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Remarks and Instructions

Remarks:

Section 9-8 and various Testing Procedures (Blue Sheets) contained in the *Construction Manual* have been revised to correspond with the recently revised *Materials Manual*. Please remove and replace the outdated material with the revised Section 9-8 and test procedures as described below. Changes are effective upon receipt.

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Instructions:

Page numbers and corresponding sheet-counts are given in the table below to indicate portions of the testing procedures in Chapter 9 of the *Construction Manual* that are to be removed and inserted to accomplish this revision.

Chapter	Remove		Insert	
	Pages	Sheets	Pages	Sheets
Chapter 9-Materials Section 9-8 Test Methods (Blue Sheets):	55-60	3	55-60	3
TM2	1-8	4	1-8	4
TM6	1-6	3	1-6	3
T23	1-12	6	1-12	6
T27/T11	1-16	8	1-16	8
T99	1-12	6	1-14	7
T119	1-6	3	1-8	4
T152	1-12	6	1-12	6

T166	1-8	4	1-8	4
T224	1-10	5	1-10	5
T304	N/A	N/A	1-12	6
T308	1-8	4	1-8	4
T309	1-6	3	1-6	3
T310	1-14	7	1-16	8
T312	N/A	N/A	1-8	4
SOP 615	1-2	1	1-4	2
SOP 731	N/A	N/A	1-6	3
T813	1-6	3	1-6	3
D4791	N/A	N/A	1-8	4

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9-6.4 Authorized Operators

The Authorized Operators will be directly responsible to the RAO for the use and storage of the nuclear density gauge in the field and to the RSO for all safety in regard to the nuclear density gauge.

The Authorized Operators shall be responsible for posting the following information at all field storage areas:

1. "CAUTION — RADIOACTIVE MATERIALS" Sign.
2. DOH Form RHF-3 "Notice to Employees."
3. WAC Chapters 246-220, 246-221, and 246-222 of the Rules and Regulations for Radiation Protection.
4. DOH Form "Notification of a Radiation Emergency."

The Authorized Operator must keep the RAO or RSO informed of the location of the nuclear density gauge at all times. (The State Radiation Control Unit inspectors will want the sources produced or the exact locations given during their periodic inspections.) If the exact location where the nuclear density gauge will be used is known in advance, it should be noted before leaving the Region office, and if unknown, shall be forwarded to the RAO or RSO as soon as it is known.

The operation of the shutter-operating device should be continuously checked and any malfunction reported to the RAO or RSO immediately. When not in use, the source index handle will be locked and the nuclear density gauge locked in an adequate storage facility. When operating the nuclear gauge (i.e., when the handle is in the "USE" position), unauthorized personnel are not to be within 15 feet (5 meters) of the gauge.

9-7 Vacant

9-8 WSDOT Testing Methods

9-8.1 Calibrated/Verified Equipment for Testing

The following listed equipment used in the Region Laboratory and in the Field Laboratory for acceptance testing is required to be verified and / or calibrated annually, and shall bear a tag indicating when the calibration or verification will expire. It is the responsibility of the testing personnel (i.e., Module Qualified Testers, Method Qualified Testers, or Interim Qualified Testers and Independent Assurance Inspectors) to check all equipment for serviceability and conformance to the requirements of the test procedure. No equipment with an expired calibration or verification shall be used for testing.

Aggregate Testing

Drying Ovens (AASHTO T-255, 265)

General Purpose Balances, Scales and Weights (AASHTO M-231)

Mechanical Sieve Shaker (AASHTO T-27)

Sand Equivalent Shaker (AASHTO T-176)

Sand Equivalent Weighted Foot Assembly (AASHTO T-176)

Sand Equivalent Irrigation Tube (AASHTO T-176)

Sieves (AASHTO M-92)

Thermometers

Timing Devices (AASHTO T-176)

Fine Aggregate Apparatus (AASHTO T-304)

Flat and Elongated Particle Shape Apparatus (ASTM D-4791)

Asphalt Testing

Drying Ovens (AASHTO T-255, 265, and WAQTC TM-6)

General Purpose Balances, Scales and Weights (AASHTO M-231)

Ignition Furnace (AASHTO T-308)

Mechanical Sieve Shaker (AASHTO T-30)

Sieves (AASHTO M-92)

Thermometer - ASTM 17C or 17F (AASHTO T-209)

Thermometer – drying temperature

Timing Devices

Vacuum System (AASHTO T-209)

Water Bath - if used (AASHTO T-209)

Pycnometer (AASHTO T-209)

Gyratory Compactor (AASHTO T-312)

Weighting Bath (AASHTO T-166)

Concrete Testing

Concrete Air Meters - Pressure gauge (AASHTO T-152)

Concrete Air Meters - Volumetric gauge (AASHTO T-152)

Cube Molds and Tamper (AASHTO T106 and WSDOT T-813) (no tag on tamper required)

General Purpose Balances, Scales and Weights (AASHTO M-231)

Rebound Hammer Type N (ASTM C-805)

Single Use Molds (AASHTO M-205) (no tag required)

Slump Cone and Rod (AASHTO T-119) (no tag on rod required)

Thermometer (AASHTO T-309)

Compression Testing Device and associated equipment (AASHTO T-22, WSDOT T-802)

Beam Molds (WSDOT T-808)

Materials

Embankment and Base Density Testing

Drying Ovens (AASHTO T-255, 265)

General Purpose Balances, Scales and Weights
(AASHTO M-231)

Manual Hammer (AASHTO T-99)

Mechanical Sieve Shaker (AASHTO T-27)

Maximum Density Devise (WSDOT T-606)

█ Nuclear Density Gauge ([AASHTO T-310](#))

Sieves (AASHTO M-92)

Speedy Moisture Meter (AASHTO T-217)

█ Soil Mold (AASHTO T-99 and [WSDOT T-606](#))

Straight Edge (AASHTO T-99)

Asphalt Pavement Density Testing

█ Nuclear Density Gauge ([WAQTC TM-8](#))

Thermometer

9-8.2 Field Test Methods for Materials

The test method as specified by WSDOT Materials Manual will be used to perform the testing. All testing will be performed by Module Qualified Testers, Individual Method Qualified Testers, or Interim Qualified Testers as defined in Chapter 9-5 of this manual. The tester can be qualified in a testing module, or by individual test methods. Section 9-8.2A is the list of the tests that are included in each of the modules. A tester can be Individual Method Qualified in any test that are included in the modules or from the list of individual tests in Section 9-8.2B, however the tester is not limited to just these tests. All of the test methods listed in each of the testing modules can be found in the blue pages following this section, see Section 9-8.2C for the Contents. In addition the WSDOT and WAQTC test methods that are performed in the field and that are listed in Section 9-8.2B are included.

9-8.2A Testing Modules

Testing Modules Procedures

Aggregate Module

Procedure Number	Test Method
AASHTO T-2	WSDOT FOP for AASHTO for the Sampling of Aggregates
AASHTO T-27/T11	WAQTC FOP for AASHTO for the Sieve Analysis of Fine & Coarse Aggregates & Materials Finer Than 75 mm (No. 200) in Mineral Aggregates by Washing
AASHTO T-176	WSDOT FOP for AASHTO for Determining the Plastic Fineness in Graded Aggregate by Use of the Sand Equivalent Test
AASHTO T-248	WSDOT FOP for AASHTO for Reducing Field Samples of Aggregates to Testing Size
AASHTO T-255	WSDOT FOP for AASHTO for Determining the Total Moisture Content of Aggregate by Drying
WAQTC TM-1	Determining the Percentage of Fracture in Coarse Aggregate

Asphalt Module

AASHTO T-168	WAQTC FOP for AASHTO for the Sampling Bituminous Paving Mixtures
AASHTO T-209	WSDOT FOP for AASHTO for Determining the Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
AASHTO T-30	WSDOT FOP for AASHTO for the Mechanical Analysis of Extracted Aggregate
AASHTO T-40	WAQTC FOP for AASHTO for Sampling Bituminous Materials
AASHTO T-308	WSDOT FOP for AASHTO for Determining Asphalt Content of Hot Mix Asphalt(HMA) by the Ignition Method
WAQTC TM-6	Moisture Content of Bituminous Mixes by Oven
WSDOT 712	Standard Method of Reducing Bituminous Paving Mixtures
WSDOT 716	Method of Random Sampling for Location of Testing and Sampling Sites

Concrete Module

AASHTO T-23	WSDOT FOP for AASHTO for Making and Curing Concrete test Specimens in the Field
AASHTO T-119	WSDOT FOP for AASHTO for Determining the Slump of Hydraulic Cement Concrete
AASHTO T-152	WAQTC FOP for AASHTO for Determining the Air Content of Freshly Mixed Concrete by the Pressure Method
WAQTC TM-2	Sampling Freshly Mixed Concrete
AASHTO T-309	WSDOT FOP for AASHTO for Determining the Temperature of Freshly Mixed Portland Cement Concrete

Embankment and Base Density Module

AASHTO T-224	WSDOT FOP for AASHTO for Correction for Coarse Particles in the Soil Compaction Test
AASHTO T-310	WSDOT FOP for AASHTO for In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Method

Asphalt Pavement Density Module

WAQTC TM-8	In-Place Density of Bituminous Mixtures Using the Nuclear Moisture Gauge
WSDOT 716	Method of Random Sampling for Location of Testing and Sampling Sites

9-8.2B Individual Tests Method

Procedure Number	Owner	TestMethod
T 11	AASHTO	Materials Finer Than 0.075 mm (No. 200) Sieve in Mineral Aggregates by Washing
T 19	AASHTO	Unit Weight and Voids in Aggregates
T 21	AASHTO	Organic Impurities in Fine Aggregates for Concrete
T 22	AASHTO	Compressive Strength of Cylindrical Concrete Specimens
T 23	AASHTO	Making and Curing Concrete Test Specimens in the Field
T 27	AASHTO	Sieve Analysis of Fine and Coarse Aggregates
T 65	AASHTO	Mass (Weight) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
T 88	AASHTO	Particle Size Analysis of Soils
T 99	AASHTO	FOP for AASHTO for Method of Test for Moisture-Density Relations of Soils
T 106	AASHTO	Compressive Strength of Mortars (Using 0-mm or 2-in.) Cube Specimens
T 121	AASHTO	Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
T 123	WSDOT	Method of Test for Bark Mulch
T 148	AASHTO	Measuring Length of Drilled Concrete Cores
T 166	AASHTO	Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
T 196	AASHTO	Air Content of Freshly Mixed Concrete by the Volumetric Method
T 217	AASHTO	WSDOT FOP for AASHTO for Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester
T 231	AASHTO	Capping Cylindrical Concrete Specimens
T 244	AASHTO	Mechanical Testing of Steel Products
T 272	AASHTO	FOP for AASHTO for Family of Curves-One Point Method
T 304	<u>AASHTO</u>	<u>FOP for AASHTO for Standard Method of Test for Uncompacted Void Content of Fine Aggregate</u>
T 312	<u>AASHTO</u>	<u>FOP for AASHTO for Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor</u>
T 417	WSDOT	Method of Test for Determining Minimum Resistivity and pH of Soil and Water
T 606	WSDOT	Method of Test for Compaction Control of Granular Materials
T 720	WSDOT	Method of Test for Thickness Measurement of Asphalt Concrete Cores
T 724	WSDOT	Method for Preparation of Aggregate for ACP Job Mix Design
T 726	WSDOT	Method of Test for Mixing Procedure for Binder and Aggregate
T 802	WSDOT	Flexural Strength of Concrete [Using Simple Beam with Center-Point Loading Breaking)
C 805	ASTM	Test Method for Rebound Number of Hardened Concrete
T 810	WSDOT	Method of Test for Determination of the Density of Portland Cement Concrete Pavement Cores
T 914	WSDOT	Practice for Sampling of Geotextiles for Testing
C 939	ASTM	Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
D 1186	ASTM	FOP for ASTM for Nondestructive Measurement of Thickness of Nonmagnetic Coating on a Ferrous Base
D 4791	<u>ASTM</u>	<u>FOP for ASTM for Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate</u>

9-8.2C Contents for Test Procedures in This Manual

Procedure Number	Owner	Test Method
TM 1	WAQTC	Determining the Percentage of Fracture in Coarse Aggregate
T 2	AASHTO	Sampling of Aggregate
TM 2	WAQTC	Sampling Freshly Mixed Concrete
TM 6	WAQTC	Moisture Content of Bituminous Mixes by Oven
TM 8	WAQTC	Method of Test for Relative Compaction of Asphalt Concrete Pavement
T 22	WSDOT	FOP for AASHTO for Compressive Strength of Cylindrical Concrete Specimens
T 23	WSDOT	FOP for AASHTO for Making and Curing Concrete test Specimens in the Field
T 27/11	WAQTC	FOP for AASHTO for Sieve Analysis of Fine & Coarse Aggregates & Materials Finer Than 75 mm (No. 200) in Mineral Aggregates by Washing
T 30	WSDOT	FOP for AASHTO for Mechanical Analysis of Extracted Aggregate
T 40	WAQTC	FOP for AASHTO for Sampling Bituminous Materials
T 99	WSDOT	FOP for AASHTO for Method of Test for Moisture-Density Relations of Soils
T 106	WSDOT	FOP for AASHTO for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)
T 119	WSDOT	FOP for AASHTO for Slump of Hydraulic Cement Concrete
T 123	WSDOT	Method of Test for Bark Mulch
T 152	WAQTC	FOP for AASHTO for Air Content of Freshly Mixed Concrete by the Pressure Method
T 166	WSDOT	FOP for AASHTO for Bulk Specific Gravities of Compacted Asphalt Mixtures Using Saturated Surface Dry Specimens
T 168	WAQTC	FOP for AASHTO for Sampling Bituminous Paving Mixtures
T 176	WSDOT	FOP for AASHTO for Plastic Fines in Grade Aggregate by Use of the Sand Equivalent Test
T 209	WSDOT	FOP for AASHTO for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures "Rice Density"
T 217	WSDOT	FOP for AASHTO for Determination of Moisture in Soils by means of a Calcium Carbide Gas Pressure Moisture Tester
T 224	WSDOT	FOP for AASHTO for Correction for Coarse Particles in Soil Compaction Test
T 231	WSDOT	FOP for AASHTO for Capping Cylindrical Concrete Specimens
T 248	WSDOT	FOP for AASHTO for Reducing Field Samples of Aggregates to Testing Size
T 255	WSDOT	FOP for AASHTO for Total Moisture Content of Aggregate by Drying
T 272	WSDOT	FOP for AASHTO for Family of Curves — One Point Method
T 304	AASHTO	FOP for AASHTO for <u>Standard Method of Test for Uncompacted Void Content of Fine Aggregate</u>
T 308	WSDOT	FOP for AASHTO for Determining Asphalt Content of Hot Mix Asphalt (HMA) by the Ignition Method
T 309	WSDOT	FOP for AASHTO for Method for Determination of the Temperature of Freshly Mixed Concrete
T 310	WSDOT	FOP for AASHTO for In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
T 312	AASHTO	FOP for AASHTO for <u>Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor</u>
T 413	WSDOT	Method of Test for Evaluating Waterproofing Effectiveness of Membranes and Membrane Pavement Systems
T 420	WSDOT	FOP for AASHTO for Determining the Maturity of Compost (Solvita Test)
T 606	WSDOT	Method of Test for Compaction Control of Granular Materials

Materials

SOP615	WSDOT	Standard Operating Procedure for the In-Place Density of Embankment and Base using the Nuclear Moisture-Density Gauge
T 712	WSDOT	Standard Method of Reducing Bituminous Paving Mixtures
T 716	WSDOT	Method of Random Sampling for Location of Testing and Sampling Sites
T 724	WSDOT	Method for Preparation of Aggregate for ACP Job Mix Design
T 726	WSDOT	Method of Test for Mixing Procedure for Binder and Aggregate
SOP728	WSDOT	Standard Operating Procedure for Determining the Ignition Furnace Calibration Factor (IFCF) for Hot Mix Asphalt (HMA)
SOP729	WSDOT	Standard Operating Procedure for the In-Place Density of Bituminous Mixes using the Nuclear Moisture-Density Gauge
SOP730	WSDOT	Standard Operating Procedure for Correlation of Nuclear Gauge Determined Density with Asphalt Concrete Pavement Cores
SOP 731	WSDOT	<u>Standard Operating Procedure for Method for Determining Volumetric Properties of Asphalt Concrete Pavement Class Superpave</u>
T 802	WSDOT	Flexural Strength of Concrete [Using Simple Beam with Center-Point Loading]
C 805	WSDOT	FOP for ASTM for Test Method for Rebound Number of Hardened Concrete
T 807	WSDOT	Method of Operation of California Profilograph and Evaluation of Profiles
T 808	WSDOT	Method for Making Flexural Test Beams
T 810	WSDOT	Method of Test for Determination of the Density of Portland Cement Concrete Pavement Cores
T 813	WSDOT	Field Method of Fabrication of 50-mm (2-in.) Cube Specimens for Compressive Strength Testing of Grouts and Mortars
T 914	WSDOT	Practice for Sampling of Geotextiles for Testing
T 939	WSDOT	FOP for ASTM for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
D 1186	WSDOT	FOP for ASTM for Nondestructive Measurement of Thickness of Nonmagnetic Coatings on a Ferrous Base
D 4791	ASTM	FOP for ASTM for Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

SAMPLING FRESHLY MIXED CONCRETE FOP FOR WAQTC TM 2



Sampling from truck mixer

01

Significance

02

Testing fresh concrete in the field begins with obtaining and preparing the sample to be tested. Standardized procedures for obtaining a representative sample from various types of mixing and/or agitating equipment have been established. Specific time limits regarding when tests for temperature, slump, and air content must be started and for when the molding of test specimens must begin are also established.

03

Technicians must be patient and refrain from obtaining the sample too quickly. Doing so would be a violation of the specifications under which the concrete is being supplied and it may result in a nonrepresentative sample of concrete. If one considers that the specifications may require strength tests to be made only once every 50 cy (40 m³), the need for a truly representative sample is apparent. The minimum 1 ft³ (0.03 m³) sample from which the compressive strength test specimens will be made represents only 0.07 to 0.08 percent of the total quantity of concrete placed. For this reason, every precaution must be taken to obtain a sample that is truly representative of the entire batch and then to protect that sample from the effects of evaporation, contamination, and physical damage.

04

Scope

This procedure provides instruction for obtaining samples of fresh concrete in accordance with WAQTC TM 2. Sources covered include stationary and paving mixers, revolving drum truck mixers or agitators, open-top truck mixers and the discharge of pump or conveyor placement systems.



Sampling apparatus

05

Apparatus

- Wheelbarrow
- Cover for wheelbarrow (plastic, canvas, or burlap)
- Shovel
- 5 gal (19 L) bucket for water

Procedure

Use every precaution in order to obtain samples representative of the true nature and condition of the concrete being placed being careful not to obtain samples from the very first or very last portions of the batch. The size of the sample will be 1.5 times the volume of concrete required for the specified testing, but not less than 1 ft³ (0.03 m³).

Random Sample Selection

WSDOT has added this section.

Concrete samples other than initial load samples or samples for questioned acceptance will be taken from each subplot by a random selection. Sublots are determined by the designated sampling frequency in the *Standard Specifications*. Random selection will be accomplished by using the random number table attached. The “X” value in the table is a decimal fraction of the subplot of concrete which will be used to determine the approximate cubic yard of concrete to be sampled.

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

The cubic meter (yard) selected for sampling will be “X” value multiplied by the subplot quantity. After the cubic yard for sampling has been selected, the load delivered which contains this cubic yard will be sampled as outlined in this test method.

Table of Random Numbers

X	X	X	X	X
(1) 0.186	(21) 0.256	(41) 0.201	(61) 0.508	(81) 0.431
(2) 0.584	(22) 0.753	(42) 0.699	(62) 0.884	(82) 0.509
(3) 0.965	(23) 0.108	(43) 0.785	(63) 0.648	(83) 0.962
(4) 0.044	(24) 0.626	(44) 0.874	(64) 0.398	(84) 0.315
(5) 0.840	(25) 0.885	(45) 0.604	(65) 0.142	(85) 0.721
(6) 0.381	(26) 0.418	(46) 0.087	(66) 0.962	(86) 0.637
(7) 0.756	(27) 0.320	(47) 0.334	(67) 0.516	(87) 0.056
(8) 0.586	(28) 0.098	(48) 0.189	(68) 0.615	(88) 0.905
(9) 0.480	(29) 0.791	(49) 0.777	(69) 0.226	(89) 0.195
(10) 0.101	(30) 0.717	(50) 0.704	(70) 0.881	(90) 0.981
(11) 0.282	(31) 0.868	(51) 0.946	(71) 0.369	(91) 0.600
(12) 0.957	(32) 0.583	(52) 0.426	(72) 0.001	(92) 0.044
(13) 0.377	(33) 0.385	(53) 0.266	(73) 0.744	(93) 0.433
(14) 0.456	(34) 0.465	(54) 0.791	(74) 0.229	(94) 0.762
(15) 0.778	(35) 0.101	(55) 0.711	(75) 0.906	(95) 0.678
(16) 0.243	(36) 0.285	(56) 0.122	(76) 0.413	(96) 0.347
(17) 0.578	(37) 0.829	(57) 0.895	(77) 0.827	(97) 0.274
(18) 0.966	(38) 0.998	(58) 0.371	(78) 0.984	(98) 0.114
(19) 0.373	(39) 0.539	(59) 0.221	(79) 0.641	(99) 0.480
(20) 0.834	(40) 0.060	(60) 0.011	(80) 0.068	(100) 0.685

Once the two digit number is selected the corresponding four digit number becomes the factor for determining the selection of the next sample.

Example:

Using an acceptable random number program from a hand held calculator, the last digit for a license plate or other acceptable means, determine a random number.

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

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

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

50 CY x 0.829 = 41.45 CY to be sampled

Therefore, the sample will be taken from the truck containing the 41st CY. After approximately a CY of concrete has been discharged the sample should be taken. This is actually the seventh truck

load delivered to the project this day as the first two truck loads were sampled before the random selection process started. The process would continue for the next sample using “38” then “39” etc. For the next days concrete delivery and placement a new random number would be selected and the process repeated.

06

- **Sampling from stationary mixers, except paving mixers**

Sample the concrete after a minimum of $1/2 \text{ yd}^3$ ($.4 \text{ m}^3$) of concrete has been discharged. Perform sampling by passing a receptacle completely through the discharge stream, or by completely diverting the discharge into a sample container. If discharge of the concrete is too rapid to divert the complete discharge stream, discharge the concrete into a container or transportation unit sufficiently large to accommodate the entire batch and then accomplish the sampling in the same manner as given above. Take care not to restrict the flow of concrete from the mixer, container, or transportation unit so as to cause segregation. These requirements apply to both tilting and nontilting mixers.

07

- **Sampling from paving mixers**

Sample after the contents of the paving mixer have been discharged. Obtain material from at least five different locations in the pile and combine into one test sample. Avoid contamination with subgrade material or prolonged contact with absorptive subgrade. To preclude contamination or absorption by the subgrade, sample the concrete by placing a shallow container on the subgrade and discharging the concrete across the container. The container shall be of a size sufficient to provide a sample size that is in agreement with the nominal maximum aggregate size.

08

- **Sampling from revolving drum truck mixers or agitators**

Sample the concrete after a minimum of 1/2 yd³ (.4 m³) of concrete has been discharged. Do not obtain samples until after all of the water has been added to the mixer. Do not obtain samples from the very first or last portions of the batch discharge. Sample by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.



Open-top truck

09

- **Sampling from open-top truck mixers, agitators, non-agitating equipment or other types of open-top containers**

Sample by whichever of the procedures described above is most applicable under the given conditions.

11

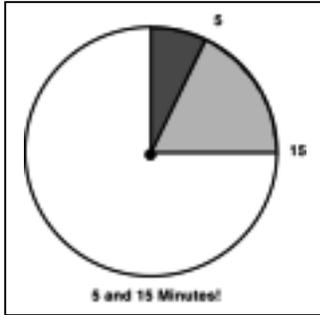
- **Sampling from pump or conveyor placement systems**

Sample after a minimum of 1/2 yd³ (.4 m³) of concrete has been discharged. Do not obtain samples until after all of the pump slurry has been eliminated. Sample by repeatedly passing a receptacle through the entire discharge system or by completely diverting the discharge into a sample container. Do not lower the pump arm from the placement position to ground level for ease of sampling, as it may modify the air content of the concrete being sampled. Do not obtain samples from the very first or last portions of the batch discharge.

12



Sampling at pump discharge



Time from sampling to start of tests

13

Transport samples to the place where fresh concrete tests are to be performed and specimens are to be molded. They shall then be combined and remixed with a shovel the minimum amount necessary to ensure uniformity. Protect the sample from direct sunlight, wind, rain, and sources of contamination.

Complete test for temperature and start tests for slump and air content within five minutes of obtaining the sample. Complete tests as expeditiously as possible. Start molding specimens for strength tests within 15 minutes of obtaining the sample.

Tips!

14

- Be patient
- Read the specs
- Start tests within the time specified
- Organize all the equipment in advance
- Do not to obtain samples form the very first or very last portions of the batch.

15

Performance Exam Checklist
Sampling Freshly Mixed Concrete
FOP for WAQTC TM 2

Participant Name _____

Exam Date _____

Procedure Element	Yes	No
1. Obtain a representative sample:		
a. Sample the concrete after 1/2 cy (1/2 m ³) discharged?	_____	_____
b. Pass receptacle through entire discharge stream or completely divert discharge stream into sampling container?	_____	_____
c. Transport samples to place of testing?	_____	_____
d. Sample remixed?	_____	_____
e. Sample protected?	_____	_____
f. Minimum size of sample used for strength tests 1 ft ³ (0.03 m ³)?	_____	_____
2. Start tests for slump and air within 5 minutes of sample being obtained?	_____	_____
3. Start molding cylinders within 15 minutes of sample being obtained?	_____	_____
4. Protect sample against rapid evaporation and contamination?	_____	_____

Comments: First attempt: Pass Fail Second attempt: Pass Fail

Signature of Examiner _____

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MOISTURE CONTENT OF BITUMINOUS MIXES BY OVEN FOP FOR WAQTC TM 6

Significance

01 Even though aggregate used in bituminous mixes is
02 heated and dried at high temperatures, some types of
rock retain moisture. The moisture content of the mix
must be known in order to correctly determine the
asphalt cement binder content of the mix. Moisture
(water) in the mix will yield erroneously high binder
content values whether binder content is determined
by the nuclear content gauge or ignition furnace
method.

Scope

This procedure covers the determination of moisture
content of bituminous mixes in accordance with
WAQTC TM 6.

Background on Test Method

03 The standard for WSDOT is to determine asphalt
content as a percent of initial mass of bituminous
mixture.

A test sample of bituminous mix is dried in an oven.
~~The moisture content is calculated by one of two
methods depending upon agency standards.~~

- When binder content is reported as a percent
of the initial mass of bituminous mix, moisture
content is reported as a percent of the initial,
moist mass of mix.
- ~~When binder content is reported as a percent
of the mass of aggregate, moisture content is
reported as a percent of the final, dry mass of mix.~~



Oven

Apparatus

- 04
- Balance or scale: 2 kg capacity, readable to 0.1 g
conforming to AASHTO M-231
 - Forced Air, Ventilated, or Convection Oven:
Capable of maintaining the temperature
surrounding the sample at $163 \pm 14^{\circ}\text{C}$ ($325 \pm 25^{\circ}\text{F}$)



Sampling from transport

05

- Sample Container: Clean, Dry Not affected by heat and of sufficient size to contain a test sample without danger of spilling
- Temperature Measuring Device – The temperature measuring device shall be capable of measuring the temperature of the hot mix asphalt throughout the entire temperature range likely to be encountered. Thermometer with a temperature range of 10–260°C (50–500°F)

Sample

~~The test sample shall be obtained in accordance with AASHTO T 168, and reduced in accordance with AASHTO T 248, Method B. The size of the test sample shall be a minimum of 500 g.~~

The test sample shall be obtained in accordance with FOP for AASHTO T 168, and reduced in accordance with WSDOT Test Method 712. The size of the test sample shall be a minimum of 500 g.

Procedure

06

1. Set the oven to 325 ± 25 °F (163 ± 13.8 °C) a ~~minimum of 105 ± 5 °C (221 ± 9 °F)~~. In no case should the Job Mix Formula (JMF) mixing temperature be exceeded.
2. Determine and record the mass of the sample container to the nearest 0.1 g.
3. Place the test sample in the sample container, and record the temperature of the test sample.
4. Remove the thermometer from the sample. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.
5. Calculate the initial, moist mass of the test sample by subtracting the mass of the sample container determined in Step 2 from total mass of the sample container and the test sample determined in Step 4.
5. Dry the test sample to a constant mass in the sample container.



Quartered sample

07

Note 1: Constant mass shall be defined as the mass at which further drying at does not alter the mass by more than 0.1 percent. The sample shall be initially dried 90 minutes,



Mass determination

08

and its mass determined at that time and at 30-minute intervals after that until a constant mass is reached.

6. Cool the sample container and test sample to approximately the same temperature as determined in Step 3.
7. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

Note 2: Do not attempt to remove the test sample from the sample container for the purposes of determining mass.

8. Calculate the final, dry mass of the test sample by subtracting the mass of the sample container determined in Step 4 2 from the total mass of the sample container and the test sample determined in Step 7 8.

Note 3: Moisture content and the number of samples in the oven will affect the rate of drying at any given time. Placing wet samples in the oven with nearly dry samples could affect the drying process.

Calculations

Moisture Content

Calculate the moisture content, as a percent, using one of the following two formulas.

Percent of Initial, Moist Mass:

$$\text{Moisture Content} = \frac{M_i - M_f}{M_i} \times 100$$

09

where M_i = initial, moist mass
 M_f = final, dry mass

Example:

$M_i = 541.2 \text{ g}$
 $M_f = 536.0 \text{ g}$

$$\text{Moisture Content} = \frac{541.2 \text{ g} - 536.0 \text{ g}}{541.2 \text{ g}} \times 100 = 0.961, \text{ say } 0.96\%$$

11

Report

Results shall be reported on standard forms approved for use by the agency. Report moisture content to 0.1 percent.

Report the moisture content on DOT Form 350-560EF.

Tips!

12

- Remember: Moisture content is expressed as a percent of initial, moist mass when binder content is reported as a percent of mix mass.
- Remember: Moisture content is expressed as a percent of final, dry mass when binder content is reported as a percent of aggregate mass.

13

WSDOT FOP for AASHTO T 23¹***Making and Curing Concrete Test Specimens in the Field*****1. SCOPE**

- 1.1 This practice covers procedures for making and curing cylinder and prismatic specimens using job concrete that can be consolidated by rodding or vibration as described herein.
- 1.2 The concrete used to make the molded specimens shall have the same level of slump, air content, and percentage of coarse aggregate as concrete being placed in the work, except as modified in Section 5.1.
- 1.3 The values stated in English units are to be regarded as the standard. The metric equivalent given in the standard may be approximate.
- 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.

2. REFERENCED DOCUMENTS**2.1 AASHTO Standards**

- 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
- T 119 Slump of Hydraulic Cement Concrete
- T 126 Making and Curing Concrete Test Specimens in the Laboratory
- T 141 Sampling Freshly Mixed Concrete
- T 152 Air Content of Freshly Mixed Concrete by the Pressure Method
- T 196 Air Content of Freshly Mixed Concrete by the Volumetric Method
- T 231 Capping Cylindrical Concrete Specimens
- T 309 Temperature of Freshly Mixed Portland-Cement Concrete

3. SIGNIFICANCE AND USE

- 3.1 This practice provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.
- 3.2 ~~If the specimens are made and standard cured, as stipulated herein, the specimens may be used to develop information for the following purposes:~~
 - 3.2.1 ~~Checking the adequacy of laboratory mixture proportions for strength.~~
 - 3.2.2 ~~serves as the basis for comparison with laboratories, field or in-place tests, as the basis for safety and in structure performance evaluation, and as basis for form and shoring removal time requirements.~~

¹This FOP is based on AASHTO T 23-97.

3.2.3 Determination of compliance with strength specifications, and,

3.2.4 Determination of time when a structure may be put in service.

4. APPARATUS

- 4.1 ~~Molds, General — Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, non-reactive with concrete containing portland or other hydraulic cements. Molds shall hold their dimensions and shape under all conditions of use. Molds shall be watertight during use as judged by their ability to hold water poured into them. Provisions for tests of water tightness are given in Section 6 of Specification M 205. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Molds shall be lightly coated with mineral oil or a suitable non-reactive form release material before use.~~
- 4.2 Cylinder Molds:
- 4.2.1 ~~Molds for Casting Specimens Vertically — Molds for casting concrete test specimens shall conform to the requirements of M 205. Shall come from an approved shipment as verified by the Quality Systems Manual Verification Procedure No. 2.~~
- 4.3 Beam Molds — Beam molds shall be rectangular in shape and of the dimensions required to produce the specimens stipulated in Section 5.2. The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed $\frac{1}{8}$ in. [3 mm] for molds with depth or breadth of 6 in. [152 mm] or more. Molds shall produce specimens at least as long but not more than $\frac{1}{16}$ in. [2 mm] shorter than the required length in accordance with Section 5.2, but may exceed it by more than that amount.
- 4.4 Tamping Rod — Two sizes are specified. 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.
- 4.4.1 Large Rod — $\frac{5}{8}$ in. (16 mm) in diameter and approximately 24 in. [610 mm] long.
- 4.4.2 Small Rod — $\frac{3}{8}$ in. [10 mm] in diameter and approximately 12 in. [305 mm] long.
- 4.5 Vibrators — Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of the vibration shall be 7,000 vibrations per minute or greater while in use. The outside diameter or side dimension of the vibrating element shall be at least 0.75 in. (19 mm) and not greater than 1.5 in. (38 mm). The combined length of the shaft and vibrating element shall exceed the maximum depth of the section being vibrated by at least 3 in. [76 mm]. When external vibrators are used, they should be the table or plank type. The frequency of external vibratory shall be at least 3,600 vibrations per minute. For both table and plant vibrators, provisions shall be made for clamping the mold securely to the apparatus. A vibrating reed tachometer should be used to check the frequency of vibration.
- 4.6 Mallet — A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb [0.57 ± 0.23 kg] shall be used.
- 4.7 Small Tools — Tools and items which may be required are shovels, pails, trowels, wood float, metal float, blunted trowels, straightedge, feeler gauge, scoops, and rules.
- 4.8 Slump Apparatus — The apparatus for measurement of slump shall conform to the requirements of T 119.

- 4.9 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.
- 4.10 Air Content Apparatus — The apparatus for measuring air content shall conform to the requirements of T 196 or T 152.

5. TESTING REQUIREMENTS

- 5.1 The number of cylinders made will be as follows:

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

Testing for compressive strength at ages less than 28 days, a single cylinder specimen for each test age will be sufficient.

- 5.2 Cylindrical Specimens — Compressive strength cylindrical specimens shall be cylinders cast and hardened in an upright position, with a length equal to twice the diameter. The standard specimen shall be the 6 by 12-in. [150 by 300-mm] cylinder when the maximum size of the coarse aggregate does not exceed 2 in. [50 mm] (Note 1). When the nominal maximum size aggregate is 1 inch or less does not exceed 1 in. [25 mm], 4 by 8-in. [100 by 200 mm] cylinders may be used. **Mixing of cylinder sizes for a particular class of mix is not permitted on a project.** When the maximum size of the coarse aggregate does exceed 2 in., contact the FOSSC Materials Laboratory for instructions. ~~When the maximum size of the coarse aggregate does exceed 2 in. [50 mm], either the concrete sample shall be treated by wet sieving as described in T 141 or the diameter of the cylinder shall be at least three times the nominal maximum size of coarse aggregate in the concrete. When the nominal maximum size of coarse aggregate 1 in. (25mm) the specimens may be 4 by 8 in. (100 by 200 mm).~~

~~For acceptance testing for specified strength, cylinders smaller than 6 by 12 in. [150 by 300 mm] shall not be used, unless another size is specified (Note 4).~~

*Note 1: The maximum size is the smallest sieve opening through which the entire amount of aggregate is **REQUIRED** to pass.*

- 5.3 Flexural Strength Specimens — Flexural strength specimens shall be rectangular beams of concrete cast and hardened with long axes horizontal. The length shall be at least 2 in. [50 mm] greater than three times the depth as tested. The ratio of width to depth as molded shall not exceed 1.5. The standard beam shall be 6 by 6 in. [150 by 150 mm] in cross section, and shall be used for concrete with nominal maximum size coarse aggregate up to 2 in. [50 mm]. When the nominal maximum size of the coarse aggregate exceeds 2 in. [50 mm], the smaller cross sectional dimension of the beam shall be at least three times the nominal maximum size of the coarse aggregate. Unless required by project specifications, beams made in the field shall not have a width or depth of less than 6 in. [150 mm].

6. SAMPLING CONCRETE

- 6.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with ~~T 141~~ FOP for WAQTC TM-2 unless an alternative procedure has been approved.
- 6.2 Record the identification of the sample with respect to the location of the concrete represented and the time of casting.

7. SLUMP, AIR CONTENT, AND TEMPERATURE

- 7.1 Slump — Measure and record the slump of each batch of concrete from which specimens are made immediately after remixing in the receptacle, as required in T 119.
- 7.2 Air Content — Determine the air content in accordance with either T 152 or T 196. The concrete used in performing the air content test shall not be used in fabricating test specimens.
- 7.3 Temperature — Determine and record the temperature in accordance with T 309.

8. MOLDING SPECIMENS

- 8.1 Place of Molding — Mold specimens promptly 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.
- 8.2 Placing 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 to ensure even distribution of the concrete and to minimize 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. Do not add nonrepresentative concrete to an underfilled mold.

8.2.1 Number of Layers — Make specimens in layers as indicated in Table 1.

8.3 Consolidation:

- 8.3.1 Method of Consolidation — Preparation of satisfactory specimens require different methods of consolidation. The methods of consolidation are rodding, and internal or external 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 concretes with a slump greater than 3 in. (75 mm). Rod or vibrate concretes with slumps of 1 to 3 in. (25 to 75 mm). Vibrate concretes with slumps less than 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 Method T 126 with regards to specimen size and shape and method of consolidation.

Table 1
Number of Layers Required for Specimens

Specimen Type and size as Total Depth, in (mm)	Mode of Compaction	Number of Layers or Depth of Layers
Cylinders:		
12 (300) or less	rodding	3 equal layers
Over 12 (300)	rodding	4 in (100 mm) in depth as near as practicable
Over 12 (300) to 18 (460)	vibration	2 equal layers
Over 460 (18)	vibration	8 in (200 mm) depth as near as practicable
Beam:		
150 (6) to 200 (8)	rodding	2 equal layers
Over 8 (200)	rodding	4 in (100 mm) in depth as near as practicable
6 (150) to 8 (200)	vibration	1 full depth layer
Over 8 (200)	vibration	8 in (200 mm) depth as near as practicable

8.3.2 **Rodding**-Place the concrete in the mold, in the required number of layers of approximately equal volume. For cylinders rod each layer with the rounded end of the rod using the required number of strokes specified in Table 2. The number of roddings per layer required for beams is one for each 2 in² (13 cm²) top surface area of the specimen. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold and for each upper layer allow the rod to penetrate about 1/2 in. (12 mm) into the underlying layer when the depth of the layer is less than 4 in. (100 mm) and about 1 in. (25 mm) when the depth is 4 in. or more. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by rodding and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gage single-use molds which are susceptible to damage if tapped with a mallet. After tapping, spade the concrete along the sides and ends of beam molds with a trowel or other suitable tool.

Table 2
**Diameter of Rod and Number of Roddings
to be Used in Molding Cylinder Test Specimens**

Diameter of Cylinder, in (mm)	Diameter of Rod, in (mm)	Number of Strokes/Layer
4 (100)	3/8 (10)	25
6 (150)	5/8 (16)	25
8 (200)	5/8 (16)	50
10 (250)	5/8 (16)	75

8.3.3 *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 smooth. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation. 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. When placing the final layer, avoid overfilling by more than $\frac{1}{4}$ in. (6 mm). Finish the surface either during or after vibration where external vibration is used. Finish the surface after vibration when internal vibration is used. When the finish is applied after vibration, add only enough concrete with a trowel to over fill the mold about $\frac{1}{8}$ in. (3 mm). Work it into the surface and then strike it off.

8.3.3.1 *Internal Vibration* – The diameter of the vibrating element, or thickness of a square vibrating element, shall be in accordance with the requirements of Section 4.5. For beams, the vibrating element shall not exceed $\frac{1}{3}$ of the width of the mold. For cylinders, the ratio of the diameter of the cylinder to the diameter of the vibrating element shall be 4.0 or higher. In compacting the specimen, the vibrator shall not be allowed to rest on the bottom or sides of the mold. Carefully withdraw the vibrator in such a manner that no air pockets are left in the specimen.

8.3.3.2 *Cylinders* — Use three insertions of the vibrator at different points for 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 mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gage single-use molds, which are susceptible to damage if tapped with a mallet.

8.3.3.3 *Beam* — Insert the vibrator at intervals not exceeding 6 in. [150 mm] along the centerline of the long dimension of the specimen. For specimens wider than 6 in., use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer approximately 1 in. (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the mallet to close any holes left by vibrating and to release any large air bubbles that may have been trapped.

8.3.4 *External Vibration* — When external vibration is used, take care to ensure that the mold is rigidly attached to or securely held against the vibrating element or vibrating surface.

8.4 *Finishing* — After consolidation, unless the finishing has been performed during the vibration (Section 8.3.3), strike off the surface of the concrete and float or trowel it as required. 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 $\frac{1}{8}$ in. (3.2 mm).

- 8.4.1 Cylinders — After consolidation, finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits or with a wood float or trowel. If desired, cap the top surface of freshly made cylinders with a thin layer of stiff Portland cement paste which is permitted to harden and cure with the specimen. See section on Capping Materials of T 231.
- 8.4.2 Beams — After consolidation of the concrete, strike off the top surface to the required tolerance to produce a flat even surface. A wood float may be used.
- 8.5 Initial Storage — Immediately after being struck off, the specimens shall be move to the storage place were they will remain undisturbed for the initial curing period. If specimens made in single use mold are move, lift and support the specimens from the bottom of the molds with a large trowel or similar device.

9. CURING

- 9.1 *Covering After Finishing* — Immediately after finishing, precautions shall be taken to prevent evaporation and loss of water from the specimens. Protect the outside surfaces of cardboard molds from contact with wet burlap or other sources of water. Cardboard molds may expand and damage specimens at an early age if the outside of the mold absorbs water. Cover specimens with a nonabsorbent, non-reactive plate or sheet of impervious plastic. When wetted burlap is used over the plate or plastic sheet to help retard evaporation, but the burlap must not be in contact with the surface of the concrete.
- 9.2 *Curing Specimens for Checking the Adequacy of Laboratory Mixture Proportions for Strength or as the Basis for Acceptance or Quality Control.*
- 9.2.1 *Initial Curing* — After molding, the specimens ~~shall~~ should be stored in a temperature range between 60 to 80°F [16 to 27°C] ~~and in a moist environment preventing moisture loss up to 48 hrs (Note 2). At all times the temperature in and between specimens shall be controlled by shielding from direct rays of the sun and radiant heating devices.~~ Specimens that are to be transported to the laboratory for standard curing (see Section 9.2.2) before 48 hours shall remain in the molds in a moist environment, until they are received in the laboratory, demolded and placed in standard curing. If specimens are not transported within 48 hours the mold shall be removed within 24 ± 8 hours and standard curing used until transported. (See Section 10.1) Except in the case of specimens that do not attain initial set within 32 hours. Specimens not attaining initial set within 32 hours must remain undisturbed until the concrete has reached initial set, then use standard curing until transported. (See Section 10.1)

Note 2: It may be necessary to create an environment during the initial curing to provide satisfactory moisture and to control the temperature. The specimens may be immediately immersed in water saturated with limewater, and/or stored in tightly constructed wooden boxes, damp sand pits, temporary buildings at construction sites, under wet burlap or in heavyweight closed plastic bags.. Immersing in saturated limewater is not acceptable for specimens in cardboard or other molds that expand when immersed in water. Other suitable methods may be used provided the foregoing requirements limiting specimen temperature and moisture loss are met. The temperature may be controlled by ventilation, thermostatically controlled thermal devices, or by heating devices such as stoves, light bulbs, or thermostatically controlled heating elements. Temperature record of the specimens may be established by means of maximum-minimum thermometers. Early age results may be lower when stored near 60°F [16°C] and higher when stored near 80°F [27°C].

9.2.2 *Standard Curing:*

9.2.3.1 *Cylinders* — Upon completion of initial curing and within 30 min after removing the molds, store specimens in a moist condition with free water maintained on their surfaces at all times at a temperature of $73 \pm 3^\circ\text{F}$ [$23 \pm 2^\circ\text{C}$]. Temperatures between 68 and 86°F [20 and 30°C] are permitted for a period not to exceed 3 hours immediately prior to test if free moisture is maintained on the surfaces of the specimen at all times, except when capping with sulfur mortar capping compound. When capping with this material, the ends of the cylinder will be dried as described in T 231. Specimens shall not be exposed to dripping or running water. The required moist storage can be obtained by immersion in saturated limewater and may be obtained by storage in a moist room or cabinet meeting the requirements of M 201.

9.2.3.2 *Beams* — Beams are to be cured the same as cylinders (see 9.2.2.1) except for 20 hours prior to testing, they shall be stored in water saturated limewater at $73.4^\circ \pm 3^\circ\text{F}$ [$23 \pm 1.7^\circ\text{C}$]. Drying of the surfaces of the beam shall be prevented between removal from limewater and completion of testing (Note 3).

Note 3: Relatively small amounts of drying of surface of flexural specimens induces tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9.3 *Curing Specimens for Checking the Adequacy of Laboratory Mixture Proportions for Strength or as the Basis for Acceptance of Quality Control at Remote Sites:*

9.3.1 Specimens prepared and stored at remote sites which do not have facilities for controlling temperature within the tolerance of $73.4^\circ \pm 3^\circ\text{F}$ [$23 \pm 1.7^\circ\text{C}$] shall be cured in accordance with the provisions of Section 9.2 except as modified by Section 9.3.

9.3.2 *Initial Curing at Remote Sites* — Specimens shall be cured in accordance with Section 9.2.1.

9.3.2.1 Specimens not to be transported or to be transported after 48 hours age may be cured without demolding provided that loss of moisture is prevented in accordance with Section 9.2.1 until the time of transportation or testing.

9.3.3 *Standard Curing at Remote Sites* — Specimens stored at a remote site and shipped to a laboratory for test or to be tested at the remote site shall be cured in accordance with Sections 9.3.1, 9.3.2, and 9.3.2.1 until the time of shipment or test. Specimens shall not be exposed to dripping or running water.

9.3.3.1 Beam specimens to be stored and tested at remote sites shall be cured in accordance with Section 9.3, except that for a minimum of 20 hours prior to testing, they shall be stored in saturated limewater at 60 to 80°F [16 to 27°C].

Drying of the surfaces of the beam shall be prevented between removal from the limewater and completion of testing (Note 4).

Note 4: Curing of specimens at remote sites in accordance with Section 9.3 may yield significantly different results as compared to specimens cured in accordance with Section 9.2.

9.4 *Curing for Determining Form Removal Time or When a Structure May be Put into Service:*

9.4.1 *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 may be put in service shall be removed from the molds at the time of removal of form work.

9.4.2 *Beams* — As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of 48 ± 4 hours after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements or slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the sides and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structure concrete as near to the point in the structure they represent as possible and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in limewater at $73.4 \pm 5^\circ \text{F}$ [$23 \pm 2.8^\circ \text{C}$] for 24 ± 4 hours immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Observe the precautions given in Section 9.2.2.2 of removal from curing to testing.

10. TRANSPORTATION OF SPECIMENS TO LABORATORY

10.1 Prior to transporting, specimens shall be cured and protected as required in Section 9. During transporting, the specimens must be protected with suitable cushioning material to prevent damage from jarring and freezing temperatures or moisture loss. Moisture loss may be prevented by wrapping the specimens in plastic, or surrounding them with wet sand or wet sawdust.

Performance Exam Checklist

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

Participant Name _____

Exam Date _____

Procedure Element	Yes	No
1. Molds placed on a level, rigid, horizontal surface free of vibration?	_____	_____
2. Representative sample selected?	_____	_____
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 three equal 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 penetrating 25 mm into the underlying layer?	_____	_____
9. Sides of the mold tapped 10-15 times after rodding each layer?		
a. with mallet for reusable steel molds	_____	_____
b. with the open hand for flexible light-gauge molds	_____	_____

Procedure Element

Yes

No

10. Concrete struck off with tamping rod or, if necessary, finished with a trowel or float, using a minimum of manipulation?

11. Specimens covered with nonabsorptive, nonreactive cap or plate?

Comments:

First attempt: Pass Fail

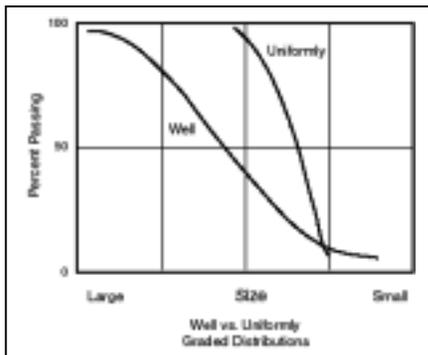
Second attempt: Pass Fail

Signature of Examiner _____

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SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES FOP FOR AASHTO T 27

MATERIALS FINER THAN No. 200 (.075 mm) SIEVE IN MINERAL AGGREGATE BY WASHING FOP FOR AASHTO T 11



Gradation curves

01 Significance

02 Sieve analyses are performed on aggregates used
03 in roadway bases and in portland cement and
04 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.

Generally, well-graded material having an even
distribution of particle sizes will have better load
handling properties than poorly graded material
consisting of a few size classes. Although other
characteristics of aggregates contribute to its
strength, the better a material is graded, the less
material will be needed.

05 Scope

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

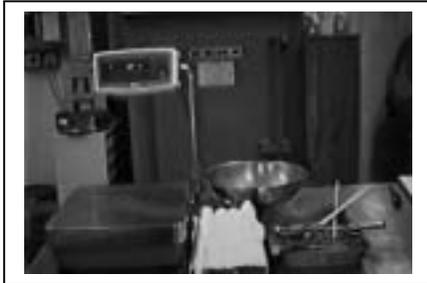
Sieve analyses determine the gradation or
distribution of aggregate particles within a given
sample in order to determine compliance with
design and production standards.



06 **Washing sample**

Accurate determination of material smaller than No. 200 (.075 mm) 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 (.075 mm) sieve. The amount of material passing this sieve is determined by comparing dry sample masses before and after the washing process. The procedure herein is a combination of the two methods.

07



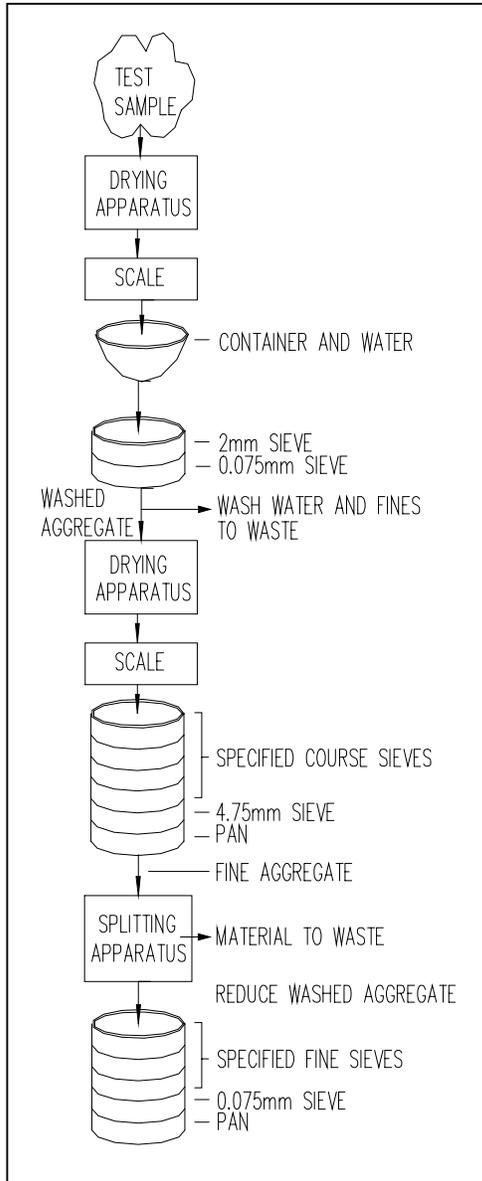
08 **Apparatus**

Apparatus

- Balance or scale: Capacity sufficient for the masses shown in Table 1, accurate to 0.1 percent of the sample mass or ~~readable to 0.1 g.~~ Meeting 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



09 **Large sieve shaker**



Sample Preparation

Obtain samples in accordance with the FOP for AASHTO T 2 and reduce to the size shown in Table 1 in accordance with the FOP for AASHTO T 248.

TABLE 1
Sample Sizes for Aggregate Gradation Test

Nominal Maximum Size* mm (in.)	Minimum Mass kg (lb)
4.75 (No. 4)	0.5 (1)
6.3 (1/4)	1 (2)
9.5 (3/8)	1 (2)
12.5 (1/2)	2 (4)
19.0 (3/4)	5 (11)
25.0 (1)	10 (22)
37.5 (1 1/2)	15 (33)
50 (2)	20 (44)
63 (2 1/2)	35 (77)
75 (3)	60 (130)
90 (3 1/2)	100 (220)

* One sieve larger than the first sieve to retain more than 10 percent of the material, using specification sieves. See definition on page 18.

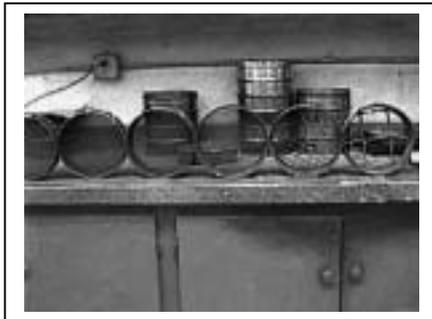
WSDOT added:

Table 1
Sample Sizes for Aggregate Gradation Test

Nominal Maximum Size* in. (mm)	Minimum Mass lb (kg)
No. 4 (4.75)	1 (0.5)
1/4 (6.3)	2 (1)
3/8 (9.5)	2 (1)
1/2 (12.5)	5 (2)
5/8 (16.0)	5 (2)
3/4 (19.0)	7 (3)
1 (25.0)	13 (6)
1 1/4 (31.5)	17 (7.5)
1 1/2 (37.5)	20 (9)
2 (50)	22 (10)
2 1/2 (63)	27 (12)
3 (75)	33 (15)
3 1/2 (90)	44 (20)

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

Washed sieve analysis



Sieves

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.

11

Note 1: These sample sizes are standard for aggregate testing but, due to equipment restraints, samples may need to be partitioned into several “subsamples.” For example, a gradation that requires 220 LBS (100 kg) of material would not fit into a large tray shaker in one batch.

Note 2: Some agencies permit reduced sample sizes if it is proven that doing so is not detrimental to the test results. Some agencies require larger sample sizes. Check agency guidelines for required or permitted test sample sizes.

Procedure

12

1. Dry the sample ~~to a constant mass~~ in accordance with the FOP for AASHTO T 255, and record to the nearest 0.1 g percent of total mass.

Note 3: AASHTO T 27 allows for coarse aggregate to be run in a moist condition unless the nominal maximum size of the aggregate is smaller than 1/2 in. (12.5 mm), the coarse aggregate (CA) contains appreciable material finer than No. 4 (4.75 mm), or the coarse aggregate is highly absorptive. AASHTO also allows for sample drying on a hot plate so long as the particles do not fracture and the aggregate does not change chemically under the heat.

2. When the specification requires that the amount of material finer than No. 200 (.075 mm) be determined, do Step 3 through Step 9 – otherwise, skip to Step 10.

Note 4: If the applicable specification requires that the amount passing the No. 200 (.075 mm) 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.

- 13 3. Nest a sieve, such as a No. 10 (2 mm), above the No. 200 (.075 mm) sieve.

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

Note 5: 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 U.S. No. 200 (.075 mm) 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.

- 14 5. Agitate vigorously to ensure complete separation of the material finer than No. 200 (.075 mm) from coarser particles and bring the fine material into suspension above the coarser material.

Note: The use of a mechanical aggregate washer is permitted in the accomplishment of step 4, through 9. Caution must be exercised that prolonged agitation does not cause degradation of the aggregate.

- 15 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.

- 16 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.

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



Separation of material



Flushing

9. Dry the washed aggregate to constant mass in accordance with the FOP for AASHTO T 255, and then cool prior to sieving. ~~AASHTO also allows for sample drying on a hot plate so long as the particles do not fracture and the aggregate does not change chemically under the heat.~~ Record the dry, constant mass if required by the agency mass.

18 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.

Note 6: Additional sieves may be necessary to provide other information, such as fineness modulus, or to keep from overloading the specified sieves. The sample may also be sieved in increments.

19 11. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation for the sieve shaker being used.

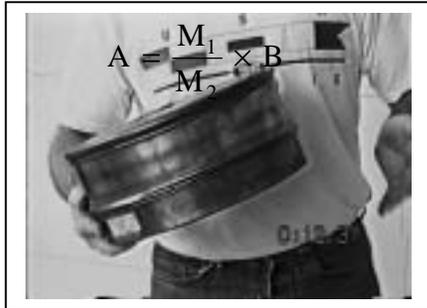
Note 7: The 10-minute requirement should be evaluated for each shaker at least annually.

20 *Note 8:* Continue shaking for a sufficient period and in such a manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during one minute of continuous hand sieving. Provide a snug-fitting pan and cover, and hold in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turning the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than 4.75 mm (No. 4), limit the material on the sieve to a single layer of particles.



Small sieve shaker

21 For sieves with openings smaller than No. 4 (4.75 mm), the mass retained on any sieve shall not exceed 7 kg/m^2 of sieving surface. For sieves with openings larger than No. 4 (4.75 mm), the mass, in kg/m^2 of sieving surface, shall not exceed the product of 2.5 x



Hand shaking

22



Mass determination



Brushing sieve

23

24

(sieve opening in mm). See Table 2.

In the case of CA and fine aggregate (FA) mixtures, the portion of the sample finer than No. 4 (4.75 mm) may be distributed among two or more sets of sieves to prevent overloading of individual sieves.

Alternatively, the portion finer than No. 4 (4.75 mm) may be reduced in size using a mechanical splitter in accordance with FOP for AASHTO T 248. If this procedure is followed, compute the mass of the size increment of the original sample as follows:

where:

A = mass of the size increment on total sample basis

M_1 = mass of fraction finer than No. 4 (4.75 mm) sieve in total sample

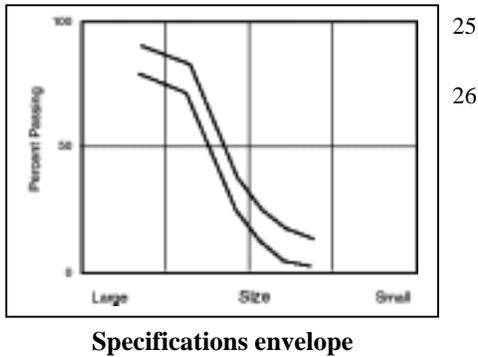
M_2 = mass of reduced portion of material finer than No. 4 (4.75 mm) sieve actually sieved

B = mass of the size increment in the reduced portion sieved.

12. Determine the mass retained on each sieve to the nearest 0.1 g. ~~Ensure that all material trapped in the openings of the sieve are cleaned out and included in the mass retained.~~ percent of the total mass.

Note 9: Use coarse wire brushes to clean the 600 μm (No. 30) and larger sieves, and soft hair brushes for smaller sieves.

13. The total mass of material after sieving should check closely with the original mass. If the masses differ by more than 0.3 percent, based on the original dry sample mass, do not use the results for acceptance purposes. Also, washed samples will not match with original sample due to the washing out of the fines.



14. Divide the 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.

TABLE 2
Maximum Allowable Mass of Material Retained on a Sieve, kg
Nominal Sieve Size, in. (mm)

Sieve Size in. (mm)	203 ϕ (8)	305 ϕ (12)	305 x 305 (12 x 12)	298 x 584 (11 1/2 x 23)	454 x 610 (18 x 24)
	Sieving Area m ²				
	0.028502	0.067012	0.092903	0.174354	0.276940
3 1/2 (90)	6.41	15.08	20.90	39.23	62.71
3 (75)	5.34	12.56	17.42	32.69	52.26
2 1/2 (63)	4.49	10.55	14.63	27.46	43.90
2 (50)	3.56	8.38	11.61	21.79	34.84
1 3/4 (45)	3.21	7.54	10.45	19.61	31.35
1 1/2 (37.5)	2.67	6.28	8.71	16.35	26.13
1 1/4 (31.5)	2.24	5.28	7.32	13.73	21.95
1 (25.0)	1.78	4.19	5.81	10.90	17.42
7/8 (22.4)	1.60	3.75	5.20	9.76	15.61
3/4 (19.0)	1.35	3.18	4.41	8.28	13.24
5/8 (16.0)	1.14	2.68	3.72	6.97	11.15
9/16 (14.3)	0.94	2.21	3.07	5.75	9.20
1/2 (12.5)	0.89	2.09	2.90	5.45	8.71
3/8 (9.5)	0.68	1.59	2.21	4.14	6.62
5/16 (8.0)	0.57	1.34	1.86	3.49	5.57
1/4 (6.3)	0.45	1.06	1.46	2.75	4.39
No. 4 (4.75)	0.34	0.80	1.10	2.07	3.31
Less than No. 4	0.20	0.47	.65	1.22	1.32

Calculation

- Sample Calculation for Percent Retained On and Passing

Calculate percent retained on and passing each sieve on the basis of the total mass of the initial dry sample. This will include any material finer than No. 200 (.075 mm) that was washed out.

Example:

Dry mass of total sample, before washing: 3322.0 g

Dry mass of sample, after washing out the No. 200 (.075 mm) minus: 2947.0 g

Amount of No. 200 (.075 mm) minus washed out: $3322.0 \text{ g} - 2947.0 \text{ g} = 375.0 \text{ g}$

27

Gradation on All Screens

28

Sieve Size in. (mm)	Mass Retained g	Percent Retained	Cumulative Mass Retained g	Cumulative Percent Retained	Percent Passing*
5/8 (16.0)	0	0	0	0	100
1/2 (12.5)	158.1	4.8	158.1	4.8	95
3/8 (9.50)	477.5	14.4	635.6	19.1	80
No. 4 (4.75)	436.5	13.1	1072.1	32.3	67
No. 10 (2.00)	781.0	23.5	1853.1	55.8	44
No. 40 (0.425)	699.5	21.1	2552.6	76.8	23
No. 80 (0.210)	200.2	6.0	2752.8	82.9	17
No. 200 (0.075)	169.9	5.1	2922.7	88.0	12.0
Pan	24.3		2947.0		

* Report 0.075 mm sieve to 0.1 percent. Report all others to 1 percent.

29,30

- Sample Calculation for Percent Retained On and Passing, Including a Split on the No. 4 (4.75 mm) Sieve 31

Calculate percent retained on and passing each sieve on the basis of the total mass of the initial dry sample. This will include any material finer than No. 200 (.075 mm) that was washed out.

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 (.075 mm) 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.

Example showing calculations when the No. 4 (4.75 mm) minus material is split:

Dry mass of total sample, before washing: 3214 g

Dry mass of sample, after washing out the No. 200 (.075 mm) minus: 3085 g

Amount of No. 200 (.075 mm) minus washed out: $3214 \text{ g} - 3085 \text{ g} = 129 \text{ g}$

Gradation on Coarse Screens

32

Sieve Size mm (in.)	Mass Retained g	Percent Retained	Cumulative Mass Retained g	Cumulative Percent Retained	Percent Passing*
5/8 (16.0)	0	0	0	0	100
1/2 (12.5)	161	5.0	161	5.0	95
3/8 (9.50)	481	15.0	642	20.0	80
No. 4 (4.75)	475	14.8	1117	34.8	65
Pan	1968		3085		

* Report 0.075 mm sieve to 0.1 percent. Report all others to 1 percent.

The actual mass of material passing the No. 4 (4.75 mm) sieve and retained in the pan is $3085 \text{ g} - 1117 \text{ g} = 1968 \text{ g}$. This is M_1 . 33

Note 10: The pan mass determined in the laboratory and the calculated M_1 should be the same.

These 1968 g were 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 . 34

Gradation on Fine Screens

35

Sieve Size in. (mm)	Mass Retained (g)	Percent Retained	Cumulative Mass Retained (g)	Cumulative Percent Retained	Percent Passing*
No. 4 (4.75)	0	0	0	0	100
No. 10 (2.00)	205.9	37.7	205.9	37.7	62
No. 40 (0.425)	188.4	34.5	394.3	72.2	27
No. 80 (0.210)	60.2	11.0	454.5	83.2	16
No. 200 (0.075)	49.1	9.0	503.6	92.2	7.8
Pan	9.2		512.8**		

* Report 0.075 mm sieve to 0.1 percent. Report all others to 1 percent.

** This cumulative mass retained and M_2 should be the same.

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

$$\text{Corrected cumulative pan mass} = M_2 + \frac{(M_2)(C)}{M_1} = 512.8 \text{ g} + \frac{(512.8 \text{ g})(129 \text{ g})}{1,968 \text{ g}} = 546.4 \text{ g}$$

36

where:

M_2 = cumulative mass retained in the pan from the split of the No. 4 (4.75 mm) minus.

M_1 = mass of the No. 4 (4.75 mm) minus of entire sample, not including No. 200 (.075 mm) minus washed out.

C = mass of No. 200 (.075 mm) minus washed out.

This corrected cumulative pan mass is the mass used to calculate the percent retained for the fine grading, as shown above.

In order to account for the fact that only a portion of the minus No. 4 (4.75 mm) material was sieved, the mass of material retained on the smaller sieves is adjusted by a factor equal to M_1/M_2 . In this example,

37

$$\frac{M_1}{M_2} = \frac{1,968 \text{ g}}{512.8 \text{ g}} = 3.838$$

and each “mass retained” on the fine sieves must be multiplied by this factor.

For example, the overall mass retained on the No. 10 (2.00 mm) sieve is:

$$205.9 \text{ g} \times \frac{1,968 \text{ g}}{512.8 \text{ g}} = 790.2 \text{ g} \text{ as shown in the following table}$$

Final Gradation on All Screens

38

Sieve Size in. (mm)	Adjusted Mass Retained g	Adjusted Cumulative Mass Retained g	Cumulative Percent Retained	Percent Passing*
5/8 (16.0)	0	0	0.0	100
1/2 (12.5)	161	161	5.0	95
3/8 (9.5)	481	642	20.0	80
No. 4 (4.75)	475	1117	34.8	65
No. 10 (2.0)	205.9 x 3.838=790.2	1907.2	59.3	40
No. 40 (0.425)	188.4 x 3.838=723.1	2630.3	81.8	18
No. 80 (0.210)	60.2 x 3.838=231.0	2861.3	89.0	11
No. 200 (0.075)	49.1 x 3.838=188.4	3049.7	94.9	5.1
Pan	9.2 x 3.838=35.3	3085.0**		

* Report 0.075 mm sieve to 0.1 percent. Report all others to 1 percent.

** The adjusted cumulative mass retained plus the No. 200 (.075 mm) material washed out should be within 0.3 percent of original dry mass of the total sample. (See AASHTO T 27, paragraph 7.7.)

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 – 65.2 percent in this case.

Final Gradation on All Screens

39

Sieve Size in. (mm)	Adjustment	Percent Passing*
5/8 (16.0)		100
1/2 (12.5)		95
3/8 (9.5)		80
No. 4 (4.75)	100 x .652 =	65
No. 10 (2.0)	62.3 x .652 =	40
No. 40 (0.425)	27.8 x .652 =	18
No. 80 (0.210)	16.8 x .652 =	11
No. 200 (0.075)	7.8 x .652 =	5.1

* Report 0.075 mm sieve to 0.1 percent. Report all others to 1 percent.

- Sample Calculation for Fineness Modulus

40

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 sum of the percentages retained on specified sieves 150, 75, 37.5, 19.0, 9.5, 4.75, 2.36, 1.18, 0.60, 0.30, and 0.15 mm divided by 100 gives the FM.

	Example A				Example B		
	Percent				Percent		
		Retained				Retained	
Sieve Size (mm)	Passing		On Spec'd Sieves*		Passing		On Spec'd Sieves*
75*	100	0	0		100	0	0
63	100	0	--		100	0	--
50	100	0	--		100	0	--
37.5*	100	0	0		100	0	0
25.0	53	47	--		100	0	--
19.0*	15	85	85		100	0	0
12.5	0	100	--		100	0	--
9.5*	0	100	100		100	0	0
6.3	0	100	--		100	0	--
4.75*	0	100	100		100	0	0
2.36*	0	100	100		87	13	13
1.18*	0	100	100		69	31	31
0.60*	0	100	100		44	56	56
0.30*	0	100	100		18	82	82
0.15*	0	100	100		4	96	96
			$\Sigma = 785$				$\Sigma = 278$
			FM = 7.85				FM = 2.78

41

* In decreasing size order, each sieve is one-half the size of the preceding sieve.

42

Report

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

- Mass retained on each sieve
- Percent retained on each sieve
- Cumulative mass retained on each sieve

- Cumulative percent retained on each sieve
- Percent passing each sieve to the nearest 1 percent except for the percent passing the No. 200 (.075 μm) sieve, which shall be reported to the nearest 0.1 percent
- FM to the nearest 0.01 percent
- Report results using WSDOT Form 422-020.

Tips!

43

- Check specification to see if material must be washed and split.
- Do not lose any material when running the test.
- Remember to base calculations on the total mass of the initial dry sample.
- Check calculations, and sieves for damage or plugging, if results look “odd” or if the material suddenly goes out of spec.
- Save all material for rerunning.

44

Performance Exam Checklist

***Sieve Analysis of Fine and Coarse Aggregates
FOP for AASHTO T 27***

***Materials Finer Than 75 µm (No. 200) Sieve in Mineral Aggregate by Washing
FOP for AASHTO T 11***

Participant Name _____

Exam Date _____

Procedure Element	Yes	No
1. Minimum sample mass meets requirement of Table 1?	_____	_____
2. Test sample dried to a constant mass by FOP for AASHTO T 255?	_____	_____
3. Test sample cooled and mass determined to nearest 0.1 percent of mass?	_____	_____
4. 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.)	_____	_____
5. Contents of the container vigorously agitated?	_____	_____
6. Complete separation of coarse and fine particles achieved?	_____	_____
7. Wash water poured through nested sieves such as No. 10 and No. 200?	_____	_____
8. Operation continued until wash water is clear?	_____	_____
9. Material retained on sieves returned to washed sample?	_____	_____
10. Washed aggregate dried to a constant mass by FOP for AASHTO T 255?	_____	_____
11. Washed aggregate cooled and mass determined to nearest 0.1 percent of mass?	_____	_____
12. Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)	_____	_____
13. Material sieved in verified mechanical shaker for minimum of 10 minutes?	_____	_____
14. Mass of residue on each sieve determined to 0.1 percent of mass?	_____	_____

Procedure Element

Yes

No

15. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent?

16. 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?

17. Percentage calculations based on original dry sample mass?

18. Calculations performed properly? If material passing No. 4 sieve is split and only a portion is tested, calculation as noted in FOP performed properly?

Comments:

First attempt: Pass Fail

Second attempt: Pass Fail

Signature of Examiner _____



WSDOT FOP for AASHTO T 99¹

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

1. SCOPE

- 1.1 These methods of test are intended for determining the relation between the moisture content and density of soils compacted in a mold of a given size with a 5.5-lb (2.5-kg) rammer dropped from a height of 12-in. (305-mm). Four alternate procedures are provided as follows:

Method A

A 4-in. (101.60-mm) mold: Soil material passing a No. 4 (4.75-mm) sieve
Sections 3 and 4.

Method B

A 6-in. (152.40-mm) mold: Soil material passing a No. 4 (4.75-mm) sieve
Sections 5 and 6.

Method C

A 4-in. (101.60-mm) mold: Soil material passing a 3/4-in. (19.0-mm) sieve
Sections 7 and 8.

Method D

A 6-in. (152.40-mm) mold: Soil material passing a 3/4-in. (19.0-mm) sieve
Sections 9 and 10.

The preferred method of WSDOT is to use Method A.

- 1.2 The method to be used should be indicated in the specifications for the material being tested. If no method is specified, the provisions of Method A shall govern.
- 1.3. This test method applies to soils mixtures that have 40% or less retained on the 4.75 mm- (No.4) sieve, when Method A or B is used and 30% or less retained on the 19.0-mm (3/4-in.) sieve, when Method C or D is used. The material retained on these sieves shall be defined as oversized particles (coarse particles).
- 1.4. If the test specimen contains oversize particles, and the test specimen is used for field density compaction control, corrections must be made according to T 224 to compare the total field density with the compacted specimen density. The person or agency specifying this method shall specify a minimum percentage below which correction for oversize need not be applied. If no minimum percentage is specified, correction shall be applied to samples with more than 5 % by weight of oversize particles.
- 1.5. If the specified oversized maximum tolerances are exceeded, other methods of compaction control must be used.

Note 1 –One method for the design and control of the compaction of such soils is to use a test fill to determine the required degree of compaction and a method to obtain that compaction. Then use a method specification to control the compaction by specifying the type and size of compaction equipment, the lift thickness and the number of passes.

¹This Test Method is based on AASHTO T 99-97 (2001).

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

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

2. Referenced Documents

2.1. AASHTO Standards:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Balances Used in the Testing of Materials
- R 11, Recommended Practice For Indicating Which Places of Figures Are to Be Considered for Significant in Specified Limiting Values
- T 19, Unit Mass and Voids in Aggregate
- T 224, Correction for Coarse Particles in the Soil Compaction Test
- T 265, Laboratory Determination of Moisture Content of Soils

2.2. ASTM Standard:

- D 2168, Calibration of Laboratory Mechanical-Rammer Soil Compactors

3. APPARATUS

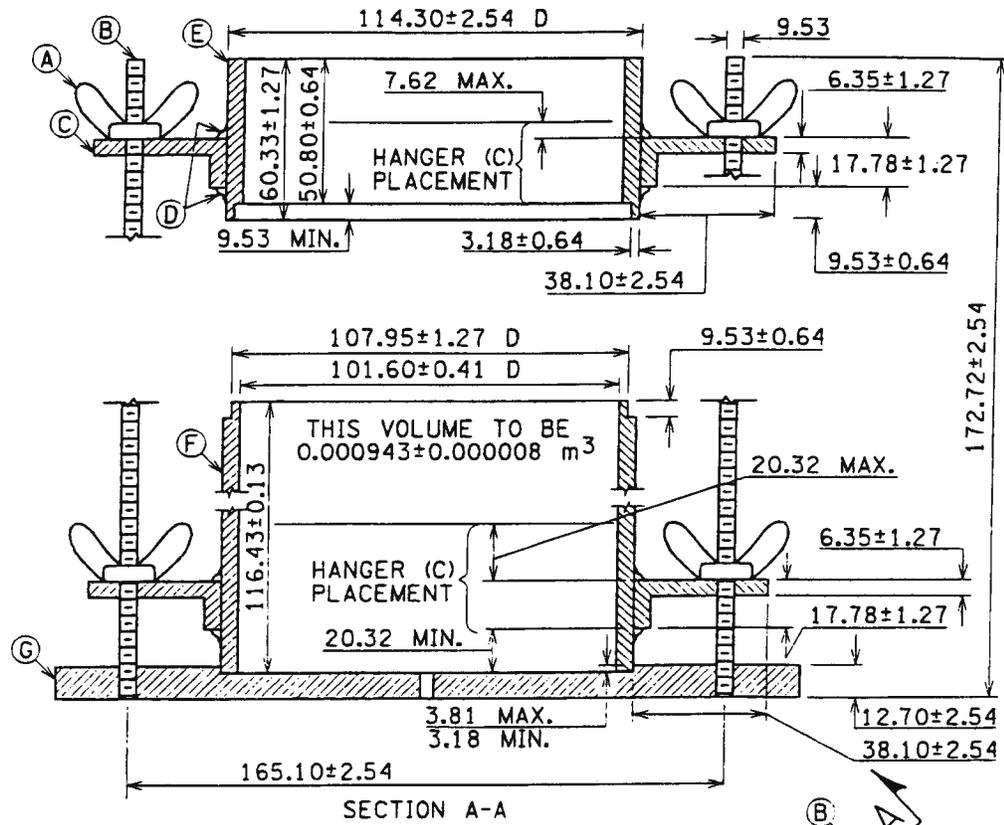
3.1 Molds — The molds shall be solid-wall, metal cylinders manufactured with dimensions and capacities shown in Sections 3.1.1 and 3.1.2 below. They shall have a detachable collar assembly approximately 2.375 in. (60 mm) in height, to permit preparation of compacted specimens of soil-water mixtures of the desired height and volume. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate made of the same material (Note 2). The base plate shall be plane to 0.005 in. as shown in Figures 1 and 2.

Note 2: Alternate types of molds with capacities as stipulated herein may be used, provided the test results are correlated with those of the solid-wall mold on several soil types and the same moisture-density results are obtained. Records of such correlation shall be maintained and readily available for inspection, when alternate types of molds are used.

3.1.1 A 4-in. (101.6-mm) mold having a capacity of $1/30 (0.0333) \pm 0.0003$ cu. ft. (0.000943 ± 0.000008 m³) with an internal diameter of 4.000 ± 0.016 in. (101.60 ± 0.41 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 0.13 mm) (Figure 1).

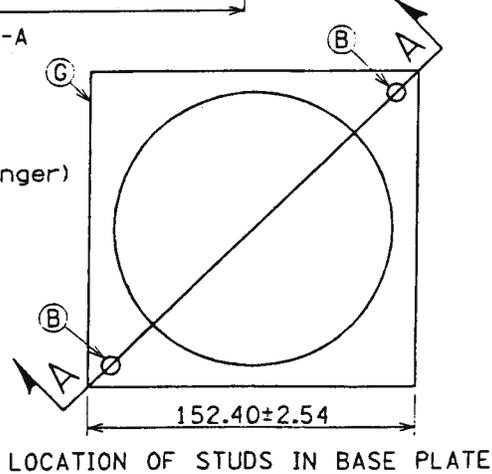
3.1.2 A 6-in. (152.4-mm) mold having a capacity of $1/13.33 (0.07500) \pm 0.00075$ cu. ft. (0.002124 ± 0.000021 m³) with an internal diameter of 6.000 ± 0.026 in. (152.40 ± 0.66 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 0.13 mm) (Figure 2).

3.1.3 Molds Out of Tolerance Due to Use — A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50 percent; and the volume of the mold, calibrated in accordance with Section 8 (Calibration of Measure) of T 19/T 19M, for Unit Mass of Aggregate, is used in the calculations.



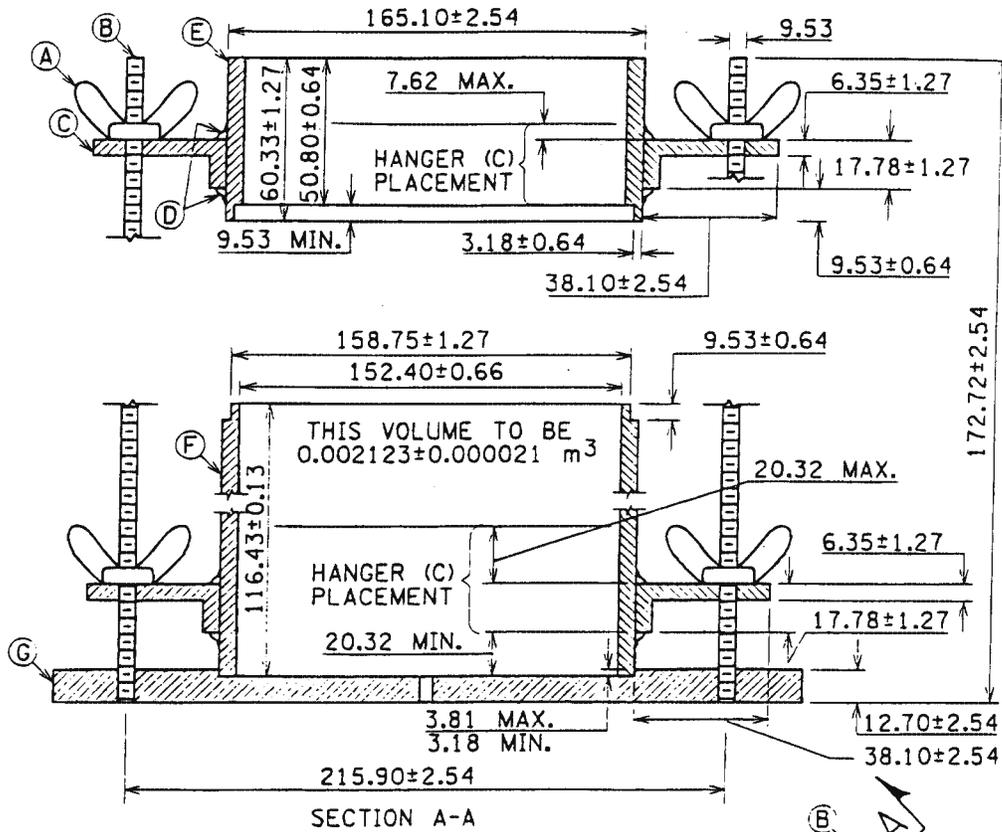
- (A) WING NUT (4)
- (B) STUD (2)
- (C) HANGER (4)
- (D) WELD (Top and bottom of each hanger)
- (E) COLLAR (1)
- (F) MOLD (1)
- (G) BASE PLATE (1)

NOTE:
ALL DIMENSIONS SHOWN IN MILLIMETERS
UNLESS OTHERWISE NOTED.



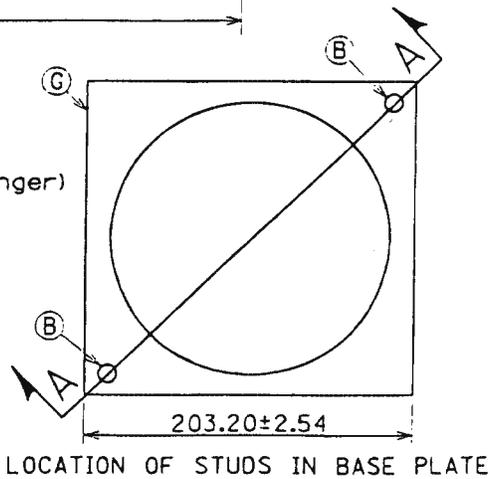
Dimensional Equivalents			
mm	in.	mm	in.
3.18 ± 0.64	0.125 ± 0.025	50.80 ± 0.64	2.000 ± 0.025
3.81	0.150	60.33 ± 1.27	2.375 ± 0.050
6.35 ± 1.27	0.250 ± 0.050	101.60 ± 0.41	4.000 ± 0.016
7.62	0.300	107.95 ± 1.27	4.250 ± 0.050
9.53 ± 0.64	0.375 ± 0.025	114.30 ± 2.54	4.500 ± 0.100
12.70 ± 2.54	0.500 ± 0.100	116.43 ± 0.13	4.584 ± 0.005
17.78 ± 1.27	0.700 ± 0.050	152.40 ± 2.54	6.000 ± 0.100
20.32	0.800	165.10 ± 2.54	6.500 ± 0.100
38.10 ± 2.54	1.500 ± 0.100	172.72 ± 2.54	6.800 ± 0.100
0.000943 ± 0.000008 m³	1/30 ± 0.0003 ft³		

Cylindrical Mold and Base Plate (101.6-mm mold)
Figure 1



- (A) WING NUT (4)
- (B) STUD (2)
- (C) HANGER (4)
- (D) WELD (Top and bottom of each hanger)
- (E) COLLAR (1)
- (F) MOLD (1)
- (G) BASE PLATE (1)

NOTE:
ALL DIMENSIONS SHOWN IN MILLIMETERS
UNLESS OTHERWISE NOTED.



Dimensional Equivalents

mm	in.	mm	in.
3.18 ± 0.64	0.125 ± 0.025	50.80 ± 0.64	2.000 ± 0.025
3.81	0.150	60.33 ± 1.27	2.375 ± 0.050
6.35 ± 1.27	0.250 ± 0.050	116.43 ± 0.13	4.584 ± 0.005
7.62	0.300	152.40 ± 0.66	6.000 ± 0.026
9.53 ± 0.64	0.375 ± 0.025	158.75 ± 1.27	6.250 ± 0.050
12.70 ± 2.54	0.500 ± 0.100	165.10 ± 2.54	6.500 ± 0.100
17.78 ± 1.27	0.700 ± 0.050	172.72 ± 2.54	6.800 ± 0.100
20.32	0.800	203.23 ± 2.54	8.000 ± 0.100
38.10 ± 2.54	1.500 ± 0.100	215.90 ± 2.54	8.500 ± 0.100

0.002123 ± 0.000021 m³ 1/13.33 ± 0.00075 ft³

Cylindrical Mold and Base Plate (152.4-mm mold)

Figure 2

3.2 Rammer

- 3.2.1 Manually Operated — Metal rammer with a mass of 5.5 ± 0.02 lb (2.495 ± 0.009 kg), and having a flat circular face of 2.000-in. (50.80-mm) diameter with a manufacturing tolerance of 0.01 in. (± 0.25 mm). The in-service diameter of the flat circular face shall be not less than 1.985 in. (50.42 mm). The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of 12.00 ± 0.06 in. (305 ± 2 mm) above the elevation of the soil. The guide-sleeve shall have at least 4 vent holes, no smaller than $3/8$ -in. (9.5-mm) diameter spaced approximately 90 degrees (1.57 rad) apart and approximately $3/4$ in. (19 mm) from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.
- 3.2.2 Mechanically Operated — A metal rammer which is equipped with a device to control the height of drop to a free fall of 12.00 ± 0.06 in. (305 ± 2 mm) above the elevation of the soil and uniformly distributes such drops to the soil surface (Note 3). The rammer shall have a mass of 5.5 ± 0.02 lb (2.495 ± 0.009 kg), and have a flat circular face of 2.000-in. (50.80 mm) diameter with a manufactured tolerance of 0.01 in. (± 0.25 mm). The in-service diameter of the flat circular face shall be not less than 1.985 in. (50.42 mm). The mechanical rammer shall be calibrated by ASTM D 2168.

Note 3: It may be impractical to adjust the mechanical apparatus so the free fall is 12 in. (305 mm) each time the rammer is dropped, as with the manually operated rammer. To make the adjustment of free fall, the portion of loose soil to receive the initial blow should be slightly compressed with the rammer to establish the point of impact from which the 12 in. (305 mm) drop is determined. Subsequent blows on the layer of soil being compacted may all be applied by dropping the rammer from a height of 12 in. (305 mm) above the initial-setting elevation; or, when the mechanical apparatus is designed with a height adjustment for each blow, all subsequent blows should have a rammer free fall of 12 in. (305 mm) measured from the elevation of the soil as compacted by the previous blow. A more detailed calibration procedure for laboratory mechanical-rammer soil compactors can be found in ASTM D 2168.

- 3.2.3 Rammer Face — The circular face rammer shall be used but a sector face may be used as an alternative provided the report shall indicate type of face used other than the 2-in. (50.8-mm) circular face and it shall have an area equal to that of the circular face rammer.
- 3.3 Sample Extruder (for Solid-Walled Molds Only) — A jack, lever, frame, or other device adopted for the purpose of extruding compacted specimens from the mold.
- 3.4 Balances and Scales — A balance or scale conforming to the requirements of AASHTO M 231, Class G 20. Also, a balance conforming to the requirements of AASHTO M 231, Class G 2.

Note 4: The capacity of the metric balance or scale should be approximately 11.5 kg when used to weigh the 6-in. (152.40-mm) mold and compacted, moist soil; however, when the 4-in. (101.60-mm) mold is used, a balance or scale of lesser capacity than the 11.5 kg may be used, if the sensitivity and readability is 5 g.

- 3.5 Drying Oven — A thermostatically controlled drying oven capable of maintaining a temperature of $230 \pm 9^{\circ}\text{F}$ ($110 \pm 5^{\circ}\text{C}$) for drying moisture samples.
- 3.6 Straightedge — A hardened-steel straightedge at least 10 in. (250 mm) in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 in. per 10 in. (0.250 mm per 250 mm) (0.1 percent) of length within the portion used for trimming the soil (Note 5).

Note 5: The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.01 in. per 10 in. (0.250 mm per 250 mm) (0.1 percent) of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil with the cutting edge will cause a concave soil surface.

- 3.7 Sieves — 2-in. (50-mm), $\frac{3}{4}$ -in. (19.0-mm), and No. 4 (4.75-mm) sieves conforming to the requirements of AASHTO M 92, Wire-Cloth Sieves for Testing Purposes.
- 3.8 Mixing Tools — Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.
- 3.9 Containers — Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

METHOD A

4. SAMPLE

- 4.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus which is maintained at a temperature not exceeding 140°F (60°C). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.
- 4.2 Sieve an adequate quantity of the representative pulverized soil over the No. 4 (4.75-mm) sieve. Discard the coarse material, if any, retained on the No. 4 (4.75-mm) sieve.
- 4.3 Select a representative sample, with a mass of approximately 7 lb (3 kg) or more, of the soil prepared as described in Sections 4.1 and 4.2.

5. PROCEDURE

- 5.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four percentage points below optimum moisture content.
- 5.2 Form a specimen by compacting the prepared soil in the 4-in. (101.60-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or similar device having a face diameter of approximately 2 in. (50 mm). Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device, and be evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil when a sleeve-

type rammer is used, or from 12 in. (305 mm) above the approximate elevation of compacted soil when a stationary mounted type of rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process (Note 6).

Note 6: Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete, with a mass not less than 200 lb (90 kg), supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as are found in concrete box culverts, bridges, and pavements.

- 5.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge, and determine the mass of the mold and moist soil in kilograms to the nearest 5 grams, or determine the mass in pounds to the nearest 0.01 pounds. For molds conforming to tolerances given in Section 3.1.1 and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 1060, and record the result as the wet density, W_1 , in kilograms per cubic meter, of compacted soil. For molds conforming to tolerances given in Section 3.1.1 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, and record the result as the wet density, W_1 , in pounds per cubic foot, of compacted soil. For used molds out of tolerance by not more than 50 percent (Section 3.1.3), use the factor for the mold as determined in accordance with Calibration of Measure in AASHTO T 19/T 19M.
- 5.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, weigh immediately and dry in accordance with T 255 or T 265, Laboratory Determination of Moisture Content of Soils, to determine the moisture content, and record the results.
- 5.4 Thoroughly break up the remaining portion of the molded specimen until it will pass a No. 4 (4.75-mm) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amount to increase the moisture content of the soil one to two percentage points (water content increments should not exceed 2.5 percent except when heavy clay soils or organic soils exhibiting flat elongated curves are encountered, the water content increments may be increased to a maximum of 4 percent), and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet unit mass, W_1 , per cubic foot (cubic meter) of the compacted soil (Note 7).

Note 7: This procedure has been found satisfactory in most cases. However, in instances where the soil material is fragile in character and will reduce significantly in grain size due to repeated compaction, and in cases where the soil is a heavy-textured clayey material into which it is difficult to incorporate water, a separate and new sample shall be used in each compaction test. In these cases, separate samples shall be thoroughly mixed with amounts of water sufficient to cause the moisture contents of the samples to vary by approximately two percentage points. The moisture points selected shall bracket the optimum moisture content, thus providing samples which, when compacted, will increase in mass to the maximum density and then decrease in mass. The samples of soil-water mixtures shall be placed in covered containers and allowed to stand for not less than 12 hours before making the moisture-density test.

- 5.4.1 In instances where the soil material is fragile in character and will be reduced significantly in grain size by repeated compaction, a separate and new sample shall be used in each compaction test.

METHOD B

6. SAMPLE

- 6.1 Select the representative sample in accordance with Section 3.3, except that it shall have a mass of approximately 16 lb (7 kg).

7. PROCEDURE

- 7.1 Follow the same procedure as described for Method A in Section 4, except for the following: Form a specimen by compacting the prepared soil in the 6-in. (152.4-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. For molds conforming to tolerances given in Section 2.1.2, and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 471, and record the result as the wet density, W_1 , in kilograms per cubic meter, of compacted soil. For molds conforming to tolerances given in Section 2.1.2, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.3, and record the result as the wet density, W_1 , in pounds per cubic foot, of compacted soil. For used molds out of tolerance by not more than 50 percent (Section 3.1.3), use the factor for the mold as determined in accordance with Calibration of Measure in AASHTO T 19/T 19M.

METHOD C

8. SAMPLE

- 8.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus which is maintained at a temperature not exceeding 140°F (60°C). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.
- 8.2 Sieve an adequate quantity of the representative pulverized soil over the 19.0-mm sieve. Discard the coarse material, if any, retained on the $\frac{3}{4}$ in. (19.0-mm) sieve (Note 8).

Note 8: If it is advisable to maintain the same percentage of coarse material (passing a 2 in. (50-mm) sieve and retained on a No. 4 (4.75-mm) sieve) in the moisture-density sample as in the original field sample, the material retained on the $\frac{3}{4}$ in. (19.0-mm) sieve shall be replaced as follows: Sieve an adequate quantity of the representative pulverized soil over the 2 in. - $\frac{3}{4}$ in. (50- and 19.0-mm) sieves. Determine the mass of the material passing the 2 in. (50-mm) sieve and retained on the $\frac{3}{4}$ in. (19.0-mm) sieve and replace it with an equal mass of material passing the $\frac{3}{4}$ in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve. Take the material for replacement from the remaining portion of the sample.

- 8.3 Select a representative sample, having a mass of approximately 11 lb (5 kg) or more, of the soil prepared as described in Sections 8.1 and 8.2.

9. PROCEDURE

- 9.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 percentage points below optimum moisture content.

- 9.2 Form a specimen by compacting the prepared soil in the 4-in. (101.60-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or similar device having a face diameter of approximately 2 in. (50 mm). Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device, and be evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil when a sleeve-type rammer is used, or from 12 in. (305 mm) above the approximate elevation of each finely compacted layer when a stationary mounted type rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation (Note 6).
- 9.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller sized material. Determine the mass of the mold and moist soil in kilograms to the nearest 5 grams, or determine the mass in pounds to the nearest 0.01 pounds. For molds conforming to tolerances given in Section 3.1.1 and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 1060, and record the result as the wet density, W_1 , in kilograms per cubic meter, of compacted soil. For molds conforming to tolerances given in Section 3.1.1 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, and record the result as the wet density, W_1 , in pounds per cubic foot, of compacted soil. For used molds out of tolerance by not more than 50 percent (3.1.3), use the factor for the mold as determined in accordance with Section 8 (Calibration of Measure), AASHTO T 19/T 19M.
- 9.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, determine the mass immediately and dry in accordance with T 255 or T 265, Laboratory Determination of Moisture Content of Soils, to determine the moisture content, and record the results.
- 9.4 Thoroughly break up the remainder of the material until it will pass a $3/4$ in. (19.0-mm) sieve and 90 percent of the soil aggregations will pass a No. 4 (4.75-mm) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points, and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet mass, W_1 , per cubic foot (cubic meter) of compacted soil (Note 7).

METHOD D

10. SAMPLE

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

11. PROCEDURE

- 11.1 Follow the same procedure as described for Method C in Section 9, except for the following: Form a specimen by compacting the prepared soil in the 6-in. (152.4-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. For molds conforming to tolerances given in Section 3.1.2, and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 471, and record the result as the wet density, W_1 , in kilograms per cubic meter, of compacted soil. For molds conforming to tolerances given in Section 3.1.2, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.33, and record the result as the wet density, W_1 , in pounds per cubic foot, of the compacted soil. For used molds out of tolerance by not more than 50 percent (Section 3.1.3), use the factor for the mold as determined in accordance with Section 9 (Calibration of Measure), AASHTO T 19/T 19M.

CALCULATIONS AND REPORT

12. CALCULATIONS

- 12.1 Calculate the moisture content and the dry unit mass of the soil as compacted for each trial, as follows:

$$w = \frac{A - B}{B - C} \times 100$$

and

$$W = \frac{W_1}{w + 100} \times 100$$

where:

- w = percentage of moisture in the specimen, based on oven dry mass of soil;
- A = mass of container and wet soil;
- B = mass of container and dry soil;
- C = mass of container;
- W = dry mass, in kilograms per cubic meter of compacted soil, or pounds per cubic foot of compacted soil; and
- W_1 = wet mass, in kilograms per cubic meter of compacted soil, or pounds per cubic foot of compacted soil.

13. MOISTURE-DENSITY RELATIONSHIP

- 13.1 The calculations in Section 12.1 shall be made to determine the moisture content and corresponding oven-dry unit mass (density) in kilograms per cubic meter or pounds per cubic foot of the compacted samples. The oven-dry densities (unit mass) of the soil shall be plotted as ordinates and the corresponding moisture content as abscissas.

13.2 Optimum Moisture Content — When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in Section 13.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the “optimum moisture content” of the soil under the above compaction.

13.3 Maximum Density — The oven-dry density in pounds per cubic foot (kilograms per cubic meter) of the soil at optimum moisture content shall be termed “maximum density” under the above compaction.

14. REPORT

14.1 The report shall include the following:

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

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

14.1.3 The maximum density in pounds per cubic foot to the nearest whole number (kilograms per cubic meter to the nearest 10 kg/m³).

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

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

15. PRECISION STATEMENT

15.1 Repeatability — (Single operator) – Two results obtained by the same operation on the same sample in the same laboratory using the same apparatus, and on different days should be considered suspect if they differ by more than 10 percent of their mean for optimum moisture content and 2.2 lb/ft³ (35 kg/m³) for maximum density.

15.2 Reproducibility — (Multi-Laboratory) – Two results obtained by different operators in different laboratories should be considered suspect if they differ by more than 15 percent of their mean for optimum moisture and 4.5 lb/ft³ (72 kg/m³) for maximum density.

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 _____

Procedure Element

Yes

No

Sample Preparation

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

Procedure

- | | | |
|--|-------|-------|
| 1. Sample mixed with water to approximately 4 percent below expected optimum moisture content? | _____ | _____ |
| 2. Layer of soil placed in mold with collar attached? | _____ | _____ |
| 3. Mold placed on rigid and stable foundation? | _____ | _____ |
| 4. Lightly tamp soil in mold? | _____ | _____ |
| 5. Soil compacted with 25 blows? | _____ | _____ |
| 6. Scrape sides of mold and evenly distributed on top of the layer? | _____ | _____ |
| 7. Soil placed and compacted in three equal layers? | _____ | _____ |
| 8. Collar removed and soil trimmed to top of mold with straightedge? | _____ | _____ |
| 9. Mass of mold and contents determined to appropriate precision? | _____ | _____ |
| 10. Wet mass of specimen multiplied by appropriate factor to obtain wet density (.03333 lbs/ft ³)? | _____ | _____ |
| 11. Soil removed from mold using sample extruder? | _____ | _____ |
| 12. Soil sliced vertically through center? | _____ | _____ |
| 13. Moisture sample removed from one cut face and moist mass determined immediately? | _____ | _____ |
| 14. Moisture sample mass of at least 100 g? | _____ | _____ |



WSDOT FOP for AASHTO T 119¹

Standard Test Method for Slump of Hydraulic-Cement Concrete

1. SCOPE

- 1.1 This test method covers determination of slump of concrete, both in the laboratory and in the field.
- 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 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.*
- 1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

T 141 Sampling Freshly Mixed Concrete

2.2 *ASTM Standards:*

C 172 Practice for Sampling Freshly Mixed Concrete

3. SUMMARY OF TEST METHOD

- 3.1 A sample of freshly mixed concrete is placed and compacted by rodding in a mold shaped as the frustum of a cone. The mold is raised, and the concrete allowed to subside. The distance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete.

4. SIGNIFICANCE AND USE

- 4.1 This test method is intended to provide the user with a procedure to determine slump of plastic hydraulic-cement concretes.

Note 1: This test method was originally developed to provide a technique to monitor the consistency of unhardened concrete. Under laboratory conditions, with strict control of all concrete materials, the slump is generally found to increase proportionally with the water content of a given concrete mixture, and thus to be inversely related to concrete strength. Under field conditions, however, such a strength relationship is not clearly and consistently shown. Care should therefore be taken in relating slump results obtained under field conditions to strength.

- 4.2 This test method is considered applicable to plastic concrete having coarse aggregate up to 1½ in. (37.5 mm) in size. If the coarse aggregate is larger than 1½ in. (37.5 mm) in size, the test method is applicable when it is performed on the fraction of concrete passing a 1½-in. (37.5-mm) sieve, with the larger aggregate being removed in accordance with the section titled “Additional Procedure for Large Maximum Size Aggregate Concrete” in Practice T 141.
- 4.3 This test method is not considered applicable to non-plastic and non-cohesive concrete.

¹This FOP is based on AASHTO T 119-99.

Note 2—Concretes having slumps less than 15mm ($\frac{1}{2}$ in.) may not be adequately plastic and concretes having slumps greater than about 230 mm (9 in.) may not be adequately cohesive for this test to have significance. Caution should be exercised in interpreting such results.

5. APPARATUS

5.1 **Mold** — The test specimen shall be formed in a mold made of metal not readily attacked by the cement paste. The metal shall not be thinner than 0.060 in. (1.5 mm) and if formed by the spinning process, there shall be no point on the mold at which the thickness is less than 0.045 in. (1.15 mm). The mold shall be in the form of the lateral surface of the frustum of a cone with the base 8 in. (200 mm) in diameter, the top 4 in. (100 mm) in diameter, and the height 12 in. (300 mm). Individual diameters and heights shall be within $\pm \frac{1}{8}$ in. (3.2 mm) of the prescribed dimensions. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles similar to those shown in Figure 1. The mold shall be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections. The mold shall be free from dents, deformation or adhered mortar. A mold which clamps to a nonabsorbent base plate is acceptable instead of the one illustrated provided the clamping arrangement is such that it can be fully released without movement of the mold and the base is large enough to contain all of the slumped concrete in an acceptable test.

5.1.1 Mold with alternative materials.

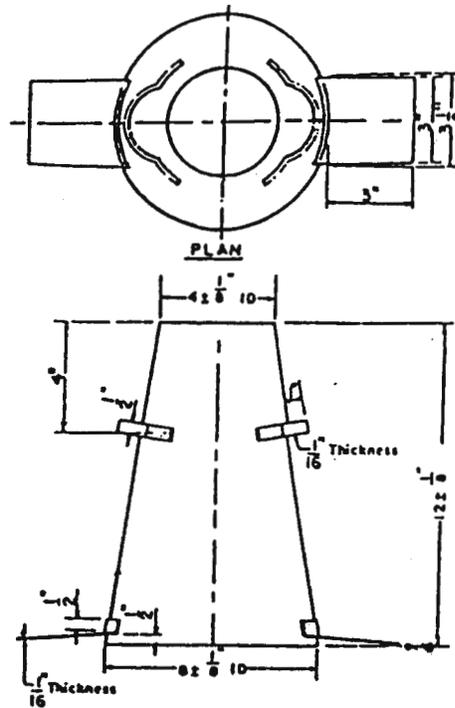
5.1.1.1 Molds other than metal are permitted if the following requirements are met: The mold shall meet the dimensional requirements of 5.1. The mold shall be sufficiently rigid to maintain the specified dimensions and tolerances during use, resistant to impact forces, and shall be nonabsorbent. The mold shall be demonstrated to provide test results comparable to those obtained when using a metal mold meeting the requirements of 5.1. Comparability shall be demonstrated on behalf of the manufacturer by an independent testing laboratory. Test for comparability shall consist of not less than 10 individual comparisons performed at each of 3 different slumps ranging from 2 in. (50 mm) to 6 in. (150 mm). No individual test results shall vary by more than 0.50 in. (15 mm) from that obtained using the metal mold. The average test results of each slump range obtained using the mold constructed of alternative material shall not vary by more than 0.30 in. (10 mm) from the average of test results obtained using the metal mold. If any changes in material or method of manufacture are made, tests for comparability shall be repeated.

5.1.1.2 If the condition of any individual mold is suspected of being out of tolerance from the as manufactured condition, a single comparative test shall be performed. If the test results differ by more than 0.50 in. (15 mm) from that obtained using the metal mold, the mold shall be removed from service.

5.2 **Tamping Rod** — The tamping rod shall be a round, straight steel rod $\frac{5}{8}$ in. (16 mm) in diameter and approximately 24 in. (600 mm) in length, having the tamping end or both ends rounded to a hemispherical tip, the diameter of which is $\frac{5}{8}$ in. (16 mm).

5.3 Torpedo leve.

5.4 Base — Flat, nonabsorbent, rigid surface.



Metric Equivalents										
mm	1.6	3.2	12.7	25.4	38.1	76.2	79.4	102	203	305
in.	1/16	1/2	1/2	1	1 1/2	3	3 1/8	4	8	12

Metric Equivalents										
mm	1.6	3.2	12.7	25.4	38.1	76.2	79.4	102	203	305
in.	1/16	1/8	1/2	1	1 1/3	3	3 1/8	4	8	12

**Mold for Slump Test
Figure 1**

6. SAMPLE

6.1 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.

7. PROCEDURE

7.1 Dampen the mold and place it on a firm, flat, nonabsorbent, level surface. It shall be held firmly in place during filling by the operator standing on the two foot pieces. From the sample of concrete obtained in accordance with Section 6, immediately fill the mold in three layers, each approximately one third the volume of the mold.

Note 3: One third of the volume of the slump mold fills it to a depth of 2⁵/₈ in. (67 mm); two thirds of the volume fills it to a depth of 6¹/₈ in. (155 mm).

7.2 Rod each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross section of each layer. For the bottom layer this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spirally toward the center. Rod the bottom layer throughout its depth. Rod the second layer and the top layer each throughout its depth, so that the strokes just penetrate into the underlying layer.

- 7.3 In filling and rodding the top layer, heap the concrete above the mold before rodding is started. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the concrete by means of a screeding and rolling motion of the tamping rod.

Remove the mold immediately from the concrete by raising it carefully in a vertical direction. Raise the mold a distance of approximately 12 in. (300 mm) in 5 ± 2 seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of the filling through removal of the mold without interruption and complete it within an elapsed time of $2\frac{1}{2}$ min.

- 7.4 Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs (Note 4), disregard the test and make a new test on another portion of the sample.

Note 4: If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.

8. Report

- 8.1 Report the slump in terms of inches (millimeters) to the nearest $\frac{1}{4}$ in. (5 mm) of subsidence of the specimen during the test as follows:

~~Slump = 12 inches of height after subsidence~~

~~Slump = 300 mm of height after subsidence~~

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

9. Precision and Bias

9.1 Precision:

9.1.1 *Interlaboratory Test Method*—No interlaboratory test program has been run on this test method. Since it is not possible to provide equivalent concretes at various test sites free of errors from sources other than the slump measurement, a multilaboratory precision statement would not be meaningful.

9.1.2 *Multi-Operator Test Results*—Extensive field data¹ allow a statement regarding the multi-operator precision of this test method.

Test Range, 38 to 70 mm (1.5 to 2.76 in.)

Total number of samples, 2,304

Pooled repeatability Standard deviation (1S), 8 mm (0.30 in.)

95 percent Repeatability Limit (D2S), 21 mm (0.83 in.)

Therefore, results of two properly conducted tests by different operators in the same laboratory on the same material should not differ by more than 21 mm (0.83 in.). Due to the limited slump range in the concrete used in this test program, caution should be exercised in applying these precision values.

9.2 *Bias*—This test method has not bias since slump is defined in terms of this test method.

Note 5—The precision data are based upon the use of metal cones. No specific data are available for multi-operator test results with alternative cone materials.

AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD FOP FOR AASHTO T 152

01

Significance

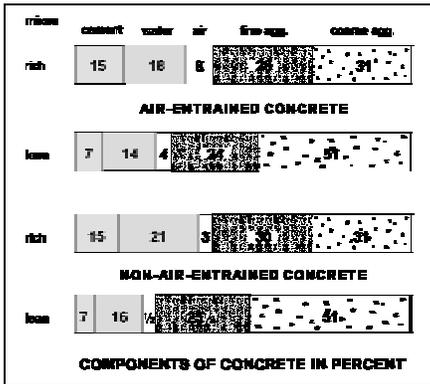
02

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.

03

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.

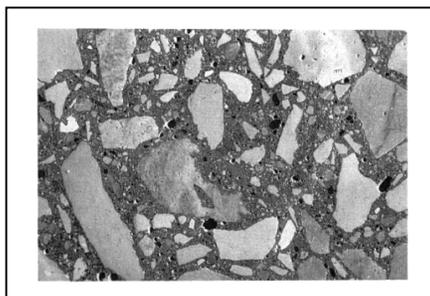
04



05

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 above the mix design value. Concrete proportioned for 5 percent air, for example, will be approximately 15 to 25 percent lower in strength if the air content were to double.

06



Air Voids

07

Scope

This procedure covers determination of the air content in freshly mixed portland cement concrete containing dense aggregates in accordance with AASHTO T 152. It is not for use with lightweight or highly porous aggregates. This procedure includes calibration of the air meter gauge, and two methods for calibrating the gauge are presented. Concrete containing aggregate that would be retained on the 50 mm (2 in) sieve must be wet



Apparatus

08

sieved. Sieve a sufficient amount of the sample over the 37.5 (1 1/2") sieve per AASHTO 141.

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)
 - Tamping rod: 5/8 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)
 - Strike-off bar: Approximately 12 in. x 3/4 in. x 1/8 in. (300 mm x 22 mm x 3 mm).
 - Strike-off Plate: A flat rectangular metal plate at least 1/4 in. (6 mm) thick or a glass or acrylic plate at least 1/2 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 1/16 in. (1.5 mm).
- Note 1:* Use either the strike-off bar or strike-off plate; both are not required.
- 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

09

Note 2: There are two methods for calibrating the air meter. They are different only in the means by which the water removed from the gauge in Step 8 is measured. Method 1 relies on a mass measurement, while Method 2 relies on a volume measurement.



Meter cover with petcocks



Gauge reading zero

- 10 1. Determine the mass of the dry, empty air meter base and cover assembly (Method 1 only).
- 11 2. Fill the base nearly full with water.
- 12 3. Screw the short piece of straight tubing into the threaded petcock hole on the underside of the cover, and clamp the cover on the base with the tube extending down into the water.
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 (Method 1 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. Remove 5 percent of water in the base of the air meter. There are ~~two~~ three methods for doing this.

Method 1:

- Determine the mass of the water in the base by subtracting 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.
- Remove water until the mass of the air meter base, lid assembly, and water has been reduced by the mass of the water that must be removed.



Air meter gauge

15

Method 2:

- Knowing the volume of the air meter, calculate 5 percent of this volume, by multiplying it by 0.05. This is the volume of the water that must be removed.
- Remove water from the air meter equal to the volume calculated above.

Note 3: A calibration vessel(s) of known volume that are used for this purpose. Calibration vessel(s) should be brass, not plastic, and must be protected from crushing or denting.

If a 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.

Place the calibration vessel upright at the bottom of the pressure meter base. It is best to place the calibration vessel after the base is filled with water. Keep the calibration vessel upright. Place the cover on the base, latch, top off the meter with water, and continue to operate the meter as in a normal test.

Using two calibration vessels will allow checking twice the air content. The small hole at the bottom of the calibration vessel must be kept unobstructed. A very small amount of water may be left in the vessel after a test, but shake it out before making another test.

16

9. 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.

10. 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 \pm 0.1 percent. If the gauge is outside that range, the meter needs adjustment. The adjustment could involve adjusting the starting point so that the gauge reads ~~5.0 \pm 0.1~~ 5.0 \pm 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.

11. 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 4: Calibration shall be performed at the frequency required by the agency. 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.

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

Method 3:

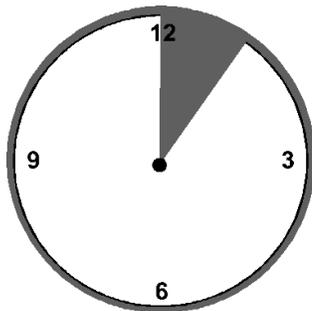
- Screw the curved tube supplied with the air meter into the outer end of the petcock and, by pressing on the thumb lever and controlling flow with the petcock lever, fill the 5 percent calibrating vessel (345 ml) level full of water from the base.

- Release the air at the free petcock. Open the other petcock and let the water in the curved pipe run back into the base. There is now 5 percent air in the base.
- With petcocks open, pump air pressure in the exact manner as outlined in step 6 above. Close petcocks and immediately press the thumb lever. Wait a few seconds for exhaust air to warm to normal temperature, and for the needle to stabilize. The dial should now read 5 percent.
- If two or more consistent tests show that the gauge reads incorrectly at 5 percent by more than ± 0.2 percent, then remove the gauge glass and reset the dial hand to 5 percent.
- When the gauge hand reads correctly at 5 percent, additional water may be withdrawn in the same manner to check the results at 10 percent, 15 percent, and 20 percent.
- Remove the extension tubing from threaded petcock hole before starting tests on concrete.
- The above calibration procedure shall be performed at least at six-month intervals, at the start of a project, or weekly when meter is used during concrete placement.
- 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.

Procedure - General

17

Note 6: There are two methods of consolidating the concrete – rodding and internal 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. The internal vibration procedure follows this general procedure.



5 Minutes!



Consolidation

18

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. With concrete using 1½ in. (37.5mm) or larger aggregate, the 1½ in. (37.5mm) aggregate must be removed.

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

19

2. Dampen the inside of the air meter base.
3. Fill the base approximately 1/3 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 2/3 full.
7. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 1 in. (25 mm) into the bottom layer.

20

21



Tapping measure



Strike off

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 1/8 in. (3 mm) above the rim. If there is a great excess of concrete, remove a portion with the 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.
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 through the funneled petcock until water emerges from the second petcock.
17. Jar the air meter gently until no air bubbles appear to be coming out of the second petcock.
18. Close the air bleeder valve and pump air into the air chamber until the needle goes past the starting point. 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 starting point. Close the air bleeder valve.
20. Close both petcocks.
21. Open the main air valve.
22. Tap the sides of the base smartly with the mallet.



Tapping air meter gauge

25

23. Lightly tap the gauge to settle the needle, and then read the air content to the nearest 0.1 percent.

24. Close the main air valve.

26

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

27

1. Perform Steps 1 and 2 in the general procedure.

2. Fill the base approximately half full.

3. 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.

28

4. Fill the base a bit over full.

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

6. Return to Step 11 of the general procedure and continue.

Report

29 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).

Note 11: Some agencies require an aggregate correction factor in order to determine total percent entrained air.

Aggregate Correction Factor

WSDOT requires the use of an aggregate correction factor to determine the total percent entrained air as follows:

$$A_s = A_1 - G$$

A_s = Air content of sample tested, percent

A_1 = Apparent air content of sample tested, percent

G = Aggregate correction factor from the mix design, percent

Tips!

- 30
- Start within 5 minutes of obtaining sample.
 - Use a calibrated air meter.
 - Protect the calibration vessel from damage.
 - Consolidation technique depends on slump. Rodding and/or vibration may be appropriate for different slumps.

31

Performance Exam Checklist

***Air Content of Freshly Mixed Concrete by the Pressure Method
FOP for AASHTO T 152***

Participant Name _____

Exam Date _____

Procedure Element

Yes

No

- | | | |
|--|-------|-------|
| 1. Representative sample selected? | _____ | _____ |
| 2. Container filled in three equal layers, slightly overfilling the last layer? | _____ | _____ |
| 3. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes? | _____ | _____ |
| 4. Bottom layer rodded throughout its depth, without forcibly striking the bottom of the container? | _____ | _____ |
| 5. Middle and top layers rodded, each throughout their depths and penetrating 1 in. (25 mm) into the underlying layer? | _____ | _____ |
| 6. Sides of the container tapped 10 to 15 times with the mallet after rodding each layer? | _____ | _____ |
| 7. Concrete struck off level with top of container using the bar and rim cleaned off? | _____ | _____ |
| 8. Inside of cover cleaned and moistened before clamping to base? | _____ | _____ |

Using a Type B Meter

- | | | |
|---|-------|-------|
| 9. Both petcocks open? | _____ | _____ |
| 10. Air valve closed between air chamber and the bowl? | _____ | _____ |
| 11. Water injected through petcock until it flows out the other petcock? | _____ | _____ |
| 12. Water injection into the petcock continued while jarring and tapping the meter to insure all air is expelled? | _____ | _____ |
| 13. Air pumped up to initial pressure line? | _____ | _____ |
| 14. A few seconds allowed for the compressed air to stabilize? | _____ | _____ |
| 15. Gauge adjusted to the initial pressure? | _____ | _____ |
| 16. Both petcocks closed? | _____ | _____ |
| 17. Air valve opened between chamber and bowl? | _____ | _____ |
| 18. Sides of bowl tapped with the mallet? | _____ | _____ |

Procedure Element

Yes

No

19. Air percentage read after lightly tapping the gauge to stabilize the hand?

20. Air valve closed and then petcocks opened to release pressure before removing the cover?

21. Aggregate correction factor applied if required?

22. Air content recorded to 0.1 percent?

Comments:

First attempt: Pass Fail

Second attempt: Pass Fail

Signature of Examiner _____

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WSDOT FOP for AASHTO T 166¹

Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens

1. SCOPE

- 1.1 This method of test covers the determination of bulk specific gravity of specimens of compacted asphalt mixtures as defined in M 132, Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases.
- ~~1.2 This method should not be used with samples that contain open or inter-connecting voids and/or absorb more than 2 percent of water by volume, as determined in Sections 5.2 or 8.2 herein.~~
- 1.3 The bulk specific gravity of the compacted asphalt mixtures may be used in calculating the unit mass of the mixture.
- 1.4 The values stated in English units are to be regarded as the standard.

Note: Method A shall be used for laboratory compacted samples, and field samples from the gyratory compactor.

Method C shall be used for cores.

2. TEST SPECIMENS

- 2.1 Test specimens may be either laboratory-molded asphalt mixtures or from HMA pavements. The mixtures may be surface or wearing course, binder or leveling course, or hot-mix base.
- 2.2 *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.
- 2.3 Specimens shall be taken from pavements with core drill, diamond or carborundum saw, or by other suitable means.
- 2.4 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.
- 2.5 Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.
- 2.6 If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage specimens.

¹This Test Method is based on AASHTO T 166-00.

METHOD A

3. APPARATUS

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

- 4.1 Dry the specimen to a constant mass (Note 1). Cool the specimen to room temperature at $77 \pm 9^\circ\text{F}$ ($25 \pm 5^\circ\text{C}$), and record the dry mass as A. Immerse each specimen in water at $77 \pm 1.8^\circ\text{F}$ ($25 \pm 1^\circ\text{C}$) 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, 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 $125 \pm 5^\circ\text{F}$ ($52 \pm 3^\circ\text{C}$) does not alter the mass by more than 0.05 percent. Samples saturated with water shall initially be dried overnight at $125 \pm 5^\circ\text{F}$ ($52 \pm 3^\circ\text{C}$) and then weighed at 2-hour drying intervals. Recently molded laboratory samples 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.

5. CALCULATION

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

$$\text{Bulk Sp. Gr.} = \frac{A}{B-C}$$

where:

A = mass in grams of sample in air,

B = mass in grams of surface-dry specimen in air,

C = mass in grams of sample in water.

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

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

- 5.3 If the percent water absorbed by the specimen in Section 5.2 exceeds 2 percent, use T 275 (Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens) to determine the bulk specific gravity.

METHOD B

6. APPARATUS

- 6.1 *The weighing device* shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.
- 6.2 *Water Bath*, Thermostatically controlled so as to maintain the bath at $77 \pm 0.9^\circ\text{F}$ ($25 \pm 0.5^\circ\text{C}$).
- 6.3 *Thermometer*, ASTM 17 C (17 F), having a range of 66 to 80°F (19 to 27°C), graduated in 0.2°F (0.1°C) subdivisions.
- 6.4 *Volumeter*, ¹ calibrated to 1200 mL or an appropriate capacity depending upon the size of test sample. The volumeter shall have a tapered lid with a capillary bore.

7. PROCEDURE

- 7.1 Dry the specimen to constant mass. (See Note 1.) Cool the specimen to room temperature at $77 \pm 9^\circ\text{F}$ ($25 \pm 5^\circ\text{C}$) and record the dry mass as A. Immerse the specimen in the water bath and let saturate for at least 10 minutes. At the end of the 10-minute period, fill a calibrated volumeter with distilled water at $77 \pm 1.8^\circ\text{F}$ ($25 \pm 1^\circ\text{C}$). Remove the saturated specimen from the water bath, damp dry the saturated specimen by blotting with a damp towel and as quickly as possible. Weigh the specimen and record the surface-dry mass as B. Any water that seeps from the specimen during the weighing operation is considered a part of the saturated specimen.
- 7.2 Place the specimen into the volumeter, and let it stand for at least 60 seconds. Bring the temperature of the water to $77 \pm 1.8^\circ\text{F}$ ($25 \pm 1^\circ\text{C}$), and cover the volumeter, making certain that some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry with a dry absorbent cloth and weigh the volumeter and contents (Note 4). Record this weight as E.

Note 4: If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the mass of saturated damp dry specimen B can be taken. Then the volumeter containing the saturated specimen and water E can be weighed. The dry mass of the specimen A can be determined last.

Note 5: Method B is not acceptable to be used for specimens that have more than 6 percent air voids.

8. CALCULATIONS

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

$$\text{Bulk Specific Gravity} = \frac{A}{B+D-E}$$

where:

A = mass in grams of dry specimen,

B = mass in grams of surface-dry specimen,

D = mass in grams of volumeter filled with water at $77 \pm 1.8^\circ\text{F}$ ($25 \pm 1^\circ\text{C}$), and

E = mass in grams of volumeter filled with the specimen and water at $77 \pm 1.8^\circ\text{F}$ ($25 \pm 1^\circ\text{C}$).

- 8.2 Calculate the percent water absorbed by the specimen (on a volume basis) as follows:

$$\text{Percent Water Absorbed by Volume} = \frac{B-A}{B+D-E} \times 100$$

- 8.3 If the percent of water absorbed by the specimen as calculated in subsection 8.2 exceeds 2 percent, use T 275 (Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens) to determine the bulk specific gravity.

METHOD C (RAPID TEST)

9. PROCEDURE

- 9.1 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.
- 9.2 The testing procedure shall be the same as given in Sections 4 and 7 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.

- 9.3 Place the specimen in a large flat bottom drying pan of known mass. Place the pan and specimen in a $230 \pm 9^\circ\text{F}$ ($110 \pm 5^\circ\text{C}$) 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 1/4 in. (6.4 mm). Place the separated specimen in the 230°F (110°C) oven and dry to a constant mass. Constant mass shall be defined as the weight at which further drying at $230 \pm 9^\circ\text{F}$ ($110 \pm 5^\circ\text{C}$) does not alter the mass by more than 0.05 percent when weighed at 2-hour intervals.
- 9.4 Cool the pan and specimen to room temperature at $77 \pm 9^\circ\text{F}$ ($25 \pm 5^\circ\text{C}$). 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.

10. CALCULATIONS

10.1 Calculate the bulk specific gravity in Sections 5.1 and 8.1.

11. REPORT

11.1 The report shall include the following:

11.1.1 *The method used (A, B, or C).*

11.1.2 *Bulk Specific Gravity reported to the nearest thousandth.*

11.1.3 *Absorption reported to the nearest hundredth.*

12. PRECISION

12.1 Duplicate specific gravity results by the same operator should not be considered suspect unless they differ more than 0.02.

Performance Exam Checklist

Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-dry Specimens
AASHTO T 166

Participant Name _____

Exam Date _____

Procedure Element	Yes	No
Method A (For use with laboratory compacted specimens.)		
1. Compacted specimen cooled to room temperature, 77 +/- 9 F, and record the dry mass?	_____	_____
2. Immerse each specimen in water at 77 +/- 2 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 +/- 9 F to the nearest 0.1 gram?	_____	_____
4. Calculate the bulk specific gravity of the specimens by following the calculation in AASHTO T166 (Section 5.1)?	_____	_____
 Method C (For use with pavement cores and chunks.)		
1. Immerse specimen in water at 77 +/- 2 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 +/- 9 F to the nearest 0.1 gram?	_____	_____
3. Place specimen in container (noting the empty container weight), then into an oven set at 230 +/- 9 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 +/- 9 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. Calculate the bulk specific gravity of the specimen by following the calculation in AASHTO T166 (Section 5.1)?	_____	_____
First attempt: Pass <input type="checkbox"/> Fail <input type="checkbox"/> Second attempt: Pass <input type="checkbox"/> Fail <input type="checkbox"/>		

Signature of Examiner _____

WSDOT FOP for AASHTO T 224¹***Correction for Coarse Particles in the Soil
Compaction Test*****1. SCOPE**

- 1.1. This method describes a procedure for adjusting the densities of soil and soil aggregate mixtures to compensate for differing percentages of coarse particles retained on either the No.4 (4.75-mm) or 3/4 in. (19.0-mm) sieve. This is necessary to adjust either the field wet density to a dry density of the material passing these sieves or the reverse, by adjusting the lab density to the field density when doing compaction control testing. Comparisons are made by comparing the field densities with the maximum dry density as determined by T 99 or T 180.

The standard for the WSDOT is to use AASHTO T 99 Method A.

The Standard Specifications define non-granular material as 30% or less retained on the No. 4 (4.75-mm) sieve.

- 1.2. Two methods are available for correction, either, lab to field or field to lab density. The method specified in Section 4.1 adjusts the compacted lab density to the field density. The method specified in Section 4.2 adjust the field wet density to dry density of the fine fraction and compares its results with the compacted lab density.

WSDOT uses the calculation specific in section 4.1 for adjusting the compacted lab density to the field density. Appendix B contains a nomograph for this adjustment.

- 1.3. This test method applies to soil mixtures that have 30 percent or less retained on the No. 4 (4.75-mm) sieve, when Method A or B of T 99 or T 180 is used, or mixtures that have 30 percent or less retained on the 3/4 in. (19.0 mm) sieve, when Method C or D of T 99 or T 180 is used. The material retained on these sieves shall be defined as oversize particles (coarse particles).
- 1.4. This method applies to soils with any percentage of oversize particles as specified in Section 1.3. However, the correction may not be of practical significance for soils with only a small percentage of oversize particles. The person or agency specifying this method shall specify a minimum percentage of oversize particles below which the method need not be applied. If a minimum percentage is not specified, this method shall be applied to samples with more than 5 percent by weight of oversize particles.
- 1.5. The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off to the nearest 1 pcf (10 kg/m³), according to R 11, Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values.
- 1.6. The values stated in SI units are to be regarded as the standard.

¹This FOP is based on AASHTO T 224-00

2. REFERENCE DOCUMENTS

2.1. AASHTO Standards:

- R 11, Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 99, The 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 217, Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester
- T 255, Total Moisture Content of Aggregate by Drying
- T 265, Laboratory Determination of Moisture Content of Soils
- T 272, Family of Curves-One Point Method

3. OUTLINE OF METHOD

- 3.1. When Method A or Method B of T 99 or T 180 is employed, the total field wet density is compared with the dry density of the soil particles passing the No. 4 (4.75-mm) sieve.
- 3.2. When Method C or Method D of T 99 or T 180 is employed, the total field wet density is compared with the dry density of the soil particles passing the 3/4 in. (19.0-mm) sieve.
- 3.3. Significant figures are as follows:
 - 3.3.1. Adjusted wet density of the fine material passing the No.4 (4.75-mm) sieve, Methods A and B; or 3/4 in.(19.0-mm) sieve, Method C and D; (D_f) 0.1 pcf (1 kg/m³).
 - 3.3.2. Bulk specific gravity of the coarse material on the 4.75-mm (No. 4) sieve, Methods A and B; or 3/4 in. (19.0-mm) sieve, Methods C & D; (G_m) 0.01.
 - 3.3.3. Percent by mass, of coarse and fine particles, of material retained and passing the No. 4 (4.75-mm) sieve, Methods A & B; or 3/4 in. (19.0-mm) sieve, Methods C and D; (P_c) and (P_f) 0.1 percent.
 - 3.3.4. In-place (field) wet density of the total sample (D) 0.1 pcf (1 kg/m³).

4. ADJUSTMENT EQUATION

4.1. Compacted Laboratory Dry Density Corrected to Field Dry Density

- 4.1.1. This Section corrects the laboratory density obtained by either T 99 or T 180 for the moisture content and density of the material retained on the No. 4 (4.75-mm) sieve, Methods A & B; or the material retained on the 3/4 in. (19.0-mm) sieve, Methods C and D. The maximum lab dry density, adjusted for oversized particles and total moisture content are compared with the field dry density and field moisture content. This method is limited to field samples containing 40 percent or less for material retained on the No. 4 (4.75-mm) sieve, Methods A and B; or 30 percent or less of material retained on the 3/4 in. (19.0-mm) sieve, Methods C and D.

- 4.1.2. Determine the moisture content of the fine particles and oversize particles of the material used during compaction. The moisture contents can be determined by either T 265, T 217 or T 255. The moisture content of the oversize material retained on the sieve can be assumed to be two (2) percent for most construction applications. If the moisture content of the oversized material is generally known, substitute that moisture content in the calculations. It is recommended if drying equipment is available, determine the actual moisture contents. Calculate the moisture contents according to the calculations specified in T 265.
- 4.1.3. Calculate the dry mass of the coarse and fine particles as follows:

$$M_D = M_M / (1 + MC)$$

where:

M_D = mass of dry material (fine or oversize particles),

M_M = mass of moist material (fine or oversize particles),

MC = moisture content of respective fine or oversized particles, expressed as a decimal.

Calculate the percentage of the fine particles and oversized particles by dry weight of the total sample as follows:

$$P_f = 100 M_{DF} / (M_{DF} + M_{DC})$$

and

$$P_c = 100 M_{DC} / (M_{DF} + M_{DC})$$

where:

P_f = percent of fine particles, of sieve used, by weight,

P_c = percent of oversize particles, of sieve used, by weight,

M_{DF} = mass of dry particles, and

M_{DC} = mass of oversize particles.

- 4.1.4. Calculate the corrected moisture content and corrected dry density of the total sample (combined fine and oversized particles) as follows:

$$MC_T = (MC_f P_f + MC_c P_c) / 100$$

where:

MC_T = corrected moisture content of the combined fine and oversized particles, expressed as a decimal,

MC_f = moisture content of the fine particles, expressed as a decimal,

MC_c = moisture content of the oversize particles, expressed as a decimal,

and

$$\text{Metric} = D_a = 100 D_f k / (D_f P_c + k P_f)$$

$$\text{English} = D_a = D_f k / (D_f P_c + k P_f)$$

where:

D_d = corrected total dry density (combined fine and oversized particles) kg/m^3 (pcf),

D_f = dry density of the fine particles kg/m^3 (pcf),

P_c = percent of oversize particles, of sieve used, by weight,

P_f = percent of fine particles, of sieve used, by weight,

$k = 1,000 * \text{Bulk Specific Gravity } (G_m) \text{ (oven dry basis) of coarse particles } (\text{kg/m}^3),$
 or $62.4 * \text{Bulk Specific Gravity } (G_m) \text{ (oven dry basis) of coarse particles (pcf).}$

Note 1 – If the specific gravity has been determined, this value may be used in the calculations. Determine the Bulk Specific Gravity according to T 85. For most construction activities the specific gravity can be assumed to be 2.60.

4.2 Field Wet Density Corrected to Compacted Laboratory Density

WSDOT has Deleted this section

5.1. Since this correction for coarse particles involves no testing but instead utilizes the results of other tests and mathematically combines the results, determination of the precision and accuracy is not applicable.

5. PRECISION

5.1. Since this correction for coarse particles involves no testing but instead utilizes the results of other tests and mathematically combines the results, determination of the precision and accuracy is not applicable.

APPENDIX A

A1. NOTES

A1.1. These methods, described for coarse particle correction, are applicable to one type of soil and soil aggregate material only. If the characteristic of the material changes, then a moisture density relationship (T 99 or T 180) test is performed to determine a new maximum density.

A1.2. T 272 describes the methods for determining different maximum densities of soil and soil-aggregate materials which reveal certain similarities and trends characteristic of the material type and source.

A1.2.1. Utilization of a Family of Curves-When using the One Point Method (T 272), Note 3 does not apply. The percentage of oversized particles, when performing the density of soil and soil aggregate in-place, must be determined to adjust the T 99 or T 180 maximum density to compensate for this percentage.

APPENDIX B

WSDOT has added the following nomograph

B1. SOLUTION

- B.1.1. The solution to this equation by nomograph is shown in Figure 1, wherein the maximum density of material passing the No. 4 (4.75 mm) sieve (Section 3.1) determined in the laboratory test is plotted and a line is drawn from this point to a point on the line representing the bulk specific gravity of the coarse particles. When the percentage of coarse particles contained in a field density of soil and soil-aggregate in-place has been determined and plotted on the above line as the abscissa on the chart (Figure 1), the ordinate will give the maximum laboratory dry density corrected to the new percentage of coarse particles.
- B.1.2. Figures 2 and 3 illustrate a solution when Method C or Method D of T 99 or T180 is utilized (Section 3.2).

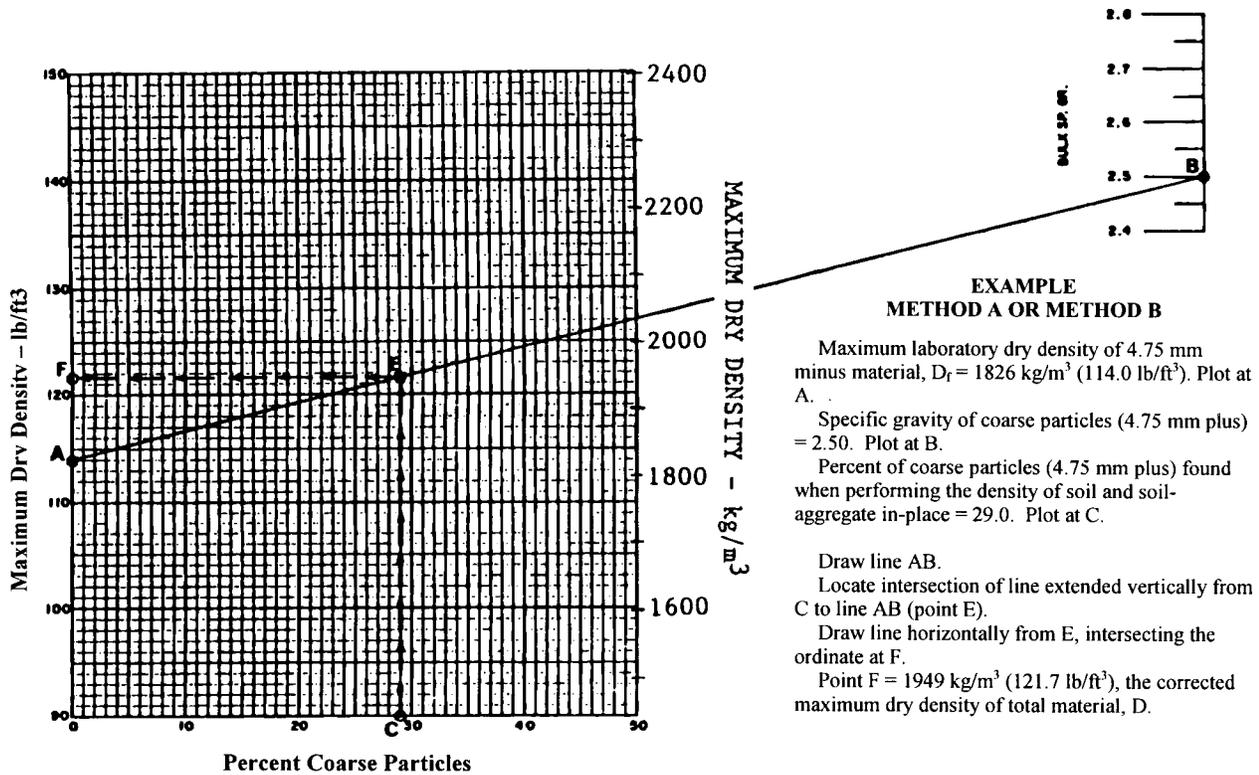


Figure 1. Density Correction Chart for Coarse Particles

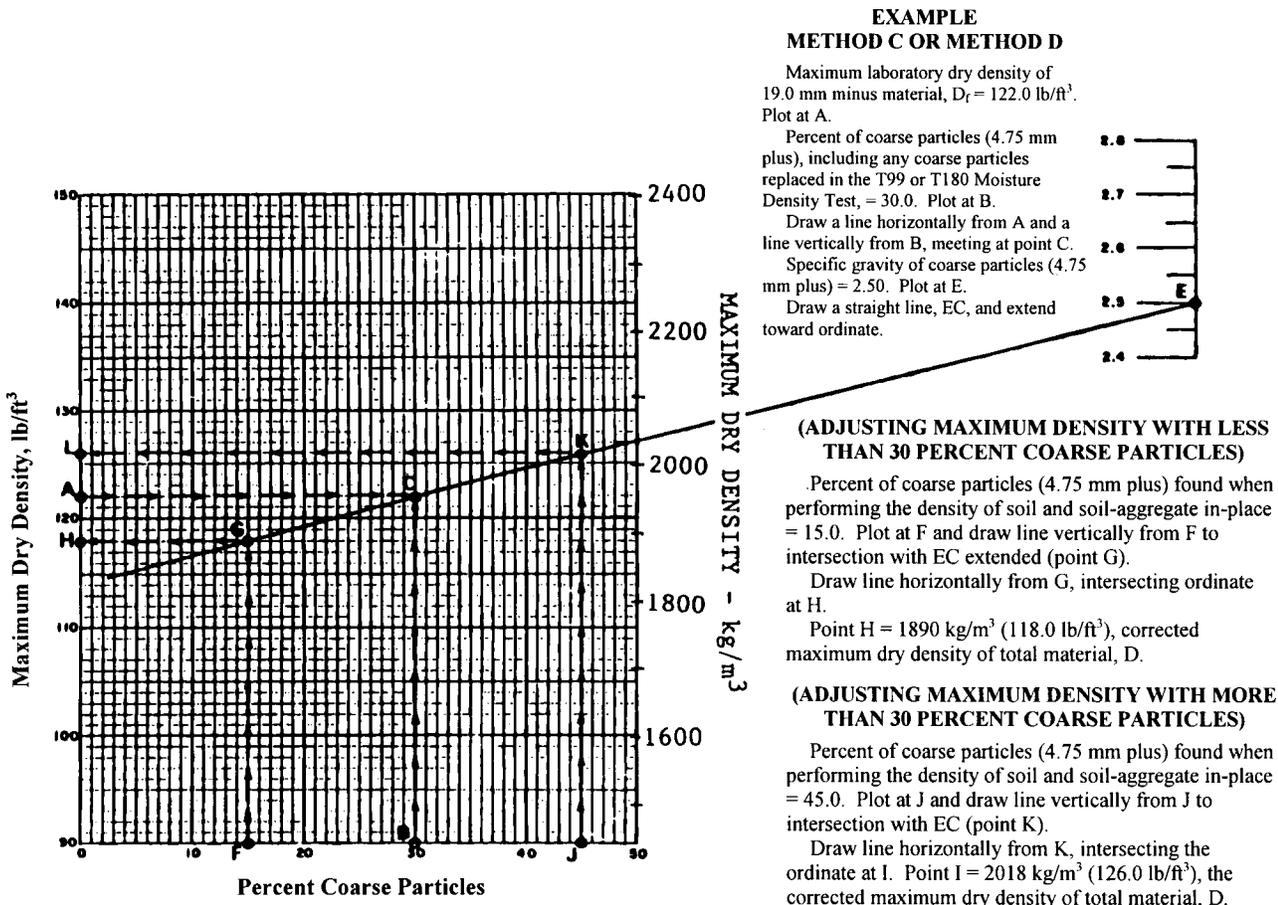


Figure 2. Density Correction Chart for Coarse Particles

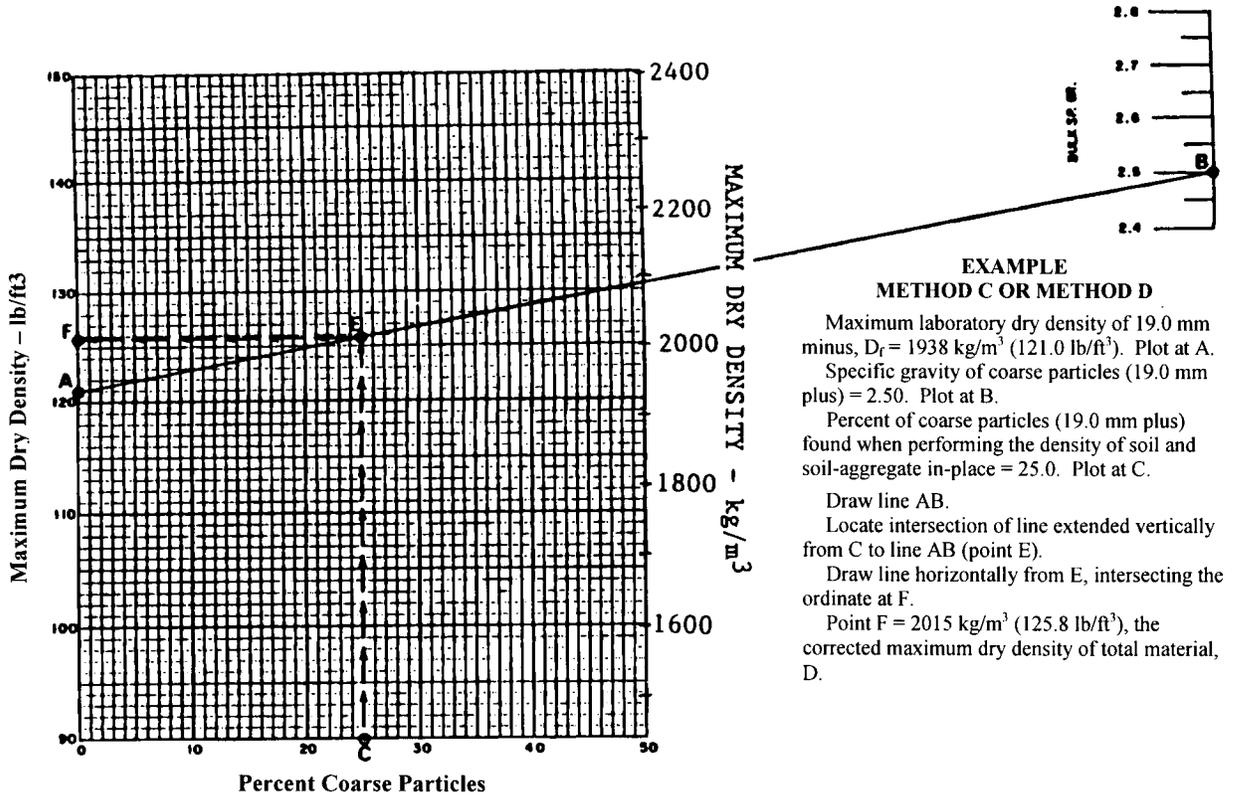
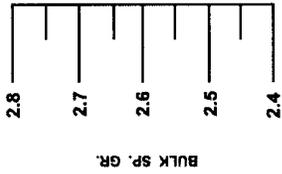


Figure 3. Density Correction Chart for Coarse Particles

B2. Report

Report the maximum density on DOT Form 350-074 and DOT Form 351-015.



If the specific gravity is unknown,
then use 2.67

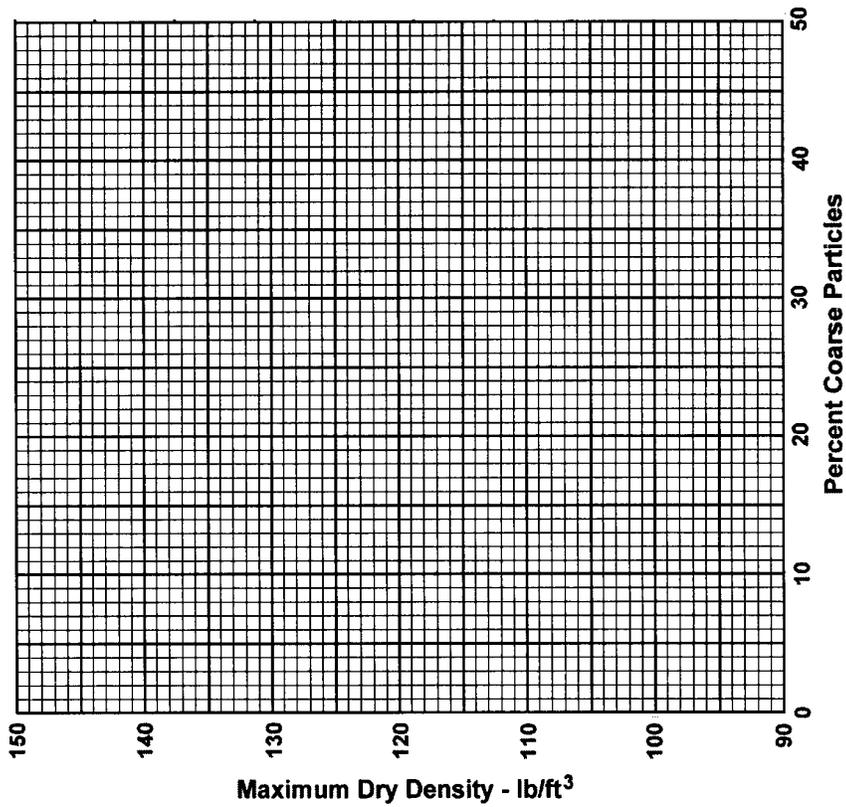


Figure 1. Density Correction Chart for Coarse Particles

Performance Exam Checklist

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

Participant Name _____

Exam Date _____

Procedure Element

Yes

No

Gradation Analysis

- | | | |
|---|-------|-------|
| 1. WSDOT SOP 615 used to identify percent of oversize material? | _____ | _____ |
| 2. Sample Dried to a SSD condition (dried until no visible surface moisture present) and mass recorded? | _____ | _____ |
| 3. Sample allowed to cool sufficiently prior to sieving? | _____ | _____ |
| 4. Sample was shaken by hand through a No. 4 sieve for a sufficient period of time? | _____ | _____ |
| 5. Recorded mass of material retained on No. 4 sieve? | _____ | _____ |
| 6. Calculated and recorded percent of material retained and passing No 4 sieve? | _____ | _____ |

Correction for Coarse Particles

- | | | |
|---|-------|-------|
| 7. Maximum density of material passing No. 4 sieve, as determined by AASHTO T-99, correctly plotted onto nomograph? | _____ | _____ |
| 8. Line correctly drawn from maximum density plot to the correct specific gravity? | _____ | _____ |
| 9. Percent of material retained on the No. 4 screen correctly plotted onto nomograph? | _____ | _____ |
| 10. Corrected maximum density correctly identified from the nomograph? | | |

Procedure Element

Yes

No

Equipment

11. Where required are calibration/verifications tags present on equipment used in this procedure?

12. All equipment functions according to the requirements of this procedure?

Comments:

First attempt:

Pass

Fail

Second attempt:

Pass

Fail

Signature of Examiner _____

WSDOT Test Method for AASHTO T 304¹***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.
 - 1.2.2. Individual Size Fractions (Method B)—This method uses each of three fine aggregate size fractions: (a) 2.36-mm (No. 8) to 1.18-mm (No.16); (b) 1.18-mm (No.16) to 600-um (No. 30); and (c) 600-um (No.30) to 300 um (No. 50). For this method, each size is tested separately.
 - 1.2.3. As-Received Grading (Method C) – This method uses that portion of the fine aggregate finer than a 4.75-mm (No. 4) sieve.
 - 1.2.4. See the section on Significance and Use for guidance on the method to be used.
- 1.3. The values stated in SI 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**AASHTO Standards**

FOP for AASHTO T 2, WSDOT FOP for AASHTO for the Sampling of Aggregates

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

FOP for AASHTO T 27/11, WAQTC FOP for AASHTO for the Sieve Analysis of Fine & Coarse Aggregates & Materials Finer Than 75 mm (No. 200) in Mineral Aggregates by Washing

T 84 Specific Gravity and Absorption of Fine Aggregate

¹This test method is based on AASHTO T304-96 (2000).

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 Terminology¹

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 (Method A or Method C) the percent void content is determined directly, and the average value from two runs is reported.

4.1.2. For the individual size fractions (Method B), the mean percent void content is calculated using the results from tests of each of the three individual size fractions.

5. SIGNIFICANCE AND USE

5.1. Methods A and B 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.

5.2. Method C measures the uncompacted void content of the minus 4.75-mm (No. 4) portion of the as-received material. This void content depends on grading as well as particle shape and texture.

- 5.3. The void content determined on the standard graded sample (Method A) is not directly comparable with the average void content of the three individual size fractions from the same sample tested separately (Method B). A sample consisting of single size particles will have a higher void content than a graded sample. Therefore, use either one method or the other as a comparative measure of shape and texture, and identify which method has been used to obtain the reported data. Method C does not provide an indication of shape and texture directly if the grading from sample to sample changes.
- 5.3.1. 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.
- 5.3.2. Obtaining and testing individual size fractions (Method B) is more time consuming and requires a larger initial sample than using the graded sample. However; Method B provides additional information concerning the shape and texture characteristics of individual sizes.
- 5.3.3. Testing samples in the as-received grading (Method C) may be useful in selecting proportions of components used in a variety of mixtures. In general, high void content suggests that the material could be improved by providing additional fines in the fine aggregate or more cementitious material may be needed to fill voids between particles.
- 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 Methods A, B, or C will be useful as an indicator of properties such as: the mixing water demand of hydraulic cement concrete; flowability, pumpability, or workability factors when formulating grouts or mortars; or, 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 $60 \pm 4^\circ$ 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.)

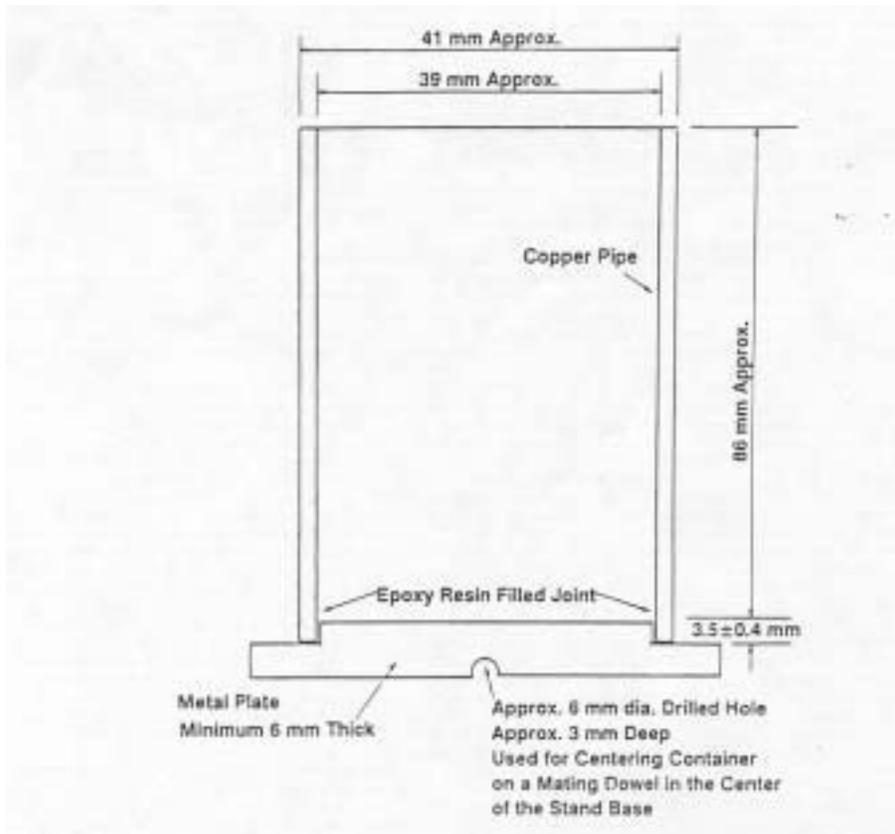


Figure 1 – Nominal 100-ml Cylindrical Measure

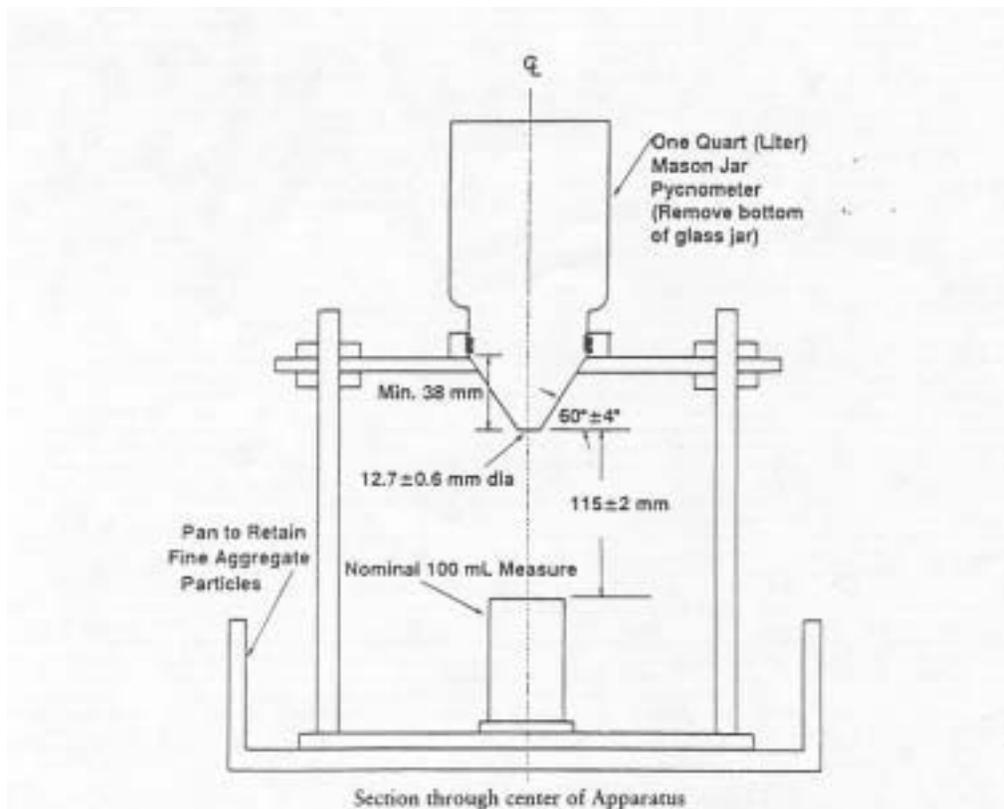


Figure 2 – Suitable Funnel Stand Apparatus with Cylindrical Measure in Place

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 4° 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.
- 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 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 ~~ASTM D 75~~ and FOP for AASHTO T 247 ~~ASTM C 702~~, or from sieve analysis samples used for FOP for AASHTO T 27/11 ~~ASTM C 136~~, or from aggregate extracted from a bituminous concrete specimen. For Methods A and B, the sample is washed over a 150-um (No. 100) or 75-um (No. 200) sieve in accordance with FOP for AASHTO T 27/11 ~~ASTM C 117~~ and then dried and sieved into separate size fractions according to FOP for AASHTO T 27/11 ~~ASTM C 136~~ procedures. Maintain the necessary size fractions obtained from one (or more) sieve analysis in a dry condition in separate containers for each size. For Method C, dry a split of the as-received sample in accordance with the drying procedure in FOP for AASHTO T 27/11 ~~ASTM C 136~~.

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 24°C. 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 ASTM C 136

<u>Individual Size Fraction</u>	<u>Mass, g</u>
2.36mm (No.8) to 1.18 mm (No. 16)	44
1.18 mm (No. 16) to 600 um (No. 30)	57
600 um (No. 30) to 300 um (No.50)	72
300 um (No. 50) to 150 um (No. 100)	<u>17</u>
	<u>190</u>

The tolerance on each of these amounts is ± 0.2 g.

9.2. *Method B – Individual Size Fractions* – Prepare a separate 190-g sample of fine aggregate, dried and sieved in accordance with FOP for AASHTO T 27/11 ASTM C 136, for each of the following size fractions:

<u>Individual Size Fraction</u>	<u>Mass, g</u>
2.36 mm (No. 8) to 1.18 mm (No. 16)	190
1.18 mm (No. 19) to 600 um (No. 30)	190
600 um (No. 30) to 300 um (No. 50)	<u>190</u>

The tolerance on each of these amounts is ± 1 g. Do not mix these samples together. Each size is tested separately.

- 9.3. *Method C – As Received Grading* – Pass the sample (dried in accordance with FOP for AASHTO T 27/11 ASTM C 136) through a 4.75-mm (No. 4) sieve. Obtain a 190 ± 1 -g sample of the material passing the 4.75-mm (No. 4) sieve for test.
- 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 4.75 mm (No. 4) material according to FOP for AASHTO T 84 ASTM C 128. 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 exceeded 0.05, determine the specific gravity of the individual 2.36 mm (No. 8) to 150 μ m (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 one 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:

$$U = \frac{V - (F/G)}{100} \times 100$$

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 .

11.3. *For the Individual Size Fractions (Method B)* calculate:

11.3.1. First, the average uncompacted voids for the determination made on each of the three size-fraction samples:

$U_1 =$ Uncompacted Voids, 2.36 mm (No. 8) to 1.18 mm (No. 16), percent;

$U_2 =$ Uncompacted Voids, 1.18 mm (No. 16) to 600 μ m (No. 30), percent; and

$U_3 =$ Uncompacted Voids, 600 μ m (No. 30) to 300 μ m (No. 50), percent.

11.3.2. Second, the mean uncompacted voids (U_m) including the results for all three sizes:

$$U_m = (U_1 + U_2 + U_3)/3$$

11.4. *For the As-Received grading (Method C)* calculate the average uncompacted voids for the two determinations and report the result as U_R .

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 one-tenth of a percent (0.1%).

12.1.2. The specific gravity value used in the calculations.

12.2. *For the Individual Size Fractions (Method B)* report the following percent voids to the nearest one-tenth of a percent (0.1%):

12.2.1. *Uncompacted Voids for size fractions:* (a) 2.36 mm (No. 8) to 1.18 mm (No. 16) (U_1); (b) 1.18 mm (No. 16) to 600 μ m (No. 30) (U_2); and (c) 600 μ m (No. 30) to 300 μ m (No. 50) (U_3).

12.2.2. Mean Uncompacted Voids (U_m).

12.2.3. Specific gravity value(s) used in the calculations, and whether the specific gravity value(s) were determined on a graded sample or the individual size fractions used in the test.

12.3. *For the As-Received Sample (Method C)* report:

12.3.1. The uncompacted voids (U_R) in percent to the nearest one-tenth of a percent (0.1%).

12.3.2. The specific gravity value used in the calculation.

12.4 Report Results using WSDOT Form 350-161

13. PRECISION AND BIAS

13.1. Precision:

13.1.1. The single-operator standard deviation has been found to be 0.13 percent voids (1S), using the graded standard silica sand as described in ASTM C 778. Therefore, results of two properly conducted tests by the same operator on similar samples should not differ by more than 0.37 percent (D2S).

13.1.2. The multilaboratory standard deviation has been found to be 0.33 percent (1S) using the standard fine aggregate as described in ASTM C 778. Therefore, results of two properly conducted tests by different laboratories on similar samples should not differ by more than 0.93 percent (D2S).

13.1.3. The above statements pertain to void contents determined on “graded standard sand” as described in Specification C 778, which is considered rounded, and is graded from 600 um (No. 30) to 150 um (No. 100, and may not be typical of other fine aggregates. Additional precision data are needed for test of fine aggregates having different levels of angularity and texture tested in accordance with this Test Method.

13.2. *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedures in this Test Method, bias has not been determined.

14. KEYWORDS

Angularity; fine aggregate; particle shape; sand; surface texture; void content.

¹Copies may be obtained from the American Concrete Institute, Box 19150, Detroit, MI 48219.

Performance Exam Checklist

**UNCOMPACTED VOID CONTENT OF FINE AGGREGATE
(AASHTO T-304-96)**

Participant Name _____

Exam Date _____

Procedure Element

Yes

No

CALIBRATION OF CYLINDRICAL MEASURE

- | | | |
|---|-------|-------|
| 1. Light coat of grease applied to top edge of the dry, empty cylindrical measure? | _____ | _____ |
| 2. Cylindrical measure, grease and glass plate weighed to the nearest 0.1 gram? | _____ | _____ |
| 3. Measure filled with freshly boiled, de-ionized water and temperature recorded? | _____ | _____ |
| 4. Glass plate placed on the measure and all air bubbles eliminated? | _____ | _____ |
| 5. Outer surface of the measure dried?. | _____ | _____ |
| 6. Combined mass of measure, glass plate, grease and water weighed to the nearest 0.1 gram? | _____ | _____ |
| 7. Grease and water removed and the combined mass of the clean, dry, empty measure weighed? | _____ | _____ |
| 8. Volume of the cylindrical measure determined as per Section 8, AASHTO T-304? | _____ | _____ |

SAMPLE PREPARATION (Method A)

Note: If Bulk Dry Specific Gravity is unknown, determine it on the minus 4.75 mm (No. 4-) material according to *AASHTO T-84*.

- | | | |
|---|-------|-------|
| 1. Field sample obtained per AASHTO T-2? | _____ | _____ |
| 2. Sample reduced to testing size per AASHTO T-248? | _____ | _____ |
| 3. Sample washed over No. 100 or No. 200 sieve in accordance with AASHTO T-27/11? | _____ | _____ |
| 4. Sample dried to constant weight? | _____ | _____ |
| 5. Standard Graded sample achieved per 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, AASHTO T-304? | _____ | _____ |

WSDOT FOP for AASHTO T 308¹***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 sample heating may be the convection method or the direct irradiation method. The aggregate remaining after burning can be used for sieve analysis using AASHTO T30.
- 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
T 2	Sampling of Aggregates
T 30	Mechanical Analysis of Extracted Aggregate
T 40	Sampling Bituminous Materials
T 110	Moisture or Volatile Distillates in Bituminous Paving Mixtures
T 168	Sampling Bituminous Paving Mixtures
T 248	Reducing Samples of Aggregate to Testing Size

2.2 *Manufacturer's Instruction Manual***2.3 WSDOT Standards**

<u>FOP for WAQTC TM 6</u>	<u>Moisture Content of Bituminous Mixes by Oven</u>
<u>FOP for AASHTO T 168</u>	<u>Sampling Bituminous Paving Materials</u>
<u>WSDOT 712</u>	<u>Reducing Samples of Hot Mix Asphalt to Testing Size</u>

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. The asphalt binder content is calculated as the difference between the initial mass of the asphalt mixture and the mass of the residual aggregate, the calibration factor, and moisture content. The asphalt content is expressed as mass percent of moisture-free mixture.

¹This procedure is based on AASHTO T 308-99.

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 samples for quality control, specification acceptance, and mixture evaluation studies. This method does not require the use of solvents. Aggregate obtained by this test method may be used for gradation analysis according to T 30.

5. SAMPLING

- 5.1 Obtain samples of aggregate in accordance with T 2.
- 5.2 Obtain samples of asphalt binder in accordance with T 40.
- 5.3 Obtain samples of freshly produced hot-mix asphalt in accordance with T 168.
- 5.4 ~~The test specimen shall be the end result of quartering a larger sample taken in accordance with T 248. The test specimen for asphalt content determination shall be the end result of a larger sample taken in accordance with FOP for AASHTO T 168.~~
- 5.5 ~~If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan in an oven at 12°C + 5°C (257°F + 9°F). If the mixture is not sufficiently soft to separate for testing, carefully heat the mixture in an oven until sufficiently soft, not to exceed 325°F (163°C).~~
- 5.6 ~~The size of the test sample shall be governed by the nominal maximum aggregate size of the mixture and shall conform to the mass requirement shown in Table 1. When the mass of the test specimen exceeds the capacity of the equipment used, the test specimen may be divided into suitable increments, tested, and the results appropriately combined for calculation of the asphalt binder content (weighted average). Specimen sizes shall not be more than 400 g greater than the minimum recommended specimen mass. The size of the test sample shall be governed by the nominal maximum aggregate size of the mixture and shall conform to the mass requirement shown in Table 1. The maximum sample size shall not exceed 4000g.~~

Note 1: Large samples of fine mixes tend to result in incomplete ignition of asphalt.

Table 1

Nominal Max. Agg. Size, mm	Sieve Size	Minimum Mass of Specimen, g
4.75	No. 4	1200
9.5	3/8 in.	1200
12.5	1/2 in.	1500
19.0	3/4 in.	2000
25.0	1 in.	3000
37.5	1 1/2 in.	4000

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

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.

6. CALIBRATION

6.1 This section has been replaced with the following:

The Calibration is to be performed according to WSDOT Standard Operating Procedure SOP 728.

Test Method A

7. APPARATUS

7.1 Ignition Furnace — A forced air ignition furnace, that heats the samples by either convection method or direct irradiation method. The convection-type furnace must be capable of maintaining the temperature at 1072°F (578°C). The furnace shall have an internal balance thermally isolated from the furnace chamber accurate to 0.1 g. The balance shall be capable of weighing a 3500 gram sample in addition to the sample baskets. A data collection system will be included so that the weight can be automatically determined and displayed during the test. The furnace shall have a built in computer program to calculate change in mass of the sample 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 content (percent), test time, and test temperature. The furnace chamber dimensions shall be adequate to accommodate a sample size of 35000 grams. The furnace shall provide an audible alarm and indicator light when the sample mass loss does not exceed 0.01 percent of the total sample mass for three consecutive minutes. 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 capability to pull air through the furnace to expedite the test and to reduce the escape of smoke into the laboratory.

Note 2: The furnace shall also allow the operator to change the ending mass loss percentage to 0.02 percent.

7.2 Sample Basket(s) — of appropriate size that allows the samples to be thinly spread and allows air to flow through and around the sample particles. Sets with two or more baskets shall be nested. The sample shall be completely enclosed with screen mesh, perforated stainless steel plate, or other suitable material.

7.2.1 Sample Basket Assembly — consisting of sample basket(s) (7.2), catch pan (7.3), and an assembly guard to secure sample basket(s) to catch pan.

Note 3: Screen mesh or other suitable material with maximum ad minimum opening of No. 8 (2.36 mm) and No. 30 (600 microns) respectively has been found to perform well.

7.3 Catch Pan — of sufficient size to hold the sample basket(s) so that aggregate particles and melting asphalt binder falling through the screen mesh are caught.

7.4 Oven or suitable devise — Capable of maintaining $325 \pm 25^\circ\text{F}$ ($163 \pm 14^\circ\text{C}$).

7.5 Balance — of sufficient capacity and conforming to the requirements of M231, Class G2, for weighting specimen in basket(s).

7.6 Safety Equipment — safety glasses or face shield, high temperature gloves, long sleeve jacket, a heat resistant surface capable of withstanding 1202°F (650°C) and a protective cage capable of surrounding the sample baskets during the cooling period.

7.7 Miscellaneous Equipment — a pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls, and wire brushes.

8. TEST PROCEDURES

8.1 Test Initiation

8.1.1 ~~For the convection-type furnace, Preheat the ignition furnace to 538°C (1000°F) or as determined in Section 6.9.1. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.~~ 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.

8.1.2 ~~For the direct irradiation-type furnace, use the same burn profile as used during the calibration.~~

8.2 ~~Oven dry the HMA sample to a constant mass at a temperature of 105 ± 5°C (221 ± 9°F) or determine the moisture content of the samples according to T 110.~~ Oven dry the HMA sample to a constant mass at a temperature of 325 ± 25°F (163 ± 14°C) or determine the moisture content of the samples according to FOP for WAQTC TM 6.

8.3 ~~Enter the calibration factor for the specific mix to be tested as determined in Section 6 in the ignition furnace.~~ Enter the calibration factor for the specific mix to be tested.

8.4 Weight and record the mass of the sample basket(s) and catch pan (with guards in place).

8.5 Prepare the sample as described in Section 5. Evenly distribute this sample in the sample 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.

8.6 Weight and record the total mass of the sample, basket(s), catch pan, and basket guards. Calculate and record the initial mass of the specimen (total mass minus the mass of the specimen basket assembly).

8.7 Input the initial mass of the specimen in whole grams into the ignition furnace controller. Verify that the correct mass has been entered.

8.8 Tare or zero furnace balance, open the chamber door, and place the sample baskets in the furnace. Close the chamber door, and verify that the sample mass (including the basket(s)) displayed on the furnace scale equals the total mass recorded in Section 8.6 within $\pm 5\text{ g} \pm 6\text{ g}$. Differences greater than 5 g 6 g or failure of the furnace scale to stabilize may indicate that the sample basket(s) are contacting the furnace wall. Initiate the test by pressing the start/stop button. This will lock the sample 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. Sample ignition typically increases the temperature well above the setpoint, depending on sample size and asphalt content.

Note: Operator should wear safety equipment – high temperature gloves, face shield, fire-retardant shop coat – when opening the door to load or unload the sample.

Safety Note: Do not attempt to open the furnace door until the binder has been completed burned off.

- 8.9 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 will unlock the sample chamber and cause the printer to print out the test results.
- Note 5:* An ending mass loss percentage of 0.02 may be substituted when aggregate that exhibits an excessive amount of loss during ignition testing is used. The precision and bias statement was developed using 0.01 percent. Both precision and accuracy may be adversely affected by using 0.02.
- 8.10 Use the corrected asphalt binder content (percent) from the printed ticket. If a moisture content has been determined, subtract the moisture content from the printed ticket corrected asphalt content, and report the difference as the corrected asphalt binder content.
- 8.11 Open the chamber door, remove the sample basket assembly and place on heat resistance surface and cover with the protective cage. Allow sample to cool to room temperature (approximately 30 minutes).

Test Method B

WSDOT has deleted Method B.

11. GRADATION

- 11.1 Allows the specimen to cool to room temperature in the sample baskets.
- 11.2 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.
- 11.3 Perform the gradation analysis according to T 30.

12. REPORT

- 12.1 Report the test method (A or B), corrected asphalt binder content, calibration factor, temperature compensation factor (if applicable), total percent loss, sample mass, moisture content (if determined) and the test temperature. Attach the original printed tickets to the report for units with internal balances.
- 12.2 The asphalt percentage and aggregate gradation shall be reported on WSDOT Form 350-560.

13. PRECISION AND BIAS

- 13.1 Precision — Precision was determined in an NCAT round-robin study for surface mixes using Test Method A. Precision has not yet been determined for Test Method B.

Asphalt Content	Acceptable Range of Standard Deviation, Percent Two Test Results, Percent	
	Single Operator Precision	0.04
Multi Lab Precision	0.06	0.17

Note 9: The precision estimates are based on 4 aggregate type, 4 replicates, and 12 laboratories participating with 0 laboratory results deleted as outlying observations. All 4 aggregates were tested in surface mixes and had relatively low absorption values.

- 13.2 Bias — The bias for Test Methods A and B has not been determined.

WSDOT FOP for AASHTO T 309¹***Temperature of Freshly Mixed Portland Cement Concrete*****1. SCOPE**

- 1.1 This test method covers the determination of temperature of freshly mixed portland cement concrete.
- 1.2 The values stated in English units are to be regarded separately as 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 141 Sampling Freshly Mixed Concrete

2.2 ASTM Standards:

C 172 Practice for Sampling Freshly Mixed Concrete

3. SIGNIFICANCE AND USE

- 3.1 This test method provides a means for measuring the temperature of freshly mixed concrete. It may be used to verify conformance to a specified requirement for temperature of concrete.
- 3.2 Concrete containing aggregate of a nominal maximum size greater than 3 in. [75 mm] may require up to 20 min for the transfer of heat from aggregate to mortar. (See ACI Committee 207.1R Report.3)

4. APPARATUS

- 4.1 Container, shall be made of nonabsorptive material and large enough to provide at least 3 in. [75 mm] of concrete in all directions around the sensor of the temperature measuring device; concrete cover must also be at least three times the nominal maximum size of the coarse aggregate.
- 4.2 Temperature Measuring Device — The temperature measuring device shall be capable of measuring the temperature of the freshly mixed concrete to $\pm 1^{\circ}\text{F}$ ($\pm 0.5^{\circ}\text{C}$) throughout the entire temperature range likely to be encountered in the fresh concrete. Liquid-in-glass thermometers having a range of 0 to 120 $^{\circ}\text{F}$ (-18 to 49 $^{\circ}\text{C}$) are satisfactory. Other thermometers of the required accuracy, including the metal immersion type, are acceptable.
- 4.3 Partial immersion liquid-in-glass thermometers (and possibly other types) shall have a permanent mark to which the device must be immersed without applying a correction factor.
- 4.4 Reference Temperature Measuring Device — The reference temperature measuring device shall be a liquid-in-glass thermometer readable to 0.5 $^{\circ}\text{F}$ (0.2 $^{\circ}\text{C}$) that has been verified and calibrated. The calibration certificate or report indicating conformance to the requirements of ASTM E 77 shall be available for inspection.

¹This FOP is based on AASHTO T 309-99.

5. CALIBRATION OF TEMPERATURE MEASURING DEVICE

- 5.1 Each temperature measuring device used for determining temperature of freshly mixed concrete shall be calibrated annually, or whenever there is a question of accuracy. This calibration shall be performed by comparing the readings of the temperature measuring device at two temperatures at least 27°F (15°C) apart.
- 5.2 Calibration of the temperature measuring devices may be made in oil or other suitable baths having uniform density if provision is made to:
 - 5.2.1 ~~Maintain the bath temperature constant within 0.5°F (0.2°C) during the period of the test.~~
 - 5.2.2 ~~Have both the temperature and reference temperature measuring devices maintained in the bath for a minimum of 5 min before reading temperatures.~~
 - 5.2.3 ~~Continuously circulate the bath liquid to provide a uniform temperature.~~
 - 5.2.4 ~~Slightly tap thermometers containing liquid to avoid adhesion of the liquid to the glass if the temperature exposure is being reduced.~~

6. SAMPLING CONCRETE

- 6.1 The temperature of freshly mixed concrete may be measured in the transporting equipment provided the sensor of the temperature measuring device has at least 3 in. [75 mm] of concrete cover in all directions around it.
- 6.2 Temperature of the freshly mixed concrete may be obtained following concrete placement using the forms as the container.
- 6.3 If the transporting equipment or placement forms are not used as the container, a sample shall be prepared as follows:
 - 6.3.1 Immediately, prior to sampling the freshly mixed concrete, dampen (with water) the sample container.
 - 6.3.2 Sample the freshly mixed concrete in accordance with Practice C 172, except that composite samples are not required if the only purpose for obtaining the sample is to determine temperature.
 - 6.3.3 Place the freshly mixed concrete into the container.
 - 6.3.4 When concrete contains a nominal maximum size of aggregate greater than 3 in. (75 mm), it may require 20 min before the temperature is stabilized after mixing.

7. PROCEDURE

- 7.1 Place the temperature measuring device in the freshly mixed concrete so that the temperature sensing portion is submerged a minimum of 3 in. (75 mm). Gently press the concrete around the temperature measuring device at the surface of the concrete so that ambient air temperature does not affect the reading.
- 7.2 Leave the temperature measuring device in the freshly mixed concrete for a minimum period of 2 min or until the temperature reading stabilizes, then read and record the temperature.
- 7.3 Complete the temperature measurement of the freshly mixed concrete within 5 min after obtaining the sample.

8. REPORT

8.1 Record the measured temperature of the freshly mixed concrete to the nearest 1°F (0.5°C).

9. PRECISION AND BIAS

9.1 The precision and bias of this test method have not been determined. A precision and bias statement will be included when sufficient test data have been obtained and analyzed.

Performance Exam Checklist

***Temperature of Freshly Mixed Concrete
for AASHTO T-309***

Participant Name _____

Exam Date _____

Procedure Element

Yes

No

- 1. Obtain sample of concrete large enough to provide a minimum of 3 in. (75 mm) of concrete cover around sensor in all directions? _____
- 2. Use calibrated thermometer:
 - Accurate to $\pm 1^\circ\text{F}$ ($\pm 0.5^\circ\text{C}$)? _____
 - Temperature range from 0 to 12 $^\circ\text{F}$ (-18 to 49 $^\circ\text{C}$)? _____
- 3. Place thermometer in sample with a minimum of 3 in. (75 mm) cover around sensor? _____
- 4. Gently press concrete around thermometer? _____
- 5. Read temperature after a minimum of 2 minutes or when temperature reading stabilizes? _____
- 6. Complete temperature measurement within 5 minutes of obtaining sample? _____
- 7. Record temperature to nearest 1 $^\circ\text{F}$ (0.5 $^\circ\text{C}$)? _____

Comments: First attempt: Pass Fail Second attempt: Pass Fail

Signature of Examiner _____



WSDOT FOP for AASHTO T 310¹

In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

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 either direct transmission, backscatter, or backscatter/air-gap ratio method. The preferred method for determining density is by direct transmission. The moisture of the material is determined only from measurements taken at the surface of the soil (i.e., Backscatter).
- 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 300 mm (12 in.) 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. The inch-pound equivalents may be approximate. It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbf) and of force (lbm). This implicitly combines two systems of units, that is, the absolute system and the gravitational system.
 - 1.4.1 This standard has been written using the absolute system for water content (kilograms per cubic meter) in SI units. Conversion to the gravitational system of unit weight in lbf/ft.³ may be made. The recording of water content in pound-force per cubic foot should not be regarded as non-conformance with this standard although the use is scientifically incorrect.
 - 1.4.2 In the SI system, the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass (lbm), or recording of density (lbm/ft.³) should not be regarded as nonconformance with this 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.

¹This FOP is based on AASHTO T 310-00.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

- T 99 Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop
- T 180 Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop
- T 191 Density of Soil In-Place by the Sand-Cone Method
- 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

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 apparatus 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 instrument 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.

- 4.1.3 Oversize rocks or large voids in the source-detector path may cause higher or lower density determination. Where lack of uniformity in the soil due to layering, rock or voids is suspected, the test site should be dug up and visually examined to determine if the test material is representative of the full material in general and if rock correction is required.
- 4.1.4 The sample volume is approximately 0.10 ft.³ (0.0028 m³) for the Backscatter Method and 0.20 ft.³ (0.0057 m³) for the Direct Transmission Method when the test depth is 6 in. (150 mm). The actual sample volume is indeterminate and varies with the apparatus and the density of the material. In general, the higher the density the smaller the volume.
- 4.1.5 Other radioactive sources must not be within 30 ft. (10 m) of equipment in operation.

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/ft.³ (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 Other neutron sources must not be within 10 m (30 ft.) of equipment in operation.

5. APPARATUS

- 5.1 *Nuclear Density/Moisture Gauge* — While exact details of construction of the apparatus 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 planning 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 Instrument by more than 1/8 in. (3 mm), used to prepare a hole in the material under test for inserting the rod.
- 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.
- 5.7.1 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.

6. HAZARDS

- 6.1 This equipment utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of this equipment 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 instrument.

7. CALIBRATION

- 7.1 Calibration of the instrument will be in accordance with Appendix A2 and A3.

8. STANDARDIZATION

- 8.1 All nuclear density/moisture gauges are subject to long-term aging of the radioactive sources, detectors, and electronic systems, which may change the relationship between count rates and the material density and water content. To offset this aging, instruments are calibrated as a ratio of the measurement count rate to a count rate made on a reference standard or to an air-gap count (for the backscatter/air-gap ratio method). The reference count rate should be in the same or higher order of magnitude than the range of measurement count rates over the useful range of the equipment.
- 8.2 Standardization of equipment on the reference standard is required at the start of each day's use and a permanent record of these data shall be retained. ~~The standardization shall be performed with the equipment at least 10 m (30 ft.) away from other nuclear density/moisture gauges and clear of large masses of water or other items which may affect the reference count rates.~~ The standardization shall be performed with the equipment away from other radioactivity devices, large masses of water and large vertical surfaces at the manufacturer's recommended distance. Standard counts should be taken in the same environment as the actual measurement counts.
- 8.2.1 Turn on the instrument and allow for stabilization according to the manufacturer's recommendations. If the instrument is to be used either continuously or intermittently during the day, it is best to leave it in the "power on" condition to prevent having to repeat the stabilization (refer to manufacturer recommendations). This will provide more stable, consistent results.

- 8.2.2 ~~Using the reference standard take at least four repetitive readings at the normal measurement period and obtain the mean. If available on the instrument, one measurement of four or more times the normal period is acceptable. This constitutes one standardization check.~~ Using the reference standard block supplied with the density/moisture gauge perform standardization using manufacture's recommendations.

Use the procedure recommended by the gauge manufacturer for determining compliance with the gauge calibration curves. Without specific recommendations for the gauge manufacturer, use the procedure in 8.2.3.

- 8.2.3 If the mean of the four repetitive readings is outside the limits set by Equation 1, repeat the standardization check. If the second standardization check satisfies Equation 1, the equipment is considered in satisfactory operating condition. If the second standardization check does not satisfy Equation 1, the instrument should be checked and verified according to Appendix A2 and A3, sections A2.8 and A3.5. If the verification shows that there is no significant change in the calibration curve, a new reference standard count, N_o , should be established. If the calibration check shows that there is a significant difference in the calibration curve, repair and recalibrate the instrument.

$$N_s = N_o \pm 1.96 \sqrt{N_o/F} \quad (\text{Eq. 1})$$

where:

N_s = value of current standardization count,

N_o = Average of the past four values of N_s taken for prior usage,

F = factory pre-scale factor (contact gauge manufacturer for the factor).

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 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.
- 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 Prepare a horizontal area sufficient in size to accommodate four gauge readings that will be 90° to each other ~~the gauge~~, by planning 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 $1/8$ 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 should not exceed approximately $1/8$ in. (3 mm).

Note 3: The placement of the gauge on the surface of the material to be tested is critical to the successful determination of density. The optimum condition is total contact between the bottom surface of the gauge and the surface of the material being tested. When optimal conditions are not present, correct surface irregularities by the use of native fines or similar filler material. The total area filled should not exceed 10 percent of the bottom area of the gauge. Several trial seatings may be required to achieve these conditions.

9.3 ~~Turn on and allow the equipment to stabilize (warm up) according to the manufacturer's recommendations (see 8.2.1).~~

9.4 Backscatter or Backscatter/Air-Gap Ratio Method of In-Place Nuclear Density & Moisture Content

This Section has been deleted

9.5 *Direct Transmission Method of In-Place Nuclear Density & Moisture Content*

9.5.1 Select a test location where the gauge in test position will be at least the minimum distance recommended by the manufacture 150 mm (6 in.) away from any vertical projection. If gauge will be within the minimum distance recommended by the manufacture follow instructions outlined by manufactures instruction manual.

9.5.2 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.

9.5.3 Mark the test area to allow the placement of the instrument over the test site and to allow the alignment of the source rod to the hole.

9.5.4 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.

9.5.5 Place the instrument on the material to be tested, making sure of maximum surface contact as described above.

9.5.6 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.

Note 4: Do not extend a rod containing radioactive sources out of its shielded position prior to placing it onto the test site. Always align the instrument so as to allow placing the rod directly into the test hole from the shielded position.

9.5.7 Keep all other radioactive sources at least 30 ft. (10 m) away from the gauge to avoid affecting the measurement.

9.5.8 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.

9.5.9 ~~Secure and record one or more 1-minute readings (see Note 5).~~ 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/cm) of each other see note 5.

- 9.5.10 Determine the in-place wet density by use of the calibration curve previously established or read the gauge directly if so equipped.

Note 5: ~~The gauge may be rotated about the axis of the probe to obtain additional readings. If two readings are not within 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, or subtract the kg/m^3 (lbm/ft.^3) of moisture from the kg/m^3 (lbm/ft.^3) of wet density, and obtain dry density in kg/m^3 (lbm/ft.^3).
- 10.1.2 If the water content is determined by other methods, and is in the form of percent, proceed as follows:

$$d = \frac{100}{100+W} (m) \quad (\text{Eq. 2})$$

where:

d = dry density in lbm/ft.^3 (kg/m^3),

m = wet density in lbm/ft.^3 (kg/m^3),

and

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

- 11.1 The report shall include the following:
- 11.1.1 Standardization and adjustment data for the date of the tests.
- 11.1.2 Make, model and serial number of the test instrument.
- 11.1.3 Name of the operator(s).
- 11.1.4 Test site identification.
- 11.1.5 Visual description of material tested.
- 11.1.6 Test mode (backscatter or direct transmission) and test depth (if applicable).
- 11.1.7 Wet and dry densities in kg/m^3 or unit weights in lb/ft.^3
- 11.1.8 Water content in percent of dry mass or dry unit weight.
- 11.1.9 Percent Compaction
- 11.1.10 Name and Signature of Operator

12. Precision and Bias

12.1. Precision:

12.1.1. Wet Density – Criteria for judging the acceptability of wet density test results obtained by this test method are given in Table 1. The figure in column three represents the standard deviations that have been found to be appropriate for the materials tested in column one. The figures given in column four are the limits that should not be exceeded by the difference between the results of two properly conducted tests. The figures given are based upon an inter-laboratory study in which five test sites containing soils, with wet densities as shown in column two were tested by eight different devices and operators. The wet density of each test site was determined three times by each device.

Table 1 – Results of Statistical Analysis (Wet Density)

Soil Type	Average lb/ft ³ (kg/m ³)	Standard Deviation	Acceptable Range of Two Results lb/ft ³ (kg/m ³)
Single Operator Precision			
Direct Transmission:			
CL	114.7(1837.3)	0.34(5.45)	0.94 (15.06)
SP	120.9(1936.6)	0.27(4.32)	0.74(11.85)
ML	130.1(2084.0)	0.46(7.37)	1.28(20.50)
Backscatter:			
ML	124.6(1995.9)	1.21(19.38)	3.39(54.30)
Multilaboratory Precision			
Direct Transmission:			
CL	114.7(1837.3)	0.66(10.57)	1.86(29.79)
SP	120.9(1936.6)	0.68(10.89)	1.91(30.59)
ML	130.1(2084.0)	0.77(12.23)	2.15(34.44)
Backscatter:			
ML	124.6(1995.9)	2.38(38.12)	6.67(106.84)

Note: The data used to establish the density and moisture content precision statements are contained in ASTM Research Report RR:D18-1004.

12.1.2. *Moisture Content* – Criteria for judging the acceptability of the moisture content results obtained by this test method are given in Table 2. The value in column two is in the units actually measured by the nuclear gauge. The figures in column three represent the standard deviations that have been found to be appropriate for the materials tests in column one. The figures given in column four are the limits that should not be exceeded by the difference between the results of two properly conducted tests. The figures given are based upon an inter-laboratory study in which five test sites containing soils, with moisture content as shown in column two were tested by eight different devices and operators. The moisture content of each test site was determined three times by each device.

Table 2 – Results of Statistical Analysis (Moisture Content)

Soil Type	Average lb/ft ³ (kg/m ³)	Standard Deviation	Acceptable Range
			of Two Results lb/ft ³ (kg/m ³)
Single Operator Precision			
CL	12.1(193.8)	0.35(5.6)	0.97(15.5)
SP	18.7(299.5)	0.46(7.4)	1.29(20.7)
ML	19.6(314.0)	0.35(5.6)	0.99(15.8)
Multilaboratory Precision			
CL	12.1(193.8)	0.52(8.3)	1.44(23.1)
SP	18.7(299.5)	0.75(12.0)	2.10(33.6)
ML	19.6(314.0)	0.58(9.3)	1.63(26.1)

12.2. Bias:

12.2.1. There are no accepted reference values for these test methods, therefore, bias cannot be determined.

13. KEYWORDS

13.1 Compaction test; density; moisture content; nuclear methods; quality control; water content.

APPENDIX

A1. WET DENSITY CALIBRATION AND VERIFICATION

A1.1. *Calibration* – Newly acquired gauges shall be calibrated initially. Existing gauges shall be calibrated after repairs that may affect the gauge geometry. Existing gauges shall be calibrated to re-establish calibration curves, tables, or equivalent coefficients if the gauge does not meet the specified tolerances in the verification process. If the Owner does not establish a Verification procedure, the gauge shall be calibrated at a minimum frequency of 24 month.

Verification – Existing gauges shall be verified at a minimum frequency of 12 months. The verification process and resultant tolerances obtained over the depths that the gauge shall be formally recorded and documented. If the verification process indicates a variance beyond the specified tolerances, the gauge shall be calibrated.

A1.2. The calibration response of the gauge shall be within $\pm 16 \text{ kg/m}^3$ ($\pm 1.0 \text{ lb.ft}^3$) on the block(s) on which the gauge was calibrated. This calibration may be done by the manufacturer, the user, or an independent vendor. Nuclear gauge response is influenced by the chemical composition of measured materials. This response must be taken into account in establishing the assigned standard block density. The block (s) used for calibration shall be capable of generating a general and reliable curve covering the entire density range of materials tested in the field. The density of these standard block(s) shall be determined to an accuracy of ± 0.2 percent.

A1.3. Sufficient data shall be taken on each density standard block to ensure a gauge count precision (see Appendix A3) of at least one-half the gauge count precision required for field use assuming field use measurement of one minute duration and four minute duration used for calibration, or an equivalent relationship. The data may be presented in the form of a graph, table, equation coefficients, or stored in the gauge, to allow converting the count rate data to density.

A1.4. The method and test procedures used in establishing the calibration count rate data shall be the same as those used for obtaining the field count rate data.

A1.5. The material type, actual density, or assigned standard block density of each calibration standard used to establish or verify the gauge calibration shall be stated as part of the calibration data for each measurement depth.

A1.6. The standards should be sufficient in size to not change the count rate if enlarged in any dimension.

Note 6- Minimum surface dimensions of approximately 610 mm by 430 mm

(24 x 17 in.), have proven satisfactory. For the Backscatter Method a minimum depth of 230 mm (9 in.) is adequate; while for the Direct Transmission Method the depth should be at least 50 mm (2 in.) deeper than the deepest rod penetration depth. A larger surface area should be considered for the backscatter air-gap method. For blocks with width and length smaller than the sizes specified, follow block manufacturers' recommendations for proper installation and use.

A1.7. The most successful standards that have been established for calibration have been made of magnesium, aluminum, aluminum/magnesium, granite, and limestone. These standards have been used in combination with each other, with historical curve information, and with other prepared block(s) to produce accurate and reliable calibration.

A1.7.1. Standards of soil, rock, and concrete that have stable characteristics for reproducibility and uniformity are difficult to prepare. These standards may be of use for specialty verification or field calibration where local site material chemistry or background situation require special adaptation.

A1.8. Verify an existing calibration by taking a sufficient number of counts at each measurement depth on one or more blocks of established density to ensure the accuracy of the existing calibration within $\pm 32 \text{ kg/m}^3$ ($\pm 2.0 \text{ lb/ft}^3$) at each measurement depth.

A1.8.1. Sufficient data shall be taken to ensure a gauge count precision of at least one-half the gauge count precision required for field use assuming field use measurement of one minute duration and four minute duration used for calibration or an equivalent relationship.

A1.8.2. Calibration block(s) which are used for calibration of the gauge or prepared block(s) which are capable of generating a general and reliable curve covering the range of densities of the materials to be tested in the field can be used to verify the gauge calibration.

A1.8.2.1. Blocks prepared of soil, rock, concrete, asphalt, and engineered blocks that have characteristics of reproducible uniformity may be used, but care must be taken to minimize changes in density and water content over time.

A1.8.2.2. Density values of prepared blocks shall be determined to an accuracy of ± 0.5 percent at each measurement depth.

A1.8.3. The assigned block density for each calibration depth used to verify the gauge calibration shall be stated as part of the verification data.

A2. WATER CONTENT CALIBRATION AND VERIFICATION

A2.1. *Calibration* – Newly acquired gauges shall be calibrated initially. Existing gauges shall be calibrated after repairs that may affect the gauge geometry. Existing gauges shall be calibrated to re-establish calibration curves, tables, or equivalent coefficients if the gauge does not meet the specified tolerances in the verification process. If the Owner does not establish a Verification procedure, the gauge shall be calibrated at a minimum frequency of 24 months.

Verification- Existing gauges shall be verified at a minimum frequency of 12 months. The verification process and resultant tolerances obtained over the depths the gauge shall be formally recorded and documented. If the verification process indicates a variance beyond the specified tolerances, the gauge shall be calibrated.

A2.2. The calibration response of the gauge shall be within $\pm 16 \text{ kg/m}^3$ ($\pm 1.0 \text{ lb/ft}^3$) on the block(s) on which the gauge was calibrated. This calibration may be done by the manufacturer, the user, or an independent vendor. The block(s) used for calibration should be capable of generating a general curve covering the entire water content range of the materials to be tested in the field. The calibration curve can be established using counts and water contents of standard blocks, previous factory curve information or historical data. Due to the effect of chemical composition, the calibration supplied by the manufacturer with the gauge will not be applicable to all materials. It shall be accurate for silica and water; therefore, the calibration must be verified and adjusted, if necessary, in accordance to Section A2.4.

- A2.3. Calibration standards may be established using any of the following methods. Prepared containers or standards must be large enough to not change the observed count rate if made larger in any dimension.

Note 7 – Dimensions of approximately 610 mm long by 460 mm wide by 360 mm deep (approximately 24 in. by 18 in. by 14 in.) have proven satisfactory. For blocks with width and length smaller than the sizes specified, follow block manufacturers' recommendations for proper installation and use.

- A2.3.1. Prepare a homogeneous standard of hydrogenous materials having an equivalent water content determined by comparison (using a nuclear gauge) with a saturated silica sand standard prepared in accordance with Section A.2.3. Metallic blocks used for wet density calibration, such as magnesium or aluminum, are convenient zero water content standard.
- A2.3.2. Prepare containers of compacted material with a percent water content determined by oven dry (ASTM Test Method D 2216) and a wet density calculated from the mass of the material and the inside dimensions of the container. The water content may be calculated as follows:

$$M_m = \frac{P \times w}{100 + W} \quad (3)$$

where:

M_m = water content, kg/m³ or lbm/ft³,
 w = water content, percent of dry mass, and
 P = wet (total) density, kg/m³ or lbm/ft³.

- A2.3.3. Where neither of the previous calibration standards are available, the gauge may be calibrated by using a minimum of our selected test sites in an area of a compaction project where material has been placed at several different water contents. The test sites shall represent the range of water contents over which the calibration is to be used. At least four replicate nuclear measurements shall be made at each test site. The density at each site shall be measured by making four closely spaced determinations with calibrated equipment in accordance with ASTM Test Methods D2922, D 1566, or D 2937. The water content of each of the density tests shall be determined by Test Method D 2216. Use the mean value of the replicate readings as the calibration point value for each site.

A2.4. *Calibration Adjustments*

- A2.4.1. The calibration of newly acquired or repaired gauges shall be verified and adjusted prior to use. Calibration curves shall be checked prior to performing tests on materials that are distinctly different from material types previously used in obtaining or adjusting the calibration. Sample materials may be selected by either Section A2.4.1.1. or Section A2.4.1.2. The amount of water shall be within ± 2 percent of the water content established as optimum for compaction. Determine the water content in kg/m³ or lb/ft³ by Equation 3. A microwave oven or direct heater may be utilized for drying materials which are not sensitive to

temperature, in addition to the methods listed in Section A2.3.3. A minimum of four comparisons is required and the mean of the observed differences used as the correction factor.

A2.4.1.1. Container(s) of compacted material taken from the test site may be prepared in **accordance with Section A2.3.2.**

A2.4.1.2. Test site(s) or the compacted material may be selected in accordance with Section A2.3.3.

A2.4.2. The method and test procedures used in obtaining the count rate to establish the error must be the same as those used for measuring the water content of the material to be tested.

A2.4.3. The mean value of the difference between the moisture content of the test samples as determined in Section A2.4.1.1 or Section A2.4.1.2 and the values measured with the gauge shall be used as a correction to measurements made in the field. Some gauges utilizing a microprocessor may have provision to input a correction factor that is established by the relative values of water content as a percentage of dry density, thus eliminating the need to determine the difference in mass units of water.

A2.5. **Verify an existing calibration** by taking sufficient number of counts on one or more blocks of established water content to ensure the accuracy of the existing calibration within $\pm 16 \text{ kg/m}^3$ ($\pm 1 \text{ lb/ft}^3$). The water content block(s) should be prepared in accordance with Sections A2.3.1 and A2.3.2.

A2.5.1. Sufficient data shall be taken to ensure a gauge count precision (see Appendix A3) of at least one-half the gauge count precision required for field use assuming field use measurement of one minute duration and four minute duration used for calibration, or an equivalent relationship.

A2.5.2. Calibration block(s) used to establish calibration parameters and prepared block(s) which are capable of generating a general and reliable curve covering the range of densities of the materials that are to be tested in the field can be used to verify calibration.

A2.5.3. Prepared block(s) that have characteristics of reproducible uniformity may be used, but care must be taken to minimize changes in density and water content over time.

A2.5.4. The assigned water content of the block(s) used for verification of the gauge shall be stated as part of the verification data.

A3. GAUGE COUNT PRECISION

A3.1. Gauge count precision is defined as the change in density or water content that occurs corresponding to a one standard deviation change in the count due to the random decay of the radioactive source. The density of the material and time period of the count must be stated. It may be determined using calibration data (Equation 4); Section A3.2; or Section A3.3. Determine the gauge count precision of the system, P , from the slope of the calibration curve, S , and the standard deviation, σ , of the signals (detected gamma rays or detected neutrons) in counts per minute (cpm), as follows:

$$P = \sigma / S$$

where:

P = precision;
 σ = standard deviation, cpm; and
 S = slope, cpm/kg/m³(cpm/lb/ft³)

A3.2. *Density* – Determine the slope of the calibration curve at the 2000 kg/m³ (125 lb/ft³) point in counts per minute per kilogram per cubic meter (counts per minute per pound per cubic foot). Determine the standard deviation of a minimum of 20 per pound repetitive readings of 1 minute each (gauge is not moved after seating for the first count) taken on material having a density of 2000 kg ± 80 kg/m³ (125.0 ± 5.0 lb/ft³). The value of P is typically less than 10 kg/m³ (0.6 lb/ft³) in the backscatter method and 5 kg/m³ (0.3 lb/ft³) in the direct transmission method at 6-in. depth.

A3.3. *Moisture* – Where the slope of the calibration curve is determined at the 160-kg/m³ (10-lb/ft³) point and the standard deviation is determined from a minimum of 20 repetitive readings of 1 minute each (the gauge is not moved after the first count) taken on material having a moisture content of 160 ± 10 kg/m³ (10.0 ± 0.6 lb/ft³) the value of P is typically less than 4.8 kg/m³ (0.30 lb/ft³).

Performance Exam Checklist

In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

FOP FOR AASHTO T 310

Participant Name _____

Exam Date _____

Procedure Element	Yes	No
1. Gauge turned on and allowed to stabilize per manufacturer's recommendations?	_____	_____
2. Gauge calibrated and standard count recorded in accordance with manufacturer's instructions?	_____	_____
3. Test location selected away from other radioactive sources, large objects, vertical projections per manufacturer's recommendations?	_____	_____
4. Loose, disturbed material removed?	_____	_____
5. Flat, smooth area prepared?	_____	_____
6. Surface voids filled with native fines (1/8 in. (3 mm) maximum thickness)?	_____	_____
7. Hole driven 2 in. (50 mm) deeper than material to be tested?	_____	_____
8. Gauge placed, probe placed, and source rod lowered without disturbing loose material?	_____	_____
9. Method A:		
a. Gauge firmly seated, and gently pulled back so that source rod is against hole?	_____	_____
b. Two, one-minute counts taken; density counts within 32 kg/m ³ ?	_____	_____
c. Density and moisture data averaged?	_____	_____
9. Method B:		
a. Gauge firmly seated, and gently pulled back so that source rod is against hole?	_____	_____
b. A Two,-minute counts taken; dry density and moisture data averages?	_____	_____
c. Gauge turned 90° (180° in trench)?	_____	_____
d. Gauge firmly seated, and gently pulled back so that source rod is against hole?	_____	_____

Procedure Element

Yes

No

e. A second one-minute counts taken; dry density and moisture data averaged?

f. Density counts within 3 lbm/ft³ (50 kg/m³)?

g. Average of two tests?

10. A minimum 9 lbs. (4kg) sample obtained from below guage?

11. Oversize determined following WSDOT SOP 615?

Comments:

First attempt: Pass Fail

Second attempt: Pass Fail

Signature of Examiner _____

WSDOT FOP for AASHTO T 312¹**Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor****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
- PP 2, Mixture Conditioning of Hot-Mix Asphalt (HMA)
- PP 28, Superpave Volumetric Design for Hot-Mix Asphalt (HMA)
- T 166, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
- T 168, Sampling Bituminous Paving Mixtures
- T 209, Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
- T 275, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens

2.2 ASTM Standard:

- D 4402, Viscosity Determinations of Unfilled Asphalts Using the Brookfield Thermosel Apparatus

2.3 Other Standards:

- WSDOT SOP 731, Method for determining volumetric properties of asphalt concrete pavement class superpave

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.
- 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.

¹This Test Method is based on AASHTO T 312-01.

4. APPARATUS

- 4.1. Superpave Gyrotory 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 angle of $1.25 \pm 0.02^\circ$ (22 ± 0.35 mrad) and gyrate the specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction.

Note 1 – This stress calculates to $10,600 \pm 310$ 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 printer connected to an RS232C port 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 μ m 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 μ m, 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. Thermometers – Armored, glass, or dial-type thermometers with metal stems 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 $\pm 5.4^\circ\text{F}$ ($\pm 3^\circ\text{C}$), 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 PP 2.
- 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.

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.

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 ASTM D 4402.

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 m^2/s ; for practical use, the submultiple mm^2/s is recommended. The more familiar centistokes is a cgs unit of kinematic viscosity; it is equal to $1 \text{ mm}^2/\text{s}$. The kinematic viscosity is the ratio of the viscosity of the binder to its density. For a binder with a density equal to $1.000 \text{ g}/\text{cm}^3$, a kinematic viscosity of $170 \text{ mm}^2/\text{s}$ is equivalent to a viscosity of $0.17 \text{ Pa}\cdot\text{s}$ measured in accordance with ASTM D 4402.

- 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 PP 2.
- 8.6. Place a compaction mold and base plate in an oven at no more than 25°F (13.9°C) above the required compaction temperature for a minimum of 30 to 60 minutes prior to the estimated beginning of compaction (during the time the mixture is being conditioned in accordance with PP 2).
- 8.7. Following the mixture conditioning period specified in PP 2, 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 PP 2, 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 $280 \pm 30 \text{ mm}^2/\text{s}$ (approximately $0.28 \pm 0.03 \text{ Pa}\cdot\text{s}$) measured in accordance with ASTM D 4402 (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 compaction temperature is achieved, 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. 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 $600 \pm 18 \text{ kPa}$ on the specimen.
- 9.5. Apply a $1.25 \pm 0.02^\circ$ ($22.0 \pm 0.35 \text{ mrad}$) angle to the mold assembly, and begin the gyratory compaction.
- 9.6. Allow the compaction to proceed until the desired number of gyrations specified in PP 28 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—No additional gyrations with the angle removed are required unless specifically called for in another standard referencing TP 4 (as in PP 2 Section 7.3.2.1.2). The extruded specimen may not be a right angle cylinder. Specimen ends may need to be sawed to conform to the requirements of specific performance tests.

Note 7—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 8—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

- 10.1 Determine the maximum specific gravity (G_{mm}) of the loose mix in accordance with T 209 using a companion sample. The companion sample shall be conditioned to the same extent as the compaction sample.
- 10.2. Determine the bulk specific gravity (G_{mb}) of the specimen in accordance with T 166 or T 275 as appropriate.
- 10.3. When the specimen height is to be monitored, record the specimen height to the nearest 0.1 mm after each revolution in addition to those specified in Section 8.

11. DENSITY CALCULATIONS

- 11.1 Calculate the uncorrected relative density (G_{mmux}) at any point in the compaction process using the following equation:

$$\%G_{mmux} = \frac{W_m}{V_{mx} G_{mm} G_m} \times 100$$

where:

$\%G_{mmux}$ = uncorrected relative density at any point during compaction expressed as a percent of the maximum theoretical specific gravity;

W_m = mass of the specimen in g;

G_{mm} = theoretical maximum specific gravity of the mix;

G_m = unit weight of water, 1 g/cm³;

x = number of gyrations; and

V_{mx} = volume of the specimen, in cm³, at any point based on the diameter (d) and height (h_x) of the specimen at that point (use “mm” for height and diameter measurements).

It can be expressed as:

$$V_{mx} = \frac{d^2 h_x}{4 \times 1000}$$

Note 9—This formula gives the volume in cm³ to allow a direct comparison with the specific gravity.

- 11.2. At the completion of the bulk specific gravity test, determine the relative density ($\%G_{\text{mmx}}$) at any point in the compaction process as follows:

$$\%G_{\text{mmx}} = \frac{G_{\text{mb}} h_{\text{m}}}{G_{\text{mm}} h_{\text{x}}} \times 100$$

where:

- $\%G_{\text{mmx}}$ = corrected relative density expressed as a percent of the maximum theoretical specific gravity;
- G_{mb} = bulk specific gravity of the extruded specimen;
- h_{m} = height in millimeters of the extruded specimen; and
- h_{x} = height in millimeters of the specimen after x gyrations.

12. REPORT

- 12.1. Report the following information in the compaction report, if applicable:

- 12.1.1. Project name
- 12.1.2. Date of the test;
- 12.1.3. Start time of the test;
- 12.1.4. Specimen identification;
- 12.1.5. Percent binder in specimen, nearest 0.1 percent;
- 12.1.6. Average diameter of the mold used (d), nearest 1.0 mm;
- 12.1.7. Mass of the specimen (W_{m}), nearest 0.1g;
- 12.1.8. Maximum specific gravity (G_{mm}) of the specimen by T 209, nearest 0.001;
- 12.1.9. Bulk specific gravity (G_{mb}) of the specimen by T 166, nearest 0.001;
- 12.1.10. Height of the specimen after each gyration (h_{x}), nearest 0.1 mm; and
- 12.1.11. Relative density ($\%G_{\text{mm}}$) expressed as a percent of the theoretical maximum specific gravity, nearest 0.1 percent.

12.2 Report results on WSDOT form 350-162

13. PRECISION AND BIAS

- 13.1 Precision—The research required to determine the precision of this procedure has not been conducted.
- 13.2 Bias—The research required to determine the bias of this procedure has not been conducted.

14. KEYWORDS

- 14.1. Gyrotory; compaction; density

Performance Exam Checklist

Determining Density of Hot Mix Asphalt (HMA) Specimens by Means of the SHRP Gyrotory Compactor

Participant Name _____

Exam Date _____

Preparation of Apparatus

Yes

No

1. Main power for compactor turned on for manufacturer’s required warm-up period? _____
2. Angle, pressure and number of gyrations set? _____
3. Bearing surfaces, rotating base surface, and rollers lubricated? _____

Preparation of Mixtures

1. Is mixture at compaction temperature? If not, was mixture placed in an oven and brought up to compaction temperature? _____
2. Mold and base plate heated for 30 to 60 minutes in an oven at the required compaction temperature? _____

Plant mix – Loose mix brought to compaction temperature by uniform heating immediately prior to molding.

Compaction Procedure

Yes

No

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 $1.25 \pm 0.02^\circ$ (22 ± 0.35 mrad) applied to the mold assembly and gyrotory compaction started? _____
5. Compactor shuts off when appropriate gyration level is reached? _____
6. No leveling off load applied (dwell gyrations or square load)? _____
7. Mold removed and specimen extruded? _____
8. Paper disks removed? _____
9. If specimens are used for determination of volumetric properties, are the heights of the specimens 115 ± 5 mm? _____

Comments: First attempt: Pass Fail Second attempt: Pass Fail

Signature of Examiner _____



WSDOT Standard Operating Procedure No. 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 FOP for AASHTO T 99 for Method of Test for Moisture-Density Relations of Soils
- b. AASHTO T 224 FOP for AASHTO T 224 for Correction for Coarse Particles in Soil Compaction Test
- c. AASHTO T 255 FOP for AASHTO T 255 for Total Moisture Content of Aggregate by Drying
- d. AASHTO T 272 FOP for AASHTO T 272 for Family of Curves — One Point Method
- e. AASHTO T 310 FOP for AASHTO T 310 for In-Place Densities and Moisture Content of Soils and Soil-Aggregate by Nuclear Methods (Shallow Depth)
- f. 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.

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 on DOT Form 350-074 "Field Density Test"

5. OVERSIZE DETERMINATION

- a. A sample weighing a minimum of 9 lbs. will be taken from beneath the gauge. This sample will be dried to SSD conditions, (i.e. dried until no visible surface moisture present, material may still appear damp). Allow the sample to cool sufficiently and record mass to the nearest 1 g.
- b. Shake sample by hand over the No. 4 (4.75 mm) sieve. Limit the quantity of material on the sieve so that all particles have opportunity to reach the sieve openings a number of times during the sieving operation. For the No. 4 (4.75 mm) sieve, the mass retained on the sieve at the completion of the sieving operation shall not exceed 12 kg/m² of sieving surface.
- c. Remove and weigh the material on the No. 4 (4.75 mm) sieve.

- d. Calculate the percentage retained and the percent passing the No. 4 (4.75 mm) sieve to the nearest percent and record on DOT Form 350-074 by the following formula:

English:

$$\% \text{ Retained No. 4} = \frac{\text{Mass retained on No. 4}}{\text{Initial dry mass}}$$

$$\% \text{ Passing} = 100 - \% \text{ Retained}$$

Metric:

$$\% \text{ Retained 4.75 mm} = \frac{\text{Mass retained on 4.75 mm}}{\text{Initial dry mass}}$$

$$\% \text{ Passing} = 100 - \% \text{ Retained}$$

6. % COMPACTION DETERMINATION BASED ON AASHTO T 99

- a. This process is applicable to nongranular, silty materials with less than 30 percent retained on the No. 4 (4.75 mm) sieve. AASHTO Test Method T-99 and WSDOT FOP for AASHTO T-272 are used to determine the maximum density of the material passing the No. 4 (4.75 mm) sieve. Record the maximum density on DOT Form 350-074 line "Maximum Density"
- b. The maximum density from AASHTO T-99 and T-272 must be corrected for material larger than the No. 4 (4.75 mm) sieve. To correct for the oversize, use WSDOT FOP for AASHTO T224, and enter this value on DOT Form 350-074 line "Corrected Maximum Density". When 0% is retained on the No. 4 (4.75 mm) sieve, no correction is necessary.
- c. Percent Compaction is calculated by the following formula and entered on DOT Form 350-074:

English:

$$\% \text{ Compaction lbs./ft.}^3 = \frac{\text{Dry Density lbs./ft.}^3 (100)}{\text{Corrected Maximum Density lbs./ft.}^3}$$

Metric:

$$\% \text{ Compaction kg/m}^3 = \frac{\text{Dry Density kg./m}^3 (100)}{\text{Corrected Maximum Density kg/m}^3}$$

7. % COMPACTION DETERMINATION BASED ON WSDOT TEST METHOD No. 606.

- a. This process is applicable to granular, free-draining materials and to materials with 30 percent or more retained on the No. 4 (4.75 mm) sieve. Test Method 606 requires specialized equipment and is run only by the Region or State Materials Laboratory.
- b. Using the appropriate computer-generated chart, determine the maximum density, based on the percent passing the No. 4 (4.75 mm) sieve. This value should be entered on DOT Form 350-074 on line "Maximum Density".
- c. Percent of compaction is then calculated by the formula and entered on DOT Form 350-074:

English:

$$\% \text{ Compaction lbs./ft.}^3 = \frac{\text{Dry Density lbs./ft.}^3 (100)}{\text{Maximum Density lbs./ft.}^3}$$

Metric:

$$\% \text{ Compaction kg/m}^3 = \frac{\text{Dry Density kg/m}^3 (100)}{\text{Maximum Density kg/m}^3}$$

8. OPTIMUM MOISTURE DETERMINATION

Record the Optimum Moisture content from the appropriate density curve on DOT Form 350-074.

For non-granular materials, the optimum moisture content will have to be corrected with the following formula:

$$\text{Corrected Optimum Moisture} = (\text{Optimum Moisture}) (\% \text{ Passing No. 4})$$

9. REPORT

Report compaction data of DOT Form 350-074, "Field Density Test" and on DOT Form 351-015 "Daily Compaction Test"



WSDOT STANDARD OPERATING PROCEDURE 731

Method for Determining Volumetric Properties of Asphalt Concrete Pavement Class Superpave

1. SCOPE

This procedure covers the determination of Asphalt Concrete Pavement Class Superpave Volumetric properties. This procedure covers the method for determining Air Voids (Va), Voids in Mineral Aggregate (VMA), Voids Filled with Asphalt (VFA), and Dust to Binder Ratio (D/A).

2. REFERENCES

- a. WAQTC FOP for TM-6 for Moisture content of Bituminous Mixtures by Oven
- b. WSDOT FOP for AASHTO T 30 for Mechanical Analysis of Extracted Aggregates
- c. WSDOT FOP for AASHTO T 166 for Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
- d. WAQTC FOP for AASHTO T168 for Sampling Bituminous Paving Mixture
- e. WSDOT FOP for AASHTO T 209 FOP for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures “Rice Density”
- f. WSDOT FOP for AASHTO T 308 FOP for Determining Asphalt Content of Hot Mix Asphalt by the Ignition Method
- g. WSDOT FOP for AASHTO T 312 Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor
- h. WSDOT Test Method 712 Standard Method for reducing Bituminous Paving Mixtures

3. CALIBRATION OF COMPACTOR

- a. The gyrotory compactor will be calibrated in accordance with WSDOT VP-58 and according to the manufacturers established calibration procedure. Anytime the testing facility is moved a new calibration is also required in accordance with WSDOT VP-58.

4. TEST SAMPLES

- a. The sample shall be obtained per WAQTC T 168, and reduced in accordance with WSDOT Test Method No. 712.
- b. The size of the sample shall be such that it will produce a compacted specimen 115 ± 5 mm in height. Generally, 4750 to 4850 grams is adequate.
- c. Because the compaction test is temperature sensitive, the compaction sample should be the first sample split out and placed in an oven set to no more than 25° F above the compaction temperature, and heated until it achieves the compaction temperature.
- d. Split out the rice, asphalt content and gradation, and moisture samples. These tests can be run in at the same time with the compaction sample.

5. PROCEDURE

- a. Place a compaction mold, base plate, and top plate (if required), in an oven set at no more than 25° F above compaction temperature for a minimum of 60 minutes prior to the estimated beginning of compaction.

Note 1: Never exceed 350° F with any Pine Brovold Mold.

- b. Place a thermometer into the center of the mix. If the sample is at the specified compaction temperature (see Mix Design Report), proceed with the compaction immediately. If the sample is not at compaction temperature, continue to heat in the oven until it is at the compaction temperature. Do not stir the mixture. Compact immediately upon achieving compaction temperature.

Note 2: While the gyratory compaction sample is heating, the rice sample can be spread out to cool and run, the asphalt content sample can be started in the ignition furnace, and the moisture sample can be weighed and placed in the oven.

- c. Prepare the compacted specimen in accordance with AASHTO T312 section 9.
- d. Determine Rice 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 AASHTO T 30.
- f. Determine moisture content per WAQTC TM 6.
- g. Allow the gyratory sample 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.

6. VOLUMETRIC CALCULATIONS

CALCULATIONS

- a. Calculate %Gmm@Ndes as follows:

$$\frac{G_{mb}}{G_{mm}} * 100 = \%G_{mm} @ N_{des}$$

Example: $\frac{2.570}{2.570} * 100 = 95.6\%$

Where:

%Gmm@Ndes = % Theoretical Maximum Specific Gravity @ Ndesign

Gmb = bulk specific gravity of the compacted mixture

Gmm = maximum specific gravity of the paving mixture (Rice)

Ndes = # of design gyrations

- b. Calculate %Gmm@Nini as follows:

$$\frac{H_{des}}{H_{ini}} * \%Gmm@N_{des} = \%Gmm@N_{ini}$$

$$\text{Example: } \frac{110.0}{123.1} * 95.6\% = 85.4\%$$

Where:

%Gmm@Nini = % Theoretical Maximum Specific Gravity @ Ninitial

Hdes = height of specimen at design gyration level

Hini = height of specimen at initial design gyration level

Nini = # of initial gyrations

- c. Calculate Air Voids (Va) as follows:

$$100 - \%Gmm@N_{des} = \%Va$$

$$\text{Example: } 100 - 95.6\% = 4.4\%$$

Where:

Va = percent air voids

- d. Calculate Voids in Mineral Aggregate (VMA) as follows:

$$100 - \left[\frac{\%Gmm@N_{des} * G_{mm} * \left(\frac{100 - \%AC}{100} \right)}{G_{sb}} \right] = \%VMA$$

$$\text{Ex: } 100 - \left[\frac{95.6\% * 2.687 * \left(\frac{100 - 5.0\%}{100} \right)}{2.860} \right] = 1.7\%$$

Ex:

Where:

AC = Asphalt Content as a percent

VMA = Voids in Mineral Aggregate, percent

Gsb = Gravity Stone Bulk (specific gravity of the total aggregate blend)

- e. Calculate Voids Filled with Asphalt (VFA) as follows:

$$100 * \left[\frac{(\%VMA - \%Va)}{\%VMA} \right] = \%VFA$$

$$\text{Example: } 100 * \left[\frac{14.7\% - 4.4\%}{14.7\%} \right] = 70.1\%$$

Where:

VFA = Voids Filled with Asphalt, percent

- f. Calculate Gravity Stone Effective (Gse) as follows:

$$\frac{100 - \%AC}{\left(\frac{100}{Gmm} - \frac{\%AC}{Gb} \right)} = Gse$$

$$\text{Example: } Gse = \frac{100 - 5.0\%}{\left(\frac{100}{2.687} - \frac{5.0\%}{1.032} \right)} = 2.934$$

Where:

Gse = Gravity Stone Effective (specific gravity of aggregates, excluding voids permeable to asphalt)

AC = Asphalt Content as a percent

- g. Calculate Percent Binder Effective (Pbe) as follows:

$$\%AC - \left\{ [(100 - \%AC) * Gb] * \left(\frac{Gse - Gsb}{Gse * Gsb} \right) \right\} = Pbe$$

Example:

$$5.0\% - \left\{ [(100 - 5.0) * 1.032] * \left(\frac{2.934 - 2.860}{2.934 * 2.860} \right) \right\} = 4.1\%$$

Where:

Pbe= percent binder effective - total asphalt content of a paving mixture, minus the portion of asphalt that is lost by absorption into the aggregate

- h. Calculate Dust to Asphalt Binder Ratio (D/A) as follows:

$$\frac{\%200-}{Pbe} = D/A$$

$$\text{Example: } \frac{5.7\%}{2.4\%} = 2.4$$

Where:

D/A= Dust to Asphalt binder ratio

%200- = percent of aggregate passing the No. 200 sieve

7. REPORT

Report asphalt content, gradation, and moisture content on WSDOT Form 350-560EF, and report volumetric properties on WSDOT Form 350-162.



WSDOT Test Method No. 813

Field Method of Fabrication of 50-mm (2-in.) Cube Specimens for Compressive Strength Testing of Grouts and Mortars

1. SCOPE

This method covers the fabrication of 50-mm (2-in.) cube specimens for compressive strength testing of grouts and mortars.

2. EQUIPMENT

a. Specimen Molds

Specimen molds for the 50 mm (2 in.) cube specimens shall be tight fitting. The molds shall not have more than three cube compartments and shall not be separable into more than two parts. The parts of the molds, when assembled, shall be positively held together. The molds shall be made of hard metal not attacked by the cement mortar. For new molds, the Rockwell hardness number shall not be less than HRB 55. The sides of the molds shall be sufficiently rigid to prevent spreading or warping. The interior faces of the molds shall be plane with a permissible variation of 0.002 in. (0.05 mm) for new molds and 0.002 in. (0.50 mm) for molds in use. The distances between opposite faces shall be 2 ± 0.02 in. (50 ± 0.50 mm). The height of each compartment shall be 1.985 in. to 2.01 in. (49.62 mm to 50.25 mm). The angle between adjacent interior faces, and between interior faces and top and bottom planes of the mold, shall be measured at points slightly removed from the intersection of the faces, and shall be 90 ± 0.5 degrees.

b. Base Plates

Base plates shall be made of a hard metal not attacked by cement mortar. The working surface shall be plane and shall be positively attached to the mold with screws into the side walls of the mold.

c. Cover Plates

Cover plate shall be made of a hard metal or glass not attacked by cement mortar. The surface shall be relatively plane.

d. Tamper

The tamper shall be made of a nonabsorptive, nonabrasive, nonbrittle material such as a rubber compound having a Shore A durometer hardness of $80 + 10$, or seasoned oak wood rendered nonabsorptive by immersion for 15 minutes in paraffin at approximately 392°F (200°C), and shall have a cross-section of $\frac{1}{2}$ in. \times 1 in. (13 mm \times 25 mm) and a length of about 5 to 6 in. (125 to 150 mm). The tamping face shall be flat and at right angles to the length of the tamper.

e. Trowel

A trowel which has a steel blade 4 to 6 in. (100 to 150 mm) in length, with straightedges.

3. FIELD PROCEDURE

- a. Three or more specimens shall be made for each period of test specified.
- b. Seal the surfaces where the halves of the mold join by applying a coating of light cup grease. The amount should be sufficient to extrude slightly when the halves are tightened together. Repeat this process for attaching the mold to the base plate. Remove any excess grease.
- c. Apply a thin coating of release agent to the interior faces of the mold and base plate. (WD-40 has been found to work well as a release agent) Wipe the mold faces and base plate as necessary to remove any excess release agent and to achieve a thin, even coating on the interior surfaces. Adequate coating is that which is just sufficient to allow a distinct fingerprint to remain following light finger pressure.
- d. The grout or mortar shall be mixed according to the manufacturer's instructions. Begin molding the specimens within an elapsed time of not more than 2 ½ minutes from completion of the mixing.
- e. For plastic mixes, place a first layer of mortar about 1 in. (25 mm) deep in all the cube compartments (about one-half the depth of the mold). Tamp the mortar in each cube compartment 32 times in about 10 seconds making four rounds, each round perpendicular to the other and consisting of eight adjoining strokes over the surface of the specimen, as illustrated in Figure 1, below. The tamping pressure should be just sufficient to ensure uniform filling of the molds. The four rounds of tamping (32 strokes) shall be completed in one cube before going on to the next. When the tamping of the first layer is completed, slightly over fill the compartments with the remaining mortar and then tamp as specified for the first layer. During tamping of the second layer, bring in the mortar forced out onto the tops of the molds after each round of tamping, by means of gloved fingers and the tamper, before starting the next round of tamping. On completion of tamping, the tops of all the cubes should extend slightly above the tops of the molds.

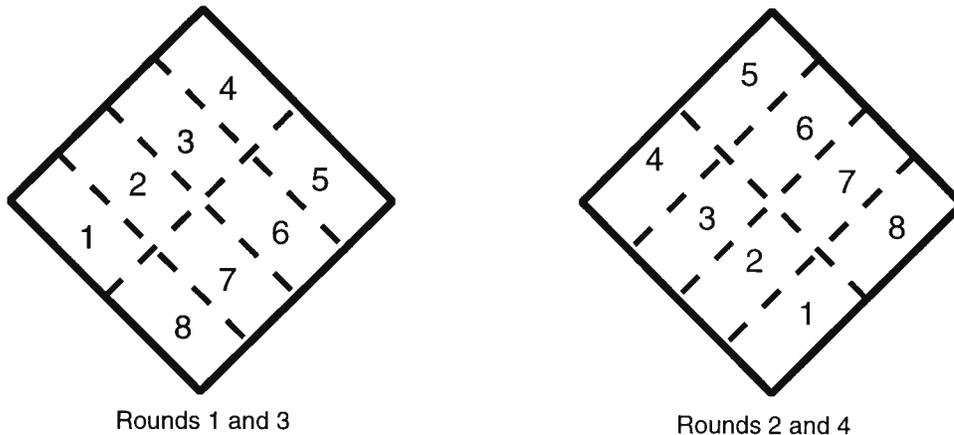


Figure 1

- f. Bring in the mortar that has been forced out onto the tops of the molds with a trowel and smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube at right angles to the length of the mold. Then, for the purpose of leveling the mortar and making the mortar that protrudes above the top of the mold of more uniform thickness, draw the flat trailing edge of the trowel (with leading edge slightly raised) once lightly along the length of the mold. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion over the length of the mold.
 - g. When fabricating fluid mixes, steps e. and f. need not be followed. Instead, the cube mold is filled with mortar and cut off to a plane surface with a sawing motion over the length of the mold.
 - h. Immediately after molding, place cover plate on top of the mold, cover the sample with wet burlap, towels, or rags, seal it in a plastic sack in a level location out of direct sunlight, and record the time. Allow the sample to set undisturbed, away from vibration, for a minimum of four hours before moving.
 - i. Deliver the sample to the Regional or State Materials Laboratory in the mold within 24 hours. **Time of molding MUST be recorded on the Transmittal.**
4. LAB PROCEDURE:
- a. Once received in the lab, the molded sample is to be immediately placed in a moist curing room, with the upper surfaces exposed to the moist air but protected from dripping until the sample is a minimum of 20 hours old. The specimens may be removed from the mold after 20 hours by lab personnel, if kept. on the shelves of the moist curing room until they are 24-36 hours old.
 - b. When the specimens are 24-36 hours old, immerse them in a lime-saturated water storage tank. (Note 1) The specimens are to remain in the storage tank until time of test. (Curing test specimens of material other than hydraulic cement shall be in conformance with the manufacturer's recommendations.)

Note 1: The storage tank shall be made of noncorroding materials. The water shall be saturated with calcium hydroxide such that excess is present. Stir the lime-saturated water once a month and clean the bath as required by AASHTO M-201.

Performance Exam Checklist

Field Method of Fabrication of 50-mm (2-in.) Cube Specimens for Compressive Strength Testing of Grouts and Mortars

Participant Name _____

Exam Date _____

Procedure Element	Yes	No
1. Three cubes made for each time period of test?	_____	_____
2. All joints (mold halves, mold to base plate) sealed with light cup grease?	_____	_____
3. Adequate coating of release agent applied to interior surfaces of the mold?	_____	_____
4. Grout or mortar mixed according to manufacturer's instructions?	_____	_____
5. Molding began within 2-1/2 minutes from completion of mixing?	_____	_____
6. Molding performed in two lifts? (not necessary if mix is fluid)	_____	_____
7. Lifts tamped 32 times, made up of 4 rounds of 8, each perpendicular to the other?	_____	_____
8. For second layer, mortar forced out of the mold brought back in before each round?	_____	_____
9. Mix extends slightly above the mold at the completion of tamping?	_____	_____
10. Mortar smoothed by drawing flat side of trowel across each cube at right angles?	_____	_____
11. Mortar leveled by drawing the flat side of trowel lightly along the length of mold?	_____	_____
12. Mortar cut off flush with mold with edge of trowel using sawing motion?	_____	_____
13. Time of molding recorded?	_____	_____
14. Cover plate placed on top of the mold and covered with wet burlap, towel or rag?	_____	_____

15. Covered sample sealed in a plastic sack in a level location out of sunlight? _____

16. Sample delivered to the laboratory in the mold within 24 hours? _____

17. Transmittal includes the time of molding? _____

Comments:

First attempt: Pass Fail

Second attempt: Pass Fail

Signature of Examiner _____



WSDOT FOP for ASTM D4791¹
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 *ASTM Standards:*

FOP for AASHTO T 2 **WSDOT FOP for AASHTO for the Sampling of Aggregates**

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

FOP for AASHTO T 27/11 **WAQTC FOP for AASHTO for the Sieve Analysis of Fine & Coarse Aggregates & 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.

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.

¹This Test Method is Based on ASTM D 4791-99

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 Fig. 1, Fig. 2, and Fig. 3 are examples of devices suitable for this test method. The device illustrated in Fig. 1 and Fig. 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. Fig. 1 illustrates a device on which ratios of 1:2, 1:3, 1:4, and 1:5 may be set. The device illustrated in Fig. 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 % of the mass of the sample.

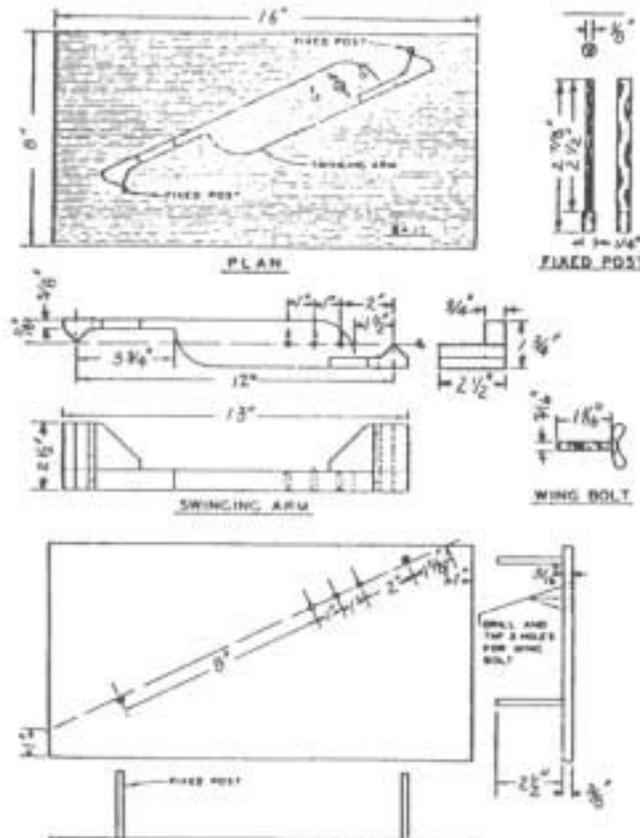


FIG. 1 Proportional Caliper

7. Sampling

- 7.1 Sample the coarse aggregate in accordance with in FOP for AASHTO T2 Practice D-75. The mass of the field sample shall be the mass shown in FOP for AASHTO T2 Practice D-75.
- 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 Practice C-702. 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:

Nominal Maximum Size Square Openings, in. (mm)	Minimum Mass of Test Sample, lb (kg.)
3/8 (9.5)	2 (1)
1/2 (12.5)	4 (2)
3/4 (19)	11 (5)
1 (25.0)	22 (10)
1 1/2 (37.5)	33 (15)
2 (50)	44 (20)
2 1/2 (63)	77 (35)
3 (75)	130 (60)
3 1/2 (90)	220 (100)
4(100)	330 (150)
4 1/2 (112)	440 (200)
5 (125)	660 (300)
6 (150)	1100 (500)

8. Procedure

- 8.1 If determination by mass is required, oven dry the sample to constant mass at a temperature of $230 \pm 9^{\circ}\text{F}$ ($110 \pm 5^{\circ}\text{C}$). 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 Test Method C-136. If the material retained on each required size (3/8 and larger) is more than 10% of the sample, reduce the material in accordance with FOP for AASHTO T 248 until approximately 100 particles are obtained for each required size. Using the material retained on the 9.5 mm (3/8 in.) or 4.75 mm (No. 4), as required by the specification being used, reduce each size fraction present in the amount of 10 % or more of the original sample in accordance with Practice C-702 until approximately 100 particles are obtained for each size fraction required.
- 8.3 *Flat Particle Test and Elongated Particle Test*—Test each of the particles in each size fraction, and place in one of three groups: (1) flat, (2) elongated, (3) neither flat nor elongated.
- 8.3.1 Use the proportional caliper device, positioned at the proper ratio, shown in Fig. 2, as follows:
- 8.3.1.1 *Flat Particle Test*—Set the larger opening equal to the particle width. The particle is flat if the thickness can be placed in the smaller opening.
- 8.3.1.2 *Elongated Particle Test*—Set the larger opening equal to the particle length. The particle is elongated if the width can be placed within the smaller opening.

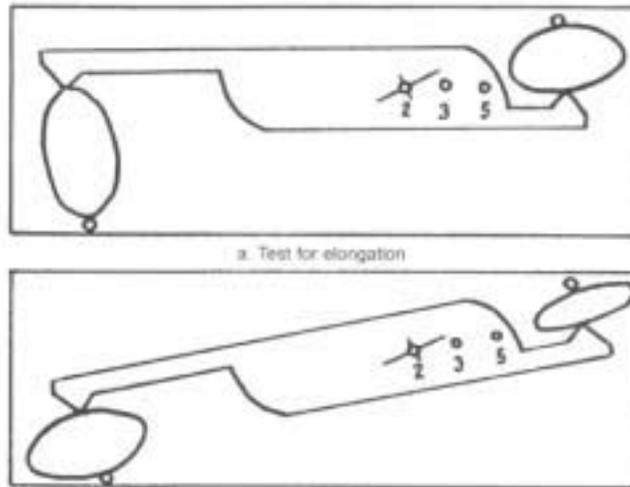
8.3.2 After the particles have been classified into the group described in 8.3, determine the proportion of the sample in each group by either count or by mass, as required.

8.4 *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.

8.4.1 Use the proportional caliper device, set at the desired ratio.

8.4.2 *Measurement:*

8.4.2.1 On proportional caliper devices similar to the devices shown in Fig. 1 and Fig. 2, set the larger opening equal to the length of the particle. The particle is flat and elongated if the particle, when oriented to measure its thickness, can pass completely through the smaller opening of the caliper.



Metric Equivalents

in.	mm	in.	mm	in.	mm
1/8	3.2	7/8	21.2	2 1/2	64.0
3/16	4.8	1	25.4	2 7/8	72.0
1/4	6.3	1 1/16	27.0	3 3/4	96.0
5/16	7.9	1 1/2	38.0	8	207.0
3/8	9.5	1 5/8	41.0	16	414.0

FIG. 2 Use of Proportional Caliper

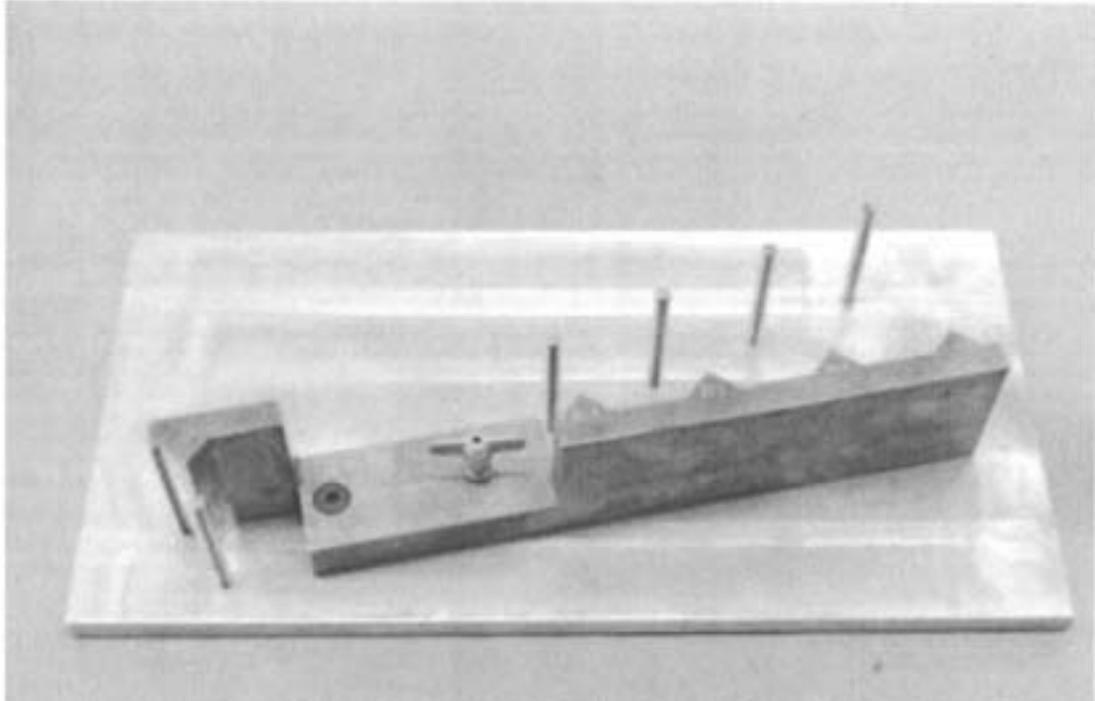


FIG. 3 Proportional Caliper

8.4.2.2 On calipers similar to the one described in Fig. 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.

9. Calculation

9.1 Calculate the percentage of flat and elongated particles to the nearest 1 % for each sieve size greater than 3/8 in. (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 particle tests and elongated particle tests:

10.1.3.1 Number of particles in each sieve size tested,

10.1.3.2 Percentages, calculated by number or by mass, or both, for: (1) flat particles, (2) elongated particles, and (3) total flat particles and elongated particles for each sieve size tested, and

10.1.3.3 The dimensional ratios used in the tests.

10.1.4 For flat and elongated particle tests:

10.1.4.1 Number of particles in each sieve size tested,

10.1.4.2 Percentages, calculated by number or by mass, or both, for flat and elongated particles for each sieve size tested,

10.1.4.3 The dimensional ratio used in the tests, and

10.1.5 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 WSDOT form 350-161

11. Precision and Bias

11.1 *Precision*—The precision of this test method is being determined.

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

12. Keywords

12.1 aggregates; coarse aggregates; particle shape

Performance Exam Checklist
FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE
ASTM D-4791-95

Participant Name _____

Exam Date _____

SAMPLING

Yes

No

- | | | |
|---|-------|-------|
| 1. Field sample obtained per AASHTO T-2? | _____ | _____ |
| 2. Sample thoroughly mixed prior to reducing to testing size? | _____ | _____ |
| 3. Sample reduced to testing size per AASHTO T-248? | _____ | _____ |
| 4. Mass of the test sample conforms to the table in Section 7.2, ASTM D-4791? | _____ | _____ |

PROCEDURE

- | | | |
|--|-------|-------|
| 1. If determination by mass, sample oven dried to a constant weight prior to mass determination? | _____ | _____ |
| 2. Sample sieved per AASHTO T-27? | _____ | _____ |
| 3. Proportional caliper device positioned at proper ratio? | _____ | _____ |
| 4. Each size fraction larger than 3/8 inch retaining 10% or more of the original sample reduced per AASHTO T-248 until approximately 100 particles are obtained for each size fraction required? | _____ | _____ |
| 5. Each particle of each size fraction tested for FLAT and ELONGATED using the proportional caliper device put in the appropriate group classification? (Flat & Elongated or Not flat & Elongated) | _____ | _____ |
| 6. Proportion of the sample of each sieve size determined by MASS ? | _____ | _____ |
| 7. Percent of Flat and Elongated particles figured to the nearest 1% for each sieve size? | _____ | _____ |
| 8. Record number of particles in each sieve size tested? | _____ | _____ |
| 9. Record percentages calculated by COUNT? | _____ | _____ |

