wrist action to propel the shaker. Continue the shaking action for 100 strokes.
8.5 Following the shaking operation, set the cylinder upright on the work table and remove the stopper.

8.6 Irrigation Procedure – Insert the irrigator tube in the cylinder and rinse material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while the working solution flows from the irrigator tip. This flushes the fine material into suspension above the coarser sand particles. (See Figure 5.) Continue to apply the stabbing and twisting action while flushing the fines upward until the cylinder is filled to the 15 in (381 mm) mark. Then raise the irrigator slowly without shutting off the flow so that the liquid level is maintained at about 15 in (381 mm) while the irrigator is being withdrawn. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 15 in (381 mm). Final level as judged by the bottom of the meniscus shall be between the top two gradations on the tube but shall not be above the 15 in (381 mm) level.

8.7 Allow the cylinder and contents to stand undisturbed for 20 minutes ± 15 seconds. Start the timing immediately after withdrawing the irrigator tube.

8.8 At the end of the 20 minute sedimentation period, read and record the level of the top of the clay suspension. This is referred to as the “clay reading.” If no clear line of demarcation has formed at the end of the specified 20 minute sedimentation period, allow the sample to stand undisturbed until a clear reading can be obtained, then immediately read and record the level of the top of the clay suspension and the total sedimentation time. If the total sedimentation time exceeds 30 minutes, it will be rejected.

8.9 After the clay reading has been taken, the “sand reading” shall be obtained by one of the following methods:

8.9.1 When using the weighted foot assembly having the sand indicator on the rod of the assembly, place the assembly over the cylinder and gently lower the assembly toward the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered. As the weighted foot comes to rest on the sand,
tip the assembly toward the graduations on the cylinder until the indicator touches the inside of the cylinder. Subtract 10 in (254 mm) from the level indicated by the extreme top edge of the indicator and record this value as the “sand reading.” (See Figure 6.)

8.9.2 If an older model weighted foot assembly having centering screws is used, keep one of the centering screws in contact with the cylinder wall near the graduations so that it can be seen at all times while the assembly is being lowered. When the weighted foot has come to rest on the sand, read the level of the centering screw and record this value as the “sand reading.”

8.10 If clay or sand readings fall between 0.1 in (2.5 mm) graduations, record the level of the higher graduation as the reading. For example, a clay reading of 7.95 would be recorded as 8.0, and a sand reading of 3.22 would be recorded as 3.3.

9. Calculations

9.1 Calculate the sand equivalent (SE) to the nearest 0.1 using the following formula:

\[
SE = \frac{\text{Sand Reading} \times 100}{\text{Clay Reading}}
\]

9.2 If the calculated sand equivalent is not a whole number, report it as the next higher whole number, as in the following example:

\[
SE = \frac{3.3 \times 100}{8} = 41.25
\]

which is reported as 42.

9.3 Average the whole number values determined as described above. If the average of these values is not a whole number, raise it to the next higher whole number, as in the following example:

Calculated SE values: 41.2, 40.9

After raising each to the next higher whole number, they become: 42, 41.
The average of these values is then determined:

\[
\frac{42 + 41}{2} = 41.5
\]

which is reported as 42.

If the two results from the same SE sample vary by more than 8 points, the test shall be invalid and a new test completed.

9.3.1 Since the average value is not a whole number, it is raised to the next higher whole number and the reported averages and equivalent value is reported as 42.

10. Report

10.1 Report the results using one or more of the following:

- Materials Testing System (MATS)
- WSDOT Form 350-161, 422-022, 422-022A, or 422-022B
- Form approved in writing by the State Materials Engineer
Performance Exam Checklist

*Plastic Fines in Graded Aggregates and Soils by the Use of the Sand Equivalent Test FOP for AASHTO T 176*

Participant Name ________________________________  Exam Date ____________________

**Procedure Element**

**Preparation**  

<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, and if required, has the current calibration/verification tags present?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Sample passed through No. 4 (4.75 mm) sieve?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Material in clods broken up and re-screened?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. No fines lost?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Temperature of working solution 72 ± 5°F (22 ± 3°C)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Working calcium chloride solution 36 ± 1 in (915 mm ± 25 mm) above the work surface?</td>
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<td>☐</td>
</tr>
<tr>
<td>8. 4 ± 0.1 in (101.6 ± 2.5 mm) working calcium chloride solution siphoned into cylinder?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Working solution dated?</td>
<td>☐</td>
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</table>

**Sample Preparation**

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. If necessary, sample sprayed with water to prevent loss of fines?</td>
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<td>☐</td>
</tr>
<tr>
<td>2. Material checked for moisture condition by tightly squeezing small portion in palm of hand and forming a cast?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Sample at proper water content?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>a. If too dry, (cast crumbles easily), water added and re-mixed?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>b. If too wet (shows free water), sample drained, air dried and mixed frequently?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Sample placed on splitting cloth and mixed by alternately lifting each corner of the cloth and pulling it over the sample toward diagonally opposite corner, causing material to be rolled?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Is material thoroughly mixed?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. When material appears to be homogeneous, mixing finished with sample in a pile near center of cloth?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Fill the 85 mL tin by pushing through base of pile with other hand on opposite side of pile?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Material fills tin to overflowing?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Material compacted into tin with palm of hand?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. Tin struck off level full with spatula or straightedge?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>11. Test sample dried to a constant mass?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12. Sample cooled to room temperature</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Procedure
1. Prepared sample funneled into cylinder with no loss of fines?  
2. Bottom of cylinder tapped sharply on heel of hand several times to release air bubbles?  
3. Wetted sample allowed to stand undisturbed for 10 min ± 1 min?  
4. Cylinder stoppered and material loosened from bottom by shaking?  
5. Properly performed shaking method?  
   Mechanical Shaker Method  
   Manual Shaker Method  
6. Following shaking, cylinder set vertical on work surface and stopper removed?  
7. Irrigator tube inserted in cylinder and material rinsed from cylinder walls as irrigator is lowered?  
8. Irrigator tube forced through material to bottom of cylinder by gently stabbing and twisting action?  
9. Stabbing and twisting motion applied until cylinder filled to 15 in (381 mm) mark?  
10. Liquid raised and maintained at 15 in (381 mm) mark while irrigator is being withdrawn?  
11. No clear solution at top of column?  
12. Contents let stand 20 minutes ± 15 seconds?  
13. Timing started immediately after withdrawal of irrigator?  
14. No vibration or disturbance of the sample?  
15. Readings taken at 20 minutes or up to 30 minutes, when a definite line appears?  
16. Weighted foot assembly lowered into cylinder without hitting mouth of cylinder?  
17. Calculations made to 0.1 and reported to the next higher whole number?  
18. SE is based on the average results of two samples?  
19. If the two SE values vary by more than 8 points additional tests run?  
20. All calculations performed correctly?  

First Attempt:  Pass ☐  Fail ☐  Second Attempt:  Pass ☐  Fail ☐

Signature of Examiner  ________________________________

Comments:
AASHTO T 180

Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18 in (457 mm) Drop

AASHTO T 180, Method D, has been adopted by WSDOT.
Performance Exam Checklist

Tester Qualification Practical Exam Checklist

*Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18 in (457 mm) Drop*

**FOP for AASHTO T 180**

Participant Name _______________________________  Exam Date __________________

<table>
<thead>
<tr>
<th>Procedure Element</th>
<th>Yes</th>
<th>No</th>
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</thead>
<tbody>
<tr>
<td>1. The tester has a copy of the current procedure on hand?</td>
<td>☐</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>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Sample Preparation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. If damp, sample dried in air or drying apparatus, not exceeding 140°F (60°C)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Sample pulverized and adequate amount sieved over the ¾ inch (19 mm) sieve?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Material retained on the sieve discarded?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Sample passing the sieve has appropriate mass?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Sample mixed with water to approximately 4 percent below expected optimum moisture content?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Layer of soil placed in mold with collar attached?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Mold placed on rigid and stable foundation?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Lightly tamp soil in mold?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Soil compacted with 56 blows?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Scrape sides of mold and evenly distributed on top of the layer?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Soil placed and compacted in five equal layers?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. No more than ½ inch of soil above the top of the bottom portion of the mold?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Collar removed and soil trimmed to top of mold with the straightedge?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. Mass of mold and contents determined to appropriate precision?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>11. Wet mass of specimen multiplied by appropriate factor to obtain wet density (.075 lbs/ft³)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12. Soil removed from mold using sample extruder?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13. Soil sliced vertically through center?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
### T 180  
**Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18 in (457 mm) Drop**

**Procedure Element**

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. Moisture sample removed from one cut face and moist mass determined immediately?</td>
<td>☐  ☐</td>
<td></td>
</tr>
<tr>
<td>15. Moisture sample mass of at least 500 g?</td>
<td>☐  ☐</td>
<td></td>
</tr>
<tr>
<td>16. Sample dried and water content determined according to AASHTO T 255 or T 265?</td>
<td>☐  ☐</td>
<td></td>
</tr>
<tr>
<td>17. Remainder of material from mold broken up to about passing sieve size and added to remainder of original test sample?</td>
<td>☐  ☐</td>
<td></td>
</tr>
<tr>
<td>18. Water added to increase moisture content in approximately 2 percent increments?</td>
<td>☐  ☐</td>
<td></td>
</tr>
<tr>
<td>19. Steps 2 through 15 repeated for each increment of water added?</td>
<td>☐  ☐</td>
<td></td>
</tr>
</tbody>
</table>
| 20. If soil is plastic (clay types):
  a. Sample mixed with water varying moisture content by approximately 2 percent, bracketing the optimum moisture content? | ☐  ☐ |
  b. Samples placed in covered containers and allowed to stand for at least 12 hours? | ☐  ☐ |
| 21. Process continued until wet density either decreases or stabilizes? | ☐  ☐ |
| 22. Water content and dry density calculated for each sample? | ☐  ☐ |
| 23. Dry density plotted on vertical axis, moisture content plotted on horizontal axis, and points connected with a smooth curve? | ☐  ☐ |
| 24. Water content at peak of curve recorded as optimum water content and recorded to nearest 1 percent? | ☐  ☐ |
| 25. Dry density at optimum water content reported as maximum density, to nearest 1 lb/ft³ (10 kg/m³)? | ☐  ☐ |
| 26. All calculations performed correctly? | ☐  ☐ |

First Attempt:  Pass ☐  Fail ☐  
Second Attempt:  Pass ☐  Fail ☐

Signature of Examiner  ________________________________

Comments:
1. Scope

1.1 This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted hot-mix asphalt paving mixtures at 77°F (25°C).

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

• M 231, Weighing Devices Used in the Testing of Materials
• PP 57, Establishing Requirements for and Performing Equipment Standardizations and Checks

2.2 ASTM Standards

D 4311 – Practice for Determining Asphalt Volume Correction to a Base Temperature
C 670 – Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3 Other Standards

T 168 – WAQTC FOP for AASHTO for Sampling Bituminous Paving Mixtures
T 712 – WSDOT Standard Method of Reducing Hot Mix Asphalt Paving Mixtures

3. Terminology

3.1 Definitions

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

3.1.2 Residual pressure, as employed by this test method. The pressure in a vacuum vessel when vacuum is applied.

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

This FOP is based on AASHTO T 209 (2011) and has been modified per WSDOT standards. To view the redline modifications, contact WSDOT Quality Systems Manager at 360-709-5412.
4. Summary of Test Method

4.1 A weighed sample of HMA paving mixture in the loose condition is placed in a tared vacuum vessel. Sufficient water is added to completely submerge the sample. Vacuum is applied for 15 ± 2 min to gradually reduce the residual pressure in the vacuum vessel. At the end of the vacuum period, the vacuum is gradually released. The volume of the sample of paving mixture is obtained by (Section 9.5.2) filling the vacuum container level full of water and weighing in air. At the time of weighing the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 77°F (25°C) is calculated. If the temperature employed is different from 77°F (25°C), an appropriate correction is applied.

5. Significance and Use

5.1 The theoretical maximum specific gravities and densities of hot-mix asphalt paving mixtures are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt binder materials.

5.1.1 These properties are used to calculate percent air voids in compacted HMA.

5.1.2 These properties provide target values for the compaction of HMA.

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

6. Apparatus

6.1 Follow the procedures for performing equipment standardizations, standardization, and checks found in PP 57.

6.2 Vacuum Container:

6.2.1 The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of No. 200 (75-μm) mesh to minimize the loss of fine material.

6.2.2 The capacity of the vacuum container should be between 2000 and 10,000-mL and depends on the minimum sample size requirements given in Section 7.2. Avoid using a small sample in a large container.

6.2.3 Vacuum Bowl – Either a metal or plastic bowl with a diameter of approximately 7.1 to 10.2 in (180 to 260 mm) and a bowl height of at least 6.3 in (160 mm) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

6.2.4 Vacuum Flask for Weighing in Air Only – A thick-walled volumetric glass flask and a rubber stopper with a connection for the vacuum line.

6.2.5 Pycnometer for Weighing in Air Only – A glass, metal or plastic pycnometer.
6.3 Balance, conforming to the requirements of AASHTO M 231, Class G 2. The balance shall be standardized at least every 12 months.

6.3.1 For the mass determination-in-water method (Section 9.5.1), the balance shall be equipped with a suitable apparatus and holder to permit determining the mass of the sample while suspended below the balance. The wire suspending the holder shall be the smallest practical size to minimize any possible effects of a variable immersed length.

6.4 Vacuum pump or water aspirator, capable of evacuating air from the vacuum container to a residual pressure of 30 mm Hg (4.0 kPa) or less.

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

6.5 Absolute pressure gauge or vacuum gauge, used for annual standardization and traceable to NIST (mandatory) to be connected directly to the vacuum vessel and to be capable of measuring residual pressure down to 30 mm Hg (4.0 kPa), or less (preferably to zero). It is to be connected at the end of the vacuum line using an appropriate tube and either a “T” connector on the top of the vessel or by using a separate opening (from the vacuum line) in the top of the vessel to attach the hose.

Note 2: A residual pressure of 30 mm Hg (4.0 kPa) absolute pressure is approximately equivalent to 730 mm Hg (97 kPa) reading on vacuum gauge at sea level.

6.6 Bleeder Valve, attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum vessel.

6.7 Thermometric Device (Mass Determination in Air), liquid-in-glass thermometers or other suitable thermometric device, accurate to 1ºF (0.5ºC). The thermometric device shall be standardized at the test temperature at least every 12 months.

6.8 Water Bath, a water bath that can be maintained at a constant temperature between 73 and 82.9ºF (22.8 and 28.3°C).

6.9 Protective Gloves, used when handling glass equipment under vacuum.

6.10 Mallet, with a rubber or rawhide head.

7. Sampling

7.1 Obtain the sample in accordance with WAQTC FOP for AASHTO T 168 and WSDOT T 712.

7.2 The size of the sample shall conform to the requirements in Table 1. Samples larger than the capacity of the container may be tested a portion at a time.
8. **Standardization of Flasks, Bowls, and Pycnometers**

   This section has been deleted by WSDOT and replaced with the following:

   The volumetric flask or metal vacuum pycnometer will be standardized periodically in conformance with established verification procedures or per AASHTO T 209. Standardization shall be done at 77°F.

9. **Sample Preparation**

   9.1 Separate the particles of the HMA sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than ¼ in (6.3 mm). If an HMA sample is not sufficiently soft to be separated manually, place it in a flat pan, and warm it in an oven until it can be separated as described.

   9.2 WSDOT has deleted this section

   9.3 Cool the sample to room temperature, and place it in a tared and standardized flask, bowl, or pycnometer. Weigh and designate the net mass of the sample as A. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

**Test Method A – Mechanical Agitation**

10. **Apparatus**

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

      10.1.1 Mechanical Shaker-Shaker for removing air from asphalt mix.

11. **Procedure**

   11.1 Remove air trapped in the sample by applying gradually increased vacuum until the absolute pressure gauge or vacuum gauge reads 30 mm HG or less (4.0 kPa or less). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents using the mechanical device during the vacuum period. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum. To aid in releasing the trapped air from the metal vacuum pycnometer, tap the sides of the metal vacuum pycnometer 3 to 5 times with the mallet at approximately two minutes intervals.

   **Note:** The release of entrapped air may be facilitated by the addition of a few drops of suitable wetting agent.
11.2 At the end of the vacuum period, release the vacuum within 10 to 15 seconds. Start the 9 to 11 minute time, as described in 13.2, immediately upon starting the release of vacuum. Proceed to 13.2.

**Test Method B – Manual Agitation**

12. Procedure

12.1 Remove air trapped in the sample by applying gradually increased vacuum until the absolute pressure gauge or vacuum gauge reads 30 mm HG or less (4.0 kPa or less). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents during the vacuum period by vigorous shaking at intervals of about 2 minutes. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

12.2 At the end of the vacuum period, release the vacuum within 10 to 15 seconds. Start the 9 to 11 minute time, as described in 13.2 immediately upon starting the release of vacuum. Proceed to 13.2.

13. Mass Determination

13.1 WSDOT has deleted this section.

13.2 Mass Determination in Air – Fill the flask or any one of the pycnometers with water and adjust the contents to a temperature of 77 ± 2°F (25 ± 1°C) in a constant temperature water bath. Determine the mass of the container (and contents), completely filled, 9 to 11 minutes after starting Section 11.2 or 12.1. Designate this mass as E. Accurate filling may be ensured by the use of a glass cover plate.

In lieu of a constant temperature water bath described in 13.2, determine the temperature of the water within the flask or metal vacuum pycnometer and determine the appropriate density correction factor “R” using Table 2.

14. Calculation

14.1 Calculate the theoretical maximum specific gravity of the sample at 77°F (25°C) as follows:

14.1.1 WSDOT has deleted this section

14.1.2 Weighing Mass Determination in Air:

\[
\text{Theoretical Maximum Specific Gravity} = \frac{A}{A + D - E}
\]

Where:

\[
A = \text{Mass of oven-dry sample in air, g}
\]
\[
D = \text{Mass of container filled with water at 77°F (25°C), g}
\]
\[
E = \text{Mass of container filled with sample and water at 77°F (25°C), g}
\]
14.1.3 If the test temperature differs significantly from 77°F (25°C), correct for thermal effects as follows:

WSDOT has removed the AASHTO calculation and replaced it with the following calculations:

a. Determination using temperature correction:

\[
\text{Theoretical Maximum Gravity} = \frac{A}{A + D - E} \times R
\]

Where:
- \( A \) = Mass of oven-dry sample in air, g;
- \( D \) = Mass of container filled with water at 77°F (25°C), g; and
- \( E \) = Mass of container filled with sample and water at 77°F (25°C), g.
- \( R \) = Factor from Table 2 to correct density of water from the test temperature to 77°F (25°C).

Note: The flask standardization is done at 77 ± 0.4°F (25 ± 0.2°C).

<table>
<thead>
<tr>
<th>C°</th>
<th>F°</th>
<th>&quot;R&quot;</th>
<th>C°</th>
<th>F°</th>
<th>&quot;R&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.8</td>
<td>73.0</td>
<td>1.00054</td>
<td>25.2</td>
<td>77.4</td>
<td>0.99995</td>
</tr>
<tr>
<td>23.0</td>
<td>73.4</td>
<td>1.00050</td>
<td>25.4</td>
<td>77.7</td>
<td>0.99990</td>
</tr>
<tr>
<td>23.2</td>
<td>73.8</td>
<td>1.00045</td>
<td>25.6</td>
<td>78.1</td>
<td>0.99984</td>
</tr>
<tr>
<td>23.3</td>
<td>73.9</td>
<td>1.00042</td>
<td>25.8</td>
<td>78.4</td>
<td>0.99979</td>
</tr>
<tr>
<td>23.4</td>
<td>74.1</td>
<td>1.00040</td>
<td>26.0</td>
<td>78.8</td>
<td>0.99974</td>
</tr>
<tr>
<td>23.6</td>
<td>74.5</td>
<td>1.00035</td>
<td>26.1</td>
<td>79.0</td>
<td>0.99971</td>
</tr>
<tr>
<td>23.8</td>
<td>74.8</td>
<td>1.00030</td>
<td>26.2</td>
<td>79.2</td>
<td>0.99968</td>
</tr>
<tr>
<td>23.9</td>
<td>75.0</td>
<td>1.00028</td>
<td>26.4</td>
<td>79.5</td>
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</tr>
<tr>
<td>24.0</td>
<td>75.2</td>
<td>1.00025</td>
<td>26.6</td>
<td>79.9</td>
<td>0.99958</td>
</tr>
<tr>
<td>24.2</td>
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<td>1.00020</td>
<td>26.7</td>
<td>80.1</td>
<td>0.99955</td>
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<td>24.4</td>
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<td>1.00015</td>
<td>27.2</td>
<td>81.0</td>
<td>0.99941</td>
</tr>
<tr>
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<td>76.3</td>
<td>1.00010</td>
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<td>0.99924</td>
</tr>
<tr>
<td>25.0</td>
<td>77.0</td>
<td>1.00000</td>
<td>28.3</td>
<td>82.9</td>
<td>0.99910</td>
</tr>
</tbody>
</table>

**Density Correction Factor \("R"\)**

*Table 2*

b. Determination using weighted average:

\[
\text{Weighted Average Maximum Specific Gravity} = \frac{(\text{Sp.G}_1 \times A_1) + (\text{Sp.G}_2 \times A_2)}{(A_1 + A_2)}
\]

Where:
- \( \text{Sp.G}_1 \) = Specific gravity of first test segment
- \( \text{Sp.G}_2 \) = Specific gravity of second test segment
- \( A_1 \) and \( A_2 \) = Mass of dry sample in air of respective test segments
14.2 Theoretical Maximum Density (Rice) at 77°F (25°C):

14.2.1 Calculate the corresponding theoretical maximum density at 77°F (25°C) as follows:

Theoretical maximum density at 77°F (25°C) = theoretical maximum specific gravity × 62.245 lb/ft³ in inch-pound units (or 997.1 kg/m³ in SI units).

Where:
The specific gravity of water at 77°F (25°C) = 62.245 in inch-pound units (or 997.1 in SI units).

15. Supplemental Procedure for Mixtures Containing Porous Aggregate

WSDOT has removed this section.

16. Report

16.1 Report the results using one of the following:

• Materials Testing System (MATS)
• WSDOT Form 350-092 and 350-157
• Form approved in writing by the State Materials Engineer

16.2 Report the Theoretical Maximum Specific Gravity \( (G_{mm}) \) to three decimal places. Report the Theoretical Maximum Density to 0.1 lb/ft³.

17. Precision

See AASHTO T 209 for Precision.
Appendix

(Nonmandatory Information)

A1. Theoretical Maximum Specific Gravity for a Loose-Paving Mixture

   WSDOT has removed this section.
### Performance Exam Checklist

**Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures**  
**FOP for AASHTO T 209**

Participant Name ________________________________  
Exam Date ____________________

<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, and if required, has the current standardization/verification tags present?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Particles of sample separated?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Care used not to fracture mineral fragments?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. After separation, fine HMA particles not larger than ¼ inch?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Sample at room temperature?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Mass of sample determined?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Mass of sample and bowl or flask determined?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Water at approximately 77°F (25°C) added to cover sample?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. Mass of bowl or flask determined?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12. Container and contents agitated continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13. For metal pycnometer, strike 3 to 5 times with a mallet?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>14. Release of entrapped air facilitated by addition of suitable wetting agent (optional)?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
| 15. Flask determination:  
  a. Flask filled with water? | ☐ | ☐ |
  1. Flask then placed in constant temperature water bath (optional) or? | ☐ | ☐ |
  2. Temperature of water in flask determined upon completion of 15d.? | ☐ | ☐ |
  b. Contents at 77 ± 2°F or density of water corrected using Table 2 in FOP? | ☐ | ☐ |
  c. Mass of filled flask determined 9 to 11 minutes after removal of entrapped air completed? | ☐ | ☐ |
| 16. All calculations performed correctly? | ☐ | ☐ |

First Attempt: Pass ☐ Fail ☐  
Second Attempt: Pass ☐ Fail ☐

Signature of Examiner
Comments:
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.

\(^1\)This FOP is based on AASHTO T 248-11.
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 at 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 ½ 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 Mixtures of Coarse and Fine Aggregates

5.2.1 If the sample does not exceed a saturated surface dry condition (there is no visible free water, sample may still appear damp) then the sample may be reduced using Method A.

5.2.2 If the sample exceeds a saturated surface dry condition the sample may be reduced using Method B or dried to a constant mass per WSDOT FOP for T 255 and then reduced using Method A.

5.3 Coarse 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.

5.4 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.

Sample Dividers (Riffles)

*Figure 1*


**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 ⅜ 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 ¾ 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).

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 or tear-resistant tarp 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 by turning the entire sample over at least three times until the material is thoroughly mixed. With the last turning, form the entire sample into a conical pile by depositing individual lifts on top of the preceding lift. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel or trowel 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. The two unused quarters may be set aside for later use or testing, if desired. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Figure 2).
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 or tear-resistant tarp and mixed with a shovel or trowel as described in 10.1.1, leaving the sample in a conical pile. As an alternative to mixing with a shovel or trowel, lift each corner of the blanket or tarp and pulling it over the sample toward the diagonally opposite corner causing the material to be rolled. After the material has been rolled a sufficient number of times so that it is thoroughly mixed, pull each corner of the blanket or tarp toward the center of the pile so the material will be left in a conical pile. Flatten the pile as described in 10.1.1. Divide the sample as described in 10.1.1 or insert a stick or pipe beneath the blanket or tarp 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 or tarp. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Figure 3).
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 by turning the entire sample over at least three times until the material is thoroughly mixed. With the last turning, form the entire sample into a conical pile by depositing individual lifts on top of the preceding lifts. If desired, the conical pile may be flattened to a uniform thickness and diameter by pressing the apex with a shovel or trowel 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

Participant Name _______________________________ Exam Date __________________

Procedure Element

<table>
<thead>
<tr>
<th>Preparation</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>
</tbody>
</table>

Selection of Method

1. Fine Aggregate or Mixture of Fine and Coarse Aggregates
   a. Saturated surface dry or drier: Method A (Splitter) used? | ☐   | ☒  |
   b. Free moisture present: Method B (Quartering) used? | ☐   | ☒  |
2. Coarse Aggregate
   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 three 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:
WSDOT FOP for AASHTO T 255
Total Evaporable Moisture Content of Aggregate by Drying

1. Scope

1.1 This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying, both surface moisture and moisture in the pores of the aggregate. Some aggregate may contain water that is chemically combined with the minerals in the aggregate. Such water is not evaporable and is not included in the percentage determined by this test method.

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

1.3 This standard does not purport to address all of the safety concerns, 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. For specific precautionary statements, see 5.3.1, 7.2.1, and 7.3.1.

2. Referenced Documents

2.1 AASHTO Standards

   M 92 – Wire-Cloth Sieves for Testing Purposes
   M 231 – Weighing Devices Used in Testing Materials
   R 16 – Regulatory Information for Chemicals Used in AASHTO Tests
   T 2 – Sampling of Aggregate
   T 19/T 19M – Bulk Density ("Unit Weight") and Voids in Aggregate
   T 84 – Specific Gravity and Absorption of Coarse Aggregate
   T 85 – Specific Gravity and Absorption of Fine Aggregate

2.2 ASTM Standards

   C 125 – Terminology Relating to Concrete and Concrete Aggregates
   C 670 – Practice for Preparing Precision Statements for Test Methods for Construction Materials

3. Terminology

3.1 Definitions

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

1This FOP is based on AASHTO T 255-00.
4. Significance and Use

4.1 This test method is sufficiently accurate for usual purposes, such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In rare cases where the aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled temperature oven.

4.2 Large particles of coarse aggregate, especially those larger than 2 in (50 mm), will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large size particles.

5. Apparatus

5.1 Balance – The balances shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.

5.2 Source of Heat – A ventilated oven capable of maintaining the temperature surrounding the sample at 110 ± 5°C (230 ± 9°F). Where close control of the temperature is not required (see Section 4.1), other suitable sources of heat may be used, such as an electric or gas hot plate, electric heat lamps, or a ventilated microwave oven.

5.3 Sample Container – A container not affected by the heat, and of sufficient volume to contain the sample without danger of spilling, and of such shape that the depth of sample will not exceed one fifth of the least lateral dimension.

5.3.1 Precaution – When a microwave oven is used, the container shall be nonmetallic.

Note 1: Except for testing large samples, an ordinary frying pan is suitable for use with a hot plate, or any shallow flat-bottomed metal pan is suitable with heat lamps or oven. Note Precaution in Section 5.3.1.

5.4 Stirrer – A metal spoon or spatula of convenient size.

6. Sampling

6.1 Sampling shall generally be accomplished in accordance with FOP for AASHTO T 2, except for the sample size may be as stated in Table 1.

6.2 Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1. Protect the sample against loss of moisture prior to determining the mass.
Table 1

<table>
<thead>
<tr>
<th>Nominal Maximum(A)</th>
<th>Minimum Mass(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size* in (mm)</td>
<td>lb</td>
</tr>
<tr>
<td>US No. 4 (4.75)</td>
<td>1</td>
</tr>
<tr>
<td>(\frac{1}{4}) (6.3)</td>
<td>2</td>
</tr>
<tr>
<td>(\frac{3}{8}) (9.5)</td>
<td>2</td>
</tr>
<tr>
<td>(\frac{1}{2}) (12.5)</td>
<td>5</td>
</tr>
<tr>
<td>(\frac{5}{8}) (16.0)</td>
<td>5</td>
</tr>
<tr>
<td>(\frac{3}{4}) (19.0)</td>
<td>7</td>
</tr>
<tr>
<td>1 (25.0)</td>
<td>13</td>
</tr>
<tr>
<td>1(\frac{1}{4}) (31.5)</td>
<td>17</td>
</tr>
<tr>
<td>1(\frac{1}{2}) (37.5)</td>
<td>20</td>
</tr>
<tr>
<td>2 (50)</td>
<td>22</td>
</tr>
<tr>
<td>2(\frac{1}{2}) (63)</td>
<td>27</td>
</tr>
<tr>
<td>3 (75)</td>
<td>33</td>
</tr>
<tr>
<td>3(\frac{1}{2}) (90)</td>
<td>44</td>
</tr>
<tr>
<td>4 (100)</td>
<td>55</td>
</tr>
<tr>
<td>6 (150)</td>
<td>110</td>
</tr>
</tbody>
</table>

\(A\)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.

\(B\)Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry-loose unit mass of the aggregate in kg/m\(^3\) (determined using T 19M/T 19) and dividing by 1600.

**Sample Size for Aggregate**

7. Procedure

7.1 Determine the mass of the sample to the nearest 0.1 percent or better of the total sample mass.

7.2 Dry the sample thoroughly in the sample container by means of the selected source of heat, exercising care to avoid loss of any particles. Very rapid heating may cause some particles to explode, resulting in loss of particles. Use a controlled temperature oven when excessive heat may alter the character of the aggregate, or where more precise measurement is required. If a source of heat other than the controlled temperature oven is used, stir the sample during drying to accelerate the operation and avoid localized overheating. When using a microwave oven, stirring of the sample is optional.

7.2.1 Caution – When using a microwave oven, occasionally minerals are present in aggregates that may cause the material to overheat and explode. If this occurs, it can damage the microwave oven.
7.3 When a hot plate is used, drying can be expedited by the following procedure. Add sufficient anhydrous denatured alcohol to cover the moist sample. Stir and allow suspended material to settle. Decant as much of the alcohol as possible without losing any of the sample. Ignite the remaining alcohol and allow it to burn off during drying over the hot plate.

7.3.1 Warning – Exercise care to control the ignition operation to prevent injury or damage from the burning alcohol.

7.4 The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 percent additional loss in mass.

WSDOT Note: When weighing hot samples, use a heat sink to protect the balance.

7.5 Determine the mass of the dried sample to the nearest 0.1 percent or better of the total sample mass after it has to room temperature.

8. Calculation

8.1 Calculate total evaporable moisture content as follows:

\[ p = \frac{100 \times (W - D)}{D} \]

where:

- \( p \) = total evaporable moisture content of sample, percent;
- \( W \) = mass of original sample, g; and
- \( D \) = mass of dried sample, g

8.2 Surface moisture content is equal to the difference between the total evaporated moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with T 85, Test for Specific Gravity and Absorption of Coarse Aggregates, or T 84, Test for Specific Gravity and Absorption of Fine Aggregates

9. Precision and Bias

See AASHTO T 255 for Precision and Bias.

10. Report

Report the results using one or more of the following:

- Materials Testing System (MATS)
- WSDOT Form 422-020, 422-020A, or 422-020B
- Form approved in writing by the State Materials Engineer
**Performance Exam Checklist**

*Total Moisture Content of Aggregate by Drying*

**FOP for AASHTO T 255**

Participant Name ________________________________ Exam Date __________________

<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, and if required, has the current calibration/verification tags present?</td>
<td>☐</td>
<td>☑</td>
</tr>
<tr>
<td>3. Representative sample of appropriate mass obtained?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>4. Mass of clean, dry container determined?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>5. Sample placed in container and mass determined?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>6. Test sample mass conforms to the required mass?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>7. Sample mass determined to 0.1 percent?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>8. Loss of moisture avoided prior to mass determination?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>9. Sample dried by a suitable heat source?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>10. Sample cooled prior to mass determination?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>11. If aggregate heated by means other than a controlled oven, is sample stirred to avoid localized overheating?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>12. Mass determined and compared to previous mass – showing less than 0.1 percent loss?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>13. Calculations performed properly and results reported to the nearest 0.1 percent?</td>
<td>☑</td>
<td>☐</td>
</tr>
</tbody>
</table>

First Attempt: Pass ☐ Fail ☐ Second Attempt: Pass ☐ Fail ☐

Signature of Examiner __________________________________________

Comments:
AASHTO T 272
Standard Method of Test for Family of Curves—One Point Method

AASHTO T 272 has been adopted by WSDOT.
Performance Exam Checklist

*Family of Curves — One-Point Method*

*FOP for AASHTO T 272*

Participant Name ________________________________  Exam Date ________________

<table>
<thead>
<tr>
<th>Procedure Element</th>
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<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. One-point determination of dry density and corresponding moisture content made</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>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>
<td>☐</td>
<td>☐</td>
</tr>
<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>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>d. Moisture content determined in accordance with FOP for AASHTO T 255/T 265 or</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>AASHTO T 217?</td>
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<td>☐</td>
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<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</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>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,</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>another one-point determination with an adjusted water content is made?</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>6. Maximum dry density and corresponding optimum moisture content correctly</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>estimated?</td>
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<td>☐</td>
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</table>

First Attempt:  Pass ☐  Fail ☐  Second Attempt:  Pass ☐  Fail ☐

Signature of Examiner  ________________________________

Comments:
WSDOT Test Method FOP for AASHTO T 304
Uncompacted Void Content of Fine Aggregate

1. Scope

1.1 This method describes the determination of the loose uncompacted void content of a sample of fine aggregate. When measured on any aggregate of a known grading, void content provides an indication of that aggregate’s angularity, sphericity, and surface texture compared with other fine aggregates tested in the same grading. When void content is measured on an as-received fine aggregate grading, it can be an indicator of the effect of the fine aggregate on the workability of a mixture in which it may be used.

1.2 Three procedures are included for the measurement of void content. Two use graded fine aggregate (standard grading or as-received grading), and the other uses several individual size fractions for void content determinations:

1.2.1 Standard Graded Sample (Method A) – This method uses a standard fine aggregate grading that is obtained by combining individual sieve fractions from a typical fine aggregate sieve analysis. See the section on Preparation of Test Samples for the Grading.

Note: WSDOT Specifications require Method A.

1.2.2 See the section on Significance and Use for guidance on the method to be used.

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

1.4 This standard does not purport to address all of the safety problems, 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. References Documents

2.1 AASHTO Standards

T 84 Specific Gravity and Absorption of Fine Aggregate

2.1 WSDOT Standards

T 2 – FOP for AASHTO for the Sampling of Aggregates

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

T 27/11 – FOP for WAQTC for the Sieve Analysis of Fine and Coarse Aggregates

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1This FOP is based on AASHTO T 304-11 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
2.1 ASTM Standards
   B 88 – Specification for Seamless Copper Water Tube
   B 88M – Specification for Seamless Copper Water Tube (Metric)
   C 29/29M – Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
   C 117 – Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
   C 125 – Terminology Relating to Concrete and Concrete Aggregates
   C 128 – Test Method for Specific Gravity and Absorption of Fine Aggregate
   C 136 – Test Method for Sieve Analysis of Fine and Coarse Aggregates
   C 702 – Practice for Reducing Samples of Aggregate to Testing Size
   C 778 – Specification for Standard Sand
   D 75 – Practice for Sampling Aggregates

2.2 ACI Document
   ACI 116R – Cement and Concrete Terminology

3. Terminology
   3.1 Terms used in this standard are defined in ASTM C 125 or ACI 116R.

4. Summary of Test Method
   4.1 A nominal 100-mL calibrated cylindrical measure is filled with fine aggregate of prescribed grading by allowing the sample to flow through a funnel from a fixed height into the measure. The fine aggregate is struck off, and its mass is determined by weighing. Uncompacted void content is calculated as the difference between the volume of the cylindrical measure and the absolute volume of the fine aggregate collected in the measure. Uncompacted void content is calculated using the bulk dry specific gravity of the fine aggregate. Two runs are made on each sample and the results are averaged.

   4.1.1 For a graded sample the percent void content is determined directly, and the average value from two runs is reported.

5. Significance and Use
   5.1 Methods A provide percent void content determined under standardized conditions which depend on the particle shape and texture of a fine aggregate. An increase in void content by these procedures indicates greater angularity, less sphericity, or rougher surface texture, or some combination of the three factors. A decrease in void content results is associated with more rounded, spherical, smooth surfaced fine aggregate, or a combination of these factors.

   5.1.1 The standard graded sample (Method A) is most useful as a quick test which indicates the particle shape properties of a graded fine aggregate. Typically, the material used to make up the standard graded sample can be obtained from the remaining size fractions after performing a single sieve analysis of the fine aggregate.
Uncompacted Void Content of Fine Aggregate

Figure 1 – Nominal 100-ml Cylindrical Measure

Figure 2 – Suitable Funnel Stand Apparatus with Cylindrical Measure in Place
5.3.4 The bulk dry specific gravity of the fine aggregate is used in calculating the void content. The effectiveness of these methods of determining void content and its relationship to particle shape and texture depends on the bulk specific gravity of the various size fractions being equal, or nearly so. The void content is actually a function of the volume of each size fraction. If the type of rock or minerals, or its porosity, in any of the size fractions varies markedly it may be necessary to determine the specific gravity of the size fractions used in the test.

5.4 Void content information from Method A, will be useful as an indicator of properties such as in bituminous concrete, the effect of the fine aggregate on stability and voids in the mineral aggregate; or the stability of the fine aggregate portion of a base course aggregate.

6. Apparatus

6.1 Cylindrical Measure – A right cylinder of approximately 100 mL capacity having an inside diameter of approximately 39 mm and an inside height of approximately 86 mm made of drawn copper water tube meeting ASTM Specification B 88 Type M, or B 88 M Type C. The bottom of the measure shall be metal at least 6 mm thick, shall be firmly sealed to the tubing, and shall be provided with means for aligning the axis of the cylinder with that of the funnel. (See Figure 1.)

6.2 Funnel – The lateral surface of the right frustum of a cone sloped 60 ± 4º from the horizontal with an opening of 12.7 ± 0.6 mm diameter. The funnel section shall be a piece of metal, smooth on the inside and at least 38 mm high. It shall have a volume of at least 200 mL or shall be provided with a supplemental glass or metal container to provide the required volume. (See Figure 2.)

Note 1: Pycnometer top C9455 sold by Hogentogler and Co., Inc., 9515 Gerwig, Columbia, MD 21045, 410-381-2390 is satisfactory for the funnel section, except that the size of the opening has to be enlarged and any burrs or lips that are apparent should be removed by light filing or sanding before use. This pycnometer top must be used with suitable glass jar with the bottom removed (Figure 2).

6.3 Funnel Stand – A three or four legged support capable of holding the funnel firmly in position with the axis of the funnel colinear (within a 4º angle and a displacement of 2 mm) with the axis of the cylindrical measure. The funnel opening shall be 115 ± 2 mm above the top of the cylinder. A suitable arrangement is shown in Figure 2.

6.4 Glass Plate – A square glass plate approximately 60 mm by 60 mm with a minimum 4 mm thickness used to calibrate the cylindrical measure.

6.5 Pan – A metal or plastic pan of sufficient size to contain the funnel stand and to prevent loss of material. The purpose of the pan is to catch and retain fine aggregate particles that overflow the measure during filling and strike off. The pan shall not be warped so as to prevent rocking of the apparatus during testing.
6.6   Metal spatula with a blade approximately 100 mm long, and at least 20 mm wide, with straight edges. The end shall be cut at a right angle to the edges. The straight edges. The straight edge of the spatula blade is used to strike off the fine aggregate.

6.7   Scale or balance accurate and readable to ±0.1 g within the range of use, capable of weighing the cylindrical measure and its contents.

7.   Sampling

7.1   The sample(s) used for this test shall be obtained using FOP for AASHTO T 2 and FOP for AASHTO T 248, or from sieve analysis samples used for FOP for WAQTC/ AASHTO T 27/11, or from aggregate extracted from a bituminous concrete specimen. For Method A, the sample is washed over a 150-um (No. 100) or 75-um (No. 200) sieve in accordance with FOP for WAQTC/AASHTO T 27/11 and then dried and sieved into separate size fractions according to FOP for WAQTC/AASHTO T 27/11 procedures. Maintain the necessary size fractions obtained from one (or more) sieve analysis in a dry condition in separate containers for each size.

8.   Calibration of Cylindrical Measure

8.1   Apply a light coat of grease to the top edge of the dry, empty cylindrical measure. Weigh the measure, grease, and glass plate. Fill the measure freshly boiled, deionized water at a temperature of 18 to 24ºC. Record the temperature of the water. Place the glass plate on the measure, being sure that no air bubbles remain Dry the outer surfaces of the measure and determine the combined mass of measure, glass plate, grease, and water by weighing. Following the final weighing, remove the grease, and determine the mass of the clean, dry, empty measure for subsequent test.

8.2   Calculate the volume of the measure as follows:

\[ V = 1000 \frac{M}{D} \]

where:

- \( V \) = volume of cylinder, mL,
- \( M \) = net mass of water, g, and
- \( D \) = density of water (see table in ASTM C 29/C 29M for density at the temperature used), Kg/m³.

Determine the volume to the nearest 0.1 mL.

Note 2: If the volume of the measure is greater than 100.0 mL, it may be desirable to grind the upper edge of the cylinder until the volume is exactly 100.0 mL, to simplify subsequent calculations.
9. Preparation of Test Samples

9.1 Method A – Standard Graded Sample – Weigh out and combine the following quantities of fine aggregate which has been dried and sieved in accordance with FOP for AASHTO T 27/11.

<table>
<thead>
<tr>
<th>Individual Size Fraction</th>
<th>Mass, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing</td>
<td>Retained on</td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>No. 16 (1.18 mm)</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>No. 30 (600 um)</td>
</tr>
<tr>
<td>No. 30 (600 um)</td>
<td>No. 50 (300 um)</td>
</tr>
<tr>
<td>No. 50 (300 um)</td>
<td>No. 100 (150 um)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
</tbody>
</table>

The tolerance on each of these amounts is ±0.2 g.

9.2 **Method B – Individual Size Fractions** – WSDOT has deleted this section they use Method A.

9.3 Method C – As Received Grading – WSDOT has deleted this section they use Method A.

9.4 Specific Gravity of Fine Aggregate – If the bulk dry specific gravity of fine aggregate from the source is unknown, determine it on the minus No. 4 (4.75 mm) material according to AASHTO T 84. Use this value in subsequent calculations unless some size fractions differ by more than 0.05 from the specific gravity typical of the complete sample, in which case the specific gravity of the fraction (or fractions) being tested must be determined. An indicator of differences in specific gravity of various particle sizes is a comparison of specific gravities run on the fine aggregate in different gradings. Specific gravity can be run on gradings with and without specific size fractions of interest. If specific gravity differences exceed 0.05, determine the specific gravity of the individual 2.36 mm (No. 8) to 150 um (No. 100) sizes for use with Method A or the individual size fractions for use with Method B either by direct measurement or by calculation using the specific gravity data on gradings with and without the size fraction of interest. A difference in specific gravity of 0.05 will change the calculated void content about 1 percent.

10. Procedure

10.1 Mix each test sample with the spatula until it appears to be homogeneous. Position the jar and funnel section in the stand and center the cylindrical measure as shown in Figure 2. Use a finger to block the opening of the funnel. Pour the test sample into the funnel. Level the material in the funnel with the spatula. Remove the finger and allow the sample to fall freely into the cylindrical measure.
10.2 After the funnel empties, strike-off excess heaped fine aggregate from the cylindrical measure by a single pass of the spatula with the width of the blade vertical using the straight part of its edge in light contact with the top of the measure. Until this operation is complete, exercise care to avoid vibration or any disturbance that could cause compaction of the fine aggregate in the cylindrical measure (Note 3). Brush adhering grains from the outside of the container and determine the mass of the cylindrical measure and contents to the nearest 0.1 g. Retain all fine aggregate particles for a second test run.

**Note 3:** After strike-off, the cylindrical measure may be tapped lightly to compact the sample to make it easier to transfer the container to scale or balance without spilling any of the sample.

10.3 Recombine the sample from the retaining pan and cylindrical measure and repeat the procedure. The results of two runs are averaged. See the Calculation section.

10.4 Record the mass of the empty measure. Also, for each run, record the mass of the measure and fine aggregate.

11. Calculation

11.1 Calculate the uncompacted voids for each determination as follows:

\[ U = \frac{V - (F/G)}{V} \times 100 \]

- **V** = volume of cylindrical measure, mL;
- **F** = net mass, g, of fine aggregate in measure (gross mass minus the mass of the empty measure);
- **G** = Bulk dry specific gravity of fine aggregate; and
- **U** = uncompacted voids, percent, in the material.

11.2 For the standard Graded Sample (Method A), calculate the average uncompacted voids for the two determinations and report the result as **U_s**.

12. Report

12.1 For the Standard Graded Sample (Method A) report:

12.1.1 The Uncompacted Voids (**U_s**) in percent to the nearest 1 percent.

12.1.2 The specific gravity value used in the calculations.

12.2 Report the results using one or more of the following:

- Materials Testing System (MATS)
- WSDOT Form 350-161
- Form approved in writing by the State Materials Engineer

13. Precision and Bias

See AASHTO T 304 for Precision and bias.
Performance Exam Checklist

Uncompacted Void Content of Fine Aggregate
FOP AASHTO T 304

Participant Name ________________________________  Exam Date ____________________

<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, and if required, has the current calibration/verification tags present?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample Preparation (Method A)

*Note:* If Bulk Dry Specific Gravity is unknown, determine it on the minus No. 4 (4.75 mm) material according to AASHTO T-84

1. Field sample obtained per FOP for AASHTO T-2?                                    |     |    |
2. Sample reduced to testing size per FOP for AASHTO T-248?                           |     |    |
3. Sample washed over No. 100 or No. 200 sieve in accordance with FOP for WAQTC/AASHTO T 27/11? |     |    |
4. Sample dried to constant weight?                                                  |     |    |
5. Standard Graded sample achieved per FOP for WAQTC/AASHTO T 27/11?                 |     |    |
6. Necessary size fractions obtained, maintained in a dry condition in separate containers for each size? |     |    |
7. Standard Graded sample-weighed out and combined per Section 9.1, FOP for AASHTO T 304? |     |    |
Procedure Element

PROCEDURE (Method A)

Note: If Bulk Dry Specific Gravity is unknown, determine it on the minus No. 4 (4.75 mm) material according to AASHTO T-84.

1. Test sample mixed until it appears to be homogeneous?  
2. Jar and funnel section positioned in stand and cylindrical measure centered on stand?  
3. Finger used to block the opening of the funnel?  
4. Test sample poured into the funnel and leveled?  
5. Finger removed and sample allowed to fall freely into cylindrical measure?  
6. After funnel empties, is excess material struck off w/single pass of upright spatula?  
7. Was care taken to avoid any vibration or disturbance that could cause compaction of material?  
8. All adhering grains brushed off before weighing the cylindrical measure?  
9. Mass of the cylindrical measure and contents weighed to nearest 0.1 gram?  
10. All fine aggregate particles retained and re-homogenized for a second test run?  
11. Percent (%) of Uncompacted Voids calculated for each run, as per FOP for AASHTO T-304, Method A?  
12. Were the results for each run averaged for a final result?  
13. Was the (%) percent of Uncompacted voids reported to the nearest one percent (1%)?  
14. All calculations performed correctly?

First Attempt: Pass ☐ Fail ☐  
Second Attempt: Pass ☐ Fail ☐

Signature of Examiner  

Comments:
WSDOT FOP for AASHTO T 308\(^1\)

*Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method*

1. **Scope**

1.1 This test method covers the determination of asphalt binder content of HMA mixtures by ignition at temperatures that reach the flashpoint of the binder in a furnace. The means of specimen heating may be the convection method or the direct infrared (IR) irradiation method. The aggregate remaining after burning can be used for sieve analysis using FOP for AASHTO T 27/T11.

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

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

2. **Referenced Documents**

2.1 AASHTO Standards

   M 231 – Weighing Devices Used in the Testing of Materials

2.2 Other Standards

   *Manufacturer’s Instruction Manual*

2.3 WSDOT Standards

   T 329 – FOP for AASHTO Moisture Content of Asphalt (HMA) by Oven Method
   T27/11 – FOP for WAQTC Sieve Analysis of Fine and Coarse Aggregates
   T 168 – FOP for WAQTC Sampling Bituminous Paving Materials
   T 712 – Reducing Samples of Hot Mix Asphalt to Testing Size
   SOP 728 – Method for Determining Ignition Furnace Calibration Factor

3. **Summary of Test Method**

3.1 The asphalt binder in the paving mixture is ignited using the furnace equipment applicable to the particular method.

3.2 The asphalt binder content is calculated as the difference between the initial mass of the asphalt mixture and the mass of the HMA residual aggregate, with adjustments for the calibration factor, and the moisture content. The asphalt content is expressed as mass percent of moisture-free mixture.

\(^1\)This FOP is based on AASHTO T 308-08 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
4. Significance and Use

4.1 This method can be used for quantitative determinations of asphalt binder content and gradation in HMA mixtures and pavement specimens for quality control, specification acceptance, and mixture evaluation studies. This method does not require the use of solvents. Aggregate obtained by this test method may be used for gradation analysis according to T 27/11.

5. Apparatus

5.1 Ignition Furnace – A forced-air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The convection-type furnace must be capable of maintaining the temperature at 578°C (1072°F). The furnace chamber dimensions shall be adequate to accommodate a specimen size of 3500 g. The furnace door shall be equipped so that the door cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside and, when set up properly, shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan with the capability to pull air through the furnace to expedite the test and reduce the escape of smoke into the laboratory.

5.1.1 For Method A, the furnace shall also have an internal balance thermally isolated from the furnace chamber and accurate to 0.1 g. The balance shall be capable of weighing a 3500-g specimen in addition to the specimen baskets. A data collection system will be included so that the mass can be automatically determined and displayed during the test. The furnace shall have a built-in computer program to calculate the change in mass of the specimen baskets and provide for the input of a correction factor for aggregate loss. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt binder content (percent), test time, and test temperature. The furnace shall provide an audible alarm and indicator light when the specimen mass loss does not exceed 0.01 percent of the total specimen mass for three consecutive minutes. The furnace shall also allow the operator to change the ending mass loss percentage to 0.02 percent.

5.2 Specimen Basket Assembly – Consisting of specimen basket(s), catch pan, and an assembly guard to secure the specimen basket(s) to the catch pan.

5.2.1 Specimen basket(s) – Of appropriate size that allows the specimens to be thinly spread and allows air to flow through and around the specimen particles. Sets with two or more baskets shall be nested. The specimen shall be completely enclosed with screen mesh, perforated stainless steel plate, or other suitable material.

Note 1: Screen mesh or other suitable material with maximum and minimum openings of 2.36 mm (No. 8) and 0.600 mm (No. 30), respectively, has been found to perform well.

5.2.2 Catch Pan – Of sufficient size to hold the specimen basket(s) so that aggregate particles and melting asphalt binder falling through the screen are caught.
Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

5.3 Oven – Capable of maintaining 110 ± 5°C (230 ± 9°F).

5.4 Balance – Of sufficient capacity and conforming to the requirements of M 231, Class G 2.

5.5 Safety Equipment – Safety glasses or face shield, dust mask, high temperature gloves, long sleeve jacket, a heat-resistant surface capable of withstanding 650°C (1202°F) and a protective cage capable of surrounding the specimen baskets during the cooling period.

5.6 Miscellaneous Equipment – A pan larger than the specimen basket(s) for transferring the specimen after ignition, spatulas, bowls, and wire brushes.

6. Sampling

6.1 Obtain specimens of freshly produced hot-mix asphalt in accordance with FOP for WAQTC T 168.

6.2 The test specimen for asphalt content determination shall be the end result of a larger specimen taken in accordance with FOP for WAQTC T 168.

6.3 If the mixture is not sufficiently soft to separate for testing, carefully heat the mixture in an oven until sufficiently soft, not to exceed 350 F or the recommended mixing temperature from the mix design verification report. Do not leave the specimen in the oven for an extended period of time.

6.4 The size of the test specimen shall be governed by the nominal maximum aggregate size of the mixture and shall conform to the mass requirement shown in Table 1. Specimen sizes shall not be more than 500 g greater than the minimum recommended specimen mass. The maximum specimen size including basket shall not exceed the capacity of the balance.

Note 2: Large specimens of fine mixes tend to result in incomplete ignition of asphalt binder.

<table>
<thead>
<tr>
<th>Nominal Max. Agg.* Size</th>
<th>Class</th>
<th>Minimum Mass of Specimen, g</th>
<th>Maximum Mass of Specimen, g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HMA</td>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>US No. 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>⅜ in</td>
<td>⅜ in</td>
<td></td>
<td>1200</td>
</tr>
<tr>
<td>½ in</td>
<td>½ in</td>
<td>ATB</td>
<td>1500</td>
</tr>
<tr>
<td>¾ in</td>
<td>¾ in</td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>1 in</td>
<td>1 in</td>
<td></td>
<td>3000</td>
</tr>
<tr>
<td>1½ in</td>
<td></td>
<td></td>
<td>4000</td>
</tr>
</tbody>
</table>

*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.

Note: For an aggregate specification having a generally unrestrictive 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.
Test Method A

7. Test Procedures

7.1 Test Initiation

7.1.1 Preheat the ignition furnace to 1000°F (538°C). Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

7.2 Determine the moisture content of the specimens according to FOP for AASHTO T 329 Moisture Content of Asphalt (HMA) by Oven Method.

7.3 Enter the calibration factor for the specific mix to be tested.

7.4 Weigh and record the mass of the specimen basket(s) and catch pan (with guards in place) to the nearest 0.1g.

7.5 Prepare the specimen as described in Section 6. Evenly distribute this specimen in the specimen basket(s) that have been placed in the catch pan, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the specimen.

7.6 Determine and record the total mass of the specimen, basket(s), catch pan, and basket guards to the nearest 0.1g. Calculate and record the initial mass of the specimen (total mass minus the mass of the specimen basket assembly).

7.7 Input the initial mass of the specimen in whole grams into the ignition furnace controller. Verify that the correct mass has been entered.

7.8 Tare or zero furnace balance, open the chamber door, and gently set the specimen baskets in the furnace. Close the chamber door, and verify that the specimen mass (including the basket(s)) displayed on the furnace scale equals the total mass recorded in Section 7.6 within ± 6 g. Differences greater than 6 g or failure of the furnace scale to stabilize may indicate that the sample basket(s) are contacting the furnace wall.

Note 3: Due to the extreme heat of the furnace, the operator should wear safety equipment high temperature gloves, face shield, fire-retardant shop coat—when opening the door to load or unload the specimen.

7.9 Initiate the test by pressing the start/stop button. This will lock the specimen chamber and start the combustion blower.

Note 4: The furnace temperature will drop below the setpoint when the door is opened, but will recover with the door closed and when ignition occurs. Specimen ignition typically increases the temperature well above the setpoint, depending on specimen size and asphalt content.

WSDOT Safety Note: Do not attempt to open the furnace door until the binder has been completely burned off.
7.10 Allow the test to continue until the stable light and audible stable indicator indicate the test is complete (the change in mass does not exceed 0.01 percent for three consecutive minutes). Press the start/stop button. This operation will unlock the specimen chamber and cause the printer to print out the test results.

7.11 Open the chamber door, remove the specimen basket assembly and place it on a heat resistance surface. Place the protective cage over the specimen basket assembly, and allow specimen to cool to room temperature (approximately 30 minutes).

7.12 Use the corrected asphalt binder content (0.01 percent) from the printed ticket. If a moisture content (0.01 percent) has been determined, subtract the percent moisture from the printed ticket corrected asphalt content, and report the resultant value as the corrected asphalt binder content to 0.1 percent.

**Test Method B**

8. Test Procedure

WSDOT does not use Method B and has deleted it from the procedure.

9. Gradation

9.1 Allow the specimen to cool to room temperature in the sample baskets.

9.2 Empty the contents of the baskets into a flat pan. Use a small wire sieve brush to ensure that any residual fines are removed from the baskets. Determine and record the total mass of the specimen to the nearest 0.1g.

9.3 Perform the gradation analysis according to FOP for WAQTC T 27/T11.

10. Report

10.1 Report the test method (A), corrected asphalt binder content, calibration factor, temperature compensation factor (if applicable), total percent loss, specimen mass, moisture content (if determined) and the test temperature. Attach the original printed tickets to the report for units with internal balances.

10.2 The asphalt percentage and aggregate gradation shall be reported on one or more of the following:

- Materials Testing System (MATS)
- WSDOT Form 350-092 and 350-157
- Form approved in writing by the State Materials Engineer

11. Precision and Bias

See AASHTO T 308 for Precision and Bias.
Performance Exam Checklist  
*WSDOT FOP for AASHTO T 308*  
*Determining the Asphalt Cement Content of Hot Mix Asphalt (HMA) by the Ignition Method*

Participant Name ________________________________  Exam Date ____________________

<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, and if required, has the current calibration/verification tags present?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Oven at correct temperature 538 C?</td>
</tr>
<tr>
<td>2. Mass of specimen baskets and catch pan recorded?</td>
</tr>
<tr>
<td>3. Specimen evenly distributed in basket?</td>
</tr>
<tr>
<td>4. Mass of specimen recorded?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method A</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Enter calibration factor for specific mix design?</td>
</tr>
<tr>
<td>6. Initial mass entered into furnace controller?</td>
</tr>
<tr>
<td>7. Specimen correctly placed into furnace?</td>
</tr>
<tr>
<td>8. Test continued until stable indicator signals?</td>
</tr>
<tr>
<td>9. Binder content obtained on printed ticket?</td>
</tr>
<tr>
<td>10. Binder content corrected for moisture?</td>
</tr>
<tr>
<td>11. All calculations performed correctly?</td>
</tr>
</tbody>
</table>

First Attempt:  Pass [ ]  Fail [ ]  Second Attempt:  Pass [ ]  Fail [ ]

Signature of Examiner

Comments:
1. Scope

1.1 This test method describes the procedure for determining the in-place density and moisture of soil and soil-aggregate by use of nuclear equipment. The density of the material may be determined by direct transmission, backscatter, or backscatter/air-gap ratio method. The WSDOT standard method for determining density is by direct transmission.

1.2 Density – The total or wet density of soil and soil-rock mixtures is determined by the attenuation of gamma radiation where the source or detector is placed at a known depth up to 12 in (300 mm) while the detector(s) or source remains on the surface (Direct Transmission Method) or the source and detector(s) remain on the surface (Backscatter Method).

1.2.1 The density in mass per unit volume of the material under test is determined by comparing the detected rate of gamma radiation with previously established calibration data.

1.3 Moisture – The moisture content of the soil and soil-rock mixtures is determined by thermalization or slowing of fast neutrons where the neutron source and the thermal neutron detector both remain at the surface.

1.3.1 The water content in mass per unit volume of the material under test is determined by comparing the detection rate of thermalized or slow neutrons with previously established calibration data.

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

1.5 This standard does not purport to address all of the safety problems, 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. See Section 6. Hazards.

2. Referenced Documents

2.1 AASHTO Standards

T 9 – Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop

T 180 – Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and a 18 in (457 mm) Drop

T 191 – Density of Soil In-Place by the Sand-Cone Method

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1This FOP is based on AASHTO 310-06 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
T 217 – Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester

T 224 – Correction for Coarse Particles in the Soil Compaction Test

T 255 – Total Evaporable Moisture Content of Aggregate by Drying

T 265 – Laboratory Determination of Moisture Content of Soils

T 272 – Family of Curves – One-Point Method

2.2 ASTM Test Method

D 2216 – Laboratory Determination of Moisture Content of Soil

D 2487 – Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D 2488 – Description and Identification for Soils (Visual-Manual Procedure)

D 2937 – Density of Soil in Place by the Drive-Cylinder Method

D 4253 – Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

D 4254 – Maximum Index Density and Unit Weight of Soils and Calculation of Relative Density


2.3 WSDOT Standards

T 606 – Method of Test for Compaction Control of Granular Materials

SOP 615 – Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge

3. Significance

3.1 The test method described is useful as a rapid, nondestructive technique for the in-place determination of the wet density and water content of soil and soil-aggregate.

3.2 The test method is used for quality control and acceptance testing of compacted soil and rock for construction and for research and development. The non-destructive nature allows repetitive measurements at a single test location and statistical analysis of the results.

3.3 Density – The fundamental assumptions inherent in the methods are that Compton scattering is the dominant interaction and that the material under test is homogeneous.

3.4 Moisture – The fundamental assumptions inherent in the test method are that the hydrogen present is in the form of water as defined by ASTM D 2216, and that the material under test is homogeneous.
3.5 Test results may be affected by chemical composition, sample heterogeneity, and, to a lesser degree, material density and the surface texture of the material being tested. The technique also exhibits spatial bias in that the gauge is more sensitive to water contained in the material in close proximity to the surface and less sensitive to water at deeper levels.

4. Interferences

4.1 In-Place Density Interferences

4.1.1 The chemical composition of the sample may affect the measurement, and adjustments may be necessary.

4.1.2 The gauge is more sensitive to the density of the material in close proximity to the surface in the Backscatter Method.

*Note 1:* The nuclear gauge density measurements are somewhat biased to the surface layers of the soil being tested. This bias has largely been corrected out of the Direct Transmission Method and any remaining bias is insignificant. The Backscatter Method is still more sensitive to the material within the first several inches from the surface. Density measurements with direct transmission is the WSDOT standard method.

4.1.3 Oversize rocks or large voids in the source-detector path may cause higher or lower density determination. Since there is lack of uniformity in the soil due to layering, rock or voids the test site beneath the gauge will be excavated and a representative sample will be taken to determine the gradation per WSDOT SOP 615.

4.1.4 Keep all other radioactive sources at least the minimum distance recommended by the manufacture away from the gauge to avoid affecting the measurement.

4.2 In-Place Moisture Content Interferences

4.2.1 The chemical composition of the sample may dramatically affect the measurement and adjustments may be necessary. Hydrogen in forms other than water, as defined by ASTM D 2216, and carbon will cause measurements in excess of the true value. Some chemical elements such as boron, chlorine, and minute quantities of cadmium will cause measurements lower than the true value.

4.2.2 The water content determined by this test method is not necessarily the average water within the volume of the sample involved in the measurement. The measurement is heavily influenced by the water content of the material closest to the surface. The volume of soil and rock represented in the measurement is indeterminate and will vary with the water content of the material. In general, the greater the water content of the material, the smaller the volume involved in the measurement. At 10 lbs/ft³ (160 kg/m³), approximately 50 percent of the typical measurement results from the water content of the upper 2 to 3 in (50 to 75 mm).

4.2.3 Keep all other neutron sources at least the minimum distance recommended by the manufacture away from the gauge to avoid affecting the measurement.
5. Apparatus

5.1 Nuclear Density/Moisture Gauge – While exact details of construction of the gauge may vary, the system shall consist of:

5.1.1 A sealed source of high energy gamma radiation such as cesium or radium.

5.1.2 Gamma Detector – Any type of gamma detector such as a Geiger-Mueller tube(s).

5.2 Fast Neutron Source – A sealed mixture of a radioactive material such as americium, radium, or californium-252 and a target material such as beryllium.

5.3 Slow Neutron Detector – Any type of slow neutron detector such as boron trifluoride or helium-3 proportional counter.

5.4 Reference Standard – A block of material used for checking instrument operation, correction of source decay, and to establish conditions for a reproducible reference count rate.

5.5 Site Preparation Device – A plate, straightedge, or other suitable leveling tool which may be used for planing the test site to the required smoothness, and in the Direct Transmission Method, guiding the drive pin to prepare a perpendicular hole.

5.6 Drive Pin – A pin not to exceed the diameter of the rod in the Direct Transmission Gauge by more than ¼ in (6mm) or as recommended by the gauge manufacturer used to prepare a hole in the material under test for inserting the rod.

5.6.1 A slide hammer, with a drive pin attached, may also be used both to prepare a hole in the material to be tested and to extract the pin without distortion to the hole. In place of a slide hammer a hammer of significant size and weight for preparing a hole in the material to be tested using the drive pin along with an extraction tool.

5.7 Drive Pin Extractor – A tool that may be used to remove the drive pin in a vertical direction so that the pin will not distort the hole in the extraction process.

6. Hazards

6.1 This gauge utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of this gauge must become familiar with applicable safety procedures and government regulations.

6.2 Effective user instructions together with routine safety procedures, such as source leak tests, recording and evaluation of film badge data, etc., are a recommended part of the operation and storage of this gauge.

7. Calibration

Nuclear gauges used for the purpose of acceptance testing, independent assurance testing, or dispute resolution shall be calibrated

WSDOT owned nuclear density gauges will be calibrated by WSDOT using the manufacturer’s recommended procedures or may be calibrated by an external calibration facility that has been approved by the State Materials Engineer.
Nuclear gauges that are not owned by WSDOT shall be calibrated in accordance with AASHTO T 310 Annexes A1, A 2, and A3.

8. Standardization

8.1 Turn the gauge on and allow it to stabilize (approximately 10 to 20 minutes) prior to standardization. Leave the power on during the day’s testing.

8.2 Standardize the nuclear gauge at the construction site at the start of each day’s work and as often as deemed necessary by the operator or agency. Daily variations in standard count shall not exceed the daily variations established by the manufacturer of the gauge. If the daily variations are exceeded after repeating the standardization procedure, the gauge should be repaired and or recalibrated.

8.3 Record the standard count for both density and moisture in the Daily Standard Count Log. The exact procedure for standard count is listed in the manufacturer’s Operators Manual.

9. Procedure

9.1 Turn on and allow the equipment to stabilize (warm up) according to the manufacturer’s recommendations (see 8.2.1). Prior to performing density test verify that today’s Standardization Count has been preformed.

Select a test location per WSDOT SOP 615.

9.2 Prepare the test site in the following manner:

9.2.1 Remove all loose and disturbed material and additional material as necessary to expose the top of the material to be tested.

Note 2: The spatial bias should be considered in determining the depth at which the gauge is to be seated.

9.2.2 Select a horizontal area sufficient in size to accommodate four gauge readings that will be 90° to each other, by planing the area to a smooth condition so as to obtain maximum contact between the gauge and material being tested.

9.2.3 The maximum void beneath the gauge shall not exceed ⅛ in (3 mm). Use native fines or fine sand to fill the voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler shall not exceed approximately ⅛ in (3 mm).

9.3 This Section has been deleted because WSDOT does not use this method

9.4 Direct Transmission Method of In-Place Nuclear Density & Moisture Content

9.4.1 Select a test location where the gauge in test position will be at least the minimum distance recommended by the manufacture away from any vertical projection. If gauge will be within the minimum distance recommended by the manufacture follow instructions outlined by manufactures instruction manual.
9.4.2 Make a hole perpendicular to the prepared surface using the guide and the hole-forming device (Section 5). The hole shall be a minimum of 2 in (50 mm) deeper than the desired measurement depth and of an alignment that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

9.4.3 Mark the test area to allow the placement of the gauge over the test site and to allow the alignment of the source rod to the hole. Follow manufacturer recommendations if applicable.

WSDOT Note: For alignment purposes, the user may expose the source rod for a maximum of ten seconds.

9.4.4 Remove the hole forming device carefully to prevent the distortion of the hole, damage to the surface, or loose material to fall into the hole.

WSDOT Note: If the hole cannot be maintained contact Regional Materials Laboratory for directions on how to proceed.

9.4.5 Place the instrument on the material to be tested, making sure of maximum surface contact as described above.

9.4.6 Lower the source rod into the hole to the desired test depth. Pull gently on the gauge in the direction that will bring the side of the probe to face the center of the gauge so that the probe is in intimate contact with the side of the hole in the gamma measurement path.

9.4.7 When selecting a test location, the tester shall visually select a site where the least compactive effort has been applied. Select a test location where the gauge will be at least 6 in (150 mm) away from any vertical mass. If closer than 24 in (600 mm) to a vertical mass, such as in a trench, follow gauge manufacturer correction procedures.

The test location should be at least 33 ft (10 m) away from other sources of radioactivity and at least 10 ft (3 m) away from large objects or the minimum distance recommended by the manufacturer, whichever is the greater distance.

9.4.8 If the gauge is so equipped, set the depth selector to the same depth as the probe before recording the automated (gauge computed densities, moisture contents, and weights) values.

9.4.9 Secure and record one, one minute dry density and moisture content readings, then turn the gauge 90° and perform another set of readings. If the two dry density readings are not within 3 lbs/cf (50 kg/m³) of each other see Note 5.

Note 5: If two readings are not within tolerances stated, rotate gauge 90° and retest. Again compare both 90° readings. If after four readings, the results are not within the tolerances stated, rotate gauge 90° and retest. Again compare both readings. If these reading are still not within tolerances stated move to another location to perform test.
10. Calculation of Results

10.1 If dry density is required, the in-place water content may be determined by using the nuclear methods described herein; gravimetric samples and laboratory determination; or other approved instrumentation.

10.1.1 If the water content is determined by nuclear methods, use the gauge readings directly.

10.1.2 If the water content is determined by other methods, and is in the form of percent, proceed as follows:

\[ d = \frac{100}{100+W} (m) \]

where:

- \( d \) = dry density in \( \text{lb/ft}^3 \) (\( \text{kg/m}^3 \))
- \( m \) = wet density in \( \text{lb/ft}^3 \) (\( \text{kg/m}^3 \))
- \( W \) = water as a percent of dry mass.

10.2. Percent Compaction

WSDOT has deleted this section refer to WSDOT SOP 615 for determining the percent compaction.

11. Report

WSDOT has deleted this section refer to WSDOT SOP 615 for reporting.

12. Precision and Bias

This section has been deleted by WSDOT. Refer to AASHTO T310 for precision and bias information.

Appendix

WSDOT has deleted this section; WSDOT uses the manufacturer’s software to calibrate the gauge.
Performance Exam Checklist

**In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)**

FOP FOR AASHTO T 310

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<thead>
<tr>
<th>Participant Name</th>
<th>Exam Date</th>
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<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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<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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<td>3. Gauge turned on and allowed to stabilize per manufacturer’s recommendations?</td>
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<td>4. Gauge standardized and standard count recorded in accordance with manufacturer’s instructions?</td>
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<td>5. Test location selected per WSDOT SOP 615?</td>
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<td>6. Loose, disturbed material removed?</td>
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<td>7. Flat, smooth area prepared?</td>
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<tr>
<td>8. Surface voids filled with native fines (⅛ in (3 mm) maximum thickness)?</td>
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<td>9. Hole driven 2 in (50 mm) deeper than material to be tested?</td>
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<td>10. Gauge placed, probe placed, and source rod lowered without disturbing loose material?</td>
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<tr>
<td>11. For alignment purposes, did not expose the source rod for more than 10 seconds.</td>
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<tr>
<td>12. Method B:</td>
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<tr>
<td>a. Gauge firmly seated, and gently pulled back so that source rod is against hole?</td>
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<tr>
<td>b. A one minute count taken; dry density and moisture data recorded?</td>
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<tr>
<td>c. Gauge turned 90° (180° in trench)?</td>
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<td>☐</td>
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<tr>
<td>d. Gauge firmly seated, and gently pulled back so that source rod is against hole?</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>e. A second one-minute count taken; dry density and moisture data recorded?</td>
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<td>f. Density counts within 3 lb/ft³ (50 kg/m³)?</td>
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<td>g. Average of two tests?</td>
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<td>13. A minimum 9 lbs (4 kg) sample obtained from below gauge?</td>
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<td>14. Oversize determined following WSDOT SOP 615?</td>
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<tr>
<td>15. All calculations performed correctly?</td>
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<tr>
<td>16. Nuclear Gauge secured in a manner consistent with current DOH requirements?</td>
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First Attempt:  Pass ☐  Fail ☐  Second Attempt:  Pass ☐  Fail ☐

Signature of Examiner  ________________________________
Comments:
1. Scope

1.1 This standard covers the compaction of cylindrical specimens of hot-mix asphalt (HMA) using the Superpave gyratory compactor.

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

2. Referenced Documents

2.1 AASHTO Standards

M 231 – Weighing Devices Used in Testing of Materials

TP 71 – Evaluation of the Superpave Gyratory Compactor (SGC) Internal Angle of Gyration Using Simulated Loading

R 30 – Mixture Conditioning of Hot-Mix Asphalt (HMA)

R 35 – Superpave Volumetric Design for Hot-Mix Asphalt (HMA)

T 166 – Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens

T 168 – Sampling Bituminous Paving Mixtures

T 209 – Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)

T 275 – Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens

T 316 – Viscosity Determination of Asphalt Binder Using Rotational Viscometer

2.2 Other Standards

WSDOT SOP 731 – Method for Determining Volumetric Properties of Hot Mix Asphalt (HMA)

3. Significance and Use

3.1. This standard is used to prepare specimens for determining the mechanical and volumetric properties of HMA. The specimens simulate the density, aggregate orientation, and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement of the paving mix.

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1This FOP is based on AASHTO T 312-09 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
3.2. This test method may be used to monitor the density of test specimens during their preparation. It may also be used for field control of an HMA production process.

4. Apparatus

4.1. Superpave Gyratory Compactor—An electrohydraulic or electromechanical compactor with a ram and ram heads as described in Section 4.3. The axis of the ram shall be perpendicular to the platen of the compactor. The ram shall apply and maintain a pressure of 600 ± 18 kPa perpendicular to the cylindrical axis of the specimen during compaction (Note 1). The compactor shall tilt the specimen molds at an average internal angle of 1.16 ± 0.02° (20.2 ± 0.35 mrad), determined in accordance with AASHTO TP 71. The compactor shall gyrate the specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction.

Note 1: This stress calculates to 10,600 ± 310 N total force for 6 inches (150 mm) specimens.

4.1.1 Specimen Height Measurement and Recording Device—When specimen density is to be monitored during compaction, a means shall be provided to continuously measure and record the height of the specimen to the nearest 0.1 mm during compaction once per gyration.

4.1.2 The system may include a connected printer capable of printing test information, such as specimen height per gyration. In addition to a printer, the system may include a computer and suitable software for data acquisition and reporting.

4.2 Specimen Molds—Specimen molds shall have steel walls that are at least 0.3 inches (7.5 mm) thick and are hardened to at least a Rockwell hardness of C48. The initial inside finish of the molds shall have a root mean square (rms) of 1.60 um or smoother (Note 2). Molds shall have an inside diameter of 5.9 to 6.0 inches (149.90 to 150.00 mm) and be at least 9.8 inches (250 mm) high at room temperature.

Note 2: Smoothness measurement is in accordance with ANSI B 46.1. One source of supply for a surface comparator, which is used to verify the rms value of 1.60 um, is GAR Electroforming, Danbury, Connecticut.

4.3 Ram Heads and Mold Bottoms—Ram heads and mold bottoms shall be fabricated from steel with a minimum Rockwell hardness of C48. The ram heads shall stay perpendicular to its axis. The platen side of each mold bottom shall be flat and parallel to its face. All ram and base plate faces (the sides presented to the specimen) shall be flat to meet the smoothness requirement in Section 4.2 and shall have a diameter of 5.88 to 5.90 inches (149.50 to 149.75 mm).

4.4 Thermometric Device—used for determining the temperature of aggregates, binder, and HMA between 18 to 418°F (10 and 232°C).

4.5 Balance—A balance meeting the requirements of M 231, Class G5, for determining the mass of aggregates, binder, and HMA.
4.6 Oven – An oven, thermostatically controlled to ± 5º F (± 3º C), for heating aggregates, binder, HMA, and equipment as required. The oven shall be capable of maintaining the temperature required for mixture conditioning in accordance with R 30.

4.7 Miscellaneous – Flat-bottom metal pans for heating aggregates, scoop for batching aggregates, containers (grill-type tins, beakers, containers for heating asphalt), large mixing spoon or small trowel, large spatula, gloves for handling hot equipment, paper disks, mechanical mixer (optional), lubricating materials recommended by the compactor manufacturer.

4.8 Maintenance – In addition to routine maintenance recommended by the manufacturer, check the Superpave gyratory compactor’s mechanical components for wear, and perform repair, as recommended by the manufacturer.

5. Hazards

5.1 Use standard safety precautions and protective clothing when handling hot materials and preparing test specimens.

6. Standardization

6.1 Items requiring periodic verification of calibration include the ram pressure, angle of gyration, gyration frequency, LVDT (or other means used to continuously record the specimen height), and oven temperature. Verification of the mold and platen dimensions and the inside finish of the mold are also required. When the computer and software options are used, periodically verify the data processing system output using a procedure designed for such purposes. Verification of calibration, system standardization, and quality checks may be performed by the manufacturer, other agencies providing such services, or in-house personnel. Frequency of verification shall follow the manufacturer’s recommendations.

6.2 The angle of gyration refers to the internal angle (tilt of mold with respect to end plate surface within the gyratory mold). The calibration of the internal angle of gyration should be verified in accordance with AASHTO TP 71.

7. Preparation of Apparatus

7.1 Immediately prior to the time when the HMA is ready for placement in the mold, turn on the main power for the compactor for the manufacturer’s required warm-up period.

7.2 Verify the machine settings are correct for angle, pressure, and number of gyrations.

7.3 Lubricate any bearing surfaces as needed per the manufacturer’s instructions.

7.4 When specimen height is to be monitored, the following additional item of preparation is required. Immediately prior to the time when the HMA is ready for placement in the mold, turn on the device for measuring and recording the height of the specimen, and verify the readout is in the proper units, mm, and the recording device is ready. Prepare the computer, if used, to record the height data, and enter the header information for the specimen.
8. HMA Mixture Preparation

8.1 Weigh the appropriate aggregate fractions into a separate pan, and combine them to the desired batch weight. The batch weight will vary based on the ultimate disposition of the test specimens. If a target air void level is desired, as would be the case for Superpave mix analysis and performance specimens, batch weights will be adjusted to create a given density in a known volume. If the specimens are to be used for the determination of volumetric properties, the batch weights will be adjusted to result in a compacted specimen having dimensions of 6 inches (150 mm) in diameter and 4.53 ± 0.12 inches (115 ± 5 mm) in height at the desired number of gyrations.

*Note 3:* It may be necessary to produce a trial specimen to achieve this height requirement. Generally, 4500–4700 g of aggregate are required to achieve this height for aggregates with combined bulk specific gravities of 2.55–2.70, respectively.

8.2 Place the aggregate and binder container in the oven, and heat them to the required mixing temperature.

8.2.1. The mixing temperature range is defined as the range of temperatures where the unaged binder has a kinematic viscosity of 170 ± 20 mm²/s (approximately 0.17 ± 0.02 Pa·s for a binder density of 1.00 g/cm³) measured in accordance with T 316.

*Note 4:* Modified asphalts may not adhere to the equi-viscosity requirements noted, and the manufacturer’s recommendations should be used to determine mixing and compaction temperatures.

*Note 5:* The SI unit kinematic viscosity is m²/s; for practical use, the submultiple mm²/s is recommended. The more familiar centistokes is a cgs unit of kinematic viscosity; it is equal to 1 mm²/s. The kinematic viscosity is the ratio of the viscosity of the binder to its density. For a binder with a density equal to 1.000 g/cm³, a kinematic viscosity of 170 mm²/s is equivalent to a viscosity of 0.17 Pa·s measured in accordance with T 316.

8.3 Charge the mixing bowl with the heated aggregate from one pan, and dry-mix thoroughly. Form a crater in the dry blended aggregate, and weigh the required amount of binder into the mix. Immediately initiate mixing.

8.4 Mix the aggregate and binder as quickly and thoroughly as possible to yield HMA having a uniform distribution of binder. As an option, mechanical mixing may be used.

8.5 After completing the mixture preparation perform the required mixture conditioning in accordance with R 30.

8.6 Place a compaction mold and base plate in an oven not to exceed 350°F for a minimum of 60 minutes prior to the estimated beginning of compaction (during the time the mixture is being conditioned in accordance with R 30).
8.7 Following the mixture conditioning period specified in R 30, if the mixture is at the compaction temperature, proceed immediately with the compaction procedure as outlined in Section 9. If the compaction temperature is different from the mixture conditioning temperature used in accordance with R 30, place the mix in another oven at the compaction temperature for a brief time (maximum of 30 minutes) to achieve the required temperature.

8.7.1. The compaction temperature is the mid-point of the range of temperatures where the unaged binder has a kinematic viscosity of 280 ± 30 mm²/s (approximately 0.28 ± 0.03 Pa·s) measured in accordance with T 316 (Note 4).

8.8 If loose HMA plant mix is used, the sample should be obtained in accordance with T 168. The mixture shall be brought to the compaction temperature range by careful, uniform heating in an oven immediately prior to molding.

9. Compaction Procedure

9.1 When the temperature of the HMA is five degrees above the compaction temperature as shown on the “Mix Design Verification Report,” remove the heated mold, base plate, and upper plate (if required) from the oven. Place the base plate and a paper disk in the bottom of the mold.

9.2 Remove the pan of HMA from the oven and in one motion invert the pan onto the construction paper, vinyl mat, etc. Quickly remove any material that remains in the pan and include it with the HMA sample to be compacted. Grasp opposing edges of the paper and roll them together to form the HMA into a cylindrical shape. Insert one end of the paper roll into the bottom of the compaction mold and remove the paper as the HMA slides into the mold. This process needs to be accomplished in approximately 60 seconds. Place the mixture into the mold in one lift. Care should be taken to avoid segregation in the mold. After all the mix is in the mold, level the mix, and place another paper disk and upper plate (if required) on top of the leveled materials.

9.3 Load the charged mold into the compactor, and center the loading ram.

9.4 Apply a pressure of 600 ± 18 kPa on the specimen.

9.5 Apply a 1.16 ± 0.02° (20.2 ± 0.35 mrad) average internal angle, as appropriate, to the mold assembly, and begin.

9.6 Allow the compaction to proceed until the desired number of gyrations specified in R 35 is reached and the gyratory mechanism shuts off.

9.7 Remove the angle from the mold assembly; retract the loading ram; remove the mold from the compactor (if required); and extrude the specimen from the mold.

Note 6: The specimens can be extruded from the mold immediately after compaction for most HMA. However, a cooling period of 5 to 10 minutes in front of a fan may be necessary before extruding some specimens to insure the specimens are not damaged.
9.8 Remove the paper disks from the top and bottom of the specimens.

*Note 7:* Before reusing the mold, place it in an oven for at least 5 minutes. The use of multiple molds will speed up the compaction process.

10. Density Procedure

10.3 When the specimen height is to be monitored, record the specimen height to the nearest 0.1 mm after each revolution.

11. Density Calculations

WSDOT has removed this section refer to WSDOT SOP 731.

12. Report

WSDOT has removed this section refer to WSDOT SOP 731.

13. Precision and Bias

See AASHTO T 312 for Precision and Bias.
## Performance Exam Checklist

### Determining Density of Hot Mix Asphalt (HMA) Specimens by Means of the SHRP Gyratory Compactor

**FOP for AASHTO T 312**

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<thead>
<tr>
<th>Participant Name</th>
<th>Exams Date</th>
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**Procedure Element**

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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. Main power for compactor turned on for manufacturer’s required warm-up period if applicable?
4. Angle, pressure and number of gyrations set?
5. Bearing surfaces, rotating base surface and rollers lubricated?

### Preparation of Mixtures

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1. Is mixture 5°F above compaction temperature? If not, was mixture placed in an oven and brought up to 5°F above compaction temperature?
2. Mold and base plate heated for a minimum of 60 minutes in an oven at a temperature not to exceed 350°F?

### Plant Mix – Loose mix brought to compaction temperature by uniform heating immediately prior to molding.

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<th>Yes</th>
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1. Mold, base plate, and upper plate (if required) removed from oven and paper disk placed on bottom of mold?
2. Mixture placed into mold in one lift, mix leveled, and paper disk and upper plate (if required) placed on top of material?
3. Mold loaded into compactor and a pressure of 600 ± 18 kPa applied?
4. Angle of 1.16 ± 0.02° (20.2 ± 0.35 mrad) applied to the mold assembly and gyratory compaction started?
5. Compactor shuts off when appropriate gyration level is reached?
6. Mold removed and specimen extruded?
7. Paper disks removed?
8. If specimens are used for determination of volumetric properties, are the heights of the specimens 115 ± 5mm?
9. All calculations performed correctly?

First Attempt:  Pass ☐ Fail ☐  
Second Attempt: Pass ☐ Fail ☐

Signature of Examiner ________________________________
Comments:
WSDOT FOP for AASHTO T 329¹
Moisture Content of Asphalt (HMA) by Oven Method

1. Scope

1.1 This method is intended for the determination of moisture content of hot mix asphalt (HMA) by drying in an oven.

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

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

2. Referenced Documents

2.1 AASHTO Standards
   M 231 – Weighing Devices Used in the Testing of Materials
   T 168 – Sampling Bituminous Paving Mixtures

2.2 WAQTC Standards
   T 168 – Sampling Bituminous Paving Mixtures

2.3 WSDOT Standards
   T 712 – Standard Method of Reducing Hot Mix Asphalt Paving Mixtures

3. Terminology

3.1 Constant mass shall be defined as the mass at which further drying at 325 ± 25°F (163 ± 14°C) does not alter the mass by more than 0.1 percent.

4. Summary of Test Method

4.1 A sample of HMA is dried in a forced-air, ventilated, or convection oven to a constant mass.

5. Apparatus

5.1 Balance or Scale – 4.4-lb (2-kg) capacity, readable to at least 0.1 g and conforming to the requirements of M 231.

5.2 Forced-Air, Ventilated, or Convection Oven – Capable of maintaining the temperature surrounding the sample at 325 ± 25°F (163 ± 14°C).

5.3 Sample Container – The container in which the sample is dried shall be of sufficient size to contain the sample without danger of spilling and to allow the sample to be evenly distributed in a manner that will allow completion of the test in an expeditious manner.

¹This FOP is based on AASHTO T 329-08 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
5.4 Thermometric Devices – Armored glass, Infrared gun or dial-type thermometers with metal stems for determining the temperature of aggregates, binder, and HMA.

6. Sample

6.1 A sample of HMA shall be obtained in accordance with WSDOT FOP for WAQTC T 168.

6.2 The sample shall be reduced in size in accordance with WSDOT T 712. The size of the test sample shall be a minimum of 1,000 g.

7. Procedure

7.1 Determine and record the mass of the sample container to the nearest 0.1 g.

7.2 Place the test sample in the sample container. Determine and record the temperature of the test sample. To facilitate drying, evenly distribute the test sample in the sample container.

7.3 Determine and record the total mass of the sample container and moist test sample to the nearest 0.1 g.

7.4 Preheat the oven to drying temperature of 325 ± 25°F (163 ± 14°C).

Note 1: For repeatability between operators and or laboratories the difference between drying temperatures for samples should not exceed 15°F (9°C).

7.5 Calculate the mass of the initial, moist test sample by subtracting the mass of the sample container determined in Section 7.1 from the total mass of the sample container and moist test sample determined in Section 7.3.

7.6 The test sample shall be initially dried for a minimum of 90 minutes, and it's mass determined. Then, at 30 min intervals until constant mass is achieved.

Note 2: The moisture content of test samples and the number of test samples in the oven will affect the rate of drying at any given time. Placing wet test samples in the oven with nearly dry test samples could affect the drying process.

7.7 Cool the sample container and test sample to approximately the same temperature as determined in Section 7.2.

7.8 Determine and record the total mass of the sample container and dry test sample to the nearest 0.1 g.

Note 3: Do not attempt to remove the test sample from the sample container for the purposes of determining the dry mass of the test sample.

7.9 Calculate the mass of the final, dry test sample by subtracting the mass of the sample container determined in Section 7.1 from the total mass of the sample container and dry test sample determined in Section 7.8.
8. Calculations

8.1 WSDOT uses the following formula to calculate moisture content:

\[
\text{Moisture Content, } \% = \frac{M_i - M_f}{M_i} \times 100
\]

Where:
- \(M_i\) = Mass of the initial, moist test sample
- \(M_f\) = Mass of the final, dry test sample

Example: \(M_i = 1,389.8\) g
\(M_f = 1,388.0\) g

\[
\text{Moisture Content} = \frac{1,389.8 - 1,388.0}{1,389.8} \times 100 = 0.129\% = 0.13\%
\]

9. Report

9.1 Report the moisture content to the nearest 0.01 percent.

9.2 Report the results using one or more of the following:
- Materials Testing System (MATS)
- WSDOT Form 350-092 and 350-157
- Form approved in writing by the State Materials Engineer
## Performance Exam Checklist

**Moisture Content of Asphalt (HMA) by Oven Method**

**WSDOT FOP for AASHTO T 329**

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

### Procedure Element

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? ☐ ☐

### Test for Moisture

1. Representative sample obtained; 1,000 g minimum? ☐ ☐
2. Mass of sample determined to nearest 0.1 g? ☐ ☐
3. Initial temperature recorded? ☐ ☐
4. Sample placed in drying oven for a minimum of 90 minutes? ☐ ☐
5. Sample dried to a constant weight at 325 ±25° F? ☐ ☐
6. Samples checked for additional loss? ☐ ☐
7. Sample and container cooled to approximately the initial temperature before mass determined? ☐ ☐
8. Calculation of moisture content performed correctly? ☐ ☐

**% Moisture as percent of Wet Mass**

\[
\frac{M_i - M_f}{M_i} \times 100
\]

First Attempt: Pass ☐ Fail ☐  
Second Attempt: Pass ☐ Fail ☐

Signature of Examiner  _______________________________

Comments:
1. Scope

1.1 This test method covers the determination of the percentage, by mass, of a coarse aggregate sample that consists of fractured particles meeting specified requirements.

1.2 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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.

1.3 The text of the standard reference notes provide explanatory material. These notes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 Method 1 will be used by WSDOT for determining the fracture of aggregate as required by the Standard Specifications.

2. Referenced Documents

2.1 AASHTO Standards

   M 92, Wire-Cloth Sieves for Testing Purposes

   M 231, Weighing Devices Used in the Testing of Materials

2.2 WSDOT Standardss

   T 2 – FOP for AASHTO Sampling of Aggregates

   T 27/11 – FOP for WAQTC/AASHTO Sieve Analysis of Fine and Coarse Aggregates

   T 248 – FOP for AASHTO Reducing Samples of Aggregate to Testing Size

   T 255 – FOP for AASHTO Total Evaporable Moisture Content of Aggregate by Drying

3. Summary of Test Method

3.1 A sample of aggregate is separated using the designated size of screen conforming to the specification controlling the determination of coarse and fine aggregate. The coarse aggregate particles are visually evaluated to determine their conformance to the defined fracture. The percentage of conforming particles, by mass, is determined for comparison to standard specifications.

4. Apparatus

4.1 Balance – Shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231 for general-purpose balance required for the principle sample mass being tested.

---

1This FOP is based on AASHTO T 335-09 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
4.2 Sieves – Meeting the requirements of M 92.

4.3 Splitter – Meeting the requirements of T 248.

5. Terminology

5.1 Fractured Face – An angular, rough, or broken surface of an aggregate particle created by crushing, or by other means. A face is considered a “fractured face” whenever one-half or more of the projected area, when viewed normal to that face, is fractured with sharp and well-defined edges (this excludes small nicks).

5.2 Fractured Particle – A particle of aggregate having at least the minimum number of fractured faces specified.

6. Sampling

Sample the aggregate in accordance with WSDOT FOP for AASHTO T 2 and reduce the sample in accordance with WSDOT FOP for AASHTO T 248, to the sample sizes shown in Table 2 of WSDOT FOP for AASHTO T 27/11.

7. Sample Preparation

7.1 Where the specifications list only a total fracture percentage, the sample shall be prepared in accordance with Method 1.

7.2 Method 1 – Combined Fracture Determination

7.2.1 Dry the sample sufficiently to obtain a clean separation of fine and coarse material in the sieving operation. Sieve the sample in accordance with WSDOT FOP for WAQTC/AASHTO T 27/11 over the No. 4 (4.75 mm) sieve.

Note 1: Where necessary, wash the sample over the sieve or sieves designated for the determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with WSDOT FOP for AASHTO T 255.

7.2.2 Reduce the sample using a splitter in accordance with WSDOT FOP for AASHTO T 248 to the appropriate size for test.
Determining the Percentage of Fracture in Coarse Aggregate

<table>
<thead>
<tr>
<th>Nominal Maximum Particle Size</th>
<th>Minimum Sample Mass Retained No. 4 (4.75 mm) Sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1½ in (37.5 mm)</td>
<td>6 lb (2500 g)</td>
</tr>
<tr>
<td>1 in (25 mm)</td>
<td>3.5 lb (1500 g)</td>
</tr>
<tr>
<td>¾ in (19.0 mm)</td>
<td>2.5 lb (1000 g)</td>
</tr>
<tr>
<td>⅜ in (16.0 mm)</td>
<td>2.0 lb (800 g)</td>
</tr>
<tr>
<td>½ in (12.5 mm)</td>
<td>1.5 lb (700 g)</td>
</tr>
<tr>
<td>⅛ in (9.5 mm)</td>
<td>0.9 lb (400 g)</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>0.4 lb (200 g)</td>
</tr>
</tbody>
</table>

*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.

**Note:** 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.

**Sample Size (Method 1, Combined Sieve Fracture)**

Table 1

7.3 **Method 2** – Individual Sieve Fracture Determination WSDOT has deleted this section

8. **Procedure**

8.1 Spread the sample on a clean flat surface large enough to permit careful inspection of each particle. To verify that a particle meets the fracture criteria, hold the aggregate particle so that the face is viewed directly. (See Section 5.1.)

8.2 To aid in making the fracture determination separate the sample into three categories: (1) fractured particles meeting the above criteria, (2) particles not meeting specification criteria, and (3) questionable or borderline particles.

8.3 Determine the mass of particles in the fractured category, the mass of questionable particles, and the mass of the unfractured particles.

9. **Calculation**

9.1 Report the following information:

9.1.1 Calculate the mass percentage of fracture faces to the nearest 1 percent as follows:

\[
P = \left( \left( \frac{F + Q}{2} \right) / \left( F + Q + N \right) \right) \times 100
\]

where:

\[
P = \text{percent of fracture},
\]

\[
F = \text{mass of fractured particles},
\]

\[
Q = \text{mass of questionable or borderline particles, and}
\]

\[
N = \text{mass of unfractured particles}.
\]
10. Report

Results shall be reported on standard forms approved for use by the agency. Report fracture to the nearest 1 percent.

Report the results using one or more of the following:

- Materials Testing System (MATS)
- WSDOT Form 350-092 and 350-157
- Form approved in writing by the State Materials Engineer

11. Precision and Bias

See AASHTO T 335 for precision and bias statements.
## Performance Exam Checklist

*Determining the Percentage of Fracture In Coarse Aggregate*

*WSDOT FOP for AASHTO T 335*

Participant Name ________________________________ Exam Date ___________________

<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, and if required, has the current calibration/verification tags present?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Sample reduced to correct size, if needed?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Sample dried and cooled, if necessary?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Sample properly sieved through specified sieve(s)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Particles separated into fractured, unfractured, and questionable categories?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Dry mass of each category determined to nearest 0.1 g?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Calculation performed correctly?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

First Attempt: Pass ☐ Fail ☐ Second Attempt: Pass ☐ Fail ☐

Signature of Examiner __________________________________________

Comments:
WSDOT Test Method T 408  
Method of Test for Quality of Water to be Used in Mixing Concrete

1. Scope
   a. This method is intended for laboratory use in determining the quality of water to be used in mixing concrete.

2. Apparatus
   a. Porcelain evaporating dish with 3.4 oz. (100 ml) minimum capacity.
   b. 3.4 oz. (100 ml) pipet.
   c. Drying oven maintained at 212°F (100°C).
   d. Analytical balance.

3. Procedure
   a. Pipet 3.4 oz. (100 ml) of sample into a weighed porcelain evaporating dish and record total weight (mass). Evaporate to dryness, cool in a desiccator and reweigh, using analytical balance for all weighing.

4. Calculation
   a. \( \frac{g \text{ of residue}}{g \text{ of sample}} \times 10^6 = \text{ppm total solids} \)

5. Report
   a. Report the results using one or more of the following:
      - Materials Testing System (MATS)
      - WSDOT Form 350-034
      - Form approved in writing by the State Materials Engineer

Note: The determination of the composition of the mineral matter in the water requires a complete chemical analysis and is not generally undertaken except when the percentage of total solids is above 1,000 ppm. When the mineral analysis is desired, the procedure starting on page 2388 of Scott’s Standard Methods of Chemical Analysis, Sixth Edition (1963), Volume II, should be used. The results should be reported as the separate constituents in parts per million. If the hypothetical combination into salts is desired, the method given by Scott, or the method given on page 336, Volume V, Number 5, Industrial and Engineering Chemistry, should be used.
WSDOT Test Method T 411
Method of Test for Water Absorption and Moisture Vapor Transpiration

1. Scope
   a. This method is intended for laboratory uses in determining the efficiency of water repellant compounds.

2. Apparatus
   a. Test blocks 1½ in (38.1 mm) thick by 3½ in (88.9 mm) wide by 6 in (152.4 mm) long.
   b. Oven maintained at 100°F (37.8°C).

3. Test Specimens
   a. Three specimens per test shall be made with one part of Type 1 or Type II Portland cement, one part hydrated lime, six parts 8- to 28-mesh sound natural sand, six parts 28- to 100-mesh sound natural sand, and 1.94 parts of water on a weight basis. These materials shall be thoroughly mixed for two minutes by hand or mechanical mixer in a suitable bowl after the water has been added. Following this the mix shall be cast in molds that will make specimens approximately 1½ in (38.1 mm) thick, 3½ in (88.9 mm) wide, and 6 in (152.4 mm) long.
   b. Specimens shall then be cured one day in the molds at 73.4 ± 3°F (23°C ± 1.7°C) and six days in 95 percent relative humidity at 73.4 ± 3°F (23°C ± 1.7°C). At the end of the moist curing period, the specimens shall be dried in 20 to 30 percent relative humidity at 100°F (37.8°C) to constant weight (mass).

4. Procedure for Water Absorption Test
   a. When the specimens reach constant weight the water repellant compound shall be applied in two applications at the rate of 150 sq ft per gallon (3.7 m² per liter) for each application to the bottom sand side surfaces of the specimens as cast. A minimum of 12 hours air drying shall be allowed between applications. The specimens shall be allowed to air dry for 24 hours after final application before starting the test.
   b. The specimens shall then be weighed to the nearest gram and placed in ¼ in (6.4 mm) of 73.4 ± 3°F (23°C ± 1.7°C) water with the treated 3½ in (88.9 mm) by 6 in (152.4 mm) surface face down. The water shall be maintained at a constant level and the units shall be supported so as to permit the free circulation of water around and under them. The specimens, after 72 hours immersion, shall be surface dried and weighed to the nearest gram. The water absorption shall be calculated as a percentage of the dry weight (mass). If the average of three specimens shows more than 2 percent moisture absorption, the water repellant compound is unsatisfactory.
5. Procedure for Moisture Vapor Transpiration Test

a. Specimens meeting the water absorption test specification, they shall then be tested for transpiration (breathing).

b. Immediately following the absorption test, the three test specimens shall be placed, untreated face down, in the water storage until they reach saturation as determined by a constant weight (mass). Total water absorbed shall then be recorded. At this point, the specimens shall be surface dried and the untreated face completely covered with an oversized piece of wax paper. The wax paper shall be applied by placing the untreated face of the specimen down on the wax paper and then pouring a hot wax fillet between the wax paper and the vertical sides of the specimen. The weight (mass) of each specimen shall then be recorded and the specimen placed, treated side up, in a suitable location where there is free circulation of air at 73.4 ± 3°F (23° ± 1.7°C) and 40 to 50 percent relative humidity. The specimens shall be weighed after seven days drying to determine the moisture loss. The loss shall be expressed as a percentage of the total water absorbed and shall be not less than 50 percent at seven days.

6. Report

a. Report the results using one or more of the following:
   - Materials Testing System (MATS)
   - WSDOT Form 350-034
   - A Form approved in writing by the State Materials Engineer
WSDOT Test Method T 426
Pull-Off Test for Hot Melt Traffic Button Adhesive

1. Scope

This method describes the procedure for determining the force (psi) required to pull a Type 1 raised pavement marker, from an asphalt or concrete surface that has been adhered with hot melt button adhesive.

2. Apparatus and Materials

a. Asphalt or concrete surface, conditioned for 24 hours at standard laboratory conditions prior to testing.

b. Raised pavement marker – WSDOT Type 1 plastic or thermoplastic, drilled in the center to accept a threaded steel rod.

c. Laboratory melter – as described in ASTM D5167.

d. Threaded steel eye bolt for attaching to the raised pavement marker.

e. Tensile testing apparatus – as described in AASHTO T 237 Section 15, fitted with a threaded steel rod with a 2” hook.

3. Procedure

a. Pull-off tests shall be run in triplicate.

b. Hot melt traffic button adhesive shall be heated in a laboratory melter to the manufacturer’s recommended application temperature.

c. A quantity of adhesive sufficient to squeeze out a small bead around the entire periphery of a 4” button shall be poured onto surface and a pre-drilled raised pavement marker shall be seated on the adhesive and allowed to cure for at least 4 hours.

d. A threaded steel eye bolt shall be inserted into the pre-drilled hole in the button.

e. The puck/block and button shall be placed in the tensile testing apparatus and the threaded hook shall be inserted in the eye bolt.

f. Load shall be applied slowly until the button pulls off from the surface and the maximum load shall be recorded.
4. Calculation

The pull-off strength shall be calculated as follows:

Pull-off Strength, psi = \( \frac{L}{A} \)

\( L = \) Maximum load, pounds
\( A = \) Surface area of Pavement marker (in\(^2\))

5. Report

The pull-off strength reported shall be the average of the three determinations.
WSDOT Test Method T 432
Flexible Test for Hot-Melt Adhesives

1. Scope

This method describes the determination of flexibility of hot-melt adhesives under specific conditions.

2. Referenced Documents


3. Apparatus and Materials

   a. 1” diameter Mandrel and holder.

   b. Three-specimen stainless steel flexibility mold, 1/8” x 1” x 6” dimensions.

4. Procedure

   a. Adhesive material is melted and prepared by Liquid Asphalt lab per WSDOT SOP 318.

   b. Test specimens poured into the flexibility mold.

   c. Test specimens allowed to cure at room temperature for at least one hour.

   d. The test specimens removed from the mold and conditioned at 20°F for minimum of four hours.

   e. The 1” diameter Mandrel and its holder are also conditioned at 20°F for minimum of four hours.

   f. Flexibility test is done in the same environment used to condition the specimens, by bending each specimen over the 1” Mandrel in an arc of 90° at a uniform rate for ten seconds.

5. Report

Flexibility shall be reported as Pass/Fail. Failure is a visible fracture, crazing, or cracking of the hot-melt adhesive that can occur at any time during the bending of two out of the three specimens.
WSDOT Test Method T 606
Method of Test for Compaction Control of Granular Materials

1. Scope

This test method is used to establish the theoretical maximum density of granular materials and non-granular materials with more than 30 percent by weight of the original specimen is retained on the No. 4 Sieve or more than 30 percent by weight of the original specimen is retained on the ¾" sieve.

2. Reference Documents

2.1 AASHTO Standards

T 99 – Moisture-Density Relations of Soils Using a 5.5-lb (2.5-kg) Rammer and a 12-in. (305-mm) Drop (Method A only)

2.2 WSDOT Standards

T 2 – FOP for AASHTO Standard Practice for Sampling Aggregates
T 248 – FOP for AASHTO Reducing Samples of Aggregate to Testing Size
T 255 – FOP for AASHTO Total Moisture Content of Aggregate by Drying

3. Definitions

3.1 Fine Aggregate Portion-Material passing the No. 4 Sieve

3.2 Coarse Aggregate Portion-Material retained on the No. 4 Sieve

4. Significance and Use

This test method consists of three separate tests which present a method for establishing the proper theoretical maximum density values to be used for controlling the compaction of granular materials. In general, this test method is applicable to granular materials having 30 to 70 percent of the material passing the No. 4 (4.75 mm) sieve. These methods account for variations of maximum obtainable density of a given material for a given compactive effort, due to fluctuations in gradation.

5. Apparatus

5.1 A vibratory spring-loaded compactor. Information on where to obtain this equipment will be provided by the State Materials Laboratory.

5.2 Standard mold and base with a piston to fit inside the mold with a maximum ⅛ inch clearance between piston and mold.
5.3 A ½ ft³ mold with a piston to fit inside mold having a maximum ¼ inch clearance
between piston and mold.

5.3.1 The molds and pistons will be constructed of metal of such dimensions as to
remain rigid and inflexible under test conditions.

5.4 Spacer blocks of varying heights compatible with the compactor and pistons

5.5 Measuring device, accurate and readable to 0.01 inch with a minimum 6 inch length

5.6 Pycnometer calibrated at the test temperature having a capacity of at least 1 quart
(100 ml). Metal pycnometers may not be used to determine the specific gravity of the
fine particles.

5.7 One vacuum pump or aspirator (pressure not to exceed 100 mm mercury).

5.8 One balance accurate to 0.1 g.

5.9 3 inch (75 mm) and a No. 4 (4.75 mm) sieve conforming to AASHTO M 92
requirements.

5.10 Balance or scale: capacity sufficient for the principle sample mass, readable to 0.1 percent
or 0.1 g and meeting the requirements of AASHTO M 231.

5.11 A 5.5 lb (2.5 kg) metal rammer conforming to the requirements of AASHTO T 99.

5.12 Tamping rod of straight steel, 5/8 inch (16 mm) in diameter and approximately 24 inch
(400 mm) long having at least one end rounded to a hemispherical tip.

5.13 Graduated cylinder, 1000 ml capacity, readable to 5 ml.

5.14 A stopwatch or timer readable to 1 second.

6. Selection of T 606 Test and Procedure

To select the proper method for determining the maximum density of the Fine Aggregate portion
of the sample, refer to the “Fine Aggregate Split of Original Sample” section of Table 1.

To select the proper procedure in Test 2 for determining the maximum density of the Coarse
Aggregate portion of the sample, refer to the “Coarse Aggregate Split of Original Sample”
section of Table 1.
### Test Selection Table 1

#### Fine Aggregate Split of Original Sample

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy, Non-plastic, permeable soils or non-cohesive soils.</td>
<td>T606 Test 1</td>
</tr>
<tr>
<td>Silt, some plasticity, low permeability</td>
<td>T 99 Method A</td>
</tr>
<tr>
<td>Sandy/silt, some plasticity, permeable</td>
<td>T606 Test 1/T99 Method A</td>
</tr>
<tr>
<td></td>
<td>(use highest results)</td>
</tr>
</tbody>
</table>

#### Coarse Aggregate Split of Original Sample

| No more than 15 percent of the coarse aggregate split exceeds \( \frac{3}{4} \) in | T606 Test 2 Procedure 1                     |
| 15 percent or more of the coarse aggregate split is greater than \( \frac{3}{4} \) in. (19 mm), but does not exceed 3 in. (76 mm) | T606 Test 2 Procedure 2                     |

7. Sampling Material

7.1 Sample the material in accordance with WSDOT FOP for AASHTO T 2.

7.2 Native soils within the contract limits to be used for embankment construction and/or backfill material do not require sampling by a qualified tester.

7.3 For material that requires gradation testing such as but not limited to manufactured aggregates and gravel borrow, sampling shall be performed by a qualified testers.

8. Sample Preparation

8.1 Prepare the field sample by splitting out a representative portion in accordance with WSDOT FOP for AASHTO T 248.

8.2 Dry the compaction sample to constant mass in accordance with WSDOT FOP for AASHTO T 255.

8.3 Scalp the plus 75mm (3 inch) material from the compaction sample and discard, if not required for other tests. Separate the remainder of the compaction sample into coarse [minus 3 inch (75mm) to No. 4 (4.75mm)] and fine [minus No. 4 (4.75mm)] aggregate portions.

8.4 The quantity of material necessary to complete tests on both fractions is:

8.4.1 Fine aggregate, minimum of 3 portions approximately 13 lb (6 kg) each.

8.5 Coarse aggregate:

8.5.1 For material containing 15 percent or less of \( \frac{3}{4} \) inch (19 mm) material, a portion of the minus \( \frac{3}{4} \) inch (19.0mm) aggregate of approximately 13 lbs (6 kg).

8.5.2 For material containing more than 15 percent plus \( \frac{3}{4} \) in (19.0 mm) aggregate, a portion of 40 to 45 lb (18 to 20 kg).
9. Procedure

9.1 Test No. 1- Compaction Test of the Fine Fraction (No. 4 minus material)

9.1.1 Assemble the small mold and determine its mass, along with the piston, to the nearest 0.01 lb (5g). Record this as the Mass of Mold Assembly.

9.1.2 Using one of the fine aggregate portions, add an amount of water estimated to produce a saturated sample when compacted and mix thoroughly.

*Note 1:* When the material is at its saturation point, free water (a drop or two) will show at the base of the mold at about the 500 lb (227 kg) load of the first compression run. The ideal saturation point would be a bead of water around the base of the mold at the end of the 10-minute compaction run. Most materials will yield the highest density at that moisture content. Some materials may continue to gain density at higher moisture contents; however, this is due to the washing out of fines, which will alter the character of the sample. Therefore, if severe washing-out or pumping of fines occurs (as evidenced by dirty water flooding off of the base or pumped on top of the piston), the sample is beyond the saturation point, will be discarded and a lower moisture content tried for the saturation point.

9.1.3 Set the piston aside and place the sample in the mold in three approximately equal layers. Consolidate each lift by 25 strokes of the tamping rod followed by 25 blows of the manual rammer. The surface of the top lift should be finished as level as possible.

9.1.4 Place the piston on top of the sample and mount the mold on the jack platform in the compactor. Spacers between the load spring and piston must be used to adjust the elevation of the mold so the hammers strike the mold in the center of the lift area. Elevate the mold until the loading head seats on top of the piston. Apply an initial seating load of approximately 100 lbs on the sample.

9.1.5 Start the compactor hammers and, by elevating the jack, begin the loading procedure. The load is applied as follows:

<table>
<thead>
<tr>
<th>Load Application Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
</tr>
<tr>
<td>0 to 500 lb</td>
</tr>
<tr>
<td>500 lb to 1000 lb</td>
</tr>
<tr>
<td>1000 lb to 2000 lb</td>
</tr>
</tbody>
</table>

9.1.6 Upon reaching the 2000 lb load at the end of the 2-minute cycle, stop the hammers, release the load on the jack, and return to zero pressure.

9.1.7 Repeat Steps 9.1.4 through 9.1.6 four additional times. After the last run, remove the mold from the compactor.

9.1.8 Measure the height of the compacted sample to the nearest 0.01 in (0.1 mm). Record as the Depth.
9.1.9 Determine the mass of the specimen in the mold to the nearest 0.01 lb (5g). Record this as:

\[
\text{Mass of Mold + Sample}
\]

9.1.10 Remove the specimen from the mold and determine the moisture content in accordance with WSDOT FOP for AASHTO T 255.

9.1.11 Vertically slice through the center of the specimen, take a representative specimen (at least 1.1 lbs (500 g)) of the materials from one of the cut faces (using the entire specimen is acceptable), weigh immediately, and dry in accordance with AASHTO T 255 to determine the moisture content, and record the results.

9.1.12 Calculate and record the dry density of fine fraction.

9.2 Test No. 2 – Compaction Test of the Coarse Fraction:

9.2.1 Procedure 1 – Minus \( \frac{3}{4} \) in (19 mm) aggregates

9.2.1.1 Determine the mass of the coarse aggregate to the nearest 0.01 lb (5g).

9.2.1.2 Add 2.5 percent moisture to the sample, mix thoroughly

9.2.1.3 Place in 0.1 ft\(^3\) (0.0028 m\(^3\)) mold in approximately three equal lifts. Compact each lift with 25 blows of the tamping rod (omit hammering). Avoid the loss of any material during placement.

9.2.1.4 Follow steps 9.1.4 through 9.1.6.

9.2.1.5 Calculate and record the dry density of coarse fraction.

9.2.2 Procedure 2 – Plus \( \frac{3}{4} \) in (19 mm) aggregates

9.2.2.1 Determine the mass of the coarse aggregate to the nearest 0.01 lb (5g) or better.

9.2.2.2 Divide the sample into five representative and approximately equal portions.

9.2.2.3 Place one of the portions into the \( \frac{1}{2} \) ft\(^3\) (0.014 m\(^3\)) mold.

9.2.2.4 Level the surface by hand and consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the material rodding full depth, if possible, without hitting the bottom too hard.

9.2.2.5 Repeat this procedure for the other four lifts, penetrating, if possible, into the lower layer. Avoid the loss of any material during this operation.

9.2.2.6 Position the piston on the sample, mount the mold in the compactor and follow the procedure described in steps 9.1.4 through 9.1.6

9.2.2.7 Calculate and record the dry density of coarse fraction.
9.3 Test No. 3 – Specific Gravity Determination for Maximum Density Test

9.3.1 Material

9.3.1.1 Fine fraction U.S. No. 4 (4.75 mm) minus 1.1 lbs. (500 g) minimum

9.3.1.2 Coarse fraction U.S. No. 4 (4.75 mm) plus 2.2 lbs. (1,000 g) minimum.

9.3.2 Procedure

9.3.2.1 Place dry materials, either fine or coarse fraction, in pycnometer, add water.

9.3.2.2 Put pycnometer jar top in place and connect to vacuum apparatus.

9.3.2.3 Apply vacuum for at a minimum of 20 minutes until air is removed from sample. Slight agitation of the jar every 2 to 5 minutes will aid the de-airing process. If the material boils too vigorously, reduce the vacuum.

9.3.2.4 Remove vacuum apparatus, fill pycnometer with water, dry outside of jar carefully and weigh.

9.3.2.5 Water temperature during test should be maintained as close to 68° ± 1°F (20° ± 0.5°C) as possible.

Calculations

10. Determine the dry density of each of the fine aggregate points as follows

10.1 Calculate Specific Gravity as follows:

\[ \text{Sp. Gr.} = \frac{a}{a/(a+b-c)} \]

Where:

\(a\) = Weight of dry material, grams
\(b\) = Weight of pycnometer + water, grams
\(c\) = Weight of pycnometer + material + water, grams

10.2 Calculate the wet sample weight:

\(e = c - d\)

Where:

\(e\) = Wet sample weight, g
\(c\) = mold and sample weight
\(d\) = Tare of mold assembly
10.3 Calculate the wet density by:

\[ g = \frac{e \times b}{f} \]

Where:

- \( g \) = wet density, lb/ft\(^3\)
- \( e \) = wet sample weight
- \( b \) = mold constant, in/ft\(^3\)
- \( f \) = height of sample, in (height constant-depth)

10.4 Calculate the dry density of each of the fine fraction specimens as follows:

\[ h = \frac{g}{1 + n} \]

Where:

- \( h \) = dry density, lb/ft\(^3\)
- \( g \) = wet density, lb/ft\(^3\)
- \( n \) = moisture content, expressed as a decimal

11. Reports

11.1 Enter information into the WSDOT Materials Testing System (MATS) or other form approved in writing by the State Materials Engineer to obtain the theoretical maximum density curve.
WSDOT Standard Operating Procedure SOP 615

**Determination of the % Compaction for Embankment & Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge**

1. **Scope**

   This procedure covers the procedures for determining the in-place density, moisture content, gradation analysis, oversize correction, and determination of maximum density of compacted soils and untreated surfacing materials using a nuclear density device in the direct transmission mode.

2. **References**

   a. AASHTO T 99 for Method of Test for Moisture-Density Relations of Soils
   b. AASHTO T 180 for Method of Test for Moisture-Density Relations of Soils
   c. AASHTO T 224 for Correction for Coarse Particles in Soil Compaction Test
   d. T 255 – WSDOT FOP for AASHTO for Total Moisture Content of Aggregate by Drying
   e. T 272 – WSDOT FOP for AASHTO for Family of Curves — One Point Method
   f. T 310 – WSDOT FOP for AASHTO for In-Place Densities and Moisture Content of Soils and Soil-Aggregate by Nuclear Methods (Shallow Depth)
   g. WSDOT T 606 Method of Test for Compaction Control of Granular Materials

3. **Test Location**

   When selecting a test location, the tester shall visually select a site where the least compactive effort has been applied. Select a test location where the gauge will be at least 6 in (150 mm) away from any vertical mass. If closer than 24 in (600 mm) to a vertical mass, such as in a trench, follow gauge manufacturer correction procedures.

   **Note 1:** When retesting is required due to a failing test; retest within a 10-foot radius of the original station and offset.

4. **Nuclear Density Test**

   Determine the dry density and moisture content of soils and untreated surfacing materials using the nuclear moisture-density gauge in accordance with WSDOT FOP for AASHTO T 310, and record in the Materials Testing System (MATS), WSDOT Form 350-074, Field Density Test, or other form approved in writing by the State Materials Engineer.
5. Oversize Determination

a. AASHTO T 99 and WSDOT T 606

A sample weighing a minimum of 9 lbs will be taken from beneath the gauge. Care shall be taken to select material that is truly representative of where the moisture density gauge determined the dry density and moisture content.

There are two methods for determining the percentage of material retained on the No. 4 sieve:

Method 1

(1) Dry the sample to SSD conditions (i.e., dried until no visible free moisture is present, material may still appear damp). Allow the sample to cool sufficiently and record mass to the nearest 0.1 percent of the total mass or better.

(2) Shake sample by hand over a verified No. 4 (4.75 mm) sieve. Limit the quantity of material on the sieve so that all particles have the opportunity to reach the sieve openings a number of times during the sieving operation. The mass retained on the No. 4 (4.75 mm) sieve at the completion of the sieving operation shall not exceed 800 grams, 1.8 pounds, for the 12 in sieve, or 340 grams, 0.75 pounds; for the 8 in sieve.

(3) Remove and weigh the material on the No. 4 (4.75 mm) sieve to the nearest 0.1 percent of the total mass or better and record.

Method 2 – Method 2 is recommended for crushed surfacing materials, materials with high clay content, or other granular materials that are at or near the optimum moisture content for compaction.

(1) Determine the mass of the sample to the nearest 0.1 percent of the total mass or better and record.

(2) Charge the material in a suitable container with water, agitate the material to suspend the fines, then slowly decant and screen the material over a verified No. 4 (4.75 mm) sieve. Repeat the process as necessary to remove as much No. 4 (4.75 mm) minus material as possible. DO NOT overload the sieve.

(3) Place the washed sample retained on the No. 4 (4.75 mm) sieve into a tared container. Blot the material to a SSD condition (i.e., no visible free moisture present, material may still appear damp) during this step.

(4) Weigh the mass of the material on the No. 4 (4.75 mm) sieve to the nearest 0.1 percent of the total mass or better and record.

b. AASHTO T 180

Follow either Method 1 or Method 2 in 5 a. with the following exception; sieve the material over a ¾ in (19.0 mm) sieve.
6. Calculations

a. Calculate the percent retained as follows:

\[
\% \text{ retained (Pc)} = 100 \times \frac{\text{mass retained on sieve}}{\text{original mass}} \quad \text{(round to nearest percent)}
\]

b. Calculate percent passing as follows:

\[
\% \text{ passing} = 100 - \% \text{ retained}
\]

c. Calculate the dry density as follows:

\[
d = \frac{100}{100 + W} \quad \text{(m)}
\]

Where:
- \(d\) = dry field density of total sample, pcf
- \(m\) = total field wet density, pcf
- \(W\) = moisture content of total field sample

d. Calculate the corrected theoretical maximum density as follows:

\[
D_f = \frac{D_d \times P_f}{100 - \left(\frac{(D_d \times P_c)}{k}\right)}
\]

Where:
- \(D_f\) = corrected theoretical maximum density, pcf
- \(D_d\) = dry density, pcf
- \(P_f\) = percent passing
- \(P_c\) = percent retained
- \(k\) = 62.4 × (specific gravity of coarse particles) (Note 2)

Note 2: If the specific gravity of the coarse particles has been determined, use this value in the calculation for the “k” value. If the specific gravity is unknown then use 2.67. Either AASHTO T 85 or WSDOT T 606 Test 3 may be used to determine the specific gravity of the coarse particles.

e. Calculate the percent of compaction using the following equation:

\[
\% \text{ compaction} = \frac{\text{Dry Density (lbs/ft}^3\text{)}}{\text{corrected theoretical maximum density (lbs/ft}^3\text{)}}
\]

7. Density Curve Tables

The Materials Testing System (MATS) Density Curve Tables is the WSDOT preferred method for determining the corrected theoretical maximum density.

a. MATS calculates the corrected theoretical maximum density in accordance with AASHTO T224 Section 4.2 and reports the results in the Density Curve Table.

b. To determine the corrected theoretical maximum density using the Density Curves Table enter the Table at the line corresponding to the % passing or % retained (T99 & T 180 requires percent retained, T 606 requires percent passing), read across to the column labeled Max this number is the Corrected Theoretical Maximum Density.
8. Report
   a. Report the results using one or more of the following:
      • Materials Testing System (MATS)
      • WSDOT Form 350-074 and 351-015
      • Form approved in writing by the State Materials Engineer
   b. Report the percent of compaction to the nearest whole number.
Performance Exam Checklist

*WSDOT Standard Operating Procedure SOP 615*

**Determination of the % Compaction for Embankment & Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge**

Participant Name __________________________ Exam Date __________

### Procedure Element

<table>
<thead>
<tr>
<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>
</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>
</tr>
</tbody>
</table>

### Gradation Analysis

#### 3(A) Method 1

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sample Dried to a SSD condition (dried until no visible free moisture present) and mass recorded?</td>
<td></td>
</tr>
<tr>
<td>2. Sample allowed to cool sufficiently prior to sieving?</td>
<td></td>
</tr>
<tr>
<td>3. Sample was shaken by hand through the appropriate sieve for a sufficient period of time?</td>
<td></td>
</tr>
<tr>
<td>4. Recorded mass of material retained on the appropriate sieve?</td>
<td></td>
</tr>
<tr>
<td>5. Calculated and recorded percent of material retained and passing the appropriate sieve?</td>
<td></td>
</tr>
</tbody>
</table>

#### 3(B) Method 2

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mass of sample determined prior to washing?</td>
<td></td>
</tr>
<tr>
<td>2. Material charged with water in suitable container and agitated to suspend fines?</td>
<td></td>
</tr>
<tr>
<td>3. Sample decanted over required sieve for a sufficient amount of time without overloading sieve?</td>
<td></td>
</tr>
<tr>
<td>4. Retained material dried to SSD condition and mass determined?</td>
<td></td>
</tr>
<tr>
<td>5. Recorded mass of material retained on appropriate sieve?</td>
<td></td>
</tr>
<tr>
<td>6. Calculated and recorded percent of material retained and passing appropriate sieve?</td>
<td></td>
</tr>
</tbody>
</table>

### Correction for Coarse Particles

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Appropriate MATS Density Curve Table used to determine the corrected theoretical maximum density, based on the percent passing or retained on the appropriate sieve?</td>
<td></td>
</tr>
<tr>
<td>8. All calculations performed correctly?</td>
<td></td>
</tr>
</tbody>
</table>

First Attempt: Pass ☐ Fail ☐ Second Attempt: Pass ☐ Fail ☐

Signature of Examiner __________________________

---

*WSDOT Materials Manual   M 46-01.10   Page 5 of 6   January 2012*
Comments:
WSDOT Test Method T 712
Standard Method of Reducing Hot Mix Asphalt Paving Mixtures

Significance

Samples of bituminous paving mixes taken in accordance with FOP for WAQTC T 168 are composites and are large to increase the likelihood that they are representative of the product being tested. Materials sampled in the field need to be reduced to appropriate sizes for testing. It is extremely important that the procedure used to reduce the field sample not modify the material properties.

1. Scope

This method covers the procedure for reducing samples of Hot Mixed Asphalt (HMA). The samples are to be acquired in accordance with FOP for WAQTC T 168. The sample is to be representative of the average of the HMA being produced.

2. Apparatus

• Flat-bottom scoop.
• Broom or brush.
• Non-stick splitting surface such as metal, paper, canvas blanket or heat-resistant plastic.
• Large spatulas, trowels, metal straight edge or 12 in dry wall taping knife, sheet metal quartering splitter.
• Mechanical Splitter – The splitter shall have four equal width chutes, which will discharge the material into four appropriate size containers. The splitter shall be designed with a receiving hopper that will hold the HMA field sample until a handle releases the material to fall through a divider and is distributed into four equal portions. The splitter shall be designed so that the HMA field sample will flow smoothly and freely through the divider without loss of materials (see Figures 1 to 3).
• Oven – An oven of appropriate size, capable of maintaining a uniform temperature within the allowable tolerance for the grade of asphalt.
• Miscellaneous equipment including trowel(s), spatula(s), hot plate, non-asbestos heat-resistant gloves or mittens, pans, buckets, cans.
Standard Method of Reducing Hot Mix Asphalt Paving Mixtures

1. SCOPE
This method covers the procedure for reducing samples of Hot Mixed Asphalt (HMA). The samples are to be acquired in accordance with FOP AASHTO T 168. The sample is to be representative of the average of the HMA being produced.

2. APPARATUS
- Flat-bottom scoop,
- Broom or brush,
- Non-stick splitting surface such as metal, paper, canvas blanket or heat-resistant plastic,
- Large spatulas, trowels, metal straight edge or 12 in. dry wall taping knife, sheet metal quartering splitter,
- Mechanical Splitter—The splitter shall have four equal width chutes, which will discharge the material into four appropriate size containers. The splitter shall be designed with a receiving hopper that will hold the HMA field sample until a handle releases the material to fall through a divider and is distributed into four equal portions. The splitter shall be designed so that the HMA field sample will flow smoothly and freely through the divider without loss of materials (See Figures 1 to 3).

![Mechanical Splitter](image1)

**Figure 1** — Mechanical Splitter

![Plan View of Splitter](image2)

**Figure 2** — Plan View of Splitter

![Elevation and Plan View of Bottom Portion of Splitter](image3)

**Figure 3** — Elevation and Plan View of Bottom Portion of Splitter

3. SAMPLE PREPARATION
The sample must be warm enough to separate. If not, warm in an oven until it is sufficiently soft to mix and separate easily.

4. PROCEDURE

A. Place the sample on a hard, clean, non-stick, level surface where there will be neither loss of material nor the accidental addition of foreign material. The surface may be

![a. Elevation View of the Top Portion of the Splitter](image4)
3. Sample Preparation

The sample must be warm enough to separate. If not, warm in an oven until it is sufficiently soft to mix and separate easily.

4. Procedure

**Initial Reduction of Field Sample**

a. Place the sample on a hard, clean, non-stick, level surface where there will be neither loss of material nor the accidental addition of foreign material. The surface may be covered with a canvas blanket, heavy paper or other suitable material. Remove the sample from the agency approved containers by dumping into a conical pile.

![Figure 4](image)

b. Divide the sample into four approximately equal quarters with a spatula, trowel, flat metal plate, sheet metal quartering splitter, or mechanical splitter.

c. With the quartering device in place remove all the material from each quarter. If needed for additional testing the material should be placed in agency approved containers for storage or shipment.

*Note 1:* When testing lean mixes or mixes with aggregate larger than ¾ in (19 mm), sampling as described in Method B, with no remixing and no removal of a similar amount of material from the opposite quarter, is recommended at this point to obtain samples for each acceptance test.

d. Pay particular attention that excessive amounts of materials is not left on the splitting surface or splitting equipment.

e. When the further reduction of the HMA is to be done, proceed according to step 2 of methods A, B, or C.

*Note 2:* Identify the opposite quarter as the “Retest.”
Method A – Reducing to Test Size

1. On a hard, clean, non-stick, level surface where there will be neither loss of material nor the accidental addition of foreign material. Remove the sample from the agency approved containers by dumping into a conical pile. The surface shall be covered with either a canvas blanket, heavy paper or other suitable material.

2. With the material on the canvas or paper, mix the sample thoroughly by turning the entire sample over the minimum amount of times to achieve a uniform distribution. Alternately lift each corner of the canvas or paper and pull it over the sample diagonally toward the opposite corner causing the material to be rolled. With the last turning, lift both opposite corners to form a conical pile.

3. Grasp the canvas or paper, roll the material into a loaf and flatten the top.

4. Pull the canvas or paper so approximately ¼ of the length of the loaf is off the edge of the counter. Allow this material to drop into a container to be saved. As an alternate, use a straight edge to slice off approximately ¼ of the length of the loaf and place in a container to be saved.

5. Pull additional material (loaf) off the edge of the counter and drop the appropriate size sample into a sample pan or container. As an alternate use a straightedge to slice off an appropriate size sample from the length of the loaf and place in a sample pan or container.

6. Repeat step 5 until the proper size sample has been acquired. Step 5 is to be repeated until all the samples for testing have been obtained.

Note 3: When reducing the sample to test size it is advisable to take several small increments determining the mass each time until the proper minimum size is achieved. Unless, the sample size is below the minimum or exceeds the maximum test size use the sample as reduced for the test.
Method B – Reducing to Test Size

1. On a hard, clean, non-stick, level surface where there will be neither loss of material nor the accidental addition of foreign material. Remove the sample from the agency approved containers by dumping into a conical pile. The surface shall be covered with either a canvas blanket, heavy paper or other suitable material. (See Note 1.)

2. With the material on the canvas or paper, mix the sample thoroughly by turning the entire sample over the minimum amount of times to achieve a uniform distribution. Alternately lift each corner of the canvas or paper and pull it over the sample diagonally toward the opposite corner causing the material to be rolled. With the last turning, lift both opposite corners to form a conical pile.

3. Quarter the conical pile using a quartering device or straightedge.

4. With the quartering device in place using a suitable straight edge slice through the quarter of the HMA from the apex of the quarter to the outer edge. Pull or drag the material from the quarter holding one edge of the straight edge in contact with the quartering device. Two straightedges may be used in lieu of the quartering device.

5. Slide or scoop the material into a sample pan. Repeat steps 4 and 5 removing a similar amount of material from the opposite quarter. Steps 4 and 5 are to be repeated until all the samples for testing have been obtained.

Note 4: When reducing the sample to test size it is advisable to take several small increments determining the mass each time until the proper minimum size is achieved. Unless, the sample size is below the minimum or exceeds the maximum test size use the sample as reduced for the test.
Method C – Reducing to Test Size

1. On a hard, clean, non-stick, level surface where there will be neither loss of material nor the accidental addition of foreign material. Remove the sample from the agency approved containers by dumping into a conical pile. The surface shall be covered with either a canvas blanket, heavy paper or other suitable material.

2. With the material on the canvas or paper, mix the sample thoroughly by turning the entire sample over the minimum amount of times to achieve a uniform distribution. Alternately lift each corner of the canvas or paper and pull it over the sample diagonally toward the opposite corner causing the material to be rolled. With the last turning, lift both opposite corners to form a conical pile.

3. Quarter the conical pile using a quartering device or straightedge.

4. Remove the opposite quarters saving the material for future use.

5. Repeat step 2 through 4 until the proper size sample has been achieved.

6. When additional test specimens are required, dump the removed material into a conical pile as in step 1 and repeat steps 2 through 5. This process may be repeated until the sample have has been reduced to testing size for all tests.

7. Sample Identification
   a. Each sample submitted for testing shall be accompanied by a transmittal letter completed in detail. Include the contract number, acceptance and mix design verification numbers, mix ID.
   b. Samples shall be submitted in standard sample boxes, secured to prevent contamination and spillage.
   c. Sample boxes shall have the following information inscribed with indelible-type marker: Contract number, acceptance and mix design verification numbers, mix ID.
   d. The exact disposition of each quarter of the original field sample shall be determined by the agency.
Performance Exam Checklist

Reducing Samples of Hot Mix Asphalt to Testing Size
WSDOT Test Method T 712

Participant Name _______________________________  Exam Date ________________

<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. Sample warmed if not sufficiently soft?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Method A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Sample placed on paper on clean, hard, and level surface?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Sample mixed thoroughly?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Rolled into loaf and then flattened?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. At least ¼ of loaf removed by slicing off or dropping off edge of counter?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Proper sample size quantity of material sliced off or dropped off edge of counter onto sample container?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Method B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Sample thoroughly mixed and conical pile formed?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Divided into 4 equal portions with quartering device or straightedge?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. With two straight edges or a splitting device and one straight edge.</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>11. Was a sample sliced from apex to outer edge of the quarter?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12. Process continued until proper test size is obtained?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Method C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Sample thoroughly mixed and conical pile formed?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>14. Divided into 4 equal portions with quartering device or straightedge?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>15. Two diagonally opposite quarters removed and saved?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>16. Cleared spaces scraped clean?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>17. Process repeated until proper test size is obtained?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>18. Were opposite quarters and combined to make sample?</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

A. Scope

1. 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.

2. 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.

B. Summary of Method for Selecting Random Test Location

- Method A – Determining a Random Location for Hot Mixture Asphalt (HMA) Density Tests
- Method B – Determining Random Test Location for Sampling HMA Mix, Aggregates, and Miscellaneous Materials
- Method C – Determining Random Test Location for Portland Cement Concrete
- Appendix A – Hot Mix Asphalt Density (400 Ton Lots)
- Appendix B – Hot Mix Asphalt Density 80 Tons (Milepost)
- Appendix C – Hot Mix Asphalt Density Test Locations for Irregular Paving Areas
- Appendix D – Hot Mix Asphalt Density 400 Ton (Milepost)

C. Procedure for Determining Random Test/Sampling Location

1. Method A – Selection of Random Location for HMA Density

This method outlines the procedure for determining the random location of HMA Density testing sites for 80 ton sublots. Calculate the linear foot distance for an 80 ton sublot.

Example:

Pavement – 12 ft wide, 0.15 ft deep, 80 ton sublot

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

\[
\text{Sublot length} = \frac{80 \text{ Tons}}{0.137 \text{ Tons per linear Foot}} = 583.9 \text{ lf (round to 584 lf)}
\]

a. Choose a number at random (see Section 2b) to enter Table 1 to determine the X and Y multiplier. The recommended method for choosing a random number for HMA density is to use the last two digits from the most recent standard count on the nuclear gauge. A new random number is selected at the start of production each day.
b. Determine the test station and offset as follows:

\[
\text{Test Station} = (\text{sublot length} \times \text{“X” multiplier}) + \text{beginning station of paving} \\
\text{Offset (from right side of pavement)} = (\text{width of pavement} \times \text{“Y” multiplier})
\]

**Note:** The values in the table have been set so that no measurements are taken within 0.5 LF of the edge of the lane. When a test falls within an area that is not appropriate for a test location (i.e., a bridge end, track crossing, night joint) move the testing location 25 ft ahead or back on stationing, as appropriate.

**Example:**

**Beginning Station** = 168 + 75  
Width = 12 ft  
Sublot length = 584  
Ending Station = (Beginning Station + Sublot length) = (16875 + 584) = 174 + 59  
Standard Count = 2951

**Beginning Test Location**  
Enter table at line (51): “X” multiplier = 0.762, “Y” multiplier = 0.65  
Stationing = (584 \times 0.762) + 16875 = 173 + 20  
Offset = (12 \times 0.65) = 7.8 ft

c. Determine subsequent testing locations as follows:

Enter the random number table on the next line in sequence (if original table entry 51, next line entry 52, then 53, etc.)

New beginning station = previous ending station  
X coordinate = (sublot length \times “X” multiplier) + new beginning station  
Y coordinate = (width of pavement \times “Y” multiplier)

**Example:**

**Second Test Location**  
New beginning station = 174 + 59  
Enter table at line (52): “X” multiplier = 0.285, “Y” multiplier = 0.28  
Test station = (584 \times 0.285) + 17459 = 176 + 25  
Offset = (12 \times 0.28) = 3.4 ft from right edge
Y values are selected so that lateral locations are no closer than 0.5 feet (0.15 m) from the edge of a paving lane.

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<th>Y</th>
<th>Sequence</th>
<th>X</th>
<th>Y</th>
<th>Sequence</th>
<th>X</th>
<th>Y</th>
<th>Sequence</th>
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<th>Y</th>
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</table>

**Random Numbers With X and Y Value**

*Table 1*

2. Method B – Hot Mix Asphalt (HMA) Pavement Mixture or Aggregates
   a. Determine the sublot increment of the material.
   b. Choose a number at random to enter Table 2. The recommended method for choosing a random number for HMA is to choose the last two digits from the first civilian license plate seen that day (do not use vehicles associated with the project site) or use a digital stopwatch or a computer generated random number. A new random number is selected for each new sublot.

**Note:** To use the stop watch method; randomly start and stop the stop watch 10 or more times then use the decimal part of the seconds as your entry point.
c. Determine the test location.
d. Calculate the first test location as follows:

\[ \text{Sampling Site} = \text{Sublot increment} \times \text{“X” multiplier (Table 2)} \]

Example:

The car license plane ends in 45. Use 45 as the starting point to enter random number Table 2. “X” = 0.604.

**First Test Location:**

- Sublot increment = 800 tons
- Beginning tonnage: 0
- Sublot increment: \(800 \times 0.604 = 483\)
- Test tonnage Sample 1: Beginning tonnage + 483 tons = 483 tons

Random sample tonnage may be adjusted per sublot to accommodate field testing. Adjustments to random sample tonnage should be documented.

Determine subsequent test locations by choosing a new random number for each new sublot and using that number to enter Table 2.

**Second Test Location:**

- Sampling Site = Sublot increment \times \text{“X” multiplier (Table 2)}
- Beginning tonnage = 800

Example:

The computer generated number was 53. Use 53 as the starting point to enter random number Table 2. “X” = 0.266.

Enter Table 2 at (53) “X” = 0.266
- Sublot increment: \(800 \times 0.266 = 212.8\)
- Testing tonnage Sample 2: \(800 + 213 = 1013\) tons

**Third Test Location:**

- Sampling Site = Sublot increment \times \text{“X” multiplier (Table 2)}
- Beginning tonnage = 1600

Example:

The computer generated number was 12. Use 12 as the starting point to enter random number Table 2. “X” = 0.957.

Enter Table 2 at (12) “X” = 0.957
- Sublot increment: \(800 \times 0.957 = 765.6\)
- Testing tonnage Sample 2: \(1600 + 766 = 2366\) tons
3. Method C – Portland Cement Concrete (PCC)

a. Determine the sublot increment for the random test sample. A sublot for PCC is based on a sampling frequency of one in five trucks after, two successive trucks within specification.

Sublot increment = Cubic Yards per truck × 5 trucks

Example:
Each truck carries 10 CY of concrete
Sublot Increment = 10 CY × 5 trucks = 50 CY

b. Choose a two digit number at random to enter Table 2. The recommended method for choosing a random number for Portland Cement Concrete is to choose the last two digits from the first civilian license plate seen that day (do not use vehicles associated with the project site).

Note: Start each day of concrete placement with a new “X” value determined by chance in order to obtain a random selection

c. Determine the sample location as follows:

Sampling Location = Sublot increment × “X” multiplier (Table 2)

Example:
The civilian license plate ends in 37. Use 37 as the starting point to enter random number Table 2 “X”= 0.829.

Sample location = 50 CY × 0.829 = 41 CY
d. Determine where the first sample will be taken:

Sample Yardage = (CY per truck × 2 (for the first two trucks)) + Sample location

Example:

**First Sample Location:**
Sample location = (10 CY × 2) + 41 CY = 61 CY

e. The sample will be taken from the truck containing the 61st CY or in this example the seventh truckload of the pour. Allow approximately ½ CY of concrete to be discharged before sampling the truck.

Example:
(41/10) CY = 4.1 trucks + original 2 truck = 6.1 trucks
Sample is located in the first ⅓ of the 7th truck of the pour.

f. Determine subsequent sampling locations as follows:

Example:

**Second Sample Location:**
Use the next sequential line of the chart after the beginning random number. Original number was 37 use line (38) as the starting point to enter random number Table 2. “X” = 0.998.
Sample location = 50 CY × 0.998 = 49.9 CY = 50 CY

g. The second sample will be taken at 120 CY

Example:

20 CY (first two trucks) + 50 (first random sample of 5 trucks) + 50 CY
The sample would come from the last ⅓ of the truck 12th truck of the pour.
Appendix A
Hot Mix Asphalt Density (400 Ton Lots)

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 A1 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:

\[
\text{Tons per linear foot} = \frac{1.0 \text{ (foot)} \times \text{width (feet)} \times \text{depth (feet)} \times 2.05 \text{ Tons/cy}}{27}
\]

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

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

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>Compacted Depth</th>
<th>Computed Lot Length</th>
<th>Recommended Lot Length</th>
</tr>
</thead>
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<td>0.12</td>
<td>3655</td>
<td>3700</td>
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<tr>
<td></td>
<td>0.15</td>
<td>2924</td>
<td>2900</td>
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<tr>
<td></td>
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<td>2193</td>
<td>2200</td>
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<td></td>
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<td>1800</td>
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<td>1900</td>
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Hot Mix Asphalt Density Test Lot Length 400 Ton Lot at 2.05 Tons/Cubic Yard

Table A1

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.
c. Determine the locations of the test (or sampling) sites by using values from the random number table 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 0.5 LF (0.15 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 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 random number table: 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
Appendix B

Hot Mix Asphalt Density 80 Ton (Milepost)

a. The testing location will be calculated using 80 ton sublots.

b. Convert to tons per mile using the roadway area based on the roadway width and depth. The calculations in Example 1 show how this is done. Table A2 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 .01 of a mile.

Example 1
Sample Computation for Sublot Length

Tons per linear foot = Tons per lf = \( \frac{1 \text{ ft x width x Depth x 2.05 tons/cy}}{27} \)

Tons per mile = Tons per lf x 5,280 lf

Sublot length = 80 tons/tons per mile

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<tr>
<th>Lane Width</th>
<th>Compacted Depth</th>
<th>Computed Sublot Length</th>
</tr>
</thead>
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<td></td>
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<td>11 feet</td>
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<tr>
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<td>0.25</td>
<td>0.07</td>
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Hot Mix Asphalt Density Test Sublot Length for 80 Ton Sublots at 2.05 Tons/Cubic Yard

Table A2

c. Determine the locations of the test (or sampling) sites by using values from the random number table 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 0.5 LF (0.15 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 milepost, as appropriate, by .01 mile.

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. 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 for Hot Mix Asphalt Density

For the Lot: (12 ft wide, 0.12 ft deep, starting at Milepost 1.00 with paving progressing ahead on Milepost), sublot length is 0.14 miles. Using the last two digits of the standard count, as in the example, 2951, assume “X” and “Y” values from line (51) in random number table: X = 0.762, Y = 0.65.

For the first test:
  Beginning Milepost: 1.00
  Sublot length increment: \(0.14 \times 0.762 = 0.11\)
  Width offset: \(12 \times 0.65 = 7.8\) ft (from right edge)
  Location is: Milepost: \((1.00) + 0.11 = 1.11\), 7.8 ft from right edge

  Ending Milepost = 1.00 + 0.14 = 1.14

For the second test:
  New Beginning Milepost: previous ending milepost
  Sublot length increment: \(0.14 \times 0.285 = 0.04\)
  Width offset: \(12 \times 0.28 = 3.4\) ft (from right edge)
  Location is: Milepost: \((1.14) + 0.04 = 1.18\), 3.4 ft from right edge

  Ending Milepost = 1.14 + 0.14 = 1.28

For the third test:
  Beginning Milepost: previous ending milepost
  Sublot length increment: \(0.14 \times 0.347 = 0.05\)
  Width offset: \(12 \times 0.87 = 10.4\) ft (from right edge)
  Location is: Milepost: \((1.28) + 0.05 = 1.78\), 10.4 ft from right edge
Appendix C  
Hot Mix Asphalt Density Test Locations for Irregular Paving Areas

a. Track tonnage placed in the irregular shaped area until 80 tons have been placed, note the stationing.

b. Measure back to the beginning of the paving or end of the previous lot to obtain the length (this is also your beginning station).

c. Choose a random number (see Section 2b) or use the next random number in sequence to enter the random number table.

d. Multiply the length by the “X” value and add to the beginning station to locate your testing site.

e. Measure the width at the testing station and multiply the width time the “Y” value to determine the offset of the testing site.

f. Make a sketch of the area to document the test location in the event a retest is required.

Example:

Paving began at Station 101 + 00. The tester determined that Station 105 + 75 was the end of the 80 ton lot. The random number was 45.

Calculate Testing Station

\[ \text{Sta } 105 + 75 - \text{Sta } 101 + 00 = 475 \text{ ft} \]
\[ \text{Random # 45 “X” value } = 0.552 \]
\[ 475 \text{ ft} \times 0.552 = 262 + 101+00=102+62 \]

Calculating Offset
\[ \text{Random # 45 “Y” value } = 0.17 \]
\[ \text{Offset } = 10.5' \times 0.17 = 1.8' \]
Appendix D
Hot Mix Asphalt Density 400 Ton (Milepost)

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 A3 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 .01 of a mile.

Example 1
Sample Computation for Lot Length

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

\[
\text{Tons per linear Foot} = \frac{1.0 \text{ (foot)} \times \text{width (feet)} \times \text{depth (feet)} \times 2.05 \text{ tons/cy}}{27}
\]

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

0.137 tons per lineal foot x 5,280 ft = 723.36 tons per mile

Lot length = \[
\frac{400 \text{ tons}}{723.36 \text{ tons per mile}} = 0.55 \text{ linear miles}
\]

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>Compacted Depth</th>
<th>Computed Lot Length</th>
<th>Recommended Lot Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 feet</td>
<td>0.12</td>
<td>0.69</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>0.55</td>
<td>0.55</td>
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<tr>
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<td>0.42</td>
<td>0.42</td>
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<tr>
<td></td>
<td>0.25</td>
<td>0.33</td>
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<td></td>
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<td>0.61</td>
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<td>0.45</td>
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</tr>
<tr>
<td></td>
<td>0.25</td>
<td>0.35</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Hot Mix Asphalt Density Test Lot Length 400 Ton Lot at 2.05 Tons/Cubic Yard
Table A3

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 mileposts.
c. Determine the locations of the test (or sampling) sites by using values from the random number table 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 0.5 LF (0.15 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 milepost, as appropriate, by .01 mile.

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 Density

For the lot: (12 ft wide, 0.15 ft deep, starting at Milepost 1.00 with paving progressing ahead on Milepost), Lot length was previously determined as 0.55 miles. Using the last two digits of the standard count, as in the example, 2951, assume “X” and “Y” values from line (51) in random number table: X = 0.762, Y = 0.65.

For the first test:
  Beginning Milepost: 1.00
  Sublot length increment: .11 × 0.762 = .08
  Width offset: 12 × 0.65 = 7.8 ft (from right edge)
  Location is: Milepost: (1.00) + .08 = 1.08, 7.8 ft from right edge

For the second test:
  Beginning Milepost: (1.00) + (.11) = 1.11
  Sublot length increment: .11 × 0.285 = .03
  Width offset: 12 × 0.28 = 3.4 ft (from right edge)
  Location is: Milepost: (1.11) + .03 = (1.14), 3.4 ft from right edge

For the third test:
  Beginning Milepost: (1.00) + .11 + .11 = 1.22
  Sublot length increment: .11 × 0.347 = .04
  Width offset: 12 × 0.87 = 10.4 ft (from right edge)
  Location is: Milepost: (1.22) + .04 = (1.26), 10.4 ft from right edge
WSDOT Test Method T 718
Method of Test for Determining Stripping of Hot Mix Asphalt

1. Scope
   a. This test is used to determine the amount of stripping resulting from the effects of water saturation and accelerated water conditioning, with a freeze-thaw cycle of laboratory – compacted Hot Mix Asphalt.
   b. This test is the WSDOT equivalent to AASHTO T 283.

2. Equipment
   a. Water bath controlled at 140 ± 1.8°F.
   b. Vacuum container capable of holding a vacuum of approximately 26mm Hg and large enough to accommodate test specimens and volume of water as described in this procedure.
   c. Perforated platform to hold test samples 2 inches off the bottom of the vacuum container.
   d. Vacuum pump, vacuum system or water aspirator, for vacuum saturation of specimens.
   e. Air-bath freezer, maintained at 0 ± 5°F.
   f. Water bath maintained at 55 ± 1°F.
   g. Testing machine – A compression testing machine having a minimum capacity of 10,000 lbf and capable of producing a uniform vertical movement of 0.065 inches per minute.
   h. Equipment for preparing and compacting specimens for WSDOT FOP for AASHTO T 312.
   i. 100 ± 0.10mm gyratory specimen mold and 99.50 to 99.75mm top/bottom plates which meet WSDOT FOP for AASHTO T 312 section 4.2 (excluding inside diameter measurements) and section 4.3 (excluding diameter measurement).

3. Preparation of Laboratory-Mixed, Laboratory-Compacted Specimens for Mix Designs
   a. Mix specimens per WSDOT Test Method 726, at optimum asphalt binder content with appropriate grade and supplier of asphalt binder per the mix design to achieve approximately 4% air voids.
   b. Mix six specimens per asphalt binder supplier, two samples with 0% anti-strip additive and the other specimens with varying amounts of anti-strip additive (Note 1).

   Note 1: Liquid anti-strip agents added directly to the asphalt binder shall be added by weight of asphalt at levels of ¼%, ½%, ¾% and 1% or levels not exceeding 1% which test an even progression of anti-strip additive per manufacture recommendation. Latex anti-strip agents shall be added to the aggregate in a Saturated Surface Dry (SSD) condition at levels of 0.08%, 0.17%, 0.33% and 0.50% by weight of dry aggregate.
c. Condition and compact the 100 mm specimens per WSDOT FOP for AASHTO T 312 sections 8.5 through 9.8.

Preconditioning of Test Specimens

a. Once the set of six specimens have been compacted and cooled to room temperature, set one of the specimens mixed with 0% anti-strip aside to be stored at room temperature, this will be the referee specimen.

b. Test remaining set of specimens per AASHTO T 166 Method A. Calculate the air void level of the specimen using mix design Theoretical Maximum Specific Gravity value.

c. Place the specimens in the vacuum container. The container must be filled with potable water at room temperature (77 ± 9°F) so that the specimens have at least 1 inch of water above their surface. Apply a vacuum for a short amount of time, suitable to saturate the specimens air voids between 60 and 80 percent.

d. Determine the mass of the saturated, surface-dry specimen after partial vacuum saturation per AASHTO T 166 Method A.

e. Calculate the volume of absorbed water (J) in cubic centimeters by use of the following equation:
\[
J = B - A
\]

Where:
- \( J \) = volume of absorbed water, cubic centimeters.
- \( B \) = mass of saturated, surface-dry specimen after partial vacuum.
- \( A \) = mass of dry specimen in air.

f. Determine the degree of saturation (S) by comparing the volume of absorbed water (J) with the volume of air voids (Va) using the following equation.
\[
S = \frac{100J}{Va}
\]

Where:
- \( S \) = Degree of saturation, percent.
- \( Va \) = Volume of air voids

Determine the Volume of air voids using the following equation:
\[
Va = \frac{Pa \times E}{100}
\]

Where:
- \( Pa \) = Percent of air voids
- \( E \) = Volume of Specimen, cubic centimeters (SSD wt. – wt. In water)

g. If the degree of saturation is between 60 and 80 percent then proceed. If the degree of saturation is less than 60 percent then repeat the procedure beginning with c above, using more vacuum and/or time. If the degree of saturation is more than 80 percent then the specimen has been damaged and must be discarded.
h. After saturation is achieved place each specimen in a plastic bag, seal the bag and place specimen in a freezer at a temperature of 0 ± 5°F for a minimum of 16 hours.

i. Remove specimens from the freezer, remove plastic bags and place them in a water bath maintained at 140 ± 2°F for 24 ± 1 hour (Note 2).

Note 2: Some specimens become fragile after curing in the hot bath for 24 hours, as a precaution it may be necessary to place samples into suitable transfer dishes prior to placing them into the hot bath, to facilitate the movement of samples for the hot bath to the cold-water bath.

j. After 24 ± 1 hours in the 140 ± 2°F water bath, remove the specimens and place them into the cold water bath maintained at 55 ± 1°F. At this time the referee specimen shall be placed into the cold water bath with the conditioned specimens. Testing must begin within 2 hours ± 10 minutes after specimens have been placed into the cold water bath.

4. Testing

a. After 2 hours ± 10 minutes in the cold water bath, remove and test one specimen at a time in the testing machine on the diametrical vertical plane. Apply the diametrical loading at a vertical deformation rate of 0.065 inches per minute. Record the maximum compressive load of each specimen.

b. Continue to load specimen until specimen can be easily broken open.

c. Remove specimen from machine, break specimen in half by hand for visual inspection. Record the visual condition of each specimen as to stripping action: none, slight, moderate, or severe.

d. Determine the Tensile Strength Ratio (TSR) of each specimen by comparing the load needed to break the testing specimen to the load needed to break the referee specimen, using the following equation:

\[
TSR = \left( \frac{S_1}{S_2} \right) \times 100
\]

Where:

- \( S_1 \) = tensile strength of the conditioned specimen
- \( S_2 \) = tensile strength of the unconditioned specimen

5. Visual Condition Definitions

- None – The specimen condition is solid with no evidence of asphalt binder withdrawing from aggregate. After the specimen has air-dried, the appearance is black.

- Slight – The specimen condition is solid to slightly soft with evidence of the asphalt binder beginning to withdraw from edges and surfaces of the aggregates. After the specimen has air-dried, the appearance remains black.

- Moderate – The specimen condition is soft, easily broken in half, with partial to completely exposed aggregates. After the specimen has air-dried, the appearance is slightly gray.
• Severe – The specimen condition is soft to falling apart with the majority of coarse aggregate completely exposed and asphalt binder almost nonexistent. After the specimen has air-dried, the appearance is gray.

6. Report

The report shall include the following: Visually estimated moisture damage (stripping) and Tensile Strength Ratio (TSR) of the specimens.
WSDOT SOP 729

Determination of the Moving Average of Theoretical Maximum Density (TMD) for HMA

1. Scope

This procedure covers the process for obtaining the moving average of the Theoretical Maximum Density (TMD) for calculating pavement compaction in accordance with WSDOT FOP for WAQTC TM 8. The TMD is to be determined in accordance with WSDOT FOP for AASHTO T 209.

2. Procedure

The procedure for determining the moving average of TMD is as follows:

a. On the initial day of production of a new Job Mix Formula, two determinations shall be made to establish an initial average value. The samples shall not be from the same truck. Average the two TMDs and report the result to the Moisture Density Gauge Operator. The TMD value from the Mix Design Verification Report shall not be included in the average. If the two TMDs determined on the initial day do not agree within 1.5 lb/ft³ (24 kg/m³), a third determination shall be made. The initial average density shall be based on the two closest results.

b. A TMD test shall be taken with each mix sample. The moving average is defined as the average of the last five TMD values for the HMA being placed. Until five TMD values have been determined, the moving average will consist of all previous TMD values plus the first TMD value for the current production shift. When five TMD values have been determined, the moving average for each shift will include the last four TMD values plus the first TMD value for the current paving shift. This new moving average value will be used for the entire paving shift.

c. Each TMD shall be compared with the previously computed moving average. If a TMD deviates from the moving average by more than 1.5 lb/ft³ (± 24 kg/m³), a second test shall be made on another portion of the same sample. If the second TMD agrees within 1.5 lb/ft³ (± 24 kg/m³) of the moving average then the first TMD will be discarded and the second TMD will be included in the moving average. If the second TMD is not within 1.5 lb/ft³ (± 24 kg/m³) of the moving average but is within 1.5 lb/ft³ (± 24 kg/m³) of the first TMD, a new moving average will be initiated, discarding all previous results. The new moving average will be sent to the Moisture Density Gauge operator and will replace the current moving average.

d. A moving average will be sent to the Moisture Density Gauge operator once per production shift, unless two tests during a shift are not within 1.5 lb/ft³ (± 24 kg/m³), then a new moving average will be calculated in accordance with “c” of this procedure and sent to the Moisture Density Gauge operator as the new moving average for the shift. The Moisture Density Gauge Operator will continue to use the previous moving average until a new moving average is available.
3. Report

The gauge operator will record the average TMD received from the tester at the HMA plant on WSDOT Form 350-092 and 350-157 or in the MATS database. The average TMD will be used in WSDOT FOP for WAQTC TM 8 to calculate the percent of compaction for statistical evaluation.
WSDOT SOP 730

Correlation of Nuclear Gauge Densities With Hot Mix Asphalt (HMA) Cores

1. When evaluating HMA compaction:
   1.1 A gauge correlation is required:
      a. For each combination of gauge and HMA Mix Design (initial JMF).
      b. When gauge mode changes (i.e., direct transmission to thin layer).
      c. When a gauge is recalibrated.

   1.2 A gauge correlation is not required but may be considered by the Region Materials Engineer when:
      a. Base material changes from the original correlation base (i.e., from a surfacing base to an asphalt base).
      b. Lift thickness change (i.e., 2” to 4”)
      c. The same gauge-HMA Mix Design (Reference Mix Design) combination are used on a different contract within the same construction year
      d. When JMF has been adjusted in accordance with Standard Specifications Section 9-03.8(7)A

2. Gauge correlation is based on 10 in-place HMA densities and 10 cores taken at the same locations. In-Place HMA 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. Correlation cores are not required to be taken at record density locations therefore, a site outside the traveled way should be considered for worker safety.

   Note 1: If a core becomes damaged, it shall be eliminated from the average.

   Note 2: Cores may be taken sooner than the day after paving if the HMA is cooled to prevent damage during coring and removal of cores. Water, ice, or dry-ice may be used to cool the pavement. Another method of cooling that may be used is substitution of nitrogen gas or CO2 for drilling fluids.

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

4. Core densities shall be determined in conformance with AASHTO T 166 Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens.

5. Correlation factor shall be determined to 0.001 using Standard Form 350-112: Correlation Nuclear Gauge to Core Density, or the MATS database.
WSDOT SOP 731
Method for Determining Volumetric Properties of Hot Mix Asphalt

1. Scope

This procedure covers the determination of volumetric properties of Hot Mix Asphalt, i.e., Air Voids (Va), Voids in Mineral Aggregate (VMA), Voids Filled with Asphalt (VFA), and Dust to Binder Ratio (P_{#200}/P_{bo}).

2. References

T 329 – WSDOT FOP for AASHTO Moisture Content of Hot Mix Asphalt (HMA) by Oven Method
T 27/11 – WSDOT FOP for WAQTC/AASHTO Sieve Analysis of Fine and Coarse Aggregates
T 166 – WSDOT FOP for AASHTO Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
T 168 – WSDOT FOP for WAQTC/AASHTO Sampling of Hot Mix Asphalt Paving Mixtures
T 209 – WSDOT FOP for AASHTO Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures
T 308 – WSDOT FOP for AASHTO Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method
T 312 – WSDOT FOP for AASHTO Preparing Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
T 712 – WSDOT Test Method Standard Method of Reducing Hot Mix Asphalt Paving Mixtures

3. Calibration of Compactor

a. The gyratory compactor will be calibrated in accordance with WSDOT VP-58 and according to the manufacturer’s established calibration procedure. Anytime the gyratory compactor is moved to a new testing site a new calibration is required in accordance with WSDOT VP-58.

4. Test Samples

a. All test samples shall be obtained per WSDOT FOP for WAQTC/AASHTO T 168, and reduced in accordance with WSDOT Test Method T 712. It is recommended that the gyratory test sample be the first sample acquired in order to minimize heat loss.

b. The size of the gyratory sample shall be such that it will produce a compacted specimen 115.0 ± 5.0 mm in height. Generally, the mix design verification report from the State Materials Laboratory initial starting mass is adequate.

c. Place the gyratory sample in an oven set no more than 25° F above the compaction temperature (Note 1) as soon as possible to reduce sample cooling. The gyratory test is
temperature sensitive. The sample should be heated five degrees above the compaction temperature as shown on the mix design verification report.

**Note 1:** Any change in compaction temperature must be confirmed by the temperature viscosity chart provided by the asphalt supplier, which can be obtained from the Paving Contractor.

5. Procedure
   
a. Place a compaction mold, base plate, and top plate (if required), in an oven set at no more than 350°F for a minimum of 60 minutes prior to the estimated beginning of compaction. Subsequent uses of a conditioned mold will require 5 minutes of reheating.
   
b. Place a thermometer into the center of the mix, do not stir the mixture. (Note 3) Compact the sample immediately upon achieving compaction temperature in accordance with step 4 (c).
   
   **Note 2:** While the gyratory test sample is heating it is beneficial to prepare and/or run the other tests as times permits.
   
c. Perform the sample compaction in accordance with WSDOT FOP for AASHTO T 312 Section 9.
   
d. Determine theoretical maximum density per WSDOT FOP for AASHTO T 209.
   
e. Determine asphalt content and gradation per WSDOT FOP for AASHTO T 308 and WSDOT FOP for WAQTC/AASHTO T 27/11.
   
f. Determine moisture content per WSDOT FOP for AASHTO T 329.
   
g. Allow the gyratory compacted specimen to cool at room temperature for 15 to 24 hours. Determine the Bulk Specific Gravity (Gmb) of the specimen in accordance with WSDOT FOP for AASHTO T 166 Method A.
   
   **Note 3:** For repeatability between operators the retest sample should be cooled for the same amount of time at room temperature as the original specimen. When sending retest samples to the Region or State Laboratory, note the time the original sample was cooled at room temperature in the remarks section of the transmittal.

6. Volumetric Calculations

   Calculations
   
a. Calculate $\%G_{\text{mm}} @ N_{\text{design}}$ as follows:

   \[
   \%G_{\text{mm}} @ N_{\text{design}} = \frac{G_{\text{mb}}}{G_{\text{mm}}} \times 100
   \]

   **Example:**

   \[
   \%G_{\text{mm}} @ N_{\text{design}} = \frac{2.383}{2.493} \times 100 = 95.6\%
   \]

   Where:

   - $\%G_{\text{mm}} @ N_{\text{design}}$ = % theoretical maximum specific gravity @ $N_{\text{design}}$
   - $G_{\text{mb}}$ = Bulk specific gravity of the compacted specimen
   - $G_{\text{mm}}$ = Maximum specific gravity of the paving mixture
   - $N_{\text{design}}$ = Number of design gyrations
b. Calculate \( \%G_{mm}@N_{ini} \) as follows:

\[
\%G_{mm}@N_{ini} = 100 \times \left( \frac{G_{mb} \times h_d}{G_{mm} \times h_i} \right)
\]

Example:

\[
\%G_{mm}@N_{ini} = 100 \times \left( \frac{2.383 \times 110.0}{2.493 \times 123.1} \right) = 85.4\%
\]

Where:
- \( %G_{mm}@N_{ini} \) = Percent theoretical maximum specific gravity @ \( N_{initial} \)
- \( h_d \) = Height of specimen at design gyration level
- \( h_i \) = Height of specimen at initial design gyration level
- \( N_{initial} \) = Number of initial gyrations

c. Calculate Air Voids (\( V_a \)) as follow:

\[
V_a = 100 \times \left( 1 - \frac{G_{mb}}{G_{mm}} \right)
\]

Example:

\[
V_a = 100 \times \left( 1 - \frac{2.383}{2.493} \right) = 4.4\%
\]

Where:
- \( V_a \) = Percent air voids

d. Calculate Voids in Mineral Aggregate (VMA) as follows:

\[
VMA = 100 - \left( \frac{G_{mb} \times P_s}{G_{sb}} \right)
\]

Example:

\[
VMA = 100 - \left( \frac{2.383 \times 94.8}{2.630} \right) = 14.1\%
\]

Where:
- \( P_s \) = Percent of aggregate in the mixture (100-\( P_b \))

Example:

100% mix – 5.2% asphalt = 94.8% aggregate

Where:
- \( G_{sb} \) = Bulk specific gravity of the combined aggregate
- \( VMA \) = Voids in Mineral Aggregate, percent

e. Calculate Voids Filled with Asphalt (VFA) as follows:

\[
VFA = 100 \times \left( \frac{VMA - V_a}{VMA} \right)
\]

Example:

\[
VFA = 100 \times \left( \frac{14.1 - 4.4}{14.1} \right) = 68.8\%
\]

Where:
- \( VFA \) = Voids Filled with Asphalt, percent
f. Calculate Gravity Stone Effective \( (G_{se}) \) as follows:

\[
G_{se} = \frac{100 - P_b}{\left(\frac{100}{G_{mm}} - \frac{P_b}{G_b}\right)}
\]

Example:

\[
G_{se} = \frac{100 - 5.2}{\left(\frac{100}{2.493} - \frac{5.2}{1.025}\right)} = 2.706
\]

Where:
- \( G_{se} \) = Gravity Stone Effective (specific gravity of aggregates, excluding voids permeable to asphalt)
- \( P_b \) = Percent of binder
- \( G_b \) = Gravity binder

Note 4: \( G_b \) is the specific gravity of the asphalt binder. It is imperative that current \( G_b \) is used in the volumetric calculations. Any changes in the binder specific gravity must be confirmed by the temperature viscosity curve provided by the asphalt supplier, which can be obtained from the paving Contractor.

g. Calculate Percent Binder Effective \( (P_{be}) \) as follows:

\[
P_{be} = P_b - \left(\frac{P_s \times G_b (G_{se} - G_{sb})}{G_{se} \times G_{sb}}\right)
\]

Example:

\[
P_{be} = 5.2 - \left(\frac{94.8 \times 1.025 \times (2.706 - 2.630)}{2.706 \times 2.630}\right) = 4.2
\]

Where:
- \( P_{be} \) = Percent binder effective, the percent by mass of effective asphalt content minus the quantity of binder lost by absorption into the aggregate particles.
- \( P_s \) = Percent of aggregate in the mixture
- \( G_b \) = Gravity binder
- \( G_{se} \) = Effective specific gravity of the aggregate
- \( G_{sb} \) = Bulk specific gravity of the combined aggregate
- \( P_b \) = Percent of binder

h. Calculate dust-to-binder ratio \( (P_{200}/P_{be}) \) as follows:

\[
P_{200}/P_{be} = P_{200} \div P_{be}
\]

Example:

\[
5.0 \div 3.6 = 1.4
\]

Where:
- \( P_{200}/P_{be} \) = Dust-to-binder ratio
- \( P_{200} \) = Percent of aggregate passing the No. 200 sieve

7. Report

Report the results using one or more of the following:
- Materials Testing System (MATS)
- WSDOT Form 350-560 EF for asphalt content, gradation, and moisture content
- WSDOT Form 350-162 for volumetric properties
- Form approved in writing by the State Materials Engineer
WSDOT SOP 732¹
Volumetric Design for Hot-Mix Asphalt (HMA)

1. SCOPE

1.1 This standard for mix design evaluation uses aggregate and mixture properties to produce a hot-mix asphalt (HMA) job-mix formula. The mix design is based on the volumetric properties of the HMA in terms of the air voids ($V_a$), voids in the mineral aggregate (VMA), and voids filled with asphalt (VFA).

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

2. Referenced Documents

2.1 AASHTO Standards
M 320 – Performance-Graded Asphalt Binder
M 323 – Superpave Volumetric Mix Design
R 30 – Mixture Conditioning of Hot-Mix Asphalt (HMA)
R 35 – Superpave Volumetric Design for Hot-Mix Asphalt (HMA)
T 2 – Sampling of Aggregates
T 11 – Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
T 27 – Sieve Analysis of Fine and Coarse Aggregates
T 84 – Specific Gravity and Absorption of Fine Aggregate
T 85 – Specific Gravity and Absorption of Coarse Aggregate
T 100 – Specific Gravity of Soils
T 166 – Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
T 209 – Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures
T 228 – Specific Gravity of Semi-Solid Bituminous Materials
T 248 – Reducing Samples of Aggregate to Testing Size
T 275 – Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens
T 283 – Resistance of Compacted Asphalt Mixture to Moisture-Induced Damage

¹This Standard Operating procedure is based on AASHTO T 323-04
T 304 – Uncompacted Void Content of Fine Aggregate
T 312 – Preparing and Determining the Density of the Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

2.2 Asphalt Institute

2.3 ASTM Standards

2.4 WSDOT Standards

M 41-01 – Construction Manual
M 41-10 – Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications)
M 46-01 – Materials Manual

SOP 731 – Method for Determining Volumetric Properties of Hot-Mix Asphalt (HMA)

T 2 – WSDOT FOP for AASHTO for Standard Practice for Sampling Aggregate
T 27/11 – WSDOT FOP for WAQTC/AASHTO for Sieve Analysis of Fine and Coarse Aggregates
T 113 – Method of Test for Determination of Degradation Value
T 166 – WSDOT FOP for AASHTO for Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
T 176 – WSDOT FOP for AASHTO for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
T 209 – WSDOT FOP for AASHTO for Method of Test for Maximum Specific Gravity of Hot Mix Asphalt Paving Mixtures “Rice Density”
T 248 – WSDOT FOP for AASHTO for Reducing Samples of Aggregates to Testing Size
T 304 – WSDOT Test Method for AASHTO T 304 Uncompacted Void Content of Fine Aggregate
T 312 – WSDOT FOP for AASHTO for Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
T 335 – WSDOT FOP for AASHTO T 335 Determining the Percentage of Fracture in Coarse Aggregate
T 718 – Method of Test for Determining Stripping of Hot Mix Asphalt
T 724 – Method of Preparation of Aggregate for HMA Mix Designs
T 726 – Mixing Procedure for Hot-Mix Asphalt (HMA)

3. Terminology

3.1 HMA – Hot-mix asphalt.

3.2 Design ESALs – Design equivalent (80kN) single-axle loads.

3.2.1 Discussion – Design ESALs are the anticipated project traffic level expected on the design lane over a 15-year period. For pavements designed for more or less than 15 years, determine the design ESALs for 15 years when using this standard.
3.3 Air voids \( (V_a) \) – The total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture (Note 1).

**Note 1:** Term defined in Asphalt Institute Manual MS-2, *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*.

3.4 Voids in the mineral aggregate (VMA) – The volume of the intergranular void space between the aggregate particles of a compacted paving mixture that includes the air voids \( (V_a) \), and the effective binder content \( (P_{be}) \), expressed as a percent of the total volume of the specimen (Note 1).

3.5 Absorbed binder volume \( (V_{ba}) \) – The volume of binder absorbed into the aggregate (equal to the difference in aggregate volume when calculated with the bulk specific gravity and effective specific gravity).

3.6 Binder content \( (P_b) \) – The percent by mass of binder in the total mixture including binder and aggregate.

3.7 Effective binder volume \( (V_{be}) \) – The volume of binder which is not absorbed into the aggregate.

3.8 Voids filled with asphalt (VFA) – The percentage of the voids in the mineral aggregate (VMA) filled with binder (the effective binder volume divided by the VMA).

3.9 Dust/Asphalt Ratio \( (P_{200}/P_{be}) \) – By mass, ratio between percent passing the No. 200 (0.075 mm) sieve \( (P_{200}) \) and the effective binder content \( (P_{be}) \).

3.10 Nominal maximum aggregate size – 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.

**WSDOT Note 1:** For an aggregate specification having a generally unrestrictive 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.

3.11 Maximum aggregate size – One size larger than the nominal maximum aggregate size (Note 2).

**Note 2:** The definitions given in sections 3.10 and 3.11 apply to Superpave mixes only and differ from the definitions published in other AASHTO standards.

3.12 Reclaimed asphalt pavement (RAP) – Removed and/or processed pavement materials containing asphalt binder and aggregate.

3.13 \( N_{\text{initial}}, N_{\text{design}}, N_{\text{maximum}} \) – the number of gyrations defined in WSDOT Standard Specification 9-03.8(2).

3.14 Effective Asphalt Content \( (P_{be}) \) – The total asphalt content of a paving mixture minus the portion of asphalt that is lost by absorption into the aggregate particles (Note 1).
4. Summary of the Practice

4.1 Materials Selection – Binder and aggregate and RAP stockpiles are selected that meet the environmental and traffic requirements applicable to the paving project. The bulk specific gravity of all aggregates proposed for blending and the specific gravity of the binder are determined.

**Note 3:** If RAP is used, the bulk specific gravity of the RAP aggregate may be estimated by determining the theoretical maximum specific gravity ($G_{mm}$) of the RAP mixture and using an assumed asphalt absorption for the RAP aggregate to back-calculate the RAP aggregate bulk specific gravity, if the absorption can be estimated with confidence. The RAP aggregate effective specific gravity may be used in lieu of the bulk specific gravity at the discretion of the Agency. The use of the effective specific gravity may introduce an error into the combined aggregate bulk specific gravity and subsequent VMA calculations. The Agency may choose to specify adjustments to the VMA requirements to account for this error based on experience with their local aggregates.

4.2 Design Aggregate Structure – It is recommended at least three trial aggregate blend gradations from selected aggregate stockpiles are blended. For each trial gradation, an initial trial binder content is determined, and at least two specimens are compacted in accordance with WSDOT FOP for AASHTO T 312. A design aggregate structure and an estimated design binder content are selected on the basis of satisfactory conformance of a trial gradation meeting the requirements given in Section 9-03.8(2) of the Standard Specifications for Road, Bridge, and Municipal Construction (*Standard Specifications*) for $V_a$, VMA, VFA, Dust/Asphalt Ratio at $N_{design}$, and relative density at $N_{initial}$.

**Note 4:** Previous Superpave mix design experience with specific aggregate blends may eliminate the need for three trial blends.

4.3 Design Binder Content Selection – Replicate specimens are compacted in accordance with WSDOT FOP for AASHTO T 312 at the estimated design binder content and at the estimated design binder content ± 0.5%. The design binder content is selected on the basis of satisfactory conformance with the requirements of Section 9-03.8(2) of the *Standard Specifications* for $V_a$, VMA, VFA, and Dust/Asphalt Ratio ($P_{200}/P_{be}$) at $N_{design}$ and the relative density at $N_{initial}$ and $N_{max}$. For WSDOT projects, the design binder content selection is determined by the Contractor and is verified by the WSDOT.

4.4 Evaluating Moisture Susceptibility – The moisture susceptibility of the design aggregate structure is evaluated at the design binder content: compacted to approximately 4.0% air voids in accordance with WSDOT FOP for AASHTO T 312, and evaluated according to WSDOT T 718. The design shall meet the tensile strength ratio requirement of WSDOT T 718. The WSDOT State Materials Laboratory will evaluate the HMA for moisture susceptibility.

5. Significance and Use

5.1 The procedure described in this practice is used to produce HMA which satisfies Superpave HMA volumetric mix design requirements.
6. Preparing Aggregate Trial Blend Gradations

6.1 The asphalt binder grade will be indicated in WSDOT Contract Plans.

6.2 Determine the specific gravity of the binder according to T 228.

6.3 Obtain samples of aggregates proposed to be used for the project from the aggregate stockpiles in accordance with WSDOT FOP for AASHTO T 2.

**Note 5:** Each stockpile usually contains a given size of an aggregate fraction. Most projects employ three to five stockpiles to generate a combined gradation conforming to the job-mix formula and Section 9-03.8(6) of the *Standard Specifications*.

6.4 Reduce the samples of aggregate fractions according to WSDOT FOP for AASHTO T 248 to samples of the size specified in WAQTC FOP for AASHTO T 27/T 11.

6.5 Wash and grade each aggregate sample according to WAQTC FOP for AASHTO T 27/T 11.

6.6 Determine the bulk and apparent specific gravity for each coarse and fine aggregate fraction in accordance with T 85 and T 84, respectively, and determine the specific gravity of the mineral filler in accordance with T 100. WSDOT requires specific gravity determinations to be reported to an accuracy of 0.001.

6.7 Blend the aggregate fractions using Equation 1:

\[ P = Aa + Bb + Cc, \text{ etc.} \]  \hspace{1cm} (1)

Where:

- \( P \) = Percentage of material passing a given sieve for the combined aggregates \( A, B, C, \text{ etc.} \).
- \( A, B, C, \text{ etc.} \) = Percentage of material passing a given sieve for aggregates \( A, B, C, \text{ etc.} \).
- \( a, b, c, \text{ etc.} \) = proportions of aggregates \( A, B, C, \text{ etc.} \) used in the combination, and where the total = 1.00.

6.8 Prepare a minimum of three trial aggregate blend gradations; plot the gradation of each trial blend on a 0.45-power gradation analysis chart, and confirm that each trial blend meets the Aggregate Gradation Control Points in Section 9-03.8(6) of the *Standard Specifications*. Gradation control is based on four control sieve sizes: the sieve for the maximum aggregate size, the sieve for the nominal maximum aggregate size, the No. 4 or No. 8 (4.75- or 2.36 mm) sieve, and the No. 200 (0.075 mm) sieve. For WSDOT projects, gradation shall be determined by the following sieves as defined in table W1T. An example of three acceptable trial blends in the form of a gradation plot is given in Figure 1.
### Sieves Required for Gradation Determination

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>3/8 in</th>
<th>1/2 in</th>
<th>3/4 in</th>
<th>1 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2”</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>1”</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3/4”</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>1/2”</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3/8”</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>No. 4</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>No. 8</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>No. 16</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>No. 30</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>No. 50</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>No. 100</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>No. 200</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*X = indicates sieve is required for gradation determination*

**Table W1T**

6.9 Obtain a test specimen from each of the trial blends according to WSDOT FOP for AASHTO T 248, and conduct the quality tests specified in Section 9-03.8(2) subsections 1, 2, 3, and 4 of the *Standard Specifications* to confirm that the aggregate in the trial blends meets the minimum quality requirements specified in Section 9-03.8(2) of the *Standard Specifications*.

**Note 6**: The designer has an option of performing the quality tests on each stockpile instead of the trial aggregate blend. The test results from each stockpile can be used to estimate the results for a given combination of materials.

**3/4” Nominal Sieve Size**

**Evaluation of the Gradations of Three Trial Blends (Example)**

*Figure 1*
7. Determining an Initial Trial Binder Content for Each Trial Aggregate Gradation

7.1 Designers can either use their experience with the materials or the procedure given in Appendix A1 to determine an initial trial binder content for each trial aggregate blend gradation.

*Note 7:* When using RAP, the initial trial asphalt content should be reduced by an amount equal to that provided by the RAP.

8. Compacting Specimens of Each Trial Gradation

8.1 Prepare replicate mixtures (Note 8) at the initial trial binder content for each of the chosen trial aggregate trial blend gradations. From Table 1, determine the number of gyrations based on the design ESALs for the project. On WSDOT projects the ESAL level will be indicated in the Contract Special Provisions.

*Note 8:* At least two replicate specimens are required, but three or more may be prepared if desired. Generally, 4500 to 4700 g of aggregate is sufficient for each compacted specimen with a height of 110 to 120 mm for aggregates with combined bulk specific gravities of 2.550 to 2.700, respectively.

8.2 Condition the mixtures according to R 30, and compact the specimens to $N_{\text{design}}$ gyrations in accordance with WSDOT FOP for AASHTO T 312. Record the specimen height to the nearest 0.1 mm after each revolution.

8.3 Determine the bulk specific gravity ($G_{mb}$) of each of the compacted specimens in accordance with WSDOT FOP for AASHTO T 166 or T 275 as appropriate. The bulk specific gravity results of the replicate specimens shall not differ by more than 0.020.

<table>
<thead>
<tr>
<th>Design ESALs$^a$ (million)</th>
<th>Compaction Parameters</th>
<th>Typical Roadway Application$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$N_{\text{initial}}$</td>
<td>$N_{\text{design}}$</td>
</tr>
<tr>
<td>&lt; 0.3</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>0.3 to &lt; 3</td>
<td>7</td>
<td>75</td>
</tr>
<tr>
<td>3 to &lt; 30</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>$\geq$ 30</td>
<td>9</td>
<td>125</td>
</tr>
</tbody>
</table>

$^a$The anticipated project traffic level expected on the design lane over a 15-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 15 years.

$^b$As defined by *A Policy on Geometric Design of Highways and Streets, 2001*, AASHTO.

Superpave Gyratory Compaction Effort

*Table 1*
8.4 Determine the theoretical maximum specific gravity \( (G_{mm}) \) according to WSDOT FOP for AASHTO T 209 of separate samples representing each of these combinations that have been mixed and conditioned to the same extent as the compacted specimens.

**Note 11:** The maximum specific gravity for each trial mixture shall be based on the average of at least two tests. The maximum specific gravity results of the replicate specimens shall not differ by more than 0.011.

9. Evaluating Compacted Trial Mixtures

9.1 Determine the volumetric requirements for the trial mixtures in accordance with Section 9-03.8(2) of the *Standard Specifications*.

9.2 Calculate \( V_a \) and VMA at \( N_{design} \) for each trial mixture using equations 2 and 3:

\[
V_a = 100 \times \left( 1 - \left( \frac{G_{mb}}{G_{mm}} \right) \right) 
\]

\[ (2) \]

\[
VMA = 100 - \left( \frac{G_{mb} P_s}{G_{sb}} \right) 
\]

\[ (3) \]

Where:
- \( G_{mb} \) = Bulk specific gravity of the extruded specimen
- \( G_{mm} \) = Theoretical maximum specific gravity of the mixture
- \( P_s \) = Percent of aggregate in the mixture (100-P_b)
- \( G_{sb} \) = Bulk specific gravity of the combined aggregate

**Note 12:** Although the initial trial binder content was estimated for a design air void content of 4.0%, the actual air void content of the compacted specimen is unlikely to be exactly 4.0%. Therefore, the change in binder content needed to obtain a 4.0% air void content, and the change in VMA caused by this change in binder content, is estimated. These calculations permit the evaluation of VMA and VFA of each trial aggregate gradation at the same design air void content, 4.0%.

9.3 Estimate the volumetric properties at 4.0 percent air voids for each compacted specimen. On WSDOT projects, the gyration level will be specified in the Contract Provisions.

9.3.1 Determine the difference in average air void content at \( N_{design} \) \( (\Delta V_a) \) of each aggregate trial blend from the design level of 4.0% using Equation 4:

\[
\Delta V_a = 4.0 - V_a 
\]

\[ (4) \]

9.3.2 Estimate the change in binder content \( (\Delta P_b) \) needed to change the air void content to 4.0% using Equation 5:

\[
\Delta P_b = -0.4 \left(\Delta V_a\right) 
\]

\[ (5) \]
9.3.3 Estimate the change in VMA (ΔVMA) caused by the change in the air void content (∆Vₐ) determined in Section 9.3.1 for each trial aggregate blend gradation, using Equations 6 or 7.

\[
\Delta VMA = 0.2(\Delta Vₐ) \text{ if } Vₐ > 4.0 \tag{6}
\]

\[
\Delta VMA = -0.1(\Delta Vₐ) \text{ if } Vₐ < 4.0 \tag{7}
\]

*Note 13:* A change in binder content affects the VMA through a change in the bulk specific gravity of the compacted specimen (Gₘₚ).

9.3.4 Calculate the VMA for each aggregate trial blend at Nₚ design gyrations and 4.0% air voids using Equation 8:

\[
VMA_{design} = VMA_{trial} + \Delta VMA \tag{8}
\]

Where:

VMAₚ design = VMA estimated at a design air void content of 4.0%
VMAₚ trial = VMA determined at the initial trial binder content

9.3.5 Using the values of ∆Vₐ determined in Section 9.3.1 and Equation 9, estimate the relative density of each specimen at N initial when the design air void content is adjusted to 4.0 percent at Nₚ design:

\[
%G_{mm initial} = 100 \times \left( \frac{Gₘₚ h_d}{Gₚ mm h_i} \right) - \Delta Vₐ \tag{9}
\]

Where:

%Gₚ mm initial = relative density at Nₚ initial gyrations at the adjusted design binder content
h_d = Height of the specimen after Nₚ design gyrations, from the Superpave gyratory compactor, mm
h_i = Height of the specimen after N initial gyrations, from the Superpave gyratory compactor, mm
9.3.6 Estimate the percent of effective binder ($P_{be}$) and calculate the Dust/Asphalt Ratio ($P_{200}/P_{be}$) for each trial blend using Equations 10 and 11:

$$P_{beest} = -(P_s \times G_b) \left( \frac{G_{se} - G_{sb}}{G_{se} \times G_{sb}} \right) + P_{best}$$  \hspace{1cm} (10)

Where:
- $P_{beest}$ = Estimated effective binder content
- $P_s$ = Percent of aggregate in the mixture (100-$P_b$)
- $G_b$ = Specific gravity of the binder
- $G_{se}$ = Effective specific gravity of the aggregate
- $G_{sb}$ = Bulk specific gravity of the combined aggregate
- $P_{best}$ = Estimated binder content

$$\text{Dust/Asphalt Ratio} = \frac{P_{200}}{P_{be}}$$  \hspace{1cm} (11)

Where:
- $P_{200}$ = Percent passing the No. 200 (0.075 mm) sieve

9.3.7 Compare the estimated volumetric properties from each trial aggregate blend gradation at the adjusted design binder content with the criteria specified in Section 9-03.8(2) of the Standard Specifications. Choose the trial aggregate blend gradation that best satisfies the volumetric criteria.

**Note 14:** Table 2 presents an example of the selection of a design aggregate structure from three trial aggregate blend gradations.

**Note 15:** Many trial aggregate blend gradations will fail the VMA criterion. Generally, the % criterion will be met if the VMA criterion is satisfied. Section 12.1 gives a procedure for the adjustment of VMA.

**Note 16:** If the trial aggregate gradations have been chosen to cover the entire range of the gradation controls, then the only remaining solution is to make adjustments to the aggregate production or to introduce aggregates from a new source. The aggregates that fail to meet the required criteria will not produce a quality mix and should not be used. One or more of the aggregate stockpiles should be replaced with another material which produces a stronger structure. For example, a quarry stone can replace a crushed gravel, or crushed fines can replace natural fines.
### Volumetric Property

**Trial Mixture (¾ Inch Nominal Maximum Aggregate) 15 Year Project Design ESALs = 5 million**

<table>
<thead>
<tr>
<th>Volumetric Property</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the Initial Trial Binder Content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_b$ (trial)</td>
<td>4.4</td>
<td>4.4</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>$%G_{mm, initial}$ (trial)</td>
<td>88.1</td>
<td>87.8</td>
<td>87.1</td>
<td></td>
</tr>
<tr>
<td>$%G_{mm, design}$ (trial)</td>
<td>95.9</td>
<td>95.3</td>
<td>94.7</td>
<td></td>
</tr>
<tr>
<td>$V_a$ at $N_{design}$</td>
<td>4.1</td>
<td>4.7</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>VMA$_{trial}$</td>
<td>12.9</td>
<td>13.4</td>
<td>13.9</td>
<td></td>
</tr>
<tr>
<td>Adjustments to Reach Design Binder Content ($V_a = 4.0%$ at $N_{design}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta V_a$</td>
<td>-0.1</td>
<td>-0.7</td>
<td>-1.3</td>
<td></td>
</tr>
<tr>
<td>$\Delta P_b$</td>
<td>0.0</td>
<td>0.3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>$\Delta$VMA</td>
<td>0.0</td>
<td>-0.1</td>
<td>-0.3</td>
<td></td>
</tr>
<tr>
<td>At the Estimated Design Binder Content ($V_a = 4.0%$ at $N_{design}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated $P_b$ (design)</td>
<td>4.4</td>
<td>4.7</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>VMA (design)</td>
<td>12.9</td>
<td>13.3</td>
<td>13.6</td>
<td>$\geq 13.0$</td>
</tr>
<tr>
<td>$%G_{mm, initial}$ (design)</td>
<td>88.2</td>
<td>89.5</td>
<td>88.4</td>
<td>$\leq 89.0$</td>
</tr>
</tbody>
</table>

**Notes:**

1. The top portion of this table presents measured densities and volumetric properties for specimens prepared for each aggregate trial blend at the initial trial binder content.
2. None of the specimens had an air void content of exactly 4.0 percent. Therefore, the procedures described in Section 9 must be applied to:
   (1) estimate the design binder content at which $TV_a = 4.0$ percent, and
   (2) obtain adjusted VMA and relative density values at this estimated binder content.
3. The middle portion of this table presents the change in binder content ($\Delta P_b$) and VMA ($\Delta$VMA) that occurs when the target air void content ($TV_a$) is adjusted to 4.0 percent for each trial aggregate blend gradation.
4. A comparison of the VMA and densities at the estimated design binder content to the criteria in the last column shows that trial aggregate blend gradation No. 1 does not have sufficient VMA (12.9% versus a requirement of $\geq 13.0$%). Trial blend No. 2 exceeds the criterion for relative density at $N_{initial}$ gyrations (89.5% versus requirement of $\leq 89.0$%). Trial No. 3 meets the requirement for relative density and VMA and, in this example, is selected as the design aggregate structure.

### Selection of a Design Aggregate Structure (Example)

**Table 2**

10. Selecting the Design Binder Content

10.1 Prepare replicate mixtures (Note 8) containing the selected design aggregate structure at each of the following three binder contents: (1) the estimated design binder content, $P_b (design)$; (2) 0.5% below $P_b (design)$; and (3) 0.5% above $P_b (design)$.

10.1.1 Use the number of gyrations previously determined in Section 8.1.

10.2 Condition the mixtures according to R 30, and compact the specimens to $N_{design}$ gyrations according to WSDOT FOP for AASHTO T 312. Record the specimen height to the nearest 0.1 mm after each revolution.
10.3 Determine the bulk specific gravity of each of the compacted specimens in accordance with WSDOT FOP for AASHTO T 166 or AASHTO T 275 as appropriate.

10.4 Determine the theoretical maximum specific gravity \((G_{mm})\) according to WSDOT FOP for AASHTO T 209 of each of the three mixtures using companion samples which have been conditioned to the same extent as the compacted specimens (Note 8).

10.5 Determine the design binder content which produces a target air void content of 4.0 percent at \(N_{\text{design}}\) gyrations using the following steps:

10.5.1 Calculate \(V'_{a},\ VMA,\ \text{and VFA}\) at \(N_{\text{design}}\) using Equations 2, 3 and 12: The volumetric properties are determined for each specimen and then averaged for each replicate mixture.

\[
VFA = 100 \times \left(\frac{VMA - V'_a}{VMA}\right)
\]  
(12)

10.5.2 Calculate the Dust/Asphalt Ratio, using Equation 13.

\[
\text{Dust/Asphalt Ration} = \frac{P_{200}}{P_{be}}
\]  
(13)

Where:
\(P_{be}\) = Effective binder content

10.5.3 For each of the three mixtures, determine the average corrected specimen relative densities at \(N_{\text{initial}}\) (%), using Equation 14.

\[
\%G_{mm_{\text{initial}}} = 100 \times \left(\frac{G_{mb}h_d}{G_{mm}h_i}\right)
\]  
(14)

10.5.4 Plot the average \(V'_{a},\ VMA,\ \text{VFA, and relative density at } N_{\text{design}}\) for replicate specimens versus binder content.

**Note 17:** All plots are generated automatically by the Superpave software. Figure 2 presents a sample data set and the associated plots.

10.5.5 By graphical or mathematical interpolation (Figure 2), determine the binder content to the nearest 0.1 percent at which the target \(V'_a\) is equal to 4.0 percent. This is the design binder content \((P_b)\) at \(N_{\text{design}}\).

10.5.6 By interpolation (Figure 2), verify that the volumetric requirements specified in Section 9-03.8(2) of the Standard Specifications are met at the design binder content.

10.6 Compare the calculated percent of maximum relative density with the design criteria at \(N_{\text{initial}}\) by interpolation, if necessary. This interpolation can be accomplished by the following procedure.

10.6.1 Prepare a densification curve for each mixture by plotting the measured relative density at \(x\) gyrations, \(%G_{mm_x}\), versus the logarithm of the number of gyrations (see Figure 3).
10.6.2 Examine a plot of air void content versus binder content. Determine the difference in air voids between 4.0 percent and the air void content at the nearest, lower binder content. Determine the air void content at the nearest, lower binder content at its data point, not on the line of best fit. Designate the difference in air void content as $\Delta V_a$.

10.6.3 Using Equation 14, determine the average corrected specimen relative densities at $N_{\text{initial}}$. Confirm that satisfies the design requirements in Section 9-03.8(2) of the Standard Specifications at the design binder content.

10.7 Prepare replicate (Note 8) specimens composed of the design aggregate structure at the design binder content to confirm that $\%G_{\text{mm max}}$ satisfies the design requirements in Section 9-03.8(2) of the Standard Specifications.

10.7.1 Condition the mixtures according to R-30, and compact the specimens according to WSDOT FOP for AASHTO T312 to the maximum number of gyrations, $N_{\text{max}}$, from Section 9-03.8(2) of the Standard Specifications.

10.7.2 Determine the average specimen relative density at $N_{\text{max}}$, $\%G_{\text{mm max}}$, by using Equation 15, and confirm that satisfies the volumetric requirement in Section 9-03.8(2) of the Standard Specifications.

\[
\%G_{\text{mm max}} = 100 \times \frac{G_m}{G_{\text{mm}}} \tag{15}
\]

Where:
$\%G_{\text{mm max}}$ = Relative density at $N_{\text{max}}$ gyrations at the design binder content

<table>
<thead>
<tr>
<th>$P_b$ (%)</th>
<th>$V_a$ (%)</th>
<th>VMA (%)</th>
<th>VFA (%)</th>
<th>Maximum Density at $N_{\text{design}}$ ($G_{\text{mm}}$)</th>
<th>Density at $N_{\text{design}}$ lbs/ft$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3</td>
<td>9.9</td>
<td>17.0</td>
<td>41.8</td>
<td>2.660</td>
<td>165.6</td>
</tr>
<tr>
<td>4.8</td>
<td>8.2</td>
<td>16.7</td>
<td>50.9</td>
<td>2.636</td>
<td>164.1</td>
</tr>
<tr>
<td>5.3</td>
<td>6.9</td>
<td>16.6</td>
<td>58.5</td>
<td>2.617</td>
<td>162.9</td>
</tr>
<tr>
<td>5.8</td>
<td>5.2</td>
<td>16.5</td>
<td>68.5</td>
<td>2.585</td>
<td>160.9</td>
</tr>
<tr>
<td>6.3</td>
<td>3.9</td>
<td>16.2</td>
<td>76.0</td>
<td>2.574</td>
<td>160.2</td>
</tr>
</tbody>
</table>

In this example, the estimated design binder content is 4.8 percent; the minimum VMA requirement for the design aggregate structure (¾ in nominal maximum size) is 13.0 percent, and the VFA requirements is 65 to 78 percent.

Entering the plot of percent air voids versus percent binder content at 4.0 percent air voids, the design binder content is determined as 6.2 percent.

Entering the plots of percent VMA versus percent binder content and percent VFA versus percent binder content at 6.2 percent binder content, the mix meets the VMA and VFA requirement.

Sample Volumetric Design Data at $N_{\text{des}}$

*Figure 2*
Sample Densification Curve

*Figure 3*
11. Evaluating Moisture Susceptibility

11.1 Prepare six mixture specimens composed of the design aggregate structure at the design binder content. Prepare the specimens according to WSDOT T 726, and compact the specimens to approximate 4.0% air voids in accordance to WSDOT FOP for AASHTO T 312. The WSDOT State Materials Laboratory will evaluate the HMA for moisture susceptibility.

11.2 Test the specimens and calculate the tensile strength ratio in accordance with WSDOT T 718.

12. Adjusting the Mixture to Meet Properties

12.1 Adjusting VMA – If a change in the design aggregate skeleton is required to meet the specified VMA, there are three likely options: (1) change the gradation (Note 18); (2) reduce the minus No. 200 (0.075 mm) fraction (Note 19); or (3) change the surface texture and/or shape of one or more of the aggregate fractions (Note 20).

Note 18: Changing gradation may not be an option if the trial aggregate blend gradation analysis includes the full spectrum of the gradation control area.

Note 19: Reducing the percent passing the No. 200 (0.075 mm) sieve of the mix will typically increase the VMA. If the percent passing the No. 200 (0.075 mm) sieve is already low, this is not a viable option.

Note 20: This option will require further processing of existing materials or a change in aggregate sources.
12.2 Adjusting VFA – The lower limit of the VFA range should always be met at 4.0% air voids if the VMA meets the requirements. If the upper limit of the VFA is exceeded, then the VMA is substantially above the minimum required. If so, redesign the mixture to reduce the VMA. Actions to consider for redesign include: (1) changing to a gradation that is closer to the maximum density line; (2) increasing the minus No. 200 (0.075 mm) fraction, if room is available within the specification control points; or (3) changing the surface texture and shape of the aggregates by incorporating material with better packing characteristics, e.g., less thin, elongated aggregate particles.

13. Report

13.1 The report shall include the identification of the project number, mix class designation, and mix design number.

13.2 The report shall include information on the design aggregate structure including the source of aggregate, and gradation, including the blending ratios.

13.3 The report shall contain information about the design binder including the source of binder and the performance grade.

13.4 The report shall contain information about the HMA including the percent of binder in the mix; the relative density; the number of initial, design, and maximum gyrations; and the VMA, VFA, $V_a$, and Dust/Asphalt Ratio $P_{bc}$, $G_{mm}$, $G_{mb}$, $G_{sb}$ and $G_{se}$ of the aggregate blend, $G_{sb}$ of the fine aggregate, and $G_b$.

13.5 The report shall contain the results of the moisture susceptibility testing and the required level of anti-strip additive needed.

14. Keywords

14.1 HMA mix design; Superpave; volumetric mix design.
Appendix

A1. Calculating an Initial Trial Binder Content for Each Aggregate Trial Blend

Nonmandatory Information

A1.1 Calculate the bulk and apparent specific gravities of the combined aggregate in each trial blend using the specific gravity data for the aggregate fractions obtained in Section 6.6 and Equations 16 and 17:

\[
G_{sb} = \frac{P_1 + P_2 + \cdots + P_n}{\frac{1}{G_1} + \frac{1}{G_2} + \cdots + \frac{1}{G_n}} \quad (16)
\]

\[
G_{sa} = \frac{P_1 + P_2 + \cdots + P_n}{\frac{1}{G_1^{sa}} + \frac{1}{G_2^{sa}} + \cdots + \frac{1}{G_n^{sa}}} \quad (17)
\]

Where:
- \( G_{sb} \) = Bulk specific gravity for the combined aggregate
- \( G_{sa} \) = Apparent specific gravity for the combined aggregate
- \( P_1, P_2, P_n \) = Percentages by mass of aggregates 1, 2, n
- \( G_1, G_2, G_n \) = Bulk specific gravities (Equation 16) or apparent specific gravities (Equation 17) of aggregates 1, 2, n.

A1.2 Estimate the effective specific gravity of the combined aggregate in the aggregate trial blend using Equation 18:

\[
G_{se} = G_{sb} + 0.8(G_{sa} - G_{sb}) \quad (18)
\]

Where:
- \( G_{se} \) = Effective specific gravity of the combined aggregate
- \( G_{sb} \) = Bulk specific gravity of the combined aggregate
- \( G_{sa} \) = Apparent specific gravity of the combined aggregate

Note 21: The multiplier, 0.8, can be changed at the discretion of the designer. Absorptive aggregates may require values closer to 0.6 or 0.5.

Note 22: The Superpave mix design system includes a mixture conditioning step before the compaction of all specimens; this conditioning generally permits binder absorption to proceed to completion. Therefore, the effective specific gravity of Superpave mixtures will tend to be close to the apparent specific gravity in contrast to other design methods where the effective specific gravity generally will lie near the midpoint between the bulk and apparent specific gravities.
A1.3 Estimate the volume of binder absorbed into the aggregate, $V_{ba}$, using Equations 19 and 20:

$$V_{ba} = W_s \left( \frac{1}{G_{sb} - 1} \frac{1}{G_{se}} \right)$$

(19)

Where:

$W_s$ = The mass of aggregate in 1 cm$^3$ of mix, g, is calculated as

$$W_s = \frac{P_b (1 - V_a)}{P_b / G_b + P_s / G_s}$$

(20)

and Where:

$P_b$ = Percent of binder, in decimal equivalent, assumed to be 0.05

$P_s$ = Percent of aggregate in mixture, in decimal equivalent, assumed to be 0.95

$G_b$ = Specific gravity of the binder

$V_a$ = Volume of air voids, assumed to be 0.04 cm$^3$ in 1 cm$^3$ of mix

Note 23: This estimate calculates the volume of binder absorbed into the aggregate, $V_{ba}$, and subsequently, the initial, trial binder content at a target air void content of 4.0%.

A1.4 Estimate the volume of effective binder using Equation 21:

$$V_{be} = 0.176 - (0.0675 \log (S_n))$$

(21)

Where:

$V_{be}$ = Volume of effective binder, cm$^3$

$S_n$ = Nominal maximum sieve size of the largest aggregate in the aggregate trial blend, mm.

Note 24: This regression Equation is derived from an empirical relationship between:

(1) VMA and $V_{be}$ when the air void content, $V_a$, is equal to 4.0 percent: $V_{be} = \text{VMA} - V_a = \text{VMA} - 4.0$; and (2) the relationship between VMA and the nominal maximum sieve size of the aggregate in MP 2. For WSDOT projects, see contract provisions.

A1.5 Calculate the estimated initial trial binder ($P_{bi}$) content for the aggregate trial blend gradation using Equation 22:

$$P_{bi} = 100 \times \left( \frac{G_b (V_{be} + V_{ba})}{G_b (V_{be} + V_{ba}) + W_s} \right)$$

(22)

Where:

$P_{bi}$ = Estimated initial trial binder content, percent by weight of total mix
WSDOT SOP 735
Standard Operating Procedure for Longitudinal Joint Density

1. General Scope
   a. This procedure describes the method for determining the location of a longitudinal joint density test.
   b. Longitudinal joint density tests are performed in addition to Quality Assurance (QA) density tests.
   c. One longitudinal joint density test will be performed on the confined or unconfined edge at each longitudinal joint.

2. Longitudinal Joint Testing
   a. The longitudinal joint density test will be conducted in accordance with WSDOT FOP for WAQTC TM 8, except “Test Site Location, Section 1, subsection c, which is modified by this procedure to read “No closer than 18 in (450mm) to any vertical mass, or less than 6 in (152 mm) from a vertical pavement edge,” making sure the gauge will sit flush with the hot-mix asphalt (HMA). See Figure 1.
   b. A longitudinal joint density will be required on the lane edge side of a shoulder if the shoulder is required to meet the same QA density requirements as the traveled lane.

   Note: Hot lap joints are not included in longitudinal joint testing.

3. Number of Longitudinal Joint Tests
   a. For projects requiring 400 tons sublot with 5 sublots – One reading, at each longitudinal joint to be tested, will be taken within each compaction lot at the same station location as the third sublot.
   b. For projects requiring 80 ton sublots – One reading, at each longitudinal joint to be tested, will be taken every four hundred tons or at every fifth sublot tested.

4. Calculation of Results
   a. Calculate the Longitudinal Joint density in accordance WSDOT SOP 729.

5. Report
   a. Report the results using one or more of the following:
      - Materials Testing System (MATS)
      - WSDOT Form 350-095
      - Form approved in writing by the State Materials Engineer

   Note: Lot Number corresponds to the lot where the set of longitudinal joint readings were taken. The station corresponds to the station within the lot (i.e., third sublot) where the set of longitudinal joint readings were taken.
Longitudinal Joint Testing Locations

Figure 1

Shoulder
(Shoulder longitudinal joint will be tested if it is the result of a mill and fill)
1. **Scope**

   1.1 This test method covers the determination of slump flow of self-consolidating concrete.

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

   1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (Warning - Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)

   1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. **Referenced Documents**

   2.1 ASTM Standards

      C 143/C 143M – Test Method for Slump of Hydraulic-Cement Concrete

      C 172 – Practice for Sampling Freshly Mixed Concrete

      C 173/C 173M – Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

      C 670 – Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

   2.2 AASHTO Standards

      T 119M/T 119 – Standard Test Method for Slump of Hydraulic-Cement Concrete

      TP 73-09 – Slump Flow of Self-Consolidating Concrete (SCC)

   2.3 WAQTC Standards

      TM 2 – Sampling Freshly Mixed Concrete

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1This Test Method is based on ASTM C 1611/C 1611M and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 halo, n – An observed cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of concrete after flowing from the slump cone.

3.1.2 spread, n – The distance of lateral flow of concrete during the slump-flow test.

3.1.3 stability, n – The ability of a concrete mixture to resist segregation of the paste from the aggregates.

3.1.4 viscosity, n – Resistance of a material to flow under an applied shearing stress.

4. Summary of Test Method

4.1 A sample of freshly mixed concrete is placed in a mold shaped as the frustum of a cone. The concrete is placed in one lift without tamping or vibration. The mold is raised, and the concrete allowed to spread. After spreading ceases, two diameters of the concrete mass are measured in approximately orthogonal directions, and slump flow is the average of the two diameters.

5. Significance and Use

5.1 This test method provides a procedure to determine the slump flow of self-consolidating concrete in the laboratory or the field.

5.2 This test method is used to monitor the consistency of fresh, unhardened self-consolidating concrete and its unconfined flow potential.

5.3 It is difficult to produce self-consolidating concrete that is both flowable and nonsegregating using coarse aggregates larger than 1 in (25 mm). Therefore, this test method is considered applicable to self-consolidating concrete having coarse aggregate up to 1 in (25 mm) in size.

6. Apparatus

6.1 Mold – The mold used in this test method shall conform to that described in FOP for AASHTO T 119.

6.2 Base Plate – The base plate on which the mold rests shall be nonabsorbent, smooth, rigid, and have a minimum diameter of 36 in (915 mm).

Note 1: Field experience and results from the round robin test program have shown that base plates made from sealed/laminated plywood, acrylic plastic, or steel are suitable for performing this test.

6.3 Strike-off Bar – As described in FOP for WAQTC T 152.

7. Sample

7.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. Sample in accordance with FOP for WAQTC TM 2.
8. Procedure

8.1 The slump-flow test shall be performed on a flat, level, nonabsorbent base plate. Position and shim the base plate so it is fully supported, flat, and level.

8.2 Filling the Mold – WSDOT requires the use of Procedure B.

8.2.1 Filling Procedure B (Inverted Mold) – Dampen and place the mold, with the smaller opening of the mold facing down, in the center of a flat, moistened base plate or concrete surface. Using a suitable container, fill the entire mold continuously. The mold shall be held firmly in place during filling. Do not rod or tamp the SCC. Slightly overfill the mold.

8.3 Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike-off bar. Remove concrete from the area surrounding the base of the mold to preclude interference with the movement of the flowing concrete. Remove the mold from the concrete by raising it vertically. Raise the mold a distance of $9 \pm 3$ in ($225 \pm 75$ mm) in $3 \pm 1$ seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test from start of the filling through removal of the mold without interruption within an elapsed time of $2\frac{1}{2}$ minutes.

8.4 Wait for the concrete to stop flowing and then measure the largest diameter of the resulting circular spread of concrete to the nearest $\frac{1}{4}$ in ($5$ mm). When a halo is observed in the resulting circular spread of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter of the circular spread at an angle approximately perpendicular to the original measured diameter.

8.5 If the measurement of the two diameters differs by more than $2$ in ($50$ mm), the test is invalid and shall be repeated.

9. Calculation

9.1 Calculate the slump flow using Eq 1:

$$\text{Slump flow} = \frac{(d_1 + d_2)}{2}$$

where:

$d_1$ = the largest diameter of the circular spread of the concrete, and

$d_2$ = the circular spread of the concrete at an angle approximately perpendicular to $d_1$

9.2 Record the average of the two diameters to the nearest $\frac{1}{4}$ in ($5$ mm).

10. Report

10.1 Report the slump flow to the nearest $\frac{1}{4}$ in ($5$ mm).

11. Precision and Bias

See ASTM C1611/C 1611M for precision and bias.
### Performance Exam Checklist

**WSDOT FOP for ASTM C 1611/C 1611M**  
*Standard Test Method for Slump Flow of Self-Consolidating Concrete*

**Participant Name** _______________________________  
**Exam Date** ____________________

<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, and if required.</td>
<td>☐</td>
<td>☑</td>
</tr>
<tr>
<td>Has the current calibration/verification tags present?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>3. Sample was taken per WSDOT FOP for WAQTC TM 2?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>4. Molds and base plate dampened and base plate is flat, level and fully supported?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>5. Mold filled completely in one lift (slightly overfilled)?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>6. Mold struck off level with top opening?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>7. Excess material removed from base plate and mold raised 9 ± 3 inches, in 3 ± 1 seconds?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>8. After flow stabilized, measured largest diameter (including halo if necessary)?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>9. Second measurement taken approximately perpendicular to first measurement?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>10. First and second measurements agree within 2&quot;?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>11. Slump flow was reported as an average of the two measurements?</td>
<td>☑</td>
<td>☐</td>
</tr>
<tr>
<td>12. Slump flow reported to the nearest ¼&quot;?</td>
<td>☑</td>
<td>☐</td>
</tr>
</tbody>
</table>

**First Attempt:**  Pass ☐  Fail ☑  
**Second Attempt:**  Pass ☐  Fail ☑

Signature of Examiner  _______________________________

Comments:
1. **Scope**

   1.1 This test method covers determination of the passing ability of self-consolidating concrete by using the J-Ring in combination with a slump cone mold. The test method is limited to concrete with maximum size of aggregate of 1 in (25 mm).

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

   1.3 The text of this standard references notes that provide explanatory material. These notes (excluding those in tables and figures) shall not be considered as requirements of the standard.

   1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (Warning – Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)

2. **Referenced Documents**

   2.1 ASTM Standards

      C 125 – Terminology Relating to Concrete and Concrete Aggregates

      C 143/C 143M – Test Method for Slump of Hydraulic-Cement Concrete

      C 172 – Practice for Sampling Freshly Mixed Concrete

      C 173/C 173M – Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

      C 1611/C 1611M – Test Method for Slump Flow of Self-Consolidating Concrete

3. **Terminology**

   3.1 Definitions

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

      3.2 Definitions of Terms Specific to This Standard

      3.2.1 *Halo* – An observed cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of concrete after flowing from the slump cone.

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1This Test Method is based on ASTM C 1621/C 1621M and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
3.2.2  **J-ring** – An apparatus consisting of a rigid ring supported on sixteen ⅝ in (16 mm) diameter rods equally spaced on a 12 in (300 mm) diameter circle 4 in (100 mm) above a flat surface as shown in Figure 1.

3.2.3  **J-ring flow** – The distance of lateral flow of concrete using the J-Ring in combination with a slump cone.

3.2.4  **Passing ability** – The ability of self-consolidating concrete to flow under its own weight (without vibration) and fill completely all spaces within intricate formwork, containing obstacles, such as reinforcement.

4.  **Summary of Test Method**

   4.1  A sample of freshly mixed concrete is placed in a slump mold (inverted position) that is concentric with the J-Ring (Figure 2). The concrete is placed in one lift without tamping or vibration. The mold is raised, and the concrete is allowed to pass through J-Ring and subside (Figure 3).

   The diameters of the concrete, in two directions approximately perpendicular to each other, are measured and averaged to obtain the J-Ring flow. The test is repeated without the J-Ring to obtain the slump flow.

   The difference between the slump flow and J-Ring flow is an indicator of the passing ability of the concrete.

5.  **Significance and Use**

   5.1  This test method provides a procedure to determine the passing ability of self-consolidating concrete mixtures. The difference between the slump flow and J-Ring flow is an indication of the passing ability of the concrete. A difference less than 1 in (25 mm) indicates good passing ability and a difference greater than 2 in (50 mm) indicates poor passing ability. The orientation of the slump cone for the J-Ring test and for the slump flow test without the J-Ring shall be the same.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>in</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12.0 ± 0.13</td>
<td>300 ± 3.3</td>
</tr>
<tr>
<td>B</td>
<td>1.5 ± 0.06</td>
<td>38 ± 1.5</td>
</tr>
<tr>
<td>C</td>
<td>0.625 ± 0.13</td>
<td>16 ± 3.3</td>
</tr>
<tr>
<td>D</td>
<td>2.36 ± 0.06</td>
<td>58.9 ± 1.5</td>
</tr>
<tr>
<td>E</td>
<td>1.0 ± 0.06</td>
<td>25 ± 1.5</td>
</tr>
<tr>
<td>F</td>
<td>4.0 ± 0.06</td>
<td>200 ± 1.5</td>
</tr>
</tbody>
</table>

Figure 1
5.2 This test method is applicable for laboratory use in comparing the passing ability of different concrete mixtures. It is also applicable in the field as a quality control test.

6. Apparatus

6.1 *J-Ring* – The apparatus shall consist of a steel (or equivalent nonabsorbent, rigid material) ring measuring 12 in (300 mm) in diameter at the center of the ring and 1 in (25 mm) in thickness, and sixteen \( \frac{5}{16} \) in (16 mm) diameter smooth steel rods spaced evenly around the ring measuring 4 in (100 mm) in length (see Figure 1).

6.2 *Mold* – The mold (slump cone) used in this test method is as described in FOP for AASHTO T 119.

6.3 *Base Plate* – A nonabsorbent, rigid plate having a diameter of at least 36 in (915 mm).

*Note 1:* Field experience has shown that base plates made from sealed or laminated plywood, rigid plastic, or steel are suitable for performing this test.

6.4 *Strike Off Bar* – As described in FOP for WAQTC T 152.

6.5 *Measuring Device* – A ruler, metal roll-up measuring tape, or similar rigid or semi-rigid length measuring instrument marked in increments of \( \frac{1}{4} \) in (5 mm) or less.

7. Sample

7.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with FOP for WAQTC TM 2.

8. Procedure

8.1 Perform the test on a flat, level, and nonabsorbent base plate. Position and shim the base plate so that it is fully supported and level. Pre-moisten base-plate with a damp towel, rag, or sponge. Rest the J-Ring at the center of the base plate.
8.2 WSDOT uses only Procedure B.

8.1.2 Filling Procedure B (Inverted Mold) – Dampen the mold, and place it on the base plate with the smaller opening facing down and concentric with the J-Ring. Support the mold and fill the mold in one lift. Heap the concrete above the top of the mold.

8.3 Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike off bar. Remove concrete from the area surrounding the mold to preclude interference with the movement of the flowing concrete. Raise the mold a distance of $9 \pm 3$ in ($230 \pm 75$ mm) in $3 \pm 1$ s by a steady vertical lift with no lateral or torsional motion. Complete the entire procedure from start of the filling through removal of the mold without interruption within an elapsed time of $2\frac{1}{2}$ min.

8.4 Wait for the concrete to stop flowing and then measure the largest diameter ($d_1$) of the resulting circular flow of concrete. When a halo is observed in the resulting circular flow of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter ($d_2$) of the circular flow at approximately perpendicular to the first measured diameter ($d_1$). Measure the diameters to the nearest $\frac{1}{4}$ in (5 mm). Determine the J-Ring flow in accordance with Section 9 of this test method.

8.5 Conduct a slump flow test without the J-Ring in accordance with Test Method C 1611/ C 1611M. Use the same filling procedure as used with the J-Ring. Complete the tests with and without the J-Ring within 6 min.

9. Calculation

9.1 Calculate J-Ring flow according to the following equation:

$$J\text{-}Ring \text{ flow} = \frac{d_1 + d_2}{2}$$

9.2 Calculate the slump flow according to the following equation:

$$Slump \text{ flow} = \frac{d_1 + d_2}{2}$$

9.3 Calculate the difference between slump flow and J-Ring flow to the nearest $\frac{1}{2}$ in (10 mm). This number represents the passing ability of the concrete.

10. Blocking Assessment

10.1 Identify blocking assessment according to Table 1.

<table>
<thead>
<tr>
<th>Difference Between Slump Flow and J-Ring Flow</th>
<th>Blocking Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1 in (0 to 25 mm)</td>
<td>No visible blocking</td>
</tr>
<tr>
<td>&gt; 1 to 2 in (&gt;25 to 50 mm)</td>
<td>Minimal to noticeable blocking</td>
</tr>
<tr>
<td>&gt; 2 in (&gt;50 mm)</td>
<td>Noticeable to extreme blocking</td>
</tr>
</tbody>
</table>

**Blocking Assessment**

Table 1
11. Report

11.1 Report the filling procedure (A or B) that was used.

11.2 Report the J-Ring flow as the average of the two measured diameters to the nearest ½ in (10 mm).

11.3 Report the slump flow (without the J-Ring) as the average of the two measured diameters to the nearest ½ in (10 mm).

11.4 Report the passing ability as the difference between the slump flow and J-Ring flow to the nearest ½ in (10 mm). Identify the blocking assessment.

12. Precision and Bias

See ASTM C 1621/C 1621M for Precision and bias.
# Performance Exam Checklist

**WSDOT FOP for ASTM C 1621/C 1621M**

*Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring*

---

**Participant Name** ________________________________  **Exam Date** ________________

---

**Procedure Element**

| Procedure | 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. Sample was taken per WSDOT FOP for WAQTC TM 2? | 4. Molds and base plate dampened and base plate is flat, level and fully supported? | 5. Mold is centered in J-Ring and centered on base plate? | 6. Mold filled completely in one lift (slightly overfilled)? | 7. Mold struck off level with top opening? | 8. Excess material removed from base plate and mold raised 9 ± 3 inches, in 3 ± 1 seconds? | 9. After flow has stabilized, measure largest diameter (including halo)? | 10. Second measurement taken approximately perpendicular to first measurement? | 11. Measurements made to nearest ⅛"? | 12. Test performed within 6 minutes of FOP for ASTM C 1611? | 13. All calculations performed correctly? | 14. Results reported to the nearest ½"? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yes | No |

| First Attempt: Pass ☐ Fail ☐ | Second Attempt: Pass ☐ Fail ☐ |

---

**Signature of Examiner** ________________________________

**Comments:**
WSDOT FOP for ASTM D 4791\(^1\)
*Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate*

1. Scope

1.1 This test method covers the determination of the percentages of flat particles, elongated particles, or flat and elongated particles in coarse aggregates.

1.2 The values stated in inch-pound units are to be regarded as the standard except in regard to sieve size and the size of aggregate, which are given in SI units in accordance with Specification E 11. The SI units in parentheses are for information purposes only.

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

*Note:* WSDOT will be determining flat and elongated particles in accordance with Section 8.4.

2. Referenced Documents

2.1 WSDOT Standards

T 2 – FOP for AASHTO for the Sampling of Aggregates

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

2.2 WAQTC Standards

T 27/11 – FOP for AASHTO for the Sieve Analysis of Fine and Coarse Aggregates and Materials Finer Than 75 mm (No. 200) in Mineral Aggregates by Washing

3. Terminology

3.1 Definitions

3.1.1 *flat or elongated particles of aggregate* – Those particles of aggregate having a ratio of width to thickness or length to width greater than a specified value (see Terminology C 125).

3.1.2 *flat and elongated particles of aggregate* – Those particles having a ratio of length to thickness greater than a specified value.

3.1.3 *length* – Maximum dimension of the particle.

3.1.4 *width* – Maximum dimension in the plane perpendicular to the length.

3.1.5 *thickness* – Maximum dimension perpendicular to the length and width.

\(^1\)This Test Method is based on ASTM D 4791-05 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.
4. Summary of Test Method

4.1 Individual particles of aggregate of specific sieve sizes are measured to determine the ratios of width to thickness, length to width, or length to thickness.

5. Significance and Use

5.1 Flat or elongated particles of aggregates, for some construction uses, may interfere with consolidation and result in harsh, difficult to place materials.

5.2 This test method provides a means for checking compliance with specifications that limit such particles or to determine the relative shape characteristics of coarse aggregates.

6. Apparatus

6.1 The apparatus used shall be equipment suitable for testing aggregate particles for compliance with the definitions in 3.1, at the dimensional ratios desired.

6.1.1 Proportional Caliper Device – The proportional caliper devices illustrated in Figures 1, 2, and 3 are examples of devices suitable for this test method. The device illustrated in Figures 1 and 2 consists of a base plate with two fixed posts and a swinging arm mounted between them so that the openings between the arms and the posts maintain a constant ratio. The axis position can be adjusted to provide the desired ratio of opening dimensions. Figure 1 illustrates a device on which ratios of 1:2, 1:3, 1:4, and 1:5 may be set. The device illustrated in Figure 3 contains several fixed posts and has the capability of measuring various ratios simultaneously.

6.1.1.1 Verification of Ratio – The ratio settings on the proportional caliper device shall be verified by the use of a machined block, micrometer, or other appropriate device.

6.1.2 Balance – The balance or scales used shall be accurate to 0.5 percent of the mass of the sample.
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6.1.1.1 Verification of Ratio—The ratio settings on the proportional caliper device shall be verified by the use of a machined block, micrometer, or other appropriate device.

6.1.2 Balance—The balance or scales used shall be accurate to 0.5% of the mass of the sample.

7. Sampling

7.1 Sample the coarse aggregate in accordance with in FOP for AASHTO T2. The mass of the field sample shall be the mass shown in FOP for AASHTO T2.

7.2 Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in FOP for AASHTO T 248. The sample for test shall be approximately the mass desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted. The mass of the test sample shall conform to the following:
### Tables

<table>
<thead>
<tr>
<th>Nominal Maximum Size*</th>
<th>Square Openings, in (mm)</th>
<th>Minimum Mass of Test Sample, lb (kg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>⅜ (9.5)</td>
<td>2 (1)</td>
<td></td>
</tr>
<tr>
<td>½ (12.5)</td>
<td>4 (2)</td>
<td></td>
</tr>
<tr>
<td>¾ (19)</td>
<td>11 (5)</td>
<td></td>
</tr>
<tr>
<td>1 (25.0)</td>
<td>22 (10)</td>
<td></td>
</tr>
<tr>
<td>1½ (37.5)</td>
<td>33 (15)</td>
<td></td>
</tr>
<tr>
<td>2 (50)</td>
<td>44 (20)</td>
<td></td>
</tr>
<tr>
<td>2½ (63)</td>
<td>77 (35)</td>
<td></td>
</tr>
<tr>
<td>3 (75)</td>
<td>130 (60)</td>
<td></td>
</tr>
<tr>
<td>3½ (90)</td>
<td>220 (100)</td>
<td></td>
</tr>
<tr>
<td>4 (100)</td>
<td>330 (150)</td>
<td></td>
</tr>
<tr>
<td>4½ (112)</td>
<td>440 (200)</td>
<td></td>
</tr>
<tr>
<td>5 (125)</td>
<td>660 (300)</td>
<td></td>
</tr>
<tr>
<td>6 (150)</td>
<td>1100 (500)</td>
<td></td>
</tr>
</tbody>
</table>

*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.

**Note:** For an aggregate specification having a generally unrestrictive 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.

### 8. Procedure

8.1 If determination by mass is required, oven dry the sample in accordance with FOP for AASHTO T 255. If determination is by particle count, drying is not necessary.

8.2 Sieve the sample to be tested in accordance with FOP for AASHTO T 27/11. If the material retained on each required size (⅜ and larger) is more than 5 percent of the sample, reduce the material in accordance with FOP for AASHTO T 248 until approximately 100 particles are obtained for each required size.

8.3 Flat and Elongated Particle Test – Test each of the particles in each size fraction and place in one of two groups: (1) flat and elongated or (2) not flat and elongated.

8.3.1 Use the proportional caliper device, set at the desired ratio.

8.3.2 Measurement

8.3.2.1 On proportional caliper devices similar to the devices shown in Figure 1 and Figure 2, set the larger opening equal to the length of the particle. The particle is flat and elongated if the particle, (biggest to smallest) when oriented to measure its thickness (biggest), can pass completely through the smaller opening of the caliper when it is rotated in any direction.
Use of Proportional Caliper

*Figure 2*

<table>
<thead>
<tr>
<th>in</th>
<th>mm</th>
<th>in</th>
<th>mm</th>
<th>in</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼</td>
<td>3.2</td>
<td>⅛</td>
<td>21.2</td>
<td>2¼</td>
<td>64.0</td>
</tr>
<tr>
<td>3/16</td>
<td>4.8</td>
<td>1</td>
<td>25.4</td>
<td>2½</td>
<td>72.0</td>
</tr>
<tr>
<td>⅛</td>
<td>6.3</td>
<td>1 1/16</td>
<td>27.0</td>
<td>3¾</td>
<td>96.0</td>
</tr>
<tr>
<td>5/16</td>
<td>7.9</td>
<td>1½</td>
<td>38.0</td>
<td>8</td>
<td>207.0</td>
</tr>
<tr>
<td>⅜</td>
<td>9.5</td>
<td>1¾</td>
<td>41.0</td>
<td>16</td>
<td>414.0</td>
</tr>
</tbody>
</table>

Metric Equivalents

Proportional Caliper

*Figure 3*
8.4.2.2 On calipers similar to the one described in Figure 3, set the minimum dimension of the proportional caliper device such that the particle, when oriented to measure its thickness, passes snugly between the post and swing arm. The particle is flat and elongated if the particle, when oriented to measure its length, fails to pass the desired large opening of the proportional caliper device.

8.4.3 After the particles have been classified into the groups described in 8.4, determine the proportion of the sample in each group by count or mass, as required.

Note: WSDOT performs this test by weight.

9. Calculation

9.1 Calculate the percentage of flat and elongated particles to the nearest 1 percent for each sieve size than 3/8 in and larger (9.5 mm), as required.

10. Report

10.1 Include the following information in the report:

10.1.1 Identification of the coarse aggregate tested, and
10.1.2 Grading of the aggregate sample, showing percentage retained on each sieve.
10.1.3 For flat and elongated particle tests:

10.1.3.1 Percentages, calculated by number or by mass, or both, for flat and elongated particles for each sieve size tested,
10.1.3.2 The dimensional ratio used in the tests, and
10.1.4 When required, weighted average percentages based on the actual or assumed proportions of the various sieve sizes tested. Report the grading used for the weighted average if different from that in 10.1.2.

10.2 Report results using one or more of the following:

- Materials Testing System (MATS)
- WSDOT Form 350-161
- Form approved in writing by the State Materials Engineer

11. Precision and Bias

See ASTM D 4791 for precision and bias statements.
Performance Exam Checklist

Flat and Elongated Particles in Coarse Aggregate
FOP for ASTM D 4791

Participant Name ________________________________  Exam Date ___________________

<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, and if required, has the current calibration/verification tags present?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Field sample obtained per AASHTO T 2?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Sample thoroughly mixed prior to reducing to testing size?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Sample reduced to testing size per AASHTO T 248?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Mass of the test sample conforms to the table in Section 7.2, ASTM D 4791?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Procedure**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. If determination by mass, sample oven dried to a constant weight prior to mass determination?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Sample sieved per AASHTO T 27/T 11?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Proportional caliper device positioned at proper ratio?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Each size fraction ⅜ inch and larger retaining more than 5% of the original sample reduced per AASHTO T 248 until approximately 100 particles are obtained for each size fraction required?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Each particle of each size fraction tested for FLAT and ELONGATED using the proportional caliper device put in the appropriate group classification? (Flat and Elongated or Not Flat and Elongated)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Proportion of the sample of each sieve size determined by Mass?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Percent of Flat and Elongated particles figured to the nearest 1% for each sieve size?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Record number of particles in each sieve size tested?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Record percentages calculated by Mass?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. All calculations performed correctly?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

First Attempt:  Pass ☐  Fail ☐  Second Attempt:  Pass ☐  Fail ☐

Signature of Examiner ____________________________________________
Comments:
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