Washington State Department of Transportation

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Materials Manual M 46-01.29	
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Remarks and Instructions

The *Materials Manual* M 46-01 has been revised. Please remove and recycle the contents of the old *Materials Manual* M 46-01 and replace with the August 2017 revision.

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

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Please contact Kevin Burns at 360-709-5412 or mawdslr@wsdot.wa.gov with comments, questions, or suggestions for improvement to the manual.

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Joe DeVol

Approved By

Signature

Washington State
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Engineering and Regional Operations
State Materials Laboratory

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English

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Hot Mix Asphalt				
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T 314	WSDOT		✓	Method of Test for Photovolt Reflectance
T 413	WSDOT		✓	Method of Test for Evaluating Waterproofing Effectiveness of Membrane and Membrane-Pavement Systems
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T 814	WSDOT		✓	Method of Test for Water Retention Efficiency of Liquid Membrane-Forming Compounds and Impermeable Sheet Materials for Curing Concrete
C 939	WSDOT	✓	✓	FOP for ASTM for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

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C 882	ASTM		✓	Bond Strength (Diagonal Shear) (Checklist Only)
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D 1429	ASTM			Standard Test Methods for Specific Gravity of Water and Brine
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D 4758	ASTM			Test Method for Nonvolatile Contents of Latexes
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C 495	ASTM			Test Method for Compressive Strength of Lightweight Insulated Concrete
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Concrete				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
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T 810	WSDOT	✓	✓	Method of Test for Determination of the Density of Portland Cement Concrete Pavement Cores
T 812	WSDOT	✓	✓	Method of Test for Measuring Length of Drilled Concrete Cores
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T 819	WSDOT		✓	Making and Curing Self-Compacting Concrete Test Specimens in the Field
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C 939	WSDOT	✓	✓	FOP for ASTM for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
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PCMZ 2000	TS			Manual on Signal Controller Evaluation
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Geotechnical – Soils				
Procedure Number	Owner	Field Use	In Manual	Test Method
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T 89	AASHTO		✓	Determining the Liquid Limit of Soils
T 90	AASHTO		✓	Determining the Plastic Limit and Plasticity Index of Soils (Checklist Only)
T 99	AASHTO			Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop
T 99	WAQTC	✓	✓	FOP for AASHTO T 99, Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop
T 100	AASHTO			Specific Gravity of Soil
T 180	AASHTO			Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18 in (457 mm) Drop Checklist
T 180	WAQTC	✓	✓	FOP for AASHTO T 180, Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18 in (457 mm) Drop
T 208	AASHTO			Unconfined Compressive Strength of Cohesive Soil
T 215	AASHTO			Permeability of Granular Soils (Constant Head)
T 216	AASHTO			One-Dimensional Consolidation Properties of Soils
T 236	AASHTO			Direct Shear Test of Soils Under Consolidated Drained Conditions
T 265	AASHTO			Laboratory Determination of Moisture Content of Soils
T 265	WAQTC	✓	✓	FOP for AASHTO T 255, Laboratory Determination of Moisture Content of Soils
T 296	AASHTO			Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression
T 297	AASHTO			Consolidated, Undrained Triaxial Compressive Test on Cohesive Soils Shear
D 2487	ASTM			Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D 2488	ASTM			Practice for Description and Identification of Soils (Visual-Manual Procedure)
D 4186	ASTM			Standard Test Method for One-Dimensional Consolidation Properties of Saturated Cohesive Soils Using Controlled-Strain Loading
D 4644	ASTM			Standard Test Method for Slake Durability of Shales and Similar Weak Rocks
T 501	WSDOT		✓	Test Method to Determine Durability of Very Weak Rock
D 5084	ASTM			Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
D 5311	ASTM			Standard Test Method for Load Controlled Cyclic Triaxial Strength of Soil
D 5731	ASTM			Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications
D 6467	ASTM			Standard Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils
D 6528	ASTM			Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Cohesive Soils
D 7012	ASTM		✓	Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens

Geotextile and Steel				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
A 143	ASTM			Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
T 244	AASHTO			Mechanical Testing of Steel Products
A 370	ASTM			Standard Test Methods and Definitions for Mechanical Testing of Steel Products
F 606	ASTM			Mechanical Properties: Steel Fasteners
T 914	WSDOT	✓	✓	Practice for Sampling of Geosynthetic Material for Testing
T 915	WSDOT		✓	Practice for Conditioning of Geotextiles for Testing
T 923	WSDOT		✓	Thickness Measurement of Geotextiles
T 925	WSDOT		✓	Standard Practice for Determination of Long-Term Strength for Geosynthetic Reinforcement
T 926	WSDOT		✓	Geogrid Brittleness Test
D 1683	ASTM			Sewen Seams (Geotextiles)
D 4355	ASTM			Standard Test Method for Deterioration of Geotextiles From Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
D 4491	ASTM			Water Permeability (Geotextiles)
D 4533	ASTM			Tear Strength (Geotextiles)
D 4354	ASTM		✓	Standard Practice for Sampling of Geosynthetics for Testing
D 4595	ASTM			Wide Width Breaking Load (Geotextiles)
D 4632	ASTM			Grab Breaking Load (Geotextiles)
D 4751	ASTM			Apparent Opening Size (Geotextiles)
D 6241	ASTM			Puncture (Geotextiles)

Paint				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
D 185	ASTM			Standard Test Methods for Coarse Particles in Pigments, Pastes, and Paints
T 314	ASTM			Method of Test for Photovolt Reflectance
D 562	ASTM			Standard Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer
D 1208	ASTM			Method for Determination of Loss on Ignition
D 1210	ASTM			Standard Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage
D 1475	ASTM			Test Method for Density of Paint and Related Products
D 2244	ASTM			Standard Practice for Calculation of Color Tolerances and Color Differences From Instrumentally Measured Color Coordinates
D 2369	ASTM			Method for Determination of Volatile and Nonvolatile Content (Ordinary Laboratory Oven)
D 2371	ASTM			Standard Test Method for Pigment Content of Solvent-Reducible Paints (Centrifuge)
D 2621	ASTM			Standard Test Method for Infrared Identification of Vehicle Solids From Solvent-Reducible Paints
D 2697	ASTM			Standard Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
3011	FTMS			Method for Determination of Condition in Container
D 3723	ASTM			Standard Test Method for Pigment Content of Water Emulsion Paints by Temperature Ashing
4053	FTMS			Method for Determination of Nonvolatile Vehicle Content
4061	FTMS			Method for Determination of Drying Time (Oil-Based Paints)
4122	FTMS			Method for Determination of Hiding Power (Contrast Ratio)
D 4505	ASTM			Standard Specification for Preformed Plastic Pavement Marking Tape for Extended Service Life Pavement Soils

Pavement Soils				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
T 242	AASHTO			Frictional Properties of Paved Surfaces Using a Full-Size Tire
T 272	AASHTO			One-Point Method for Determining Maximum Dry Density and Optimum Moisture
T 272	WAQTC	✓	✓	FOP for AASHTO T 272, One-Point Method for Determining Maximum Dry Density and Optimum Moisture
T 307	AASHTO		✓	Determining the Resilient Modulus of Soils and Aggregate Materials
T 310	WAQTC	✓	✓	FOP for AASHTO T 310, In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
T 606	WSDOT		✓	Method of Test for Compaction Control of Granular Materials
T 610	WSDOT		✓	Method of Test for the Capillary Rise of Soils
SOP 615	WSDOT	✓	✓	Determination of the % Compaction for Embankment & Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge
T 807	WSDOT	✓	✓	Method of Operation of California Profilograph and Evaluation of Profiles
D 4694	ASTM			Test Method for Deflections With Falling-eight Type Impulse Load Device

Standard Practice				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
QC 1	WSDOT		✓	Standard Practice for Cement Producers/Importers/Distributors That Certify Portland Cement and Blended Hydraulic Cement
QC 2	WSDOT		✓	Standard Practice for Asphalt Suppliers That Certify Performance Graded and Emulsified Asphalts
QC 3	WSDOT		✓	Quality System Laboratory Review
QC 4	WSDOT		✓	Standard Practice for Fly Ash Producers/Importers/Distributors That Certify Fly Ash
QC 5	WSDOT		✓	Standard Practice for Ground Granulated Blast-Furnace Slag Producers/ Importers/Distributors That Certify Ground Granulated Blast-Furnace Slag
QC 6	WSDOT		✓	Annual Prestressed Plant Review and Approval Process
QC 7	WSDOT		✓	Annual Precast Plant Review and Approval Process
QC 8	WSDOT		✓	Standard Practice for Approval of Hot Mix Asphalt Mix Designs for the Qualified Products List

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
QC 1	WSDOT		✓	Standard Practice for Cement Producers/Importers/Distributors That Certify Portland Cement and Blended Hydraulic Cement
QC 2	WSDOT		✓	Standard Practice for Asphalt Suppliers That Certify Performance Graded and Emulsified Asphalts
QC 3	WSDOT		✓	Quality System Laboratory Review
QC 4	WSDOT		✓	Standard Practice for Fly Ash Producers/Importers/Distributors That Certify Fly Ash
QC 5	WSDOT		✓	Standard Practice for Ground Granulated Blast-Furnace Slag Producers/ Importers/Distributors That Certify Ground Granulated Blast-Furnace Slag
QC 6	WSDOT		✓	Annual Prestressed Plant Review and Approval Process
QC 7	WSDOT		✓	Annual Precast Plant Review and Approval Process
QC 8	WSDOT		✓	Standard Practice for Approval of Hot Mix Asphalt Mix Designs for the Qualified Products List
TS1	NEMA			Signal Controller Evaluation Geotechnical – Soils
T 2	WAQTC	✓	✓	FOP for AASHTO T 2, Sampling of Aggregates
TM 2	WAQTC	✓	✓	FOP for WAQTC TM 2, Sampling Freshly Mixed Concrete
T 11	AASHTO			Materials Finer Than 0.075 mm (No. 200) Sieve in Mineral Aggregates by Washing
E 18	ASTM			Standard Test Methods for Rockwell Hardness of Metallic Materials
T 19	AASHTO	✓	✓	Bulk Density (“Unit Weight”) and Voids in Aggregate (Rodding Procedure Only) (Checklist Only)
T 21	AASHTO			Organic Impurities in Fine Aggregates for Concrete
T 22	AASHTO			Compressive Strength of Cylindrical Concrete Specimens
T 22	WSDOT	✓	✓	FOP for AASHTO for Compressive Strength of Cylindrical Concrete Specimens
T 23	AASHTO			Making and Curing Concrete Test Specimens in the Field
T 23	WAQTC	✓	✓	FOP for AASHTO T 23, Making and Curing Concrete Test Specimens in the Field
T 24	AASHTO			Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
T 27	AASHTO			Sieve Analysis of Fine and Coarse Aggregates
T 27_T 11	WAQTC	✓	✓	FOP for AASHTO T 27_T 11, Sieve Analysis of Fine and Coarse Aggregates
R 28	AASHTO			Practice of Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel
R 29	AASHTO			Practice for Grading or Verifying the Performance Grade of an Asphalt Binder
R 30	AASHTO			Practice for Short and Long Term Aging of Hot Mix Asphalt (HMA)
T 30	AASHTO			Mechanical Analysis of Extracted Aggregate
T 30	WAQTC	✓	✓	FOP for AASHTO T 30, Mechanical Analysis of Extracted Aggregate
T 37	AASHTO			Sieve Analysis of Mineral Filler
R 39	AASHTO			Making and curing Concrete Test Specimens in the Laboratory
T 44	AASHTO			Solubility of Bituminous Materials
R 47	AASHTO			Standard Recommended Practice for Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
R 47	WAQTC	✓	✓	FOP for AASHTO R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
T 48	AASHTO			Flash and Fire Points by Cleveland Cup
T 49	AASHTO			Penetration of Bituminous Materials
T 50	AASHTO			Float Test for Bituminous Materials
T 51	AASHTO			Ductility of Bituminous Materials
T 53	AASHTO			Softening Point of Bituminous (Ring and Ball Apparatus)
R 58	AASHTO			Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
T 59	AASHTO			Emulsified Asphalts
T 65	AASHTO			Mass (Weight) of Coating on Iron and Steel Articles With Zinc or Zinc-Alloy Coatings
R 66	WAQTC	✓	✓	FOP for AASHTO R 66, Sampling Asphalt Materials
E 70	ASTM			pH of Aqueous Solutions With the Glass Electrode
T 72	AASHTO			Saybolt Viscosity
R 75	WAQTC			FOP for AASHTO R 75, Developing a Family of Curves
R 76	AASHTO			Reducing Samples of Aggregate to Testing Size
R 76	WAQTC	✓	✓	FOP for AASHTO R 76, Reducing Samples of Aggregate to Testing Size
IP 78-16	FHWA			Signal Controller Evaluation
R 79	AASHTO			Vacuum Drying Compacted Asphalt Specimens
T 84	AASHTO			Specific Gravity and Absorption of Fine Aggregates
T 85	AASHTO			Specific Gravity and Absorption of Coarse Aggregates
T 85	WAQTC	✓	✓	FOP for AASHTO T 85, Specific Gravity and Absorption of Coarse Aggregate
T 88	AASHTO			Particle Size Analysis of Soils
T 89	AASHTO		✓	Determining the Liquid Limit of Soils
T 90	AASHTO		✓	Determining the Plastic Limit and Plasticity Index of Soils (Checklist Only)
T 96	AASHTO			Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
T 99	AASHTO			Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop
T 99	WAQTC	✓	✓	FOP for AASHTO T 99, Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop
T 100	AASHTO			Specific Gravity of Soil
T 105	AASHTO			Chemical Analysis of Hydraulic Cement
T 106	AASHTO			Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)
T 106	WSDOT	✓	✓	FOP for AASHTO for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)
T 107	AASHTO			Autoclave Expansion of Hydraulic Cement
T 112	AASHTO		✓	Clay Lumps and Friable Particles in Aggregate
T 113	WSDOT		✓	Method of Test for Determination of Degradation Value
T 119	AASHTO			Slump of Hydraulic Cement Concrete
T 119	WAQTC	✓	✓	FOP for AASHTO T 119, Slump of Hydraulic Cement Concrete

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
T 121	WAQTC	✓	✓	FOP for AASHTO T 121, Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
T 123	WSDOT	✓	✓	Method of Test for Bark Mulch
T 125	WSDOT		✓	Determination of Fiber Length Percentages in Wood Strand Mulch
T 126	WSDOT		✓	Determination of Fiber Length Percentages in Hydraulically-Applied Erosion Control Products
T 127	WSDOT		✓	Preparation of Leachate Sample for Testing Toxicity of HECP Effluent
SOP 128	WSDOT	✓	✓	Sampling for Aggregate Source Approval
T 129	AASHTO			Normal Consistency of Hydraulic Cement
T 131	AASHTO			Time of Setting of Hydraulic Cement by Vicat Needle
T 133	AASHTO			Density of Hydraulic Cement
T 137	AASHTO			Air Content of Hydraulic Cement Mortar
C 140	ASTM			Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
T 141	AASHTO			Sampling Freshly Mixed Concrete
A 143	ASTM			Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
T 152	AASHTO			Air Content of Freshly Mixed Concrete by the Pressure Method
T 152	WAQTC	✓	✓	FOP for AASHTO T 152, Air Content of Freshly Mixed Concrete by the Pressure Method
T 153	AASHTO			Fineness of Hydraulic Cement by Air Permeability Apparatus
T 162	AASHTO			Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
T 166	AASHTO			Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
T 166	WAQTC	✓	✓	FOP for AASHTO T 166, for Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface Dry Specimens
T 168	AASHTO			Sampling Bituminous Paving Mixtures
T 168	WAQTC	✓	✓	FOP for AASHTO T 168, Sampling of Hot Mix Asphalt Paving Mixtures
T 176	AASHTO			Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
T 176	WAQTC	✓	✓	FOP for AASHTO T 176, Plastic Fines in Graded Aggregates and Soils by the Use of the Sand Equivalent Test
T 180	AASHTO			Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18 in (457 mm) Drop
T 180	WAQTC	✓	✓	FOP for AASHTO T 180, Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18 in (457 mm) Drop
D 185	ASTM			Standard Test Methods for Coarse Particles in Pigments, Pastes, and Paints
T 196	AASHTO		✓	Air Content of Concrete (Volumetric Method) (Checklist Only)
T 197	AASHTO			Time of Setting of Concrete Mixtures by Penetration Resistance
T 198	AASHTO			Splitting Tensile Strength of Cylindrical Concrete Specimens
T 208	AASHTO			Unconfined Compressive Strength of Cohesive Soil

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
T 209	AASHTO			Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)
T 209	WAQTC	✓	✓	FOP for AASHTO T 209, Theoretical Maximum Specific Gravity (Gmm) and Density of Hot Mix Asphalt (HMA) Paving Mixtures
T 215	AASHTO			Permeability of Granular Soils (Constant Head)
T 216	AASHTO			One-Dimensional Consolidation Properties of Soils
T 228	AASHTO			Specific Gravity of Semi-Solid Bituminous Material
T 231	AASHTO			Capping Cylindrical Concrete Specimens
T 231	WSDOT	✓	✓	FOP for AASHTO for Capping Cylindrical Concrete Specimens
T 236	AASHTO			Direct Shear test of Soils Under Consolidated Drained Conditions
T 240	AASHTO			Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)
T 242	AASHTO			Frictional Properties of Paved Surfaces Using a Full-Size Tire
T 244	AASHTO			Mechanical Testing of Steel Products
T 255	AASHTO			Total Evaporable Moisture Content of Aggregate by Drying
T 255	WAQTC	✓	✓	FOP for AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying
T 257	AASHTO			Instrumental Photometeric Measurements of Retroreflectivie Material and Retroreflective
T 260	AASHTO			Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials
T 265	AASHTO			Laboratory Determination of Moisture Content of Soils
T 265	WAQTC	✓	✓	FOP for AASHTO T 255, Laboratory Determination of Moisture Content of Soils
T 267	AASHTO			Determination of Organic Content in Soils by Loss on Ignition
T 269	AASHTO			Percent Air Void in Compacted Dense and Open Asphalt Mixtures
T 272	AASHTO			One-Point Method for Determining Maximum Dry Density and Optimum Moisture
T 272	WAQTC	✓	✓	FOP for AASHTO T 272, One-Point Method for Determining Maximum Dry Density and Optimum Moisture
T 277	AASHTO			Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
T 288	AASHTO		✓	Determining Minimum Laboratory Soil Resistivity (Checklist Only)
T 289	AASHTO			Determining pH of Soil for Use in Corrosion
T 296	AASHTO			Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression
T 297	AASHTO			Consolidated, Undrained Triaxial Compressive Test on Cohesive Soils Shear
T 301	AASHTO			Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer
T 303	AASHTO			Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction
T 304	WSDOT	✓	✓	FOP for AASHTO for Uncompacted Void Content of Fine Aggregate
T 307	AASHTO		✓	Determining the Resilient Modulus of Soils and Aggregate Materials
T 308	AASHTO			Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
T 308	WAQTC	✓	✓	FOP for AASHTO T 308, Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method
T 309	AASHTO			Temperature of Freshly Mixed Hydraulic Cement Concrete
T 309	WAQTC	✓	✓	FOP for AASHTO T309, Temperature of Freshly Mixed Portland Cement Concrete
T 310	WAQTC	✓	✓	FOP for AASHTO T 310, In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
T 312	AASHTO			Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
T 312	WAQTC	✓	✓	FOP for AASHTO T 312, Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
T 313	AASHTO			Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
T 313	WSDOT		✓	Method of Test for Cement-Latex Compatibility
T 314	WSDOT		✓	Method of Test for Photovolt Reflectance
T 315	AASHTO			Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
T 316	AASHTO			Viscosity Determination of Asphalt Binder Using Rotational Viscometer
SOP 318	WSDOT		✓	Standard Operating Procedure for Melting of Flexible Bituminous Pavement Marker Adhesive for Evaluation
T 324	AASHTO		✓	Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)
T 329	AASHTO			Moisture Content of Asphalt Mixtures by Oven Method
T 329	WAQTC	✓	✓	FOP for AASHTO T 329, Moisture Content of Asphalt Mixture by Oven Method
T 331	WSDOT		✓	Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method
T 335	AASHTO			Determining the Percentage of Fracture in Coarse Aggregate
T 335	WAQTC	✓	✓	FOP for AASHTO T 335, Determining the Percentage of Fracture in Coarse Aggregate
T 355	WAQTC	✓	✓	FOP for AASHTO T 355, In-Place Density of Asphalt Mixtures by Nuclear Method
A 370	ASTM			Standard Test Methods and Definitions for Mechanical Testing of Steel Products
T 413	WSDOT	✓	✓	Method of Test for Evaluating Waterproofing Efectiveness of Membrane and Membrane-Pavement Systems
T 417	WSDOT		✓	Method of Test for Determining Minimum Resistivily and pH of Soil and Water
T 420	WSDOT	✓	✓	Test Method for Determining the Maturity of Compost (Solvita Test)
T 421	WSDOT		✓	Test Method for Traffic Controller Inspection and Test Procedure
T 422	WSDOT		✓	Test Method for Traffic Controller Transient Voltage Test (Spike Test) Procedure
T 423	WSDOT		✓	Test Method for Traffic Controller Conflict Monitoresting
T 424	WSDOT		✓	Test Method for Traffic Controller Power Interruption Test Procedure

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
T 425	WSDOT		✓	Test Method for Traffic Controller NEM and 170 Type Environmental Chamber Test
T 426	WSDOT		✓	Pull-Off Test for Hot Melt Traffic Button Adhesive
T 427	WSDOT		✓	Test Method for Loop Amplifier Testing Procedure
T 428	WSDOT		✓	Test Method for Traffic Controller Compliance Inspection and Test Procedure
SOP 429	WSDOT		✓	Methods for Determining the Acceptance of Traffic Signal Controller Assembly
T 432	WSDOT		✓	Flexibility Test for Hot-Melt Adhesives
C 457	ASTM			Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete
C 495	ASTM			Test Method for Compressive Strength of Lightweight Insulated Concrete
T 501	WSDOT		✓	Test Method to Determine Durability of Very Weak Rock
D 562	ASTM			Standard Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer
F 606	ASTM			Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
T 606	WSDOT		✓	Method of Test for Compaction Control of Granular Materials
T 610	WSDOT		✓	Method of Test for the Capillary Rise of Soils
SOP 615	WSDOT	✓	✓	Determination of the % Compaction for Embankment and Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge
DMCT 700	ATSI			Manual on Signal Controller Evaluation
T 716	WSDOT	✓	✓	Method of Random Sampling for Locations of Testing and Sampling Sites
T 718	WSDOT		✓	Method of Test for Determining Stripping of Hot Mix Asphalt
T 720	WSDOT		✓	Method of Test for Thickness Measurement of Hot Mix Asphalt (HMA) Cores
SOP 723	WSDOT		✓	Standard Operating Procedure for Submitting Hot Mix Asphalt (HMA) Mix Designs for Verification
T 724	WSDOT	✓	✓	Method of Preparation of Aggregate for Hot Mix Asphalt (HMA) Mix Designs
T 726	WSDOT	✓	✓	Mixing Procedure for Hot Mix Asphalt (HMA)
SOP 728	WSDOT	✓	✓	Standard Operating Procedure for Determining the Ignition Furnace Calibration Factor (IFCF) for Hot Mix Asphalt (HMA)
SOP 729	WSDOT	✓	✓	Standard Operating Procedure for Determination of the Moving Average of Theoretical Maximum Density (TMD) for HMA
SOP 730	WSDOT	✓	✓	Standard Operating Procedure for Correlation of Nuclear Gauge Densities With Hot Mix Asphalt (HMA) Cores
SOP 731	WSDOT	✓	✓	Standard Operating Procedure for Determining Volumetric Properties of Hot Mix Asphalt
SOP 732	WSDOT	✓	✓	Standard Operating Procedure for Volumetric Design for Hot-Mix Asphalt (HMA)
SOP 733	WSDOT	✓	✓	Standard Operating Procedure for Determination of Pavement Density Differentials Using the Nuclear Density Gauge

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
SOP 734	WSDOT	✓	✓	Standard Operating Procedure for Sampling Hot Mix Asphalt After Compaction (Obtaining Cores)
SOP 735	WSDOT	✓	✓	Standard Operating Procedure for Longitudinal Joint Density
SOP 736	WSDOT		✓	In-Place Density of Bituminous Mixes Using Cores
SOP 737			✓	Procedure for the Forensic Testing of HMA Field Cores
T 802	WSDOT	✓	✓	Method of Test for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)
C 805	ASTM			Test Method for Rebound Number of Hardened Concrete
C 805	WSDOT	✓	✓	Rebound Hammer Determination of Compressive Strength 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 812	WSDOT	✓	✓	Method of Test for Measuring Length of Drilled Concrete Cores
T 813	WSDOT	✓	✓	Field Method of Fabrication of 2 in (50 mm) Cube Specimens for Compressive Strength Testing of Grouts and Mortars
T 814	WSDOT		✓	Method of Test for Water Retention Efficiency of Liquid Membrane-Forming Compounds and Impermeable Sheet Materials for Curing Concrete
T 818	WSDOT		✓	Air Content of Freshly Mixed Self-Compacting Concrete by the Pressure Method
T 819	WSDOT		✓	Making and Curing Self-Compacting Concrete Test Specimens in the Field
C 881	ASTM			Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
C 882	ASTM		✓	Bond Strength (Diagonal Shear) (Checklist Only)
T 914	WSDOT	✓	✓	Practice for Sampling of Geosynthetic Material for Testing
T 915	WSDOT		✓	Practice for Conditioning of Geotextiles for Testing
T 923	WSDOT		✓	Thickness Measurement of Geotextiles
T 925	WSDOT		✓	Standard Practice for Determination of Long-Term Strength for Geosynthetic Reinforcement
T 926	WSDOT		✓	Geogrid Brittleness Test
C 939	ASTM			Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
C 939	WSDOT	✓	✓	FOP for ASTM for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
D 1208	ASTM			Test Methods for Common Properties of Certain Pigments (Loss on Ignition)
D 1210	ASTM			Standard Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage
C 1218	ASTM			Standard Test Method for Water-Soluble Chloride in Mortar and Concrete
D 1429	ASTM			Standard Test Methods for Specific Gravity of Water and Brine
C 1437	ASTM			Standard Test Method for Flow of Hydraulic Cement Mortar

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
D 1475	ASTM			Test Method for Consistency of Paints Test Method for Density of Paint, Varnish, Lacquer, and Related Products
C 1611	WSDOT	✓	✓	FOP for ASTM C 1611/C 1611M Standard Test Method for Slump Flow of Self-Consolidating Concrete
C 1621	WSDOT	✓	✓	FOP for ASTM C 1621/C 1621M Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring
D 1683	ASTM			Standard Test Method for Failure in Sewn Seams of Woven Apparel Fabrics
PCMZ 2000	TS			Manual on Signal Controller Evaluation
D 2240	ASTM			Standard Test Method for Rubber Property – Durometer Hardness
D 2244	ASTM			Standard Practice for Calculation of Color Tolerances and Color Differences From Instrumentally Measured Color Coordinates
D 2369	ASTM			Test Method for Volatile Content of Coatings (Ordinary Laboratory Oven)
D 2371	ASTM			Standard Test Method for Pigment Content of Solvent-Reducible Paints (Centrifuge)
D 2487	ASTM			Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D 2488	ASTM			Practice for Description and Identification of Soils (Visual-Manual Procedure)
D 2621	ASTM			Standard Test Method for Infrared Identification of Vehicle Solids From Solvent-Reducible Paints
D 2628/ M 220	ASTM	✓	✓	Test for High and Low Temperature Recovery of Elastomeric Joint Seals for Concrete Pavements
D 2697	ASTM			Standard Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
3011	FTMS			Method for Determination of Condition in Container
D 3111	ASTM			Standard Test Method for Flexibility Determination of Hot-Melt Adhesives by Mandrel Bend Test Method
D 3723	ASTM			Standard Test Method for Pigment Content of Water Emulsion Paints by Temperature Ashing
4053	FTMS			Method for Determination of Nonvolatile Vehicle Content
4061	FTMS			Method for Determination of Drying Time (Oil-Based Paints)
4122	FTMS			Method for Determination of Hiding Power (Contrast Ratio)
D 4186	ASTM			Standard Test Method for One-Dimensional Consolidation Properties of Saturated Cohesive Soils Using Controlled-Strain Loading
D 4354	ASTM		✓	Standard Practice for Sampling of Geosynthetics for Testing
D 4355	ASTM			Standard Test Method for Deterioration of Geotextiles From Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
D 4491	ASTM			Standard Test Methods for Water Permeability of Geotextiles by Permittivity
D 4505	ASTM			Standard Specification for Preformed Plastic Pavement Marking Tape for Extended Service Life
D 4533	ASTM			Standard Test Method for Trapezoid Tearing Strength of Geotextiles
D 4595	ASTM			Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
D 4632	ASTM			Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
D 4644	ASTM			Standard Test Method for Slake Durability of Shales and Similar Weak Rocks
D 4694	ASTM			Test Method for Deflections With Falling-Eight Type Impulse Load Device
D 4751	ASTM			Test Method for Determining Apparent Opening Size of a Geotextile
D 4758	ASTM			Test Method for Nonvolatile Contents of Latexes
D 4956	ASTM			Standard Specification for Retroreflective Sheeting for Traffic Control
D 5084	ASTM			Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
D 5311	ASTM			Standard Test Method for Load Controlled Cyclic Triaxial Strength of Soil
D 5329	ASTM			Standard Test Methods for Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements
D 5731	ASTM			Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications
D 6241	ASTM			Puncture (Geotextiles)
D 6467	ASTM			Standard Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils
D 6528	ASTM			Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Cohesive Soils
D 6931	ASTM		✓	Standard Test Method for Indirect Tensile (IDT) Strength of Bituminous Mixtures
D 7012	ASTM		✓	Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens
D 7091	ASTM	✓	✓	Nondestructive Measurement of Thickness of Nonmagnetic Coatings on a Ferrous Base (Checklist Only)

Washington State
Department of Transportation

WSDOT Standard Practice for HMA Mix Designs QC 8

Standard Practice for Development of Hot Mix Asphalt Mix Designs

1. Scope

1.1. This standard specifies requirements and procedures for approval Hot Mix Asphalt mix designs for the Qualified Products List.

1.2. This standard may involve hazardous materials, operations and equipment. It does not address all of the safety problems associated with their use. It is the responsibility of 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. WSDOT Standards

2.1.1. *Standard Specifications for Road, Bridge, and Municipal Construction* M 41-10

3. Terminology

1.1. AASHTO – American Association of State Highway and Transportation Officials

1.2. Contractor/Producer – The Contractor, Producer or production facility that has the capacity for producing HMA meeting WSDOT *Standard Specifications*.

1.3. ASA – Aggregate Source Approval

1.4. ASTM – American Society of Testing and Materials

1.5. HMA – Hot Mix Asphalt

1.6. PG – Performance Graded asphalt binder

1.7. QPL – Qualified Products List

1.8. State Materials Laboratory – 1655 S. 2nd Avenue SW, Tumwater, WA 98512-6951

1.9. WSDOT – Washington State Department of Transportation.

4. Significance and Use

4.1. This standard specifies procedures for designing, submitting, evaluating and approving HMA mix designs for inclusion to the QPL.

5. Mix Design Development

5.1. The Contractor/Producer or designee shall develop a HMA mix design in accordance with Section 5-04.2(1) of the *Standard Specifications*. The HMA mix design aggregate structure, asphalt binder content, anti-stripping additive, rutting susceptibility and indirect tensile strength shall be determined in accordance with WSDOT SOP 732, FOP for AASHTO T 324 and WSDOT FOP for ASTM D 6931 and meet the requirements of Sections 9-03.8(2) and 9-03.8(6) of the *Standard Specifications*.

6. Submission to the WSDOT Qualified Products List

6.1. Once the HMA mix design has been developed, the Contractor/Producer shall contact the QPL Engineer (www.wsdot.wa.gov/Business/MaterialsLab/QPL.htm) or 360-709-5442 to initiate the HMA mix design submittal process.

6.2. To initiate the mix design submittal process the Contractor/Producer shall provide the following:

- Company contact and billing information
- A completed copy of WSDOT Form 350-042EF. A completed QPL Application
- ASA Report for the aggregate source(s)
- QPL Contractor/Producer Product Information page(s) for the PG asphalt binder and the anti-stripping additive

6.3. The QPL Engineer will provide the following to the Contractor/Producer:

- QPL evaluation tracking number
- Initial letter detailing mix design evaluation
- Cost sheet for mix design evaluation detailing submittal requirements and associated charges

6.4. After payment is received for the mix design evaluation the QPL Engineer shall provide:

- Assigned delivery date of materials and documentation to State Materials Laboratory
- Estimated date of completion
- Final letter indicating QPL status

6.5. A priority queue will be established by the State Materials Laboratory for HMA mix design evaluations.

6.6. Preference will be given to mix designs submitted for WSDOT contracts.

6.6.1. HMA mix design evaluation for WSDOT contracts shall be completed within 25 calendar days of acceptance by the State Materials Laboratory. Acceptance will be determined when all required documentation, materials and payment have been received at the State Materials Laboratory.

6.6.2. HMA mix design evaluations submitted that are not for WSDOT contracts will be completed within approximately 40 calendar days of acceptance by the State Materials Laboratory.

6.6.3. The State Materials Laboratory reserves the right to limit the number of HMA mix design evaluations accepted that are not for WSDOT contracts at any given time. Workload and staffing will dictate the number of HMA mix designs accepted at one time.

7. Mix Design Evaluation

7.1. The HMA mix design submitted by the Contractor/Producer will be evaluated by the State Materials Laboratory in accordance with Section 9-03.8(2) and 9-03.8(6) of the *Standard Specifications*. All communication from the State Materials Laboratory will be to the Contractor's/Producer's contact as specified on WSDOT Form 350-042EF.

7.2. HMA mix designs will be placed on the QPL provided they meet the requirements of Section 9-03.8(2) and 9-03.8(6) of the *Standard Specifications*.

7.2.1. Voids in Mineral Aggregate (VMA) must be within 1.0% of the minimum specification in accordance with Section 9-03.8(2) of the *Standard Specifications* for the class of HMA evaluated.

7.2.2. % Gmm at N design must be within 1.5% of the specification in Section 9-03.8(2) of the *Standard Specifications* for the class of HMA evaluated.

7.2.3. Voids Filled with Asphalt (VFA) in Section 9-03.8(2) will not be part of the mix design evaluation.

7.3. A mix design that fails to meet the requirements listed in Section 7.2, 7.2.1 and 7.2.2 will not be accepted or placed on the QPL.

7.4. Adjustments to mix designs will not be allowed once they have been evaluated.

7.5. The Contractor/Producer will be issued a QPL mix design record providing the mix design is in compliance with Section 9 of this Standard Practice.

7.6. The QPL listing for HMA mix designs will show the following information:

- Company name
- HMA Class
- Aggregate Source(s)
- PG Grade
- PG Supplier

Anti-stripping additive brand and quantity (if applicable)

8. Referencing Mix Designs From The QPL

8.1. Requests for reference HMA mix designs for non WSDOT projects will be completed on WSDOT Form 350-041EF and emailed to BituminousMaterials@wsdot.wa.gov.

8.2. Reference HMA mix design reports will be issued for new mix designs on active and awarded WSDOT contracts once accepted and placed on the QPL.

8.3. Reference HMA mix design reports will be issued for current mix designs on active and awarded WSDOT contracts provided the HMA production history is in compliance with *Standard Specifications* Section 5-04.3(11)D.

9. Removal From The QPL

9.1. HMA mix designs will be automatically removed from the QPL in accordance with *Standard Specifications* Section 5-04.2(1).

9.2. HMA mix designs may be removed from the QPL if found in nonconformance with the *Standard Specifications* or this Standard Practice. Causes for removal from the QPL may include, but are not limited to the following:

- Failure to comply with requirements of Standard Practice QC 8.
- HMA mix designs that are out of compliance in accordance with Section 5-04.3(11)F of the *Standard Specifications*.
- Failure to notify WSDOT of changes in HMA production.
- Removal at the request of the Contractor/Producer

10. Ignition Furnace Calibration Factor (IFCF) Samples

10.2. Each HMA mix design submitted for evaluation will have 12 IFCF samples produced for WSDOT as part of the QPL evaluation process.

10.3. The Contractor/Producer may elect to have 4 IFCF samples produced as part of the QPL evaluation process.

WSDOT Errata to FOP for AASHTO T 2

Sampling of Aggregates

WAQTC FOP for AASHTO T 2 has been adopted by WSDOT with the following changes:

Procedure – General

TABLE 1 Recommended Sample Sizes – *Shall conform to the following table and note.*

Nominal Maximum Size*in (mm)		Minimum Mass lb (kg)	
US No. 4	(4.75)	5	(2)
¼	(6.3)	10	(4)
⅜	(9.5)	10	(4)
½	(12.5)	20	(8)
⅝	(16.0)	20	(8)
¾	(19.0)	30	(12)
1	(25.0)	55	(25)
1¼	(31.5)	70	(30)
1½	(37.5)	80	(36)
2	(50)	90	(40)
2½	(63)	110	(50)
3	(75)	140	(60)
3½	(90)	180	(80)

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 percent of the materials.

Procedure – Specific Situations

Roadways

Method A (Berm or Windrow) – *Method not recognized by WSDOT.*

Method B (In-Place) – *Method not recognized by WSDOT.*

FOP for AASHTO T 2

Sampling of Aggregates

Scope

This procedure covers sampling of coarse, fine, or a combination of coarse and fine aggregates (CA and FA) in accordance with AASHTO T 2-91. Sampling from conveyor belts, transport units, roadways, and stockpiles is covered.

Apparatus

- Shovels or scoops, or both
- Sampling tubes of acceptable dimensions
- Mechanical sampling systems: normally a permanently attached device that allows a sample container to pass perpendicularly through the entire stream of material or diverts the entire stream of material into the container by manual, hydraulic, or pneumatic operation
- Belt template
- Sampling containers

Procedure – General

Sampling is as important as testing. The technician shall use every precaution to obtain samples that are representative of the material. Determine the time or location for sampling in a random manner.

1. Wherever samples are taken, obtain multiple increments of approximately equal size.
2. Mix the increments thoroughly to form a field sample that meets or exceeds the minimum mass recommended in Table 1.

Table 1 Recommended Sample Sizes

Nominal Maximum Size* mm (in)		Minimum Mass g (lb)	
90	(3½)	175,000	(385)
75	(3)	150,000	(330)
63	(2½)	125,000	(275)
50	(2)	100,000	(220)
37.5	(1½)	75,000	(165)
25.0	(1)	50,000	(110)
19.0	(¾)	25,000	(55)
12.5	(½)	15,000	(35)
9.5	(⅜)	10,000	(25)
4.75	(No. 4)	10,000	(25)
2.36	(No. 8)	10,000	(25)

*One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size. Maximum size is one size larger than nominal maximum size.

Note 1: Sample size is based upon the test(s) required. As a general rule, the field sample size should be such that, when split twice will provide a testing sample of proper size. For example, the sample size may be four times that shown in Table 2 of the FOP for AASHTO T 27/T 11, if that mass is more appropriate.

Procedure – Specific Situations

Conveyor Belts

Avoid sampling at the beginning or end of the aggregate run due to the potential for segregation. Be careful when sampling in the rain. Make sure to capture fines that may stick to the belt or that the rain tends to wash away.

Method A (From the Belt)

1. Stop the belt.
2. Set the sampling template in place on the belt, avoiding intrusion by adjacent material.
3. Remove the material from inside the template, including all fines.
4. Obtain at least three approximately equal increments.
5. Combine the increments to form a single sample.

Method B (From the Belt Discharge)

1. Pass a sampling device through the full stream of the material as it runs off the end of the conveyor belt. The sampling device may be manually, semi-automatic or automatically powered.
2. The sampling device shall pass through the stream at least twice, once in each direction, without overfilling while maintaining a constant speed during the sampling process.
3. When emptying the sampling device into the container, include all fines.
4. Combine the increments to form a single sample.

Transport Units

1. Visually divide the unit into four quadrants.
2. Identify one sampling location in each quadrant.
3. Dig down and remove approximately 0.3 m (1 ft) of material to avoid surface segregation. Obtain each increment from below this level.
4. Combine the increments to form a single sample.

Roadways

Method A (Berm or Windrow)

1. Obtain sample before spreading.
2. Take the increments from at least three random locations along the fully-formed windrow or berm. Do not take the increments from the beginning or the end of the windrow or berm.
3. Obtain full cross-section samples of approximately equal size at each location. Take care to exclude the underlying material.
4. Combine the increments to form a single sample.

Note 2: Obtaining samples from berms or windrows may yield extra-large samples and may not be the preferred sampling location.

Method B (In-Place)

1. Obtain sample after spreading and before compaction.
2. Take the increments from at least three random locations.
3. Obtain full-depth increments of approximately equal size from each location. Take care to exclude the underlying material.
4. Combine the increments to form a single sample.

Stockpiles

Method A– Loader sampling

1. Direct the loader operator to enter the stockpile with the bucket at least 150 mm (6 in) above ground level without contaminating the stockpile.
2. Discard the first bucketful.
3. Have the loader re-enter the stockpile and obtain a full loader bucket of the material, tilt the bucket back and up.
4. Form a small sampling pile at the base of the stockpile by gently rolling the material out of the bucket with the bucket just high enough to permit free-flow of the material. (Repeat as necessary.)
5. Create a flat surface by having the loader back drag the small pile.
6. Visually divide the flat surface into four quadrants.
7. Collect an increment from each quadrant by fully inserting the shovel into the flat pile as vertically as possible, take care to exclude the underlying material, roll back the shovel and lift the material slowly out of the pile to avoid material rolling off the shovel.

Method B – Stockpile Face Sampling

1. Create horizontal surfaces with vertical faces in the top, middle, and bottom third of the stockpile with a shovel or loader.
2. Prevent continued sloughing by shoving a flat board against the vertical face. Sloughed material will be discarded to create the horizontal surface.
3. Obtain sample from the horizontal surface as close to the intersection as possible of the horizontal and vertical faces.
4. Obtain at least one increment of equal size from each of the top, middle, and bottom thirds of the pile.
5. Combine the increments to form a single sample.

Method C – Alternate Tube Method (Fine Aggregate)

1. Remove the outer layer that may have become segregated.
2. Using a sampling tube, obtain one increment of equal size from a minimum of five random locations on the pile.
3. Combine the increments to form a single sample.

Note 3: Obtaining samples at stockpiles should be avoided whenever possible due to problems involved in obtaining a representative gradation of material.

Report

- On forms approved by the agency
- Date
- Time
- Sample ID
- Location
- Quantity represented

Performance Exam Checklist

FOP for AASHTO T 2
Sampling of Aggregates

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
Conveyor Belts – Method A (From the Belt)		
1. Belt stopped?	_____	_____
2. Sampling template set on belt, avoiding intrusion of adjacent material?	_____	_____
3. Sample, including all fines, scooped off?	_____	_____
4. Samples taken in at least three approximately equal increments?	_____	_____
Conveyor Belts – Method B (From the Belt Discharge)		
5. Sampling device passed through full stream of material twice (once in each direction) as it runs off end of belt?	_____	_____
Transport Units		
6. Unit divided into four quadrants?	_____	_____
7. Increment obtained from each quadrant, 0.3 m (1 ft) below surface?	_____	_____
8. Increments combined to make up the sample?	_____	_____
Roadways Method A (Berm or Windrow)		
9. Sample taken prior to spreading?	_____	_____
10. Full depth of material taken?	_____	_____
11. Underlying material excluded?	_____	_____
12. Samples taken in at least three approximately equal increments?	_____	_____
Roadways Method B (In-place)		
13. Sample taken after spreading?	_____	_____
14. Full depth of material taken?	_____	_____
15. Underlying material excluded?	_____	_____
16. Samples taken in at least three approximately equal increments?	_____	_____

Procedure Element	Trial 1	Trial 2
Stockpile Method A– (Loader sampling)		
17. Loader operator directed to enter the stockpile with the bucket at least 150 mm (6 in) above ground level without contaminating the stockpile?	_____	_____
18. First bucketful discarded?	_____	_____
19. The loader re-entered the stockpile and obtained a full loader bucket of the material with the bucket tilted back and up?	_____	_____
20. A small sampling pile formed at the base of the stockpile by gently rolling the material out of the bucket with the bucket just high enough to permit free-flow of the material?	_____	_____
21. A flat surface created by the loader back dragging the small pile?	_____	_____
22. Increment sampled from each quadrant by fully inserting the shovel into the flat pile as vertically as possible, care taken to exclude the underlying material?	_____	_____
Stockpile Method B (Stockpile Face)		
23. Created horizontal surfaces with vertical faces?	_____	_____
24. At least one increment taken from each of the top, middle, and bottom thirds of the stockpile.	_____	_____
Stockpile Method C – Alternate Tube Method (Fine Aggregate)		
25. Outer layer removed?	_____	_____
26. Increments taken from at least five locations with a sampling tube?	_____	_____
General		
27. Increments mixed thoroughly to form sample?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

FOP for WAQTC TM 2

Sampling Freshly Mixed Concrete

Scope

This method covers procedures for obtaining representative samples of fresh concrete delivered to the project site. The method includes sampling from stationary, paving and truck mixers, and from agitating and non-agitating equipment used to transport central mixed concrete.

This method also covers the removal of large aggregate particles by wet sieving.

Sampling concrete 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.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Wheelbarrow
- Cover for wheelbarrow (plastic, canvas, or burlap)
- Buckets
- Shovel
- Cleaning equipment, including scrub brush, rubber gloves, water
- Apparatus for wet sieving, including: a sieve(s), meeting the requirements of FOP for AASHTO T 27/T 11, minimum of 2 ft^2 (0.19 m^2) of sieving area, conveniently arranged and supported so that the sieve can be shaken rapidly by hand.

Procedure

1. 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 0.03 m^3 (1 ft^3).
2. Dampen the surface of the receptacle just before sampling, empty any excess water.

   Note 1: Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms; however, specifications may require other points of sampling, such as at the discharge of a concrete pump.
3. Use one of the following methods to obtain the sample:
   - **Sampling from stationary mixers**

     Obtain the sample after a minimum of ½ m^3 (½ yd^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. 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.

- **Sampling from paving mixers**

  Obtain the 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, the concrete may be sampled by placing a shallow container on the subgrade and discharging the concrete across the container.

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

  Obtain the sample after a minimum of ½ m^3 (½ yd^3) of concrete has been discharged. Obtain samples 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. Perform sampling 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.

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

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

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

  Obtain sample after a minimum of ½ m^3 (½ yd^3) of concrete has been discharged. Obtain samples after all of the pump slurry has been eliminated. Perform sampling 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.

4. 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.

5. Complete test for temperature and start tests for slump and air content within 5 minutes of obtaining the sample. Start molding specimens for strength tests within 15 minutes of obtaining the sample. Complete the test methods as expeditiously as possible.

Wet Sieving

When required due to oversize aggregate, the concrete sample shall be wet sieved, after transporting but prior to remixing, for slump testing, air content testing or molding test specimens, by the following:

1. Place the sieve designated by the test procedure over the dampened sample container.
2. Pass the concrete over the designated sieve. Do not overload the sieve (one particle thick).
3. Shake or vibrate the sieve until no more material passes the sieve. A horizontal back and forth motion is preferred.
4. Discard oversize material including all adherent mortar.
5. Repeat until sample of sufficient size is obtained. Mortar adhering to the wet-sieving equipment shall be included with the sample.
6. Using a shovel, remix the sample the minimum amount necessary to ensure uniformity.

Note 2: Wet sieving is not allowed for samples being used for density determinations according to the FOP for AASHTO T 121.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

Performance Exam Checklist

FOP for WAQTC TM 2
Sampling Freshly Mixed Concrete

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		Trial 1	Trial 2
1.	Receptacle dampened and excess water removed?		
2.	Obtain a representative sample from drum mixer:		
	a. Concrete sampled after ½ m^3 (½ yd^3) discharged?		
	b. Receptacle passed through entire discharge stream or discharge stream completely diverted into sampling container?		
3.	Obtain a representative sample from a paving mixer:		
	a. Concrete sampled after all the concrete has been discharged?		
	b. Material obtained from at least 5 different locations in the pile?		
	c. Avoid contaminating the sample with sub-grade materials.		
4.	Obtain a representative sample from a pump:		
	a. Concrete sampled after ½ m^3 (½ yd^3) has been discharged?		
	b. All the pump slurry is out of the lines?		
	c. Receptacle passed through entire discharge stream or discharge stream completely diverted into sampling container?		
	d. Do not lower the pump arm from the placement position.		
5.	Samples transported to place of testing?		
6.	Sample(s) combined, or remixed, or both?		
7.	Sample protected?		
8.	Minimum size of sample used for strength tests 0.03 m^3 (1 ft^3)?		
9.	Completed temperature test within 5 minutes of obtaining sample?		
10.	Start tests for slump and air within 5 minutes of obtaining sample?		
11.	Start molding cylinders within 15 minutes of obtaining sample?		
12.	Protect sample against rapid evaporation and contamination?		

Procedure Element	**Trial 1**	**Trial 2**
13. Wet Sieving:		
a. Required sieve size determined for test method to be performed?	_____	_____
b. Concrete placed on sieve and doesn't overload the sieve.	_____	_____
c. Sieve shaken until no more material passes the sieve.	_____	_____
d. Sieving continued until required testing size obtained.	_____	_____
e. Oversized aggregate discarded.	_____	_____
f. Sample remixed.	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

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Comments:

WSDOT Errata to FOP for AASHTO T 23

Method of Making and Curing Concrete Test Specimens in the Field

WAQTC FOP for AASHTO T 23 has been adopted by WSDOT with the following changes:

Apparatus and Test Specimens

- Initial curing facilities:

Include details below:

Cure Box – The cure box shall be a commercially manufactured cure box meeting AASHTO T 23 standards and the following requirements:

1. The interior shall be rustproof with a moisture-proof seal between the lid and the box.
2. The lid shall lock or have loops for padlocks that allow the box to be locked.
3. The box shall be equipped with a heating and cooling system. If the system uses a water circulating system, the box shall be equipped with a bottom drain and an overflow port. The cure box shall provide an environment that prevents loss of moisture from the specimens. The curing temperature and moist environment shall be controlled by the use of heating and cooling devices installed in the cure box.

Procedure – Initial Curing

Method 2 – Initial cure by burying in earth or by using a curing box over the cylinder – Method not recognized by WSDOT.

Include item below when required:

Field Curing

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

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

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

Beams – After applying the curing compound to the top surface, cover the beam specimen with white reflective sheeting and allow beams to remain undisturbed for an initial cure period of 24 ± 4 hours at ambient conditions. After the initial cure period, remove the specimen from the mold and cure the specimen either by:

(1) Burying the specimen in wet sand making sure that the specimen is never allowed to become surface dry. Temperature of the sand should be similar to the concrete pavement temperature.

Or

(2) Wrap the beam in a saturated towel, place in a plastic bag, and seal the opening. The plastic should be at least 4 mils thick. Leave the specimen on the pavement in the vicinity where it was molded until time to test. Take specimen to the testing location and store in lime water at 73.4° ± 5°F (23° ± 2.8°C) for 24 ± 4 hours immediately before time of testing to ensure uniform moisture condition from specimen to specimen.

Note: The beam specimen must be kept in a surface moist condition or wet environment for the entire time in storage and testing. Even minor amounts of surface drying of the specimen induces extreme fiber stresses which can markedly reduce the flexural strength.

FOP for AASHTO T 23

Method of Making and Curing Concrete Test Specimens in The Field

Scope

This procedure covers the method for making, initially curing, and transporting concrete test specimens in the field in accordance with AASHTO T 23-17.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus and Test Specimens

- Concrete cylinder molds: Conforming to AASHTO M 205 with a length equal to twice the diameter. Standard specimens shall be 150 mm (6 in) by 300 mm (12 in) cylinders. Mold diameter must be at least three times the maximum aggregate size unless wet sieving is conducted according to the FOP for WAQTC TM 2. Agency specifications may allow cylinder molds of 100 mm (4 in) by 200 mm (8 in) when the nominal maximum aggregate size does not exceed 25 mm (1 in).
- Beam molds: Rectangular in shape with ends and sides at right angles to each other. Must be sufficiently rigid to resist warpage. Surfaces must be smooth. Molds shall produce length no more than 1.6 mm (1/16 in) shorter than that required (greater length is allowed). Maximum variation from nominal cross section shall not exceed 3.2 mm (⅛ in). Ratio of width to depth may not exceed 1:5; the smaller dimension must be at least 3 times the maximum aggregate size. Standard beam molds shall result in specimens having width and depth of not less than 150 mm (6 in). Agency specifications may allow beam molds of 100 mm (4 in) by 100 mm (4 in) when the nominal maximum aggregate size does not exceed 38 mm (1.5 in). Specimens shall be cast and hardened with the long axes horizontal.
- Standard tamping rod: 16 mm (⅝ in) in diameter and 400 mm (16 in) to 600 mm (24 in) long, having a hemispherical tip of the same diameter as the rod for preparing 150 mm (6 in) x 300 mm (12 in) cylinders.
- Small tamping rod: 10 mm (⅜ in) diameter and 305 mm (12 in) to 600 mm (24 in) long, having a hemispherical tip of the same diameter as the rod for preparing 100 mm (4 in) x 200 mm (8 in) cylinders.
- Vibrator: At least 9000 vibrations per minute, with a diameter no more than ¼ the diameter or width of the mold and at least 75 mm (3 in) longer than the section being vibrated for use with low slump concrete.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Trowel or float
- Mallet: With a rubber or rawhide head having a mass of 0.57 ± 0.23 kg (1.25 ± 0.5 lb).
- Rigid base plates and cover plates: may be metal, glass, or plywood.

- Initial curing facilities: Temperature-controlled curing box or enclosure capable of maintaining the required range of 16 to 27°C (60 to 80°F) during the entire initial curing period (for concrete with compressive strength of 40 Mpa (6000 psi) or more, the temperature shall be 20 to 26°C (68 to 78°F). As an alternative, sand or earth for initial cylinder protection may be used provided that the required temperature range is maintained and the specimens are not damaged.
- Thermometer: Capable of registering both maximum and minimum temperatures during the initial cure.

Procedure – Making Specimens – General

1. Obtain the sample according to the FOP for WAQTC TM 2.
2. Wet Sieving per the FOP for WAQTC TM 2 is required for 150 mm (6 in) diameter specimens containing aggregate with a nominal maximum size greater than 50 mm (2 in); screen the sample over the 50 mm (2 in) sieve.
3. Remix the sample after transporting to testing location.
4. Begin making specimens within 15 minutes of obtaining the sample.
5. Set molds upright on a level, rigid base in a location free from vibration and relatively close to where they will be stored.
6. Fill molds in the required number of layers, attempting to slightly overfill the mold on the final layer. Add or remove concrete prior to completion of consolidation to avoid a deficiency or excess of concrete.
7. There are two methods of consolidating the concrete – rodding and internal vibration. If the slump is greater than 25 mm (1 in), consolidation may be by rodding or vibration. When the slump is 25 mm (1 in) or less, consolidate the sample by internal vibration. Agency specifications may dictate when rodding or vibration will be used.

Procedure – Making Cylinders –Self Consolidating Concrete

1. Use the scoop to slightly overfill the mold. Evenly distribute the concrete in a circular motion around the inner perimeter of the mold.
2. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
3. Immediately begin initial curing.

Procedure – Making Cylinders – Rodding

1. For the standard 150 mm (6 in) by 300 mm (12 in) specimen, fill each mold in three approximately equal layers, moving the scoop or trowel around the perimeter of the mold to evenly distribute the concrete. For the 100 mm (4 in) by 200 mm (8 in) specimen, fill the mold in two layers. When filling the final layer, slightly overfill the mold.
2. Consolidate each layer with 25 strokes of the appropriate tamping rod, using the rounded end. Distribute strokes evenly over the cross section of the concrete. Rod the first layer throughout its depth without forcibly hitting the bottom. For subsequent layers, rod the layer throughout its depth penetrating approximately 25 mm (1 in) into the underlying layer.

3. After rodding each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Procedure – Making Cylinders – Internal Vibration

1. Fill the mold in two layers.
2. Insert the vibrator at the required number of different points for each layer (two points for 150 mm (6 in) diameter cylinders; one point for 100 mm (4 in) diameter cylinders). When vibrating the bottom layer, do not let the vibrator touch the bottom or sides of the mold. When vibrating the top layer, the vibrator shall penetrate into the underlying layer approximately 25 mm (1 in)
3. Remove the vibrator slowly, so that no large air pockets are left in the material.

   Note 1: 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.
4. After vibrating each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
5. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
6. Immediately begin initial curing.

Procedure – Making Flexural Beams – Rodding

1. Fill the mold in two approximately equal layers with the second layer slightly overfilling the mold.
2. Consolidate each layer with the tamping rod once for every 1300 mm^2 (2 in^2) using the rounded end. Rod each layer throughout its depth, taking care to not forcibly strike the bottom of the mold when compacting the first layer. Rod the second layer throughout its depth, penetrating approximately 25 mm (1 in) into the lower layer.
3. After rodding each layer, strike the mold 10 to 15 times with the mallet and spade along the sides and end using a trowel.
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Procedure – Making Flexural Beams – Vibration

1. Fill the mold to overflowing in one layer.
2. Consolidate the concrete by inserting the vibrator vertically along the centerline at intervals not exceeding 150 mm (6 in). Take care to not over-vibrate, and withdraw the vibrator slowly to avoid large voids. Do not contact the bottom or sides of the mold with the vibrator.
3. After vibrating, strike the mold 10 to 15 times with the mallet.
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Procedure – Initial Curing

- When moving cylinder specimens made with single use molds support the bottom of the mold with trowel, hand, or other device.
- For initial curing of cylinders, there are two methods, use of which depends on the agency. In both methods, the curing place must be firm, within ¼ in of a level surface, and free from vibrations or other disturbances.
- Maintain initial curing temperature of 16 to 27°C (60 to 80°F) or 20 to 26°C (68 to 78°F) for concrete with strength of 40 Mpa (6000 psi) or more.
- Prevent loss of moisture.

Method 1 – Initial cure in a temperature controlled chest-type curing box

1. Finish the cylinder using the tamping rod, straightedge, float, or trowel. The finished surface shall be flat with no projections or depressions greater than 3.2 mm (⅛ in).
2. Place the mold in the curing box. When lifting light-gauge molds be careful to avoid distortion (support the bottom, avoid squeezing the sides).
3. Place the lid on the mold to prevent moisture loss.
4. Mark the necessary identification data on the cylinder mold and lid.

Method 2 – Initial cure by burying in earth or by using a curing box over the cylinder

Note 2: This procedure may not be the preferred method of initial curing due to problems in maintaining the required range of temperature.

1. Move the cylinder with excess concrete to the initial curing location.
2. Mark the necessary identification data on the cylinder mold and lid.
3. Place the cylinder on level sand or earth, or on a board, and pile sand or earth around the cylinder to within 50 mm (2 in) of the top.
4. Finish the cylinder using the tamping rod, straightedge, float, or trowel. Use a sawing motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 3.2 mm (⅛ in).
5. If required by the agency, place a cover plate on top of the cylinder and leave it in place for the duration of the curing period, or place the lid on the mold to prevent moisture loss.

Procedure – Transporting Specimens

- Initially cure the specimens for 24 to 48 hours. Transport specimens to the laboratory for final cure. Specimen identity will be noted along with the date and time the specimen was made and the maximum and minimum temperatures registered during the initial cure.
- Protect specimens from jarring, extreme changes in temperature, freezing, or moisture loss during transport.
- Secure cylinders so that the axis is vertical.
- Do not exceed 4 hours transportation time.

Final Curing

- Upon receiving cylinders at the laboratory, remove the cylinder from the mold and apply the appropriate identification.
- For all specimens (cylinders or beams), final curing must be started within 30 minutes of mold removal. Temperature shall be maintained at 23° ± 2°C (73 ± 3°F). Free moisture must be present on the surfaces of the specimens during the entire curing period. Curing may be accomplished in a moist room or water tank conforming to AASHTO M 201.
- For cylinders, during the final 3 hours prior to testing the temperature requirement may be waived, but free moisture must be maintained on specimen surfaces at all times until tested.
- Final curing of beams must include immersion in lime-saturated water for at least 20 hours before testing.

Report

- On forms approved by the agency
- Pertinent placement information for identification of project, element(s) represented, etc.
- Sample ID
- Date and time molded.
- Test ages.
- Slump, air content, and density.
- Temperature (concrete, initial cure max. and min., and ambient).
- Method of initial curing.
- Other information as required by agency, such as: concrete supplier, truck number, invoice number, water added, etc.

Performance Exam Checklist

Making and Curing Concrete Test Specimens in the Field FOP for AASHTO T 23 (4 X 8)

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
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?		
First layer		
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 approximately half full?		
6. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?		
7. Sides of the mold tapped 10-15 times after rodding?		
a. With mallet for reusable steel molds		
b. With the open hand for flexible light-gauge molds		
Second layer		
8. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?		
9. Mold slightly overfilled on the last layer?		
10. Layer rodded 25 times with hemispherical end of rod, uniformly distributing strokes and penetrating 25 mm (1 in) into the underlying layer?		
11 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		
12. Concrete struck off with tamping rod, float or trowel?		
13. Specimens covered with non-absorptive, non-reactive cap or plate?		
14. Initial curing addressed?		

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

Signature of Examiner _____ WAQTC #:_____

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Comments:

Performance Exam Checklist

FOP for AASHTO T 23 (6 X 12)
Making and Curing Concrete Test Specimens in the Field

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
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?		
First layer		
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 approximately one third full?		
6. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?		
7. 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		
Second layer		
8. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?		
9. Mold filled approximately two thirds full?		
10. Layer rodded 25 times with hemispherical end of rod, uniformly distributing strokes and penetrating 25 mm (1 in) into the underlying layer?		
11 Sides of the mold tapped 10-15 times after rodding?		
a. With mallet for reusable steel molds		
b. With the open hand for flexible light-gauge molds		
Third layer		
12. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?		
13. Mold slightly overfilled on the last layer?		
14. Layer rodded 25 times with hemispherical end of rod, uniformly distributing strokes and penetrating 25 mm (1 in) into the underlying layer?		

Procedure Element	Trial 1	Trial 2
15. Sides of the mold tapped 10-15 times after rodding?		
a. With mallet for reusable steel molds	_____	_____
b. With the open hand for flexible light-gauge molds	_____	_____
16. Concrete struck off with tamping rod, straightedge, float, or trowel?	_____	_____
17. Specimens covered with non-absorptive, non-reactive cap or plate?	_____	_____
18. Initial curing addressed?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

This checklist is derived, in part, from copyrighted material printed in ACI CP-1, published by the American Concrete Institute.

Comments:

WSDOT Errata to WAQTC FOP for AASHTO T 27_T 11

Sieve Analysis of Fine and Coarse Aggregates

WAQTC FOP for AASHTO T 27_T 11 has been adopted by WSDOT with the following changes:

Procedure Method C – *Method not recognized by WSDOT.*

Sample Preparation

Table 1 Test Sample Sizes for Aggregate Gradation Test – *Shall conform to the following table.*

Nominal Maximum Size*in (mm)		Minimum Dry Mass lb (kg)	
US No. 4	(4.75)	1	(0.5)
¼	(6.3)	2	(1)
⅜	(9.5)	2	(1)
½	(12.5)	5	(2)
⅝	(16.0)	5	(2)
¾	(19.0)	7	(3)
1	(25.0)	13	(6)
1¼	(31.5)	17	(7.5)
1½	(37.5)	20	(9)
2	(50)	22	(10)
2½	(63)	27	(12)
3	(75)	33	(15)
3½	(90)	44	(20)

FOP for AASHTO T 27

Sieve Analysis of Fine and Coarse Aggregates

FOP for AASHTO T 11

Materials Finer Than 75 µm (No. 200) Sieve In Mineral Aggregate By Washing

Scope

A sieve analysis, or 'gradation,' measures distribution of aggregate particle sizes within a given sample.

Accurate determination of the amount of material smaller than 75 µm (No. 200) cannot be made using just AASHTO T 27. If quantifying this material is required, use AASHTO T 11 in conjunction with AASHTO T 27.

This FOP covers sieve analysis in accordance with AASHTO T 27-14 and materials finer than 75 µm (No. 200) in accordance with AASHTO T 11-05 performed in conjunction with AASHTO T 27. The procedure includes three methods: A, B, and C.

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, and meeting the requirements of AASHTO M 231
- Sieves: Meeting the requirements of ASTM E11
- Mechanical sieve shaker: Meeting the requirements of AASHTO T 27
- Suitable drying equipment (refer to FOP for AASHTO T 255)
- Containers and utensils: A pan or vessel of sufficient size to contain the test sample covered with water and permit vigorous agitation without loss of test material or water
- Optional: mechanical washing device

Sample Sieving

- In all procedures, the test sample is shaken in nested sieves. Sieves are selected to furnish information required by specification. Intermediate sieves are added for additional information or to avoid overloading sieves, or both.
- The sieves are nested in order of increasing size from the bottom to the top, and the test sample, or a portion of the test sample, is placed on the top sieve.
- The loaded sieves are shaken in a mechanical shaker for approximately 10 minutes, refer to Annex A; *Time Evaluation*.
- Care must be taken so that sieves are not overloaded, refer to Annex B; *Overload Determination*. The test sample may be sieved in increments and the mass retained for each sieve added together from each test sample increment to avoid overloading sieves.

Sample Preparation

Obtain samples according to the FOP for AASHTO T 2 and reduce to test sample size, shown in Table 1, according to the FOP for AASHTO R 76.

Table 1 Test Sample Sizes for Aggregate Gradation Test

Nominal Maximum Size* mm (in)		Minimum Dry Mass g (lb)	
125	(5)	300,000	(660)
100	(4)	150,000	(330)
90	(3½)	100,000	(220)
75	(3)	60,000	(130)
63	(2½)	35,000	(77)
50	(2)	20,000	(44)
37.5	(1½)	15,000	(33)
25.0	(1)	10,000	(22)
19.0	(¾)	5000	(11)
12.5	(½)	2000	(4)
9.5	(⅜)	1000	(2)
6.3	(¼)	1000	(2)
4.75	(No. 4)	500	(1)

*Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps between specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Test sample sizes in Table 1 are standard for aggregate sieve analysis, due to equipment restraints samples may need to be divided into several "subsamples." For example, a gradation that requires 100 kg (220 lbs) of material would not fit into a large tray shaker all at once.

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

Selection of Procedure

Agencies may specify which method to perform. If a method is not specified, perform Method A.

Overview

Method A

- Determine dry mass of original test sample
- Wash over a 75mm (No. 200) sieve
- Determine dry mass of washed test sample
- Sieve washed test sample
- Calculate and report percent retained and passing each sieve

Method B

- Determine dry mass of original test sample
- Wash over a 75mm (No. 200) sieve
- Determine dry mass of washed test sample
- Sieve test sample through coarse sieves, 4.75 mm (No. 4) sieves and larger
- Determine dry mass of fine material, minus 4.75 mm (No. 4)
- Reduce fine material
- Determine mass of reduced portion
- Sieve reduced portion
- Calculate and report percent retained and passing each sieve

Method C

- Determine dry mass of original test sample
- Sieve test sample through coarse sieves, 4.75 mm (No. 4) sieves and larger
- Determine mass of fine material, minus 4.75 mm (No. 4)
- Reduce fine material
- Determine mass of reduced portion
- Wash reduced portion over a 75mm (No. 200) sieve
- Determine dry mass of washed reduced portion
- Sieve washed reduced portion
- Calculate and report percent retained and passing each sieve

Procedure Method A

1. Dry the test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the total dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as *M*.

   When the specification does not require the amount of material finer than 75 µm (No. 200) be determined by washing, skip to Step 11.

2. Nest a sieve, such as a 2.0 mm (No. 10), above the 75 µm (No. 200) sieve.

3. Place the test sample in a container and cover with water.

   Note 1: A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75 µm (No. 200) 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.

4. Agitate vigorously to ensure complete separation of the material finer than 75 µm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.

5. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75 µm (No. 200) sieve.

6. Add water to cover material remaining in the container, agitate, and repeat Step 5. Continue until the wash water is reasonably clear.
7. Remove the upper sieve and return material retained to the washed test sample.
8. Rinse the material retained on the 75 µm (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
9. Return all material retained on the 75 µm (No. 200) sieve to the container by rinsing into the washed sample.

   Note 2: Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75 µm (No. 200) sieve to prevent loss of fines.
10. Dry the washed test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the dry mass.
11. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 75 µm (No. 200).
12. Place the test sample, or a portion of the test sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place sieves in mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

    Note 3: Excessive shaking (more than 10 minutes) may result in degradation of the sample.
13. Determine and record the individual or cumulative mass retained for each sieve and in the pan. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.

    Note 4: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.

    Note 5: In the case of coarse/fine aggregate mixtures, distribute the minus 4.75 mm (No. 4) among two or more sets of sieves to prevent overloading of individual sieves.
14. Perform the *Check Sum* calculation – Verify the *total mass after sieving* agrees with the *dry mass before sieving* to within 0.3 percent. The *dry mass before sieving* is the dry mass after wash or the original dry mass (*M*) if performing the sieve analysis without washing. Do not use test results for acceptance if the *Check Sum* result is greater than 0.3 percent.
15. Calculate the total percentages passing, and the individual or cumulative percentages retained to the nearest 0.1 percent by dividing the individual sieve masses or cumulative sieve masses by the total mass of the initial dry sample (*M*).
16. Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Method A Calculations

Check Sum

$$Check\ Sum = \frac{dry\ mass\ before\ seiving - total\ mass\ after\ sieving}{dry\ mass\ before\ sieving} \times 100$$

Percent Retained

$$IPR = \frac{IMR}{M} \times 100 \qquad or \qquad CPR = \frac{CMR}{M} \times 100$$

Where:

IPR = Individual Percent Retained
CPR = Cumulative Percent Retained
M = Total Dry Sample mass before washing
IMR = Individual Mass Retained
CMR = Cumulative Mass Retained

Percent Passing (PP)

$$PP = PPP - IPR \qquad or \qquad PP = 100 - CPR$$

Where:

PP = Percent Passing
PPP = Previous Percent Passing

Method A Example Individual Mass Retained

Dry mass of total sample before washing (*M*):	5168.7 g
Dry mass of sample after washing:	4911.3 g
Total mass after sieving is equals	
Sum of Individual Masses Retained (IPR), including pan:	4905.9 g
Amount of 75µm (No. 200) minus washed out (5168.7 g – 4911.3 g):	257.4 g

Check Sum

$$Check\ Sum = \frac{4911.3\ g - 4905.9\ g}{4911.3\ g} \times 100 = 0.1\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

Individual Percent Retained (IPR) for 9.5 mm (⅜ in) sieve:

$$CPR = \frac{1343.9\ g}{5168.7\ g} \times 100 = 26.0\%$$

Percent Passing (PP) 9.5 mm (⅜ in) sieve:

$$PP = 86.0\% - 12.0\% = 74.0\%$$

Reported Percent Passing = 74 percent

As shown in the following table:

Gradation on All Sieves Individual Mass

Sieve Size mm (in)		Individual Mass Retained g (IMR)	Individual Percent Retained (IPR)	Percent Passing (PP)	Reported Percent Passing*
19.0	(¾)	0	0	100.0	100
12.5	(½)	724.7	14.0	86.0	86
9.5	(⅜)	619.2	12.0	74.0	74
4.75	(No. 4)	1189.8	23.0	51.0	51
2.36	(No. 8)	877.6	17.0	34.0	34
1.18	(No. 16)	574.8	11.1	22.9	23
0.600	(No. 30)	329.8	6.4	16.5	17
0.300	(No. 50)	228.5	4.4	12.1	12
0.150	(No. 100)	205.7	4.0	8.1	8
0.075	(No. 200)	135.4	2.6	5.5	5.5
Pan		20.4			

*Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Method A Example Cumulative Mass Retained

Dry mass of total sample before washing (*M*): 5168.7 g

Dry mass of sample after washing: 4911.3 g

Total mass after sieving is equals

Final Cumulative Mass Retained (CMR) in pan: 4905.9 g

Amount of 75µm (No. 200) minus washed out (5168.7 g – 4911.3 g): 257.4 g

Check Sum

$$Check\ Sum = \frac{4911.3\ g - 4905.9\ g}{4911.3\ g} \times 100 = 0.1\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

Cumulative Percent Retained (CPR) for 9.5 mm (⅜ in) sieve:

$$CPR = \frac{1343.9\ g}{5168.7\ g} \times 100 = 26.0\%$$

Percent Passing (PP) 9.5 mm (⅜ in) sieve:

$$PP = 86.0\% - 12.0\% = 74.0\%$$

Reported Percent Passing = 74 percent

As shown in the following table:

Gradation on All Sieves					
Sieve Size mm (in)		**Cumulative Mass Retained g (CMR)**	**Cumulative Percent Retained (CPR)**	**Percent Passing (PP)**	**Reported Percent Passing***
19.0	(¾)	0	0.0	100.0	100
12.5	(½)	724.7	14.0	86.0	86
9.5	(⅜)	1343.9	26.0	74.0	74
4.75	(No. 4)	2533.7	49.0	51.0	51
2.36	(No. 8)	3411.3	66.0	34.0	34
1.18	(No. 16)	3986.1	77.1	22.9	23
0.600	(No. 30)	4315.9	83.5	16.5	17
0.300	(No. 50)	4544.4	87.9	12.1	12
0.150	(No. 100)	4750.1	91.9	8.1	8
0.075	(No. 200)	4885.5	94.5	5.5	5.5
Pan		4905.9			
* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.					

Procedure Method B

1. Dry the test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the total dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as *M*.

   When the specification does not require the amount of material finer than 75 µm (No. 200) be determined by washing, skip to Step 11.

2. Nest a protective sieve, such as a 2.0 mm (No. 10), above the 75 µm (No. 200) sieve.

3. Place the test sample in a container and cover with water.

   Note 1: A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75 µm (No. 200) 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.

4. Agitate vigorously to ensure complete separation of the material finer than 75 µm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.

5. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75 µm (No. 200) sieve.

6. Add water to cover material remaining in the container, agitate, and repeat Step 5. Continue until the wash water is reasonably clear.

7. Remove the upper sieve and return material retained to the washed test sample.

8. Rinse the material retained on the 75 µm (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
9. Return all material retained on the 75 µm (No. 200) sieve to the container by rinsing into the washed sample.

   Note 2: Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75 µm (No. 200) sieve to prevent loss of fines.
10. Dry the washed test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the dry mass.
11. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 4.75 mm (No. 4).
12. Place the test sample, or a portion of the test sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place the sieves in the mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

    Note 3: Excessive shaking (more than 10 minutes) may result in degradation of the sample.
13. Determine and record the individual or cumulative mass retained for each sieve. Ensure that all particles trapped in full openings of the sieve are removed and included in the mass retained.

    Note 4: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft hair bristle for smaller sieves.
14. Determine and record the mass of the minus 4.75 mm (No. 4) material in the pan. Designate this mass as M_1.
15. Perform the *Coarse Check Sum* calculation – Verify the *total mass after coarse sieving* agrees with the *dry mass before sieving* to within 0.3 percent. The *dry mass before sieving* is the dry mass after wash or the original dry mass (*M*) if performing the sieve analysis without washing. Do not use test results for acceptance if the *Check Sum* result is greater than 0.3 percent.
16. Reduce the minus 4.75 mm (No. 4) according to the FOP for AASHTO R 76 to produce a sample with a minimum mass of 500 g. Determine and record the mass of the minus 4.75 mm (No. 4) split, designate this mass as M_2.
17. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 75 µm (No. 200) up to, but not including, the 4.75 mm (No. 4) sieve.
18. Place the test sample portion on the top sieve and place the sieves in the mechanical shaker. Shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

19. Determine and record the individual or cumulative mass retained for each sieve and in the pan. Ensure that all particles trapped in full openings of the sieve are removed and included in the mass retained.

    Note 4: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft hair bristle for smaller sieves.

20. Perform the *Fine Check Sum* calculation – Verify the *total mass after sieving* agrees with the *dry mass before sieving* (M_2) to within 0.3 percent. Do not use test results for acceptance if the *Check Sum* result is greater than 0.3 percent.

21. Calculate to the nearest 0.1 percent, the Individual Mass Retained (IMR) or Cumulative Mass Retained (CMR) of the size increment of the reduced sample and the original sample.

22. Calculate the total percent passing.

23. Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Method B Calculations

Check Sum

$$Coarse\ Check\ Sum = \frac{dry\ mass\ before\ sieveing - total\ mass\ after\ coarse\ sieving}{dry\ mass\ before\ sieving} \times 100$$

$$Fine\ Check\ Sum = \frac{M_2 - total\ mass\ after\ fine\ sieving}{M_2} \times 100$$

Percent Retained for 4.75 mm (No. 4) and larger

$$IPR = \frac{IMR}{M} \times 100 \qquad or \qquad CPR = \frac{CMR}{M} \times 100$$

Where:

IPR = Individual Percent Retained
CPR = Cumulative Percent Retained
M = Total dry test sample mass before washing
IMR = Individual Mass Retained
CMR = Cumulative Mass Retained

Percent Passing (PP) for 4.75 mm (No. 4) and larger

$$PP = PPP - IPR \qquad or \qquad PP = 100 - CPR$$

Where:

PP = Percent Passing
PPP = Previous Percent Passing

Minus 4.75mm (No. 4) adjustment factor (R)

The mass of material retained for each sieve is multiplied by the adjustment factor, the total mass of the minus 4.75 mm (No. 4) from the pan, M_1, divided by the mass of the reduced split of minus 4.75 mm (No. 4), M_2. For consistency, this adjustment factor is carried to three decimal places.

$$R = \frac{M_1}{M_2}$$

Where:

R = minus 4.75 mm (No. 4) adjustment factor
M_1 = total mass of minus 4.75 mm (No. 4) before reducing
M_2 = mass of the reduced split of minus 4.75 mm (No. 4)

Adjusted Individual Mass Retained (AIMR):

$$AIMR = R \times B$$

Where:

AIMR = Adjusted Individual Mass Retained
R = minus 4.75 mm (No. 4) adjustment factor
B = individual mass of the size increment in the reduced portion sieved

Adjusted Cumulative Mass Retained (ACMR)

$$ACMR = (R \times B) + D$$

Where:

ACMR = Adjusted Cumulative Mass Retained
R = minus 4.75 mm (No. 4) adjustment factor
B = cumulative mass of the size increment in the reduced portion sieved
D = cumulative mass of plus 4.75mm (No. 4) portion of sample

Method B Example Individual Mass Retained

Dry mass of total sample, before washing:	3214.0 g
Dry mass of sample after washing:	3085.1 g
Total mass after sieving	
Sum of Individual Masses Retained (IPR) and pan	3085.0 g
Amount of 75 µm (No. 200) minus washed out (3214.0 g – 3085.1 g):	128.9 g

Coarse Check Sum

$$Coarse\ Check\ Sum = \frac{3085.1\ g - 3085.0\ g}{3085.1\ g} \times 100 = 0.0\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

Individual Percent Retained (IPR) for 9.5 mm (⅜ in) sieve

$$IPR = \frac{481.4\ g}{3214.0\ g} \times 100 = 15.0\%$$

Percent Passing (PP) for 9.5 mm (⅜ in) sieve:

$$PP = 95.0\% - 15.0\% = 80.0\%$$

As shown in the following table:

Gradation on Coarse Sieves Individual Mass

Sieve Size mm (in)		Individual Mass Retained g (IMR)	Individual Percent Retained (IPR)	Percent Passing (PP)
16.0	(⅝)	0	0	100
12.5	(½)	161.1	5.0	95.0
9.50	(⅜)	481.4	15.0	80.0
4.75	(No. 4)	475.8	14.8	65.2
Pan		1966.7 ($\mathbf{M}_1$)		
Total mass after sieving = sum of sieves + pan = 3085.0				
Dry mass of total sample, before washing (M): 3214.0 g				

Fine Test Sample

The pan, M_1 (1966.7 g), was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **512.8 g**. This is M_2.

The reduced mass was sieved.

Total mass after sieving equals

Sum of Individual Masses Retained (IPR) and pan 511.8 g

Fine Check Sum

$$Fine\ Check\ Sum = \frac{512.8\ g - 511.8\ g}{512.8\ g} \times 100 = 0.2\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

Adjustment Factor (R) for Adjusted Individual Mass Retained (AIMR) on minus 4.75 (No. 4) sieves

The mass of material retained for each sieve is multiplied by the adjustment factor (R) carried to three decimal places.

$$R = \frac{M_1}{M_2} = \frac{1{,}966.7\ g}{512.8\ g} = 3.835$$

Where:

R = minus 4.75 mm (No. 4) adjustment factor
M_1 = total mass of minus 4.75 mm (No. 4) from the pan
M_2 = mass of the reduced split of minus 4.75 mm (No. 4)

Each “individual mass retained” on the fine sieves must be multiplied by R to obtain the Adjusted Individual Mass Retained.

Adjusted Individual Mass Retained (AIMR) for 2.00 mm (No. 10) sieve

$$AIMR = 3.835 \times 207.1\ g = 794.2\ g$$

Individual Percent Retained (IPR) for 2.00 mm (No. 10) sieve:

$$IPR = \frac{794.2\ g}{3214.0\ g} \times 100 = 24.7\%$$

Percent Passing (PP) 2 mm (No. 10) sieve:

$$PP = 65.2\% - 24.7\% = 40.5\%$$

As shown in the following table:

Final Gradation on All Sieves Individual Mass

Sieve Size mm (in)		Individual Mass Retained, g (IMR)	Adjusted Individual Mass Retained (AIMR)	Individual Percent Retained (IPR)	Percent Passing (PP)	Reported Percent Passing*
16.0	(⅝)	0		0.0	100.0	100
12.5	(½)	161.1		5.0	95.0	95
9.5	(⅜)	481.4		15.0	80.0	80
4.75	(No. 4)	475.8		14.8	65.2	65
2.00	(No. 10)	207.1 × 3.835	794.2	24.7	40.5	41
0.425	(No. 40)	187.9 × 3.835	720.6	22.4	18.1	18
0.210	(No. 80)	59.9 × 3.835	229.7	7.1	11.0	11
0.075	(No. 200)	49.1 × 3.835	188.3	5.9	5.1	5.1
Pan		7.8 × 3.835	29.9			
Total Sum of masses on fine sieves + pan = 511.8						
Dry mass of total sample, before washing: 3214.0 g						

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Method B Example Cumulative Mass Retained

Dry mass of total sample, before washing: 3214.0 g

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

Total mass after sieving equals

Cumulative Mass Retained (CMR) on the 4.75 (No. 4) plus the pan: 3085.0 g

Amount of 75 µm (No. 200) minus washed out (3214.0 g – 3085.1 g): 128.9 g

Coarse Check Sum

$$\boldsymbol{Coarse\ Check\ Sum} = \frac{3085.1\ g - 3085.0\ g}{3085.1\ g} \times 100 = 0.0\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

Cumulative Percent Retained (CPR) for 9.5 mm (⅜ in) sieve

$$CPR = \frac{642.5\ g}{3214.0\ g} \times 100 = 20.0\%$$

Percent Passing (PP) for 9.5 mm (⅜ in) sieve

$$PP = 100.0\% - 20.0\% = 80.0\%$$

Reported Percent Passing = 80 percent

As shown in the following table:

Gradation on Coarse Sieves Cumulative Mass

Sieve Size mm (in)		Cumulative Mass Retained g (CMR)	Cumulative Percent Retained (CPR)	Percent Passing (PP)
16.0	(⅝)	0	0	100
12.5	(½)	161.1	5.0	95.0
9.50	(⅜)	642.5	20.0	80.0
4.75	(No. 4)	1118.3 (*D*)	34.8	65.2
Mass in Pan		1966.7 (M_1)		
Cumulative sieved mass: 1118.3 + 1966.7 = 3085.0				
Dry mass of total sample, before washing (M): 3214.0 g				

The mass of minus 4.75 mm (No. 4) material in the pan, M_1 (1966.7 g), was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **512.8 g**. This is M_2.

The reduced mass was sieved.

Total mass after sieving equals

Final Cumulative Mass Retained (CMR) in pan: 511.8 g

Fine Check Sum

$$Fine\ Check\ Sum = \frac{512.8\ g - 511.8\ g}{512.8\ g} \times 100 = 0.2\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

The cumulative mass of material retained for each sieve is multiplied by the adjustment factor (R) carried to three decimal places and added to the cumulative mass retained on the 4.75 mm (No. 4) sieve, D, to obtain the Adjusted Cumulative Mass Retained (ACMR).

Adjustment factor (R) for Cumulative Mass Retained (CMR) in minus 4.75 (No. 4) sieves

$$R = \frac{M_1}{M_2} = \frac{1{,}966.7\ g}{512.8\ g} = 3.835$$

Where:

R = minus 4.75 mm (No. 4) adjustment factor
M_1 = total mass of minus 4.75 mm (No. 4) from the pan
M_2= mass of the reduced split of minus 4.75 mm (No. 4)

Adjusted Cumulative Mass Retained (ACMR) for the 2.00 mm (No. 10) sieve

$$ACMR\ = 3.835 \times 207.1\ g\ =\ 794.2\ g$$

Total Cumulative Mass Retained (TCMR) for the 2.00 mm (No. 10) sieve

$$TCMR = 794.2\ g + 1118.3\ g = 1912.5\ g$$

Cumulative Percent Retained (CPR) for 2.00 mm (No. 10) sieve:

$$CPR\ = \frac{1912.5\ g}{3214.0\ g} \times 100 = 59.5\%$$

Percent Passing (PP) 2.00 mm (No. 10) sieve:

$$PP = 100.0\% - 59.5\% = 40.5\%$$

Reported Percent Passing = 41 percent

As shown in the following table:

Final Gradation on All Sieves Cumulative Mass

Sieve Size mm (in)		Cumulative Mass Retained g (CMR)	Adjusted Cumulative Mass Retained, g (ACMR)	Total Cumulative Mass Retained g (TCMR)	Cumulative Percent Retained (CPR)	Percent Passing (PP)	Reported Percent Passing*
16.0	(⅝)	0		0	0.0	100.0	100
12.5	(½)	161.1		161.1	5.0	95.0	95
9.5	(⅜)	642.5		642.5	20.0	80.0	80
4.75	(No. 4)	1118.3		1118.3	34.8	65.2	65
2.00	(No. 10)	207.1 × 3.835	794.2 + 1118.3	1912.5	59.5	40.5	41
0.425	(No. 40)	395.0 × 3.835	1514.8 + 1118.3	2633.1	81.9	18.1	18
0.210	(No. 80)	454.9 × 3.835	1744.5 + 1118.3	2862.8	89.1	10.9	11
0.075	(No. 200)	504.0 × 3.835	1932.8 + 1118.3	3051.1	94.9	5.1	5.1
Pan		511.8 × 3.835	1962.8 + 1118.3	3081.1			
Total sum of masses on fine sieves + pan = 511.8							
Dry mass of total sample, before washing: 3214.0 g							

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Procedure Method C

1 Dry the test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the total dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as *M*.

2. Break up any aggregations or lumps of clay, silt or adhering fines to pass the 4.75 mm (No. 4) sieve.

3. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 4.75 mm (No. 4) sieve.

4. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place the sieves in the mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

   Note 3: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

5. Determine and record the cumulative mass retained for each sieve. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.

   Note 4: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brush for smaller sieves.

6. Determine and record the mass of the minus 4.75 mm (No. 4) material in the pan. Designate this mass as M_1.

7. Perform the *Coarse Check Sum* calculation –Verify the *total mass after coarse sieving* agrees with the *dry mass before sieving (M)* within 0.3 percent.

8. Reduce the minus 4.75 mm (No. 4) according to the FOP for AASHTO R 76, to produce a sample with a minimum mass of 500 g.

9. Determine and record the mass of the minus 4.75 mm (No. 4) split, designate this mass as M_3.

10. Nest a protective sieve, such as a 2.0 mm (No. 10), above the 75 µm (No. 200) sieve.

11. Place the test sample in a container and cover with water.

    Note 1: A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75 µm (No. 200) 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.

12. Agitate vigorously to ensure complete separation of the material finer than 75 µm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.

13. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75 µm (No. 200) sieve.
14. Add water to cover material remaining in the container, agitate, and repeat Step 12. Repeat until the wash water is reasonably clear.
15. Remove the upper sieve and return material retained to the washed test sample.
16. Rinse the material retained on the 75 µm (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
17. Return all material retained on the 75 µm (No. 200) sieve to the container by flushing into the washed sample.

    Note 2: Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75 µm (No. 200) sieve to prevent loss of fines.
18. Dry the washed test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the dry mass, designate this mass as *dry mass before sieving*.
19. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 75 µm (No. 200) sieve up to, but not including, the 4.75 mm (No. 4) sieve.
20. Place the sample on the top sieve. Place the sieves in the mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

    Note 3: Excessive shaking (more than 10 minutes) may result in degradation of the sample.
21. Determine and record the cumulative mass retained for each sieve. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.

    Note 4: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.
22. Perform the *Fine Check Sum* calculation – Verify the *total mass after fine sieving* agrees with the *dry mass before sieving* within 0.3 percent. Do not use test results for acceptance if the Check Sum is greater than 0.3 percent.
23. Calculate the Cumulative Percent Retained (CPR) and Percent Passing (PP) for the 4.75 mm (No. 4) and larger.
24. Calculate the Cumulative Percent Retained ($CPR_{-\#4}$) and the Percent Passing ($PP_{-\#4}$) for minus 4.75 mm (No. 4) split and Percent Passing (PP) for the minus 4.75 mm (No. 4).
25. Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Method C Calculations

Check Sum

$$Coarse\ check\ sum = \frac{M - total\ mass\ after\ coarse\ sieving}{M} \times 100$$

$$Fine\ check\ sum = \frac{dry\ mass\ before\ sieving - total\ mass\ after\ fine\ sieving}{dry\ mass\ before\ sieving} \times 100$$

where:

M = Total dry sample mass before washing

Cumulative Percent Retained (CPR) for 4.75 mm (No. 4) sieve and larger

$$CPR = \frac{CMR}{M} \times 100$$

where:

CPR = Cumulative Percent Retained of the size increment for the total sample
CMR = Cumulative Mass Retained of the size increment for the total sample
M = Total dry sample mass before washing

Percent Passing (PP) 4.75 mm (No. 4) sieve and larger

$$PP = 100 - CPR$$

where:

PP = Percent Passing of the size increment for the total sample
CPR = Cumulative Percent Retained of the size increment for the total sample

Or, calculate PP for sieves larger than 4.75 mm (No. 4) sieve without calculating CPR

$$\frac{M - CMR}{M} \times 100$$

Cumulative Percent Retained ($CPR_{-\#4}$) for minus 4.75 mm (No. 4) split

$$CPR_{-\#4} = \frac{CMR_{-\#4}}{M_3} \times 100$$

Where:

$CPR_{-\#4}$ = Cumulative Percent Retained for the sieve sizes of M_3
$CMR_{-\#4}$ = Cumulative Mass Retained for the sieve sizes of M_3
M_3 = Total mass of the minus 4.75 mm (No. 4) split before washing

Percent Passing ($PP_{-\#4}$) for minus 4.75 mm (No. 4) split

$$PP_{-\#4} = 100 - CPR_{-\#4}$$

where:

$PP_{-\#4}$ = Percent Passing for the sieve sizes of M_3
$CPR_{-\#4}$ = Cumulative Percent Retained for the sieve sizes of M_3

Percent Passing (PP) for sieves smaller than 4.75 mm (No. 4) sieve

$$PP = \frac{(PP_{-\#4} \times \#4\ PP)}{100}$$

where:

PP = Total Percent Passing
$PP_{-\#4}$ = Percent Passing for the sieve sizes of M_3
#4 PP = Total Percent Passing the 4.75 mm (No. 4) sieve

Or, calculate PP for sieves smaller than 4.75 mm (No. 4) sieve without calculating $CPR_{-\#4}$ and $PP_{-\#4}$

$$PP = \frac{\#4\ PP}{M_3} \times (M_3 - CMR_{-\#4})$$

Where:

PP = Total Percent Passing
#4 PP = Total Percent Passing the 4.75 mm (No. 4) sieve
M_3 = Total mass of the minus 4.75 mm (No. 4) split before washing
$CMR_{-\#4}$ = Cumulative Mass Retained for the sieve sizes of M_3

Method C Example

Dry Mass of total sample (M): 3304.5 g

Total mass after sieving equals

Cumulative Mass Retained (CMR) on the 4.75 (No. 4) plus the pan: 3085.0 g

Coarse Check Sum

$$Coarse\ Check\ Sum = \frac{3304.5\ g - 3304.5\ g}{3304.5\ g} \times 100 = 0.0\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

Cumulative Percent Retained (CPR) for the 9.5 mm (⅜ in) sieve:

$$CPR = \frac{604.1\ g}{3304.5\ g} \times 100 = 18.3\%$$

Percent Passing (PP) for the 9.5 mm (⅜ in) sieve:

$$PP = 100.0\% - 18.3\% = 81.7\%$$

Reported Percent Passing = 82 percent

Example for Alternate Percent Passing (PP) formula for the 9.5 mm (⅜ in) sieve:

$$PP = \frac{3304.5 - 604.1}{3304.5} \times 100 = 81.7\%$$

Reported Percent Passing = 82 percent

Gradation on Coarse Sieves Cumulative Mass

Sieve Size mm (in)	Cumulative Mass Retained, g (CMR)	Cumulative Percent Retained (CPR)	Percent Passing (PP)	Reported Percent Passing*
16.0 (⅝)	0	0.0	100.0	100
12.5 ½)	125.9	3.8	96.2	96
9.5 (⅜)	604.1	18.3	81.7	82
4.75 (No. 4)	1295.6	39.2	**60.8 (#4 PP)**	61
Mass in Pan	2008.9			
Cumulative sieved mass: 1295.6 + 2008.9 = 3304.5				
Total Dry Sample (**M**) = 3304.5				

Fine Test Sample

The pan (2008.9 g) was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **527.6 g**. This is M_3.

Dry Mass of minus 4.75mm (No. 4) reduced portion before wash (M_3): 527.6 g

Dry Mass of minus 4.75mm (No. 4) reduced portion after wash: 495.3 g

Total mass after sieving equals

Final Cumulative Mass Retained (CMR) in pan: 495.1 g

Fine Check Sum

$$Fine\ Check\ Sum = \frac{495.3\ g - 495.1\ g}{495.3\ g} \times 100 = 0.04\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

Cumulative Percent Retained ($CPR_{-\#4}$) for minus 4.75 mm (No. 4) for the 2.0 mm (No. 10) sieve:

$$CPR_{-\#4} = \frac{194.3\ g}{527.6\ g} \times 100 = 36.8\%$$

Percent Passing ($PP_{-\#4}$) for minus 4.75 mm (No. 4) for the 2.0 mm (No. 10) sieve:

$$PP_{-\#4} = 100.0\% - 36.8\% = 63.2\%$$

Gradation on Minus No. 4 Sieves Cumulative Mass

Sieve Size mm (in)	Cumulative Mass Retained g ($CMR_{-\#4}$)	Cumulative Percent Retained$_{-\#4}$ ($CPR_{-\#4}$)	Percent Passing$_{-\#4}$ ($PP_{-\#4}$)
2.0 (No. 10)	194.3	36.8	63.2
0.425 (No. 40)	365.6	69.3	30.7
0.210 (No. 80)	430.8	81.7	18.3
0.075 (No. 200)	484.4	91.8	8.2
Pan	495.1		
Dry mass before washing (M_3): 527.6 g Dry mass after washing: 495.3 g			

Percent Passing (PP) for the 2.0 mm (No. 10) sieve for the entire test sample:

#4 PP (Total Percent Passing the 4.75 mm (No. 4) sieve) = 60.8 percent

$$PP = \frac{63.2\% \times 60.8\%}{100} = 38.4\%$$

Reported Percent Passing = 38 percent

As shown in the following table:

Final Gradation on All Sieves Cumulative Mass

Sieve Size mm (in)	Cumulative Mass Retained, g (CMR)	Cumulative Percent Retained (CPR)	Percent Passing ($PP_{-\#4}$)	Percent Passing (PP)	Reported Percent Passing*
16.0 (⅝)	0	0.0		100.0	100
12.5 (½)	125.9	3.8		96.2	96
9.5 (⅜)	604.1	18.3		81.7	82
4.75 (No. 4)	1295.6	39.2		**60.8 (#4 PP)**	61
2.0 (No. 10)	194.3	36.8	63.2	38.4	38
0.425 (No. 40)	365.6	69.3	30.7	18.7	19
0.210 (No. 80)	430.8	81.7	18.3	11.1	11
0.075 (No. 200)	484.4	91.8	8.2	5.0	5.0
Pan	495.1				

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Example for Alternate Percent Passing (PP) for the 2.0 mm (No. 10) sieve for the entire test sample:

#4 PP (Total Percent Passing the 4.75 mm (No. 4) sieve) = 60.8 percent

$$PP = \frac{60.8\%}{527.6} \times (527.6 - 194.3) = 38.4\%$$

Reported Percent Passing = 38 percent

As shown in the following table:

Final Gradation on All Sieves Cumulative Mass

Sieve Size mm (in)	Cumulative Mass Retained, g (CMR)	Cumulative Percent Retained (CPR)	Determined Percent Passing (PP)	Reported Percent Passing*
16.0 (⅝)	0	0.0	100.0	100
12.5 (½)	125.9	3.8	96.2	96
9.5 (⅜)	604.1	18.3	81.7	82
4.75 (No. 4)	1295.6	39.2	**60.8 (#4 PP)**	61
2.0 (No. 10)	194.3		38.4	38
0.425 (No. 40)	365.6		18.7	19
0.210 (No. 80)	430.8		11.2	11
0.075 (No. 200)	484.4		5.0	5.0
Pan	495.1			
Dry mass before washing (M_3): 527.6 g				

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Fineness Modulus

Fineness Modulus (FM) is used in determining the degree of uniformity of the 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 fine aggregate in PCC.

The sum of the cumulative percentages retained on specified sieves in the following table divided by 100 gives the FM.

Sample Calculation

		Example A			Example B		
		Percent			Percent		
			Retained			Retained	
Sieve Size mm (in)		Passing		On Spec'd Sieves*	Passing		On Spec'd Sieves*
75*	(3)	100	0	0	100	0	0
37.5*	(1½)	100	0	0	100	0	0
19*	(¾)	15	85	85	100	0	0
9.5*	(⅜)	0	100	100	100	0	0
4.75*	(No.4)	0	100	100	100	0	0
2.36*	(No.8)	0	100	100	87	13	13
1.18*	(No.16)	0	100	100	69	31	31
0.60*	(No. 30	0	100	100	44	56	56
0.30*	(No. 50)	0	100	100	18	82	82
0.15*	(100)	0	100	100	4	96	96
				∑ = 785			∑ = 278
				FM = 7.85			FM = 2.78

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

Report

- Results on forms approved by the agency
- Sample ID
- Percent passing for each sieve
- Individual mass retained for each sieve
- Individual percent retained for each sieve

  or
- Cumulative mass retained for each sieve
- Cumulative percent retained for each sieve
- FM to the nearest 0.01

Report percentages to the nearest 1 percent except for the percent passing the 75 µm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

ANNEX A Time Evaluation

The sieving time for each mechanical sieve shaker shall be checked at least annually to determine the time required for complete separation of the test sample by the following method:

1. Shake the sample over nested sieves for approximately 10 minutes.
2. Provide a snug-fitting pan and cover for each sieve, and hold in a slightly inclined position in one hand.
3. Hand-shake each sieve by striking 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.

If more than 0.5 percent by mass of the total sample before sieving passes any sieve after one minute of continuous hand shaking adjust shaker time and re-check.

In determining sieving time for sieve sizes larger than 4.75 mm (No. 4), limit the material on the sieve to a single layer of particles.

ANNEX B Overload Determination

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

- For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 7 kg/m^2 (4 g/in^2) of sieving surface.
- For sieves with openings 4.75 mm (No. 4) and larger, the mass, in grams shall not exceed the product of 2.5 × (sieve opening in mm) × (effective sieving area). See Table B1.

Table B1 Maximum Allowable Mass of Material Retained on a Sieve, g
Nominal Sieve Size, mm (in)
Exact size is smaller (see AASHTO T 27)

Sieve Size mm (in)		203 dia (8)	305 dia (12)	305 by 305 (12 × 12)	350 by 350 (14 × 14)	372 by 580 (16 × 24)
		Sieving Area m^2				
		0.0285	0.0670	0.0929	0.1225	0.2158
90	(3½)	*	15,100	20,900	27,600	48,500
75	(3)	*	12,600	17,400	23,000	40,500
63	(2½)	*	10,600	14,600	19,300	34,000
50	(2)	3600	8400	11,600	15,300	27,000
37.5	(1½)	2700	6300	8700	11,500	20.200
25.0	(1)	1800	4200	5800	7700	13,500
19.0	(¾)	1400	3200	4400	5800	10,200
16.0	(⅝)	1100	2700	3700	4900	8600
12.5	(½)	890	2100	2900	3800	6700
9.5	(⅜)	670	1600	2200	2900	5100
6.3	(¼)	440	1100	1500	1900	3400
4.75	(No. 4)	330	800	1100	1500	2600
-4.75	(-No. 4)	200	470	650	860	1510

PERFORMANCE EXAM CHECKLIST

METHOD A

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

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

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
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 or 0.1 g?		
4.	Test sample placed in container and covered with water?		
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 2 mm (No. 10) and 75 µm (No. 200)?		
8.	Operation continued until wash water is clear?		
9.	Material retained on sieves returned to washed sample?		
10.	Washed test sample dried to a constant mass by FOP for AASHTO T 255?		
11.	Washed test sample cooled and mass determined to nearest 0.1 percent or 0.1 g?		
12.	Test 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 proper time?		
14.	Mass of material on each sieve and pan determined to 0.1 g?		
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 75 µm (No. 200) which is reported to the nearest 0.1 percent?		
17.	Percentage calculations based on original dry sample mass?		
18.	Calculations performed properly?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

Performance Exam Checklist

METHOD B

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

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

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
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 or 0.1 g?		
4.	Test sample placed in container and covered with water?		
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 2 mm (No. 10) and 75 µm (No. 200)?		
8.	Operation continued until wash water is clear?		
9.	Material retained on sieves returned to washed sample?		
10.	Washed test sample dried to a constant mass by FOP for AASHTO T 255?		
11.	Washed test sample cooled and mass determined to nearest 0.1 percent or 0.1 g?		
12.	Test 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 proper time?		
14.	Mass of material on each sieve and pan determined to the nearest 0.1 percent or 0.1 g?		
15.	Total mass of material after sieving agrees with mass before sieving to within 0.3 percent?		
16.	Material in pan reduced in accordance with FOP for AASHTO R 76 to at least 500 g and weighed to the nearest 0.1 g?		
17.	Test sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)		
18.	Material sieved in verified mechanical shaker for proper time?		
19.	Mass of material on each sieve and pan determined to the nearest percent or 0.1 g?		

Procedure Element	**Trial 1**	**Trial 2**
20. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent?		
21. Percentages calculated to the nearest 0.1 percent and reported to the nearest whole number, except 75 µm (No. 200) which is reported to the nearest 0.1 percent?		
22. Percentage calculations based on original dry sample mass?		
23. Calculations performed properly?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

WSDOT Errata to FOP for AASHTO T 30

Mechanical Analysis of Extracted Aggregate

WAQTC FOP for AASHTO T 30 has been adopted by WSDOT with the following changes:

Procedure

15. *Step not recognized by WSDOT.*

FOP for AASHTO T 30

Mechanical Analysis of Extracted Aggregate

Scope

This procedure covers mechanical analysis of aggregate recovered from asphalt mix samples in accordance with AASHTO T 30-15. This FOP utilizes the aggregate recovered from the ignition oven used in AASHTO T 308. AASHTO T 30 was developed for analysis of extracted aggregate and thus includes references to extracted bitumen and filter element, which do not apply in this FOP.

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

Apparatus

- Balance or scale: Capacity sufficient for the sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g
- Sieves, meeting the requirements of FOP for AASHTO T 27/T 11.
- Mechanical sieve shaker, meeting the requirements of FOP for AASHTO T 27/T 11.
- Mechanical Washing Apparatus (optional)
- Suitable drying equipment, meeting the requirements of the 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

Sample Sieving

- In this procedure, it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification. Intermediate sieves are added for additional information or to avoid overloading sieves, or both.
- The sieves are nested in order of increasing size from the bottom to the top, and the test sample, or a portion of the test sample, is placed on the top sieve.
- The loaded sieves are shaken in a mechanical shaker for approximately 10 minutes, refer to Annex A; *Time Evaluation*.

Mass Verification

Using the aggregate sample obtained from the FOP for AASHTO T 308, determine and record the mass of the sample, $M_{(T30)}$, to 0.1 g. This mass shall agree with the mass of the aggregate remaining after ignition, M_f from T 308, within 0.10 percent. If the variation exceeds 0.10 percent the results cannot be used for acceptance.

Calculation

$$Mass\ verification = \frac{M_{f\,(T308)} - M_{(T30)}}{M_{f\,(T308)}} \times 100$$

Where:

$M_{f(T308)}$ = Mass of aggregate remaining after ignition from the FOP for AASHTO T 308
$M_{(T30)}$ = Mass of aggregate sample obtained from the FOP for AASHTO T 308

Example:

$$Mass\ verification = \frac{2422.5\ g\ -\ 2422.3\ g}{2422.5\ g} \times 100\ = 0.01\%$$

Where:

$M_{f(T308)}$ = 2422.5 g
$M_{(T30)}$ = 2422.3 g

Procedure

1. Nest a sieve, such as a 2.0 mm (No. 10) or 1.18 mm (No. 16), above the 75µm (No. 200) sieve.
2. Place the test sample in a container and cover with water. Add a detergent, dispersing agent, or other wetting solution to the water to assure a thorough separation of the material finer than the 75µm (No. 200) 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.
3. Agitate vigorously to ensure complete separation of the material finer than 75µm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device. Maximum agitation is 10 min.

   Note 1: When mechanical washing equipment is used, the introduction of water, agitating, and decanting may be a continuous operation. Use care not to overflow or overload the 75µm (No. 200) sieve.
4. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75 µm (No. 200) sieve.
5. Add water to cover material remaining in the container, agitate, and repeat Step 4. Continue until the wash water is reasonably clear.
6. Remove the upper sieve, return material retained to the washed sample.
7. Rinse the material retained on the 75 µm (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed.

8. Return all material retained on the 75 µm (No. 200) sieve to the washed sample by rinsing into the washed sample.
9. Dry the washed test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the "dry mass after washing."
10. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 75 µm (No. 200).
11. Place the test sample, or a portion of the test sample, on the top sieve. Place sieves in mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

    Note 2: Excessive shaking (more than 10 minutes) may result in degradation of the sample.
12. Determine and record the individual or cumulative mass retained for each sieve including the pan. Ensure that all material trapped in full openings of the sieves are removed and included in the mass retained.

    Note 3: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.
13. Perform the Check Sum calculation – Verify the total mass after sieving of material agrees with the dry mass after washing within 0.2 percent. Do not use test results for acceptance if the Check Sum result is greater than 0.2 percent.
14. Calculate the total percentages passing, and the individual or cumulative percentages retained, to the nearest 0.1 percent by dividing the individual sieve masses or cumulative sieve masses by the total mass of the initial dry sample.
15. Apply the Aggregate Correction Factor (ACF) to the calculated percent passing, as required in the FOP for AASHTO T 308 "Correction Factor," to obtain the reported percent passing.
16. Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Calculations

Check Sum

$$check\ sum = \frac{dry\ mass\ after\ washing - total\ mass\ after\ sieving}{dry\ mass\ after\ washing} \times 100$$

Percent Retained

Individual

$$\text{IPR} = \frac{IMR}{M_{T30}} \times 100$$

Cumulative

$$\text{CPR} = \frac{CMR}{M_{T30}} \times 100$$

Where:

IPR = Individual Percent Retained
CPR = Cumulative Percent Retained
M_{T30} = Total dry sample mass before washing
IMR = Individual Mass Retained
CMR = Cumulative Mass Retained

Percent Passing

Individual

$$PP = PCP - IPR$$

Cumulative

$$PP = 100 - CPR$$

Where:

PP = Calculated Percent Passing
PCP = Previous Calculated Percent Passing

Reported Percent Passing

$$RPP = PP + ACF$$

Where:

RPP = Reported Percent Passing
ACF = Aggregate Correction Factor (if applicable)

Example

Dry mass of total sample, before washing (M_{T30}):	2422.3 g
Dry mass of sample, after washing out the 75 µm (No. 200) minus:	2296.2 g
Amount of 75 µm (No. 200) minus washed out (2422.3 g – 2296.2g):	126.1 g

Check sum

$$check\ sum = \frac{2296.2\ g - 2295.3\ g}{2296.2\ g} \times 100 = 0.04\%$$

This is less than 0.2 percent therefore the results can be used for acceptance purposes.

Percent Retained for the 75 µm (No. 200) sieve

$$IPR = \frac{63.5\ g}{2422.3\ g} \times 100 = 2.6\%$$

or

$$CPR = \frac{2289.6\ g}{2422.3\ g} \times 100 = 94.5\%$$

Percent Passing using IPR and PCP for the 75 µm (No. 200) sieve

$$PP = 8.1\% - 2.6\% = 5.5\%$$

Percent Passing using CPR for the 75 µm (No. 200) sieve

$$PP = 100.0\% - 94.5\% = 5.5\%$$

Reported Percent Passing

$$RPP = 5.5\% = (-0.6\%) = 4.9\%$$

Gradation on All Screens

Sieve Size mm (in)		Mass Retained (g) (MR)	Percent Retained (PR)	Cumulative Mass Retained (g) (CMR)	Cumulative Percent Retained (CPR)	Percent Passing (PP)	Agg. Corr. Factor from T 308 (ACF)	Reported Percent Passing (RPP)
19.0	(¾)	0.0		0.0	0	100.0		100
12.5	(½)	346.9	14.3	346.9	14.3	85.7		86
9.5	(⅜)	207.8	8.6	554.7	22.9	77.1		77
4.75	(No. 4)	625.4	25.8	1180.1	48.7	51.3		51
2.36	(No. 8)	416.2	17.2	1596.3	65.9	34.1		34
01.18	(No. 16)	274.2	11.3	1870.5	77.2	22.8		23
0.600	(No. 30)	152.1	6.3	2022.6	83.5	16.5		16
0.300	(No. 50)	107.1	4.4	2129.7	87.9	12.1		12
0.150	(No. 100)	96.4	4.0	2226.1	91.9	8.1		8
75 µm	(No. 200)	63.5	2.6	2289.6	94.5	5.5	-0.6	4.9
Pan		5.7		2295.3				

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Report

- Results on forms approved by the agency
- Sample ID
- Depending on the agency, this may include:
  - Individual mass retained on each sieve
  - Individual percent retained on each sieve
  - Cumulative mass retained on each sieve
  - Cumulative percent retained on each sieve
  - Aggregate Correction Factor for each sieve from AASHTO T 308
  - Calculated percent passing each sieve to 0.1 percent
- Percent passing to the nearest 1 percent, except 75 µm (No. 200) sieve to the nearest 0.1 percent.

ANNEX A Time Evaluation

The minimum time requirement should be evaluated for each shaker at least annually by the following method:

1. Shake the sample over nested sieves for approximately 10 minutes.
2. Provide a snug-fitting pan and cover for each sieve, and hold in a slightly inclined position in one hand.
3. Hand-shake each sieve by striking 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.

If more than 0.5 percent by mass of the total sample before sieving passes any sieve after one minute of continuous hand sieving adjust shaker time and re-check.

In determining sieving time for sieve sizes larger than 4.75 mm (No. 4), limit the material on the sieve to a single layer of particles.

ANNEX B Overload Determination

- For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 7 kg/m^2 (4 g/in^2) of sieving surface.
- For sieves with openings 4.75 mm (No. 4) and larger, the mass (in kg) shall not exceed the product of 2.5 × (sieve opening in mm) × (effective sieving area). See Table B1.

Additional sieves may be necessary to keep from overloading the specified sieves. The sample may also be sieved in increments or sieves with a larger surface area.

Table B1 Maximum Allowable Mass of Material Retained on a Sieve, g
Nominal Sieve Size, mm (in)
Exact size is smaller (see AASHTO T 27)

		203 dia (8)	305 dia (12)	305 by 305 (12 × 12)	350 by 350 (14 × 14)	372 by 580 (16 × 24)
		Sieving Area m^2				
Sieve Size mm (in)		0.0285	0.0670	0.0929	0.1225	0.2158
90	(3½)	*	15,100	20,900	27,600	48,500
75	(3)	*	12,600	17,400	23,000	40,500
63	(2½)	*	10,600	14,600	19,300	34,000
50	(2)	3600	8400	11,600	15,300	27,000
37.5	(1½)	2700	6300	8700	11,500	20,200
25.0	(1)	1800	4200	5800	7700	13,500
19.0	(¾)	1400	3200	4400	5800	10,200
16.0	(⅝)	1100	2700	3700	4900	8600
12.5	(½)	890	2100	2900	3800	6700
9.5	(⅜)	670	1600	2200	2900	5100
6.3	(¼)	440	1100	1500	1900	3400
4.75	(No. 4)	330	800	1100	1500	2600
-4.75	(-No. 4)	200	470	650	860	1510

Performance Exam Checklist

FOP for AASHTO T 30
Mechanical Analysis of Extracted Aggregate

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	Total dry mass determined to 0.1 g		
2.	Dry mass agrees with sample mass after ignition (M_f) from AASHTO T 308 within 0.1 percent?		
3.	Sample placed in container and covered with water?		
4.	Wetting agent added?		
5.	Contents of container agitated vigorously?		
6.	Wash water poured through proper nest of two sieves?		
7.	Washing continued until wash water is clear and no wetting agent remaining?		
8.	Retained material returned to washed sample?		
9.	Washed material coarser than 75 µm (No. 200) dried to constant mass at 110 ± 5°C (230 ± 9°F)?		
10.	Sample cooled to room temperature?		
11.	Dry mass after washing determined to 0.1 g?		
12.	Material sieved on specified sieves?		
13.	Mass of each fraction of aggregate, including minus 75 µm (No. 200), determined and recorded to 0.1 g?		
14.	Total mass of material after sieving agrees with mass before sieving to within 0.2 percent?		
15.	Percent passing each sieve determined correctly to the nearest 0.1 percent?		
16.	Aggregate correction factor applied?		
17.	Percent passing on each sieve reported correctly to the nearest 1 percent and nearest 0.1 percent on the 75 µm (No. 200)?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

WSDOT Errata to FOP for AASHTO R 47

Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size

WAQTC FOP for AASHTO R 47 has been adopted by WSDOT with the following changes:

Procedure

Include items below:

Sample Identification

1. Each sample submitted for testing shall be accompanied by a transmittal letter completed in detail. Include the contract number, acceptance and mix design verification numbers, mix ID.
2. Samples shall be submitted in standard sample boxes, secured to prevent contamination and spillage.
3. Sample boxes shall have the following information inscribed with indelible-type marker: Contract number, acceptance and mix design verification numbers, mix ID.
4. The exact disposition of each quarter of the original field sample shall be determined by the agency.

FOP for AASHTO R 47

Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size

Scope

This procedure covers sample reduction of Hot Mix Asphalt (HMA) to testing size in accordance with AASHTO R 47-14. The reduced portion is to be representative of the original sample.

Apparatus

- Thermostatically controlled oven capable of maintaining a temperature of at least 110°C (230°F) or high enough to heat the material to a pliable condition for splitting.
- Non-contact temperature measuring device.
- Metal spatulas, trowels, metal straightedges, or drywall taping knives, or a combination thereof; for removing HMA samples from the quartering device, cleaning surfaces used for splitting, etc.
- Square-tipped, flat-bottom scoop, shovel or trowel for mixing HMA prior to quartering.
- Miscellaneous equipment including hot plate, non-asbestos heat-resistant gloves or mittens, pans, buckets, and cans.
- Sheeting: Non-stick heavy paper, heat-resistant plastic, or other material as approved by the agency.
- Agency-approved release agent, free of solvent or petroleum-based material that could affect asphalt binder.
- Mechanical Splitter Type A (Quartermaster): having four equal-width chutes discharging into four appropriately sized sample receptacles. Splitter is to be equipped with a receiving hopper that will hold the sample until the release lever is activated with four sample receptacles of sufficient capacity to accommodate the reduced portion of the HMA sample from the mechanical splitter. Refer to AASHTO R 47, Figures 1 through 3, for configuration and required dimensions of the mechanical splitter.
- Mechanical Splitter Type B (Riffle): having a minimum of eight equal-width chutes discharging alternately to each side with a minimum chute width of at least 50 percent larger than the largest particle size. A hopper or straight-edged pan with a width equal to or slightly smaller than the assembly of chutes in the riffle splitter to permit uniform discharge of the HMA through the chutes without segregation or loss of material. Sample receptacles of sufficient width and capacity to receive the reduced portions of HMA from the riffle splitter without loss of material.
- Quartering Template: formed in the shape of a cross with equal length sides at right angles to each other. Template shall be manufactured of metal that will withstand heat and use without deforming. The sides of the quartering template should be sized so that the length exceeds the diameter of the flattened cone of HMA by an amount allowing complete separation of the quartered sample. Height of the sides must exceed the thickness of the flattened cone of HMA.
- Non-stick mixing surface that is hard, heat-resistant, clean, level, and large enough to permit HMA samples to be mixed without contamination or loss of material.

Sampling

Obtain samples according to the FOP for AASHTO T 168.

Sample Preparation

The sample must be warm enough to separate. If not, warm in an oven until it is sufficiently soft to mix and separate easily. Do not exceed either the temperature or time limits specified in the test method(s) to be performed.

Selection of Procedure (Method)

Refer to agency requirements when determining the appropriate method(s) of sample reduction. In general, the selection of a particular method to reduce a sample depends on the initial size of the sample vs. the size of the sample needed for the specific test to be performed. It is recommended that, for large amounts of material, the initial reduction be performed using a mechanical splitter. This decreases the time needed for reduction and minimizes temperature loss. Further reduction of the remaining HMA may be performed by a combination of the following methods, as approved by the agency. The methods for reduction are:

- Mechanical Splitter Method
  - Type A (Quartermaster)
  - Type B (Riffle Splitter)
- Quartering Method
  - Full Quartering
  - By Apex
- Incremental Method

Procedure

Mechanical Splitter Type A (Quartermaster)

1. Clean the splitter and apply a light coating of approved release agent to the surfaces that will contact HMA.
2. Close and secure hopper gates.
3. Place the four sample receptacles in the splitter so that there is no loss of material.
4. Remove the sample from the agency-approved container(s) and place in the mechanical splitter hopper. Avoid segregation, loss of HMA or the accidental addition of foreign material.
5. Release the handle, allowing the HMA to drop through the divider chutes and discharge into the four receptacles.
6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.
7. Close and secure the hopper gates.
8. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.

9. Combine the material contained in the receptacles from opposite corners and repeat the splitting process until an appropriate sample size is obtained.
10. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Mechanical Splitter Type B (Riffle)

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed 110ºC (230ºF).
2. Clean the splitter and apply a light coating of approved release agent to the surfaces that will come in contact with HMA (hopper or straight-edged pan, chutes, receptacles).
3. Place two empty receptacles under the splitter.
4. Carefully empty the HMA from the agency-approved container(s) into the hopper or straight-edged pan without loss of material. Uniformly distribute from side to side of the hopper or pan.
5. Discharge the HMA at a uniform rate, allowing it to flow freely through the chutes.
6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.
7. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.
8. Using one of the two receptacles containing HMA, repeat the reduction process until the HMA contained in one of the two receptacles is the appropriate size for the required test.
9. After each split, remember to clean the splitter hopper and chute surfaces if needed.
10. Retain and properly identify the remaining unused HMA sample for further testing if required by the agency.

Quartering Method

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed the maximum mixing temperature.
2. If needed, apply a light coating of release agent to quartering template.
3. Dump the sample from the agency approved container(s) into a conical pile on a hard, “non-stick,” clean, level surface where there will be neither a loss of material nor the accidental addition of foreign material. The surface can be made non-stick by the application of an approved asphalt release agent, or sheeting.
4. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one, or lifting both opposite corners.
5. Flatten the conical pile to a uniform diameter and thickness where the diameter is four to eight times the thickness. Make a visual observation to ensure that the material is homogeneous.

6. Divide the flattened cone into four equal quarters using the quartering template. Press the template down until it is in complete contact with the surface on which the sample has been placed, assuring complete separation.

   Note 1: Straightedges may be used in lieu of the quartering device to completely separate the material in approximately equal quarters.

7. Reduce the sample by quartering the sample completely or by removing the sample from the apex.

8. Full Quartering

   8a. Remove two diagonally opposite quarters, including all of the fine material.

   8b. Remove the quartering template and combine the remaining quarters, again forming a conical pile.

   8c. Repeat steps 4, 5, 6, 8a, and 8b until a sample of the required size has been obtained. The final sample must consist of the two remaining diagonally opposite quarters.

   8d. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

9. By Apex

   9a. Using a straightedge, slice through a quarter of the HMA from the center point to the outer edge of the quarter.

   9b. Pull or drag the material from the quarter with two straight edges or hold one edge of the straightedge in contact with quartering device.

   9c. Remove an equal portion from the opposite quarter and combine these increments to create the required sample size.

   9d. Continue using the apex method with the unused portion of the HMA until samples have been obtained for all required tests.

   9e. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Incremental Method

1. Cover a hard, clean, level surface with sheeting. This surface shall be large enough that there will be neither a loss of material nor the accidental addition of foreign material.

2. Place the sample from the agency approved container(s) into a conical pile on that surface.

3. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one, or lifting both opposite corners.

4. Grasp the sheeting and roll the conical pile into a cylinder (loaf), then flatten the top. Make a visual observation to determine that the material is homogenous.

5. Pull the sheeting so at least ¼ of the length of the loaf is off the edge of the counter. Allow this material to drop into a container to be saved. As an alternate, using a straightedge, slice off approximately ¼ of the length of the loaf and place in a container to be saved.
6. Pull material off the edge of the counter and drop into an appropriate size sample pan or container for the test to be performed. Continue removing material from the loaf until the proper size sample has been acquired. As an alternate, using a straightedge, slice off an appropriate size sample from the length of the loaf and place in a sample pan or container.
7. Repeat step 6 until all the samples for testing have been obtained.

   Note 2: When reducing the sample to test size it is advisable to take several small increments, determining the mass each time until the proper minimum size is achieved. Unless the sample size is grossly in excess of the minimum or exceeds the maximum test size, use the sample as reduced for the test.
8. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Performance Exam Checklist

FOP for AASHTO R 47
Reducing Samples of Hot Mix Asphalt (HMA) To Testing Size

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Sample made soft enough to separate easily without exceeding temperature limits?		
Mechanical Splitter Method Type A (Quartermaster)		
2. Splitter cleaned and surfaces coated with release agent?		
3. Hopper closed and receptacles in place?		
4. Sample placed into hopper without segregation or loss of material?		
5. Hopper handle released allowing the HMA to uniformly flow into receptacles?		
6. Splitter surfaces cleaned of all retained HMA, allowing it to fall into appropriate receptacles?		
7. Further reduction with the quartermaster:		
a. Material in receptacles from opposite corners combined?		
b. Splitting process repeated until appropriate sample size is obtained?		
8. Remaining HMA stored in suitable container and properly labeled?		
Mechanical Splitter Method Type B (Riffle)		
9. Splitting apparatus and tools, if preheated, not exceeding 110°C (230°F)?		
10. Splitter cleaned and surfaces coated with release agent?		
11. Two empty receptacles placed under splitter?		
12. Sample placed in hopper or straight edged pan without loss of material and uniformly distributed from side to side?		
13. Material discharged across chute assembly at controlled rate allowing free flow of HMA through chutes?		
14. Splitter surfaces cleaned of all retained HMA allowing it to fall into appropriate receptacles?		
15. Further reduction with the riffle splitter:		
a. Material from one receptacle discharged across chute assembly at controlled rate, allowing free flow of HMA through chutes?		
b. Splitting process continued until appropriate sample size obtained, with splitter surfaces cleaned of all retained HMA after every split?		
16. Remaining unused HMA stored in suitable container, properly labeled?		

Procedure Element	Trial 1	Trial 2
Quartering Method		
17. Testing equipment preheated to a temperature not to exceed mix temperature?	_____	_____
18. Sample placed in a conical pile on a hard, non-stick, heat-resistant splitting surface such as metal or sheeting?	_____	_____
19. Sample mixed by turning the entire sample over a minimum of 4 times?	_____	_____
20. Conical pile formed and then flattened uniformly to diameter equal to about 4 to 8 times thickness?	_____	_____
21 Sample divided into 4 equal portions either with a metal quartering template or straightedges such as drywall taping knives?	_____	_____
22. Reduction by Full Quartering:		
a. Two diagonally opposite quarters removed and returned to sample container?	_____	_____
b. Two other diagonally opposite quarters combined and process continued until appropriate sample size has been achieved?	_____	_____
23. Reduction by Apex:		
a. Using two straightedges or a splitting device and one straightedge, was one of the quarters split from apex to outer edge of material?	_____	_____
b. Similar amount of material taken from opposite quarter?	_____	_____
c. Increments combined to produce appropriate sample size?	_____	_____
24. Remaining unused HMA stored in suitable container, properly labeled?	_____	_____
Incremental Method		
25. Sample placed on hard, non-stick, heat-resistant splitting surface covered with sheeting?	_____	_____
26. Sample mixed by turning the entire sample over a minimum of 4 times?	_____	_____
27. Conical pile formed?	_____	_____
28. HMA rolled into loaf and then flattened?	_____	_____
29. The first quarter of the loaf removed by slicing off or dropping off edge of counter and set aside?	_____	_____
30. Proper sample size sliced off or dropped off edge of counter into sample container?	_____	_____
31. Process continued until all samples are obtained?	_____	_____
32. All remaining unused HMA stored in suitable container, properly labeled?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments

FOP for AASHTO R 66

Sampling Asphalt Materials

Scope

This procedure covers obtaining samples of liquid asphalt materials in accordance with AASHTO R 66-16. Sampling of solid and semi-solid asphalt materials – included in AASHTO R 66 – is not covered here.

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

Warning: Always use appropriate safety equipment and precautions for hot liquids.

Terminology

- Asphalt binder: Asphalt cement or modified asphalt cement that binds the aggregate particles into a dense mass.
- Asphalt emulsion: A mixture of asphalt binder and water.
- Cutback asphalt: Asphalt binder that has been modified by blending with a chemical solvent.

Procedure

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

Containers

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

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

- Emulsified asphalt: Use wide-mouth plastic jars with screw caps. Protect the samples from freezing since water is a part of the emulsion. The sample container should be completely filled to minimize a skin formation on the sample.
- Asphalt binder and cutbacks: Use metal cans.

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

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

FOP for AASHTO R 75

Developing a Family of Curves

Scope

This procedure provides a method to develop a family of curves in accordance with AASHTO R 75-16 using multiple moisture density relationships developed using the same method, A, B, C, or D, from the FOP for AASHTO T 99/T 180.

All curves used in a family must be developed using a single Method: A, B, C, or D of a procedure for AASHTO T 99 or T 180. See the FOP for AASHTO T 99/T 180.

Terminology

family of curves — a group of soil moisture-density relationships (curves) determined using AASHTO T 99 or T 180, which reveal certain similarities and trends characteristic of the soil type and source.

spine — smooth line extending through the point of maximum density/optimum moisture content of a family of moisture-density curves.

Procedure

1. Sort the curves by Method (A, B, C, or D of the FOP for T 99/T 180). At least three curves are required to develop a family.
2. Select the highest and lowest maximum dry densities from those selected to assist in determining the desired scale of the subsequent graph.
3. Plot the maximum density and optimum moisture points of the selected curves on the graph.
4. Draw a smooth, "best fit," curved line through the points creating the spine of the family of curves.
5. Remove maximum density and optimum moisture points that were not used to establish the spine.
6. Add the moisture/density curves associated with the points that were used to establish the spine. It is not necessary to include the portion of the curves over optimum moisture.

   Note 1: Intermediate template curves using slopes similar to those of the original moisture-density curves may be included when maximum density points are more than 2.0 lb/ft^3 apart. Template curves are indicated by a dashed line.
7. Plot the 80 percent of optimum moisture range when desired:
   a. Using the optimum moisture of an existing curve, calculate 80 percent of optimum moisture and plot this value on the curve. Repeat for each curve in the family.
   b. Draw a smooth, "best fit," curved line connecting the 80 percent of optimum moisture points plotted on the curves that parallel the spine.

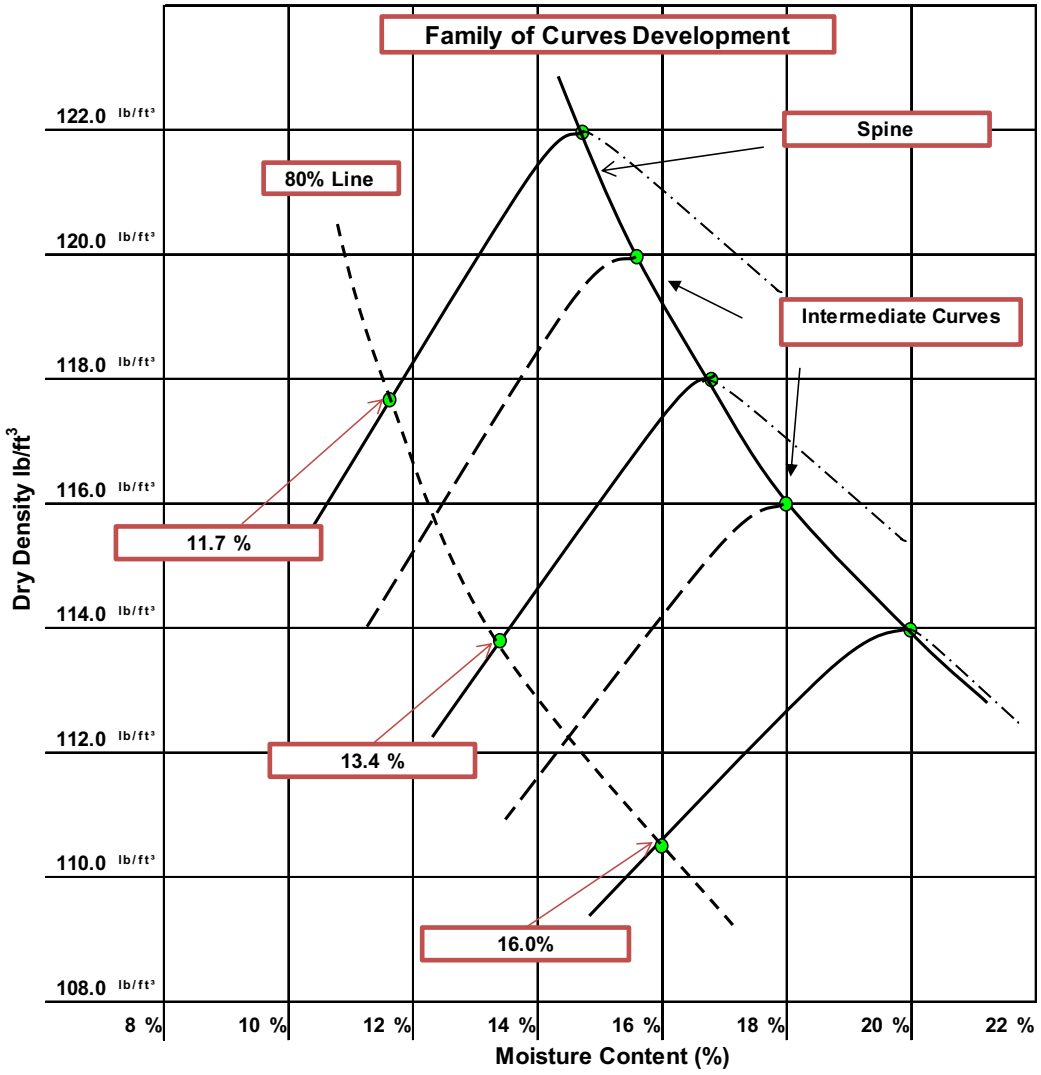
Calculations

Calculate 80 percent of optimum moisture of each curve:

Example:

Optimum moisture of the highest density curve = 14.6 percent

$$80\%\ point = \frac{80}{100} \times 14.6\% = 11.7\%$$



Performance Exam Checklist

FOP for AASHTO R 75
Developing a Family of Curves

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Curves sorted by method and procedure (A, B, C, or D of the FOP for T 99/T 180)?		
a. At least three curves per family?		
2. Maximum density and optimum moisture points plotted on the graph?		
3. Spine drawn correctly?		
4. Maximum density and optimum moisture points removed that were not used for the spine?		
5. Moisture/density curves added?		
6. Optimum moisture range?		
a. 80 percent of optimum moisture calculated for each curve?		
b. Curved line through 80 percent of optimum moisture drawn correctly?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

FOP FOR AASHTO R 76

Reducing Samples of Aggregates to Testing Size

Scope

This procedure covers the reduction of samples to the appropriate size for testing in accordance with AASHTO R 76-16. Techniques are used that minimize variations in characteristics between test samples and field samples. Method A (Mechanical Splitter) and Method B (Quartering) are covered.

This FOP applies to fine aggregate (FA), coarse aggregate (CA), and mixes of the two (FA/CA), and may also be used on soils.

Apparatus

Method A – Mechanical Splitter

Splitter chutes:

- Even number of equal width chutes
- Discharge alternately to each side
- Minimum of 8 chutes total for CA and FA/CA , 12 chutes total for FA
- Width:
  - Minimum 50 percent larger than largest particle
  - Maximum chute width of 19 mm (¾ in) for fine aggregate passing the 9.5 mm (⅜ in) sieve

Feed control:

- Hopper or straightedge pan with a width equal to or slightly less than the overall width of the assembly of chutes
- Capable of feeding the splitter at a controlled rate

Splitter receptacles/pans:

- Capable of holding two halves of the sample following splitting

The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material.

Method B – Quartering

- Straightedge scoop, shovel, or trowel
- Broom or brush
- Canvas or plastic sheet, approximately 2 by 3 m (6 by 9 ft)

Method Selection

Samples of CA may be reduced by either Method A or Method B.

Samples of FA which are drier than the saturated surface dry (SSD) condition, as described in AASHTO T 84, shall be reduced by a mechanical splitter according to Method A. As a quick approximation, if the fine aggregate will retain its shape when molded with the hand, it is wetter than SSD.

Samples of FA/CA which are drier than SSD may be reduced by Method A or Method B.

Samples of FA and FA/CA that are at SSD or wetter than SSD shall be reduced by Method B, or the entire sample may be dried to the SSD condition – using temperatures that do not exceed those specified for any of the tests contemplated – and then reduced to test sample size using Method A.

Table 1

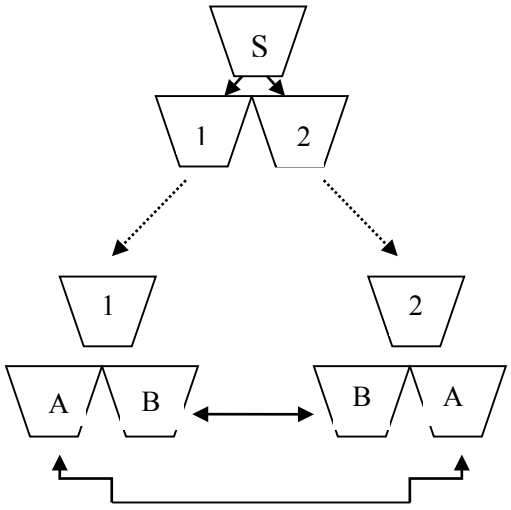
	Drier than SSD	Wetter than SSD
Fine Aggregate (FA)	Method A (Mechanical)	Method B (Quartering)
Mixture of FA/CA	Either Method	Method B (Quartering)
Coarse Aggregate (CA)	Either Method	Either Method

Procedure

Method A – Mechanical Splitter

1. Place the sample in the hopper or pan and uniformly distribute it from edge to edge so that approximately equal amounts flow through each chute. The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the pans below.
2. Reduce the sample from one of the two pans as many times as necessary to reduce the sample to meet the minimum size specified for the intended test. The portion of the material collected in the other pan may be reserved for reduction in size for other tests.
3. As a check for effective reduction, determine the mass of each reduced portion. If the percent difference of the two masses is greater than 5 percent, corrective action must be taken. In lieu of the check for effective reduction, use the method illustrated in Figure 1.

Figure 1



Sample (S) is an amount greater than or equal to twice the mass needed for testing. Sample (S) is reduced in a mechanical splitter to yield parts (1) and (2)

Part (1) is further reduced yielding (A) and (B) while part (2) is reduced to yield (B) and (A).

Final testing sample is produced by combining alternate pans, i.e. A/A or B/B only.

Calculation

$$\frac{Smaller\ Mass}{Larger\ Mass} = Ratio \quad (1 - ratio)\times 100 = \%\ Difference$$

Splitter check: 5127 g total sample mass

Splitter pan #1: 2583 g

Splitter pan #2: 2544 g

$$\frac{2544\ \text{g}}{2583\ \text{g}} = 0.985 \qquad (1 - 0.985)\times 100 = 1.5\%$$

Procedure

Method B – Quartering

Use either of the following two procedures or a combination of both.

Procedure # 1: Quartering on a clean, hard, level surface:

1. Place the sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material.
2. Mix the material thoroughly by turning the entire sample over a minimum of four times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one.
3. Flatten the conical pile to a uniform thickness and diameter by pressing down with a shovel. The diameter should be four to eight times the thickness.
4. Divide the flattened pile into four approximately equal quarters with a shovel or trowel.
5. Remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean.
6. Successively mix and quarter the remaining material until the sample is reduced to the desired size.
7. The final test sample consists of two diagonally opposite quarters.

Procedure # 2: Quartering on a canvas or plastic sheet:

1. Place the sample on the sheet.
2. Mix the material thoroughly a minimum of four times by pulling each corner of the sheet horizontally over the sample toward the opposite corner. After the last turn, form a conical pile.
3. Flatten the conical pile to a uniform thickness and diameter by pressing down with a shovel. The diameter should be four to eight times the thickness.
4. Divide the flattened pile into four approximately equal quarters with a shovel or trowel, or, insert a stick or pipe beneath the sheet and under the center of the pile, then lift both ends of the stick, dividing the sample into two roughly equal parts. Remove the stick leaving a fold of the sheet between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four roughly equal quarters.
5. Remove two diagonally opposite quarters, being careful to clean the fines from the sheet.
6. Successively mix and quarter the remaining material until the sample size is reduced to the desired size.
7. The final test sample consists of two diagonally opposite quarters.

Performance Exam Checklist

FOP for AASHTO R 76
Reducing Field Samples of Aggregates to Testing Size

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
Method A - Splitting		
1. Material spread uniformly on feeder?	_____	_____
2. Rate of feed slow enough so that sample flows freely through chutes?	_____	_____
3. Material in one pan re-split until desired mass is obtained?	_____	_____
Method B - Quartering		
1. Sample placed on clean, hard, and level surface?	_____	_____
2. Mixed by turning over 4 times with shovel or by pulling sheet horizontally over pile?	_____	_____
3. Conical pile formed?	_____	_____
4. Diameter equal to about 4 to 8 times thickness?	_____	_____
5. Pile flattened to uniform thickness and diameter?	_____	_____
6. Divided into 4 equal portions with shovel or trowel?	_____	_____
7. Two diagonally opposite quarters, including all fine material, removed?	_____	_____
8. Cleared space between quarters brushed clean?	_____	_____
9. Process continued until desired sample size is obtained when two opposite quarters combined?	_____	_____
The sample may be placed upon a sheet and a stick or pipe may be placed under the sheet to divide the pile into quarters.		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

FOP for AASHTO T 85

Specific Gravity and Absorption of Coarse Aggregate

Scope

This procedure covers the determination of specific gravity and absorption of coarse aggregate in accordance with AASHTO T 85-14. Specific gravity may be expressed as bulk specific gravity (G_{sb}), bulk specific gravity, saturated surface dry (G_{sb} SSD), or apparent specific gravity (G_{sa}). G_{sb} and absorption are based on aggregate after soaking in water. This procedure is not intended to be used with lightweight aggregates.

Terminology

Absorption – the increase in the mass of aggregate due to water being absorbed into the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered "dry" when it has been maintained at a temperature of 110 ± 5°C (230 ± 9°F) for sufficient time to remove all uncombined water.

Saturated Surface Dry (SSD) – condition of an aggregate particle when the permeable voids are filled with water, but no water is present on exposed surfaces.

Specific Gravity – the ratio of the mass, in air, of a volume of a material to the mass of the same volume of gas-free distilled water at a stated temperature.

Apparent Specific Gravity (G_{sa})– the ratio of the mass, in air, of a volume of the impermeable portion of aggregate to the mass of an equal volume of gas-free distilled water at a stated temperature.

Bulk Specific Gravity (G_{sb})– the ratio of the mass, in air, of a volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of gas-free distilled water at a stated temperature.

Bulk Specific Gravity (SSD) (G_{sb} SSD) – the ratio of the mass, in air, of a volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for 15 to 19 hours (but not including the voids between particles), to the mass of an equal volume of gas-free distilled water at a stated temperature.

Apparatus

- Balance or scale: with a capacity of 5 kg, sensitive to 1 g. Meeting the requirements of AASHTO M 231.
- Sample container: a wire basket of 3.35 mm (No. 6) or smaller mesh, with a capacity of 4 to 7 L (1 to 2 gal) to contain aggregate with a nominal maximum size of 37.5 mm (1½ in) or smaller; or a larger basket for larger aggregates, or both.
- Water tank: watertight and large enough to completely immerse aggregate and basket, equipped with an overflow valve to keep water level constant.
- Suspension apparatus: wire used to suspend apparatus shall be of the smallest practical diameter.
- Sieves 4.75 mm (No. 4) or other sizes as needed, meeting the requirements of FOP for AASHTO T 27/T 11.
- Large absorbent towel

Sample Preparation

1. Obtain the sample in accordance with the FOP for AASHTO T 2 (see Note 1).
2. Mix the sample thoroughly and reduce it to the approximate sample size required by Table 1 in accordance with the FOP for AASHTO R 76.
3. Reject all material passing the appropriate sieve by dry sieving.
4. Thoroughly wash sample to remove dust or other coatings from the surface.
5. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F) and cool in air at room temperature for 1 to 3 hours.

   Note 1: Where the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated, and, if the surfaces of the particles in the sample have been kept continuously wet until test, the 15-to-19 hour soaking may also be eliminated.
6. Re-screen the sample over the appropriate sieve. Reject all material passing that sieve.
7. The sample shall meet or exceed the minimum mass given in Table 1.

   Note 2: If this procedure is used only to determine the G_{sb} of oversized material for the FOP for AASHTO T 99/T 180, the material can be rejected over the appropriate sieve. For T 99/T 180 Methods A and B, use the 4.75 mm (No. 4) sieve; T 99/T 180 Methods C and D use the 19 mm (¾ in).

Table 1

Nominal Maximum Size* mm (in)		Minimum Mass of Test Sample, g (lb)	
12.5	(½) or less	2000	(4.4)
19.0	(¾)	3000	(6.6)
25.0	(1)	4000	(8.8)
37.5	(1½)	5000	(11)
50	(2)	8000	(18)
63	(2½)	12,000	(26)
75	(3)	18,000	(40)

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Procedure

1. Immerse the aggregate in water at room temperature for a period of 15 to 19 hours.

   Note 3: When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more subsamples, and then combine the values obtained.

2. Place the empty basket into the water bath and attach to the balance. Inspect the immersion tank to ensure the water level is at the overflow outlet height. Tare the balance with the empty basket attached in the water bath.

3. Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. If the test sample dries past the SSD condition, immerse in water for 30 min, and then resume the process of surface-drying.

   Note 4: A moving stream of air may be used to assist in the drying operation, but take care to avoid evaporation of water from aggregate pores.

4. Determine the SSD mass of the sample, and record this and all subsequent masses to the nearest 0.1 g or 0.1 percent of the sample mass, whichever is greater. Designate this mass as “B.”

5. Immediately place the SSD test sample in the sample container and weigh it in water maintained at 23.0 ± 1.7°C (73.4 ± 3°F). Shake the container to release entrapped air before recording the weight. Re-inspect the immersion tank to insure the water level is at the overflow outlet height. Designate this submerged weight as “C.”

   Note 5: The container should be immersed to a depth sufficient to cover it and the test sample during mass determination. Wire suspending the container should be of the smallest practical size to minimize any possible effects of a variable immersed length.

6. Remove the sample from the basket. Ensure all material has been removed. Place in a container of known mass.

7. Dry the test sample to constant mass in accordance with the FOP for AASHTO T 255/T 265 (Aggregate section) and cool in air at room temperature for 1 to 3 hours. Designate this mass as “A.”

Calculations

Perform calculations and determine values using the appropriate formula below.

Bulk specific gravity (G_{sb})

$$G_{sb} = \frac{A}{B - C}$$

Bulk specific gravity, SSD (G_{sb} SSD)

$$G_{sb}SSD = \frac{B}{B - C}$$

Apparent specific gravity (G_{sa})

$$G_{sa} = \frac{A}{A - C}$$

Absorption

$$\text{Absorption} = \frac{B - A}{A} \times 100$$

Where:

A = oven dry mass, g
B = SSD mass, g
C = weight in water, g

Sample Calculations

Sample	A	B	C	B - C	A - C	B - A
1	2030.9	2044.9	1304.3	740.6	726.6	14.0
2	1820.0	1832.5	1168.1	664.4	651.9	12.5
3	2035.2	2049.4	1303.9	745.5	731.3	14.2

Sample	G_{sb}	G_{sb} SSD	G_{sa}	Absorption
1	2.742	2.761	2.795	0.7
2	2.739	2.758	2.792	0.7
3	2.730	2.749	2.783	0.7

These calculations demonstrate the relationship between G_{sb}, G_{sb} SSD, and G_{sa}. G_{sb} is always lowest, since the volume includes voids permeable to water. G_{sb} SSD is always intermediate. G_{sa} is always highest, since the volume does not include voids permeable to water. When running this test, check to make sure the values calculated make sense in relation to one another.

Report

- Results on forms approved by the agency
- Sample ID
- Specific gravity values to 3 decimal places
- Absorption to 0.1 percent

Performance Exam Checklist

FOP for AASHTO T 85
Specific Gravity and Absorption of Coarse Aggregate

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	Sample obtained by FOP for AASHTO T 2 and reduced by FOP for AASHTO R 76 or from FOP for AASHTO T 99/T 180?		
2.	Screened on the appropriate size sieve?		
3.	Sample mass appropriate?		
4.	Particle surfaces clean?		
5.	Dried to constant mass 110 ± 5°C (230 ± 9°F) and cooled to room temperature?		
6.	Re-screen over appropriate sieve?		
7.	Covered with water for 15 to 19 hours?		
8.	Basket placed into immersion tank and attached to balance?		
9.	Immersion tank inspected for proper water height?		
10.	Balance tared with basket in tank and temperature checked 23.0 ± 1.7°C (73.4 ± 3°F)?		
11.	Sample removed from water and rolled in cloth to remove visible films of water?		
12.	Larger particles wiped individually?		
13.	Evaporation avoided?		
14.	Sample mass determined to 0.1 g?		
15.	Sample immediately placed in basket, in immersion tank?		
16.	Entrapped air removed before weighing by shaking basket while immersed?		
17.	Immersion tank inspected for proper water height?		
18.	Immersed sample weight determined to 0.1 g?		
19.	All the sample removed from basket?		
20.	Sample dried to constant mass and cooled to room temperature?		
21.	Sample mass determined to 0.1 g?		
22.	Proper formulas used in calculations?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

MOISTURE-DENSITY RELATIONS OF SOILS:

FOP for AASHTO T 99

USING A 2.5 kg (5.5 lb) RAMMER AND A 305 mm (12 in) DROP

FOP for AASHTO T 180

USING A 4.54 kg (10 lb) RAMMER AND A 457 mm (18 in) DROP

Scope

This procedure covers the determination of the moisture-density relations of soils and soil-aggregate mixtures in accordance with two similar test methods:

- AASHTO T 99-17: Methods A, B, C, and D
- AASHTO T 180-17: Methods A, B, C, and D

This test method applies to soil mixtures having 40 percent or less retained on the 4.75 mm (No. 4) sieve for methods A or B, or, 30 percent or less retained on the 19 mm (¾ in) with methods C or D. The retained material is defined as oversize (coarse) material. If no minimum percentage is specified, 5 percent will be used. Samples that contain oversize (coarse) material that meet percent retained criteria should be corrected by using *Annex A*, *Correction of Maximum Dry Density and Optimum Moisture for Oversized Particles*. Samples of soil or soil-aggregate mixture are prepared at several moisture contents and compacted into molds of specified size, using manual or mechanical rammers that deliver a specified quantity of compactive energy. The moist masses of the compacted samples are multiplied by the appropriate factor to determine wet density values. Moisture contents of the compacted samples are determined and used to obtain the dry density values of the same samples. Maximum dry density and optimum moisture content for the soil or soil-aggregate mixture is determined by plotting the relationship between dry density and moisture content.

Apparatus

- Mold – Cylindrical mold made of metal with the dimensions shown in Table 1 or Table 2. If permitted by the agency, the mold may be of the "split" type, consisting of two half-round sections, which can be securely locked in place to form a cylinder. Determine the mold volume according to *Annex B*, *Standardization of the Mold*.
- Mold assembly – Mold, base plate, and a detachable collar.
- Rammer –Manually or mechanically-operated rammers as detailed in Table 1 or Table 2. A manually-operated rammer shall be equipped with a guide sleeve to control the path and height of drop. The guide sleeve shall have at least four vent holes no smaller than 9.5 mm (⅜ in) in diameter, spaced approximately 90 degrees apart and approximately 19 mm (¾ in) from each end. A mechanically-operated rammer will uniformly distribute blows over the sample and will be calibrated with several soil types, and be adjusted, if necessary, to give the same moisture-density results as with the manually operated rammer. For additional information concerning calibration, see the FOP for AASHTO T 99 and T 180.
- Sample extruder – A jack, lever frame, or other device for extruding compacted specimens from the mold quickly and with little disturbance.

- Balance(s) or scale(s) of the capacity and sensitivity required for the procedure used by the agency.

  A balance or scale with a capacity of 11.5 kg (25 lb) and a sensitivity of 1 g for obtaining the sample, meeting the requirements of AASHTO M 231, Class G 5.

  A balance or scale with a capacity of 2 kg and a sensitivity of 0.1 g is used for moisture content determinations done under both procedures, meeting the requirements of AASHTO M 231, Class G 2.
- Drying apparatus – A thermostatically controlled drying oven, capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F) for drying moisture content samples in accordance with the FOP for AASHTO T 255/T 265.
- Straightedge – A steel straightedge at least 250 mm (10 in) long, with one beveled edge and at least one surface plane within 0.1 percent of its length, used for final trimming.
- Sieve(s) – 4.75 mm (No. 4) and/or 19.0 mm (¾ in), meeting the requirements of FOP for AASHTO T 27/T 11.
- Mixing tools – Miscellaneous tools such as a mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device, for mixing the sample with water.
- Containers with close-fitting lids to prevent gain or loss of moisture in the sample.

Table 1 Comparison of Apparatus, Sample, and Procedure – Metric

	T 99	T 180
Mold Volume, m^3	Methods A, C: 0.000943 ± 0.000014	Methods A, C: 0.000943 ± 0.000014
	Methods B, D: 0.002124 ± 0.000025	Methods B, D: 0.002124 ± 0.000025
Mold Diameter, mm	Methods A, C: 101.60 ± 0.40	Methods A, C: 101.60 ± 0.4
	Methods B, D: 152.40 ± 0.70	Methods B, D: 152.40 ± 0.70
Mold Height, mm	116.40 ± 0.50	116.40 ± 0.50
Detachable Collar Height, mm	50.80 ± 0.64	50.80 ± 0.64
Rammer Diameter, mm	50.80 ± 0.25	50.80 ± 0.25
Rammer Mass, kg	2.495 ± 0.009	4.536 ± 0.009
Rammer Drop, mm	305	457
Layers	3	5
Blows per Layer	Methods A, C: 25	Methods A, C: 25
	Methods B, D: 56	Methods B, D: 56
Material Size, mm	Methods A, B: 4.75 minus	Methods A, B: 4.75 minus
	Methods C, D: 19.0 minus	Methods C, D: 19.0 minus
Test Sample Size, kg	Method A: 3 Method B: 7 Method C: 5 (1) Method D: 11(1)	
Energy, kN-m/m^3	592	2,693

(1) This may not be a large enough sample depending on your nominal maximum size for moisture content samples.

Table 2 Comparison of Apparatus, Sample, and Procedure – English

	T 99	T 180
Mold Volume, ft^3	Methods A, C: 0.0333 ± 0.0005	Methods A, C: 0.0333 ± 0.0005
	Methods B, D: 0.07500 ± 0.0009	Methods B, D: 0.07500 ± 0.0009
Mold Diameter, in	Methods A, C: 4.000 ± 0.016	Methods A, C: 4.000 ± 0.016
	Methods B, D: 6.000 ± 0.026	Methods B, D: 6.000 ± 0.026
Mold Height, in	4.584 ± 0.018	4.584 ± 0.018
Detachable Collar Height, in	2.000 ± 0.025	2.000 ± 0.025
Rammer Diameter, in	2.000 ± 0.025	2.000 ± 0.025
Rammer Mass, lb	5.5 ± 0.02	10 ± 0.02
Rammer Drop, in	12	18
Layers	3	5
Blows per Layer	Methods A, C: 25	Methods A, C: 25
	Methods B, D: 56	Methods B, D: 56
Material Size, in	Methods A, B: No. 4 minus	Methods A, B: No.4 minus
	Methods C, D: ¾ minus	Methods C, D: ¾ minus
Test Sample Size, lb	Method A: 7 Method B: 16 Method C: 12(1) Method D: 25(1)	
Energy, lb-ft/ft^3	12,375	56,250

(1) This may not be a large enough sample depending on your nominal maximum size for moisture content samples.

Sample

If the sample is damp, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus maintained at a temperature not exceeding 60°C (140°F). Thoroughly break up aggregations in a manner that avoids reducing the natural size of individual particles.

Obtain a representative test sample of the mass required by the agency by passing the material through the sieve required by the agency. See Table 1 or Table 2 for test sample mass and material size requirements.

In instances where the material is prone to degradation, i.e., granular material, a compaction sample with differing moisture contents should be prepared for each point.

Note 1: Both T 99 and T 180 have four methods (A, B, C, D) that require different masses and employ different sieves.

Note 2: If the sample is plastic (clay types), it should stand for a minimum of 12 hours after the addition of water to allow the moisture to be absorbed. In this case, several samples at different moisture contents should be prepared, put in sealed containers and tested the next day.

Procedure

During compaction, rest the mold firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process.

1. Determine the mass of the clean, dry mold. Include the base plate, but exclude the extension collar. Record the mass to the nearest 1 g (0.005 lb).
2. Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 to 8 percentage points below optimum moisture content. See Note 2. For many materials, this condition can be identified by forming a cast by hand.
3. Form a specimen by compacting the prepared soil in the mold assembly in approximately equal layers. For each layer:
   a. Spread the loose material uniformly in the mold.

      Note 3: It is recommended to cover the remaining material with a non-absorbent sheet or damp cloth to minimize loss of moisture.

   b. Lightly tamp the loose material with the manual rammer or other similar device, this establishes a firm surface.
   c. Compact each layer with uniformly distributed blows from the rammer. See Table 1 for mold size, number of layers, number of blows, and rammer specification for the various test methods. Use the method specified by the agency.
   d. Trim down material that has not been compacted and remains adjacent to the walls of the mold and extends above the compacted surface.
4. Remove the extension collar. Avoid shearing off the sample below the top of the mold. The material compacted in the mold should not be over 6 mm (¼ in) above the top of the mold once the collar has been removed.
5. Trim the compacted soil even with the top of the mold with the beveled side of the straightedge.
6. Determine and record the mass of the mold, base plate, and wet soil to the nearest 1 g (0.005 lb) or better.
7. Determine and record the wet mass (M_w) of the sample by subtracting the mass in Step 1 from the mass in Step 6.
8. Calculate the wet density, in kg/m^3 (lb/ft^3), by dividing the wet mass by the measured volume (V_m).
9. Extrude the material from the mold. For soils and soil-aggregate mixtures, slice vertically through the center and take a representative moisture content sample from one of the cut faces, ensuring that all layers are represented. For granular materials, a vertical face will not exist. Take a representative sample. This sample must meet the sample size requirements of the test method used to determine moisture content.

   Note 4: When developing a curve for free-draining soils such as uniform sands and gravels, where seepage occurs at the bottom of the mold and base plate, taking a representative moisture content from the mixing bowl may be preferred in order to determine the amount of moisture available for compaction.

10. Determine and record the moisture content of the sample in accordance with the FOP for AASHTO T 255/T 265.
11. Thoroughly break up the remaining portion of the molded specimen until it will again pass through the sieve, as judged by eye, and add to the remaining portion of the sample being tested. See Note 2.
12. Add sufficient water to increase the moisture content of the remaining soil by 1 to 2 percentage points and repeat steps 3 through 11.
13. Continue determinations until there is either a decrease or no change in the wet mass. There will be a minimum of three points on the dry side of the curve and two points on the wet side. For non-cohesive, drainable soils, one point on the wet side is sufficient.

Calculations

Wet Density

$$D_w = \frac{M_w}{V_m}$$

Where:

D_w = wet density, kg/m^3 (lb/ft^3)
M_w = wet mass
V_m = volume of the mold, Annex B

Dry Density

$$D_d = \left(\frac{D_w}{w + 100}\right) \times 100 \quad or \quad D_d = \frac{D_w}{\left(\frac{w}{100}\right) + 1}$$

Where:

D_d = dry density, kg/m^3 (lb/ft^3)
w = moisture content, as a percentage

Example for 4-inch mold, Methods A or C

Wet mass, M_w	= 1.944 kg (4.25 lb)
Moisture content, w	= 11.3 percent
Measured volume of the mold, V_m	= 0.000946 m^3 (0.0334 ft^3)

Wet Density

$$D_w = \frac{1.944\ kg}{0.000946\ m^3} = 2055\ kg/m^3 \quad D_w = \frac{4.25\ lb}{0.0334\ ft^3} = 127.2\ lb/ft^3$$

Dry Density

$$D_d = \left(\frac{2055\ kg/m^3}{11.3 + 100}\right) \times 100 = 1846\ kg/m^3 \quad D_d = \left(\frac{127.2\ lb/ft^3}{11.3 + 100}\right) \times 100 = 114.3\ lb/ft^3$$

Or

$$D_d = \left(\frac{2055\ kg/m^3}{\frac{11.3}{100} + 1}\right) = 1846\ kg/m^3 \quad D_d = \left(\frac{127.2\ lb/ft^3}{\frac{11.3}{100} + 1}\right) = 114.3\ lb/ft^3$$

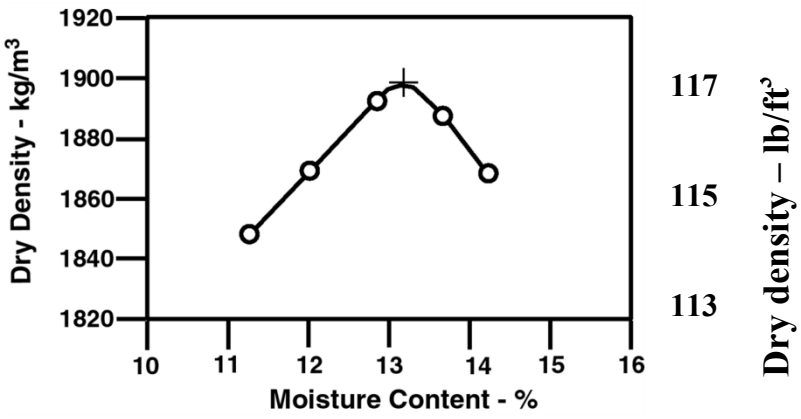
Moisture-Density Curve Development

When dry density is plotted on the vertical axis versus moisture content on the horizontal axis and the points are connected with a smooth line, a moisture-density curve is developed. The coordinates of the peak of the curve are the maximum dry density, or just "maximum density," and the "optimum moisture content" of the soil.

Example

Given the following dry density and corresponding moisture content values develop a moisture-density relations curve and determine maximum dry density and optimum moisture content.

Dry Density		Moisture Content, %
kg/m³	lb/ft³	
1846	114.3	11.3
1868	115.7	12.1
1887	116.9	12.8
1884	116.7	13.6
1871	115.9	14.2



In this case, the curve has its peak at:

Maximum dry density = 1890 kg/m³ (117.0 lb/ft³)

Optimum moisture content = 13.2 percent

Note that both values are approximate, since they are based on sketching the curve to fit the points.

Report

- Results on forms approved by the agency
- Sample ID
- Maximum dry density to the closest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the closest 0.1 percent

ANNEX A

Correction of Maximum DRY Density and Optimum Moisture for Oversized Particles

This section corrects the maximum dry density and moisture content of the material retained on the 4.75 mm (No. 4) sieve, Methods A and B; or the material retained on the 19 mm (¾ in) sieve, Methods C and D. The maximum dry density, corrected for oversized particles and total moisture content, are compared with the field-dry density and field moisture content.

This correction can be applied to the sample on which the maximum dry density is performed. A correction may not be practical for soils with only a small percentage of oversize material. The agency shall specify a minimum percentage below which the method is not needed. If not specified, this method applies when more than 5 percent by weight of oversize particles is present.

Bulk specific gravity (G_{sb}) of the oversized particles is required to determine the corrected maximum dry density. Use the bulk specific gravity as determined using the FOP for AASHTO T 85 in the calculations. For construction activities, an agency established value or specific gravity of 2.600 may be used.

This correction can also be applied to the sample obtained from the field while performing in-place density.

1. Use the sample from this procedure or a sample obtained according to the FOP for AASHTO T 310.
2. Sieve the sample on the 4.75 mm (No. 4) sieve for Methods A and B or the 19 mm (¾ in) sieve, Methods C and D.
3. Determine the dry mass of the oversized and fine fractions (M_{DC} and M_{DF}) by one of the following:
    a. Dry the fractions, fine and oversized, in air or by use of a drying apparatus that is maintained at a temperature not exceeding 60°C (140°F).
    b. Calculate the dry masses using the moisture samples.

To determine the dry mass of the fractions using moisture samples.

1. Determine the moist mass of both fractions, fine (M_{Mf}) and oversized (M_{Mc}):
2. Obtain moisture samples from the fine and oversized material.
3. Determine the moisture content of the fine particles (MC_f) and oversized particles (MC_C) of the material by FOP for AASHTO T 255/T 265 or agency approved method.
4. Calculate the dry mass of the oversize and fine particles.

$$M_D = \frac{M_m}{1 + \mathrm{MC}}$$

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, expressed as a decimal

5. Calculate the percentage of the fine (P_f) and oversized (P_c) particles by dry weight of the total sample as follows: See Note 2.

$$P_f = \frac{100 \times M_{DF}}{M_{DF} + M_{DC}} \qquad \frac{100 \times 15.4\ lb}{15.4\ lbs + 5.7\ lb} = 73\% \qquad \frac{100 \times 6.985\ kg}{6.985\ kg + 2.602\ kg} = 73\%$$

And

$$P_c = \frac{100 \times M_{DC}}{M_{DF} + M_{DC}} \qquad \frac{100 \times 5.7\ lb}{15.4\ lbs + 5.7\ lb} = 27\% \qquad \frac{100 \times 2.585 kg}{6.985\ kg + 2.585\ kg} = 27\%$$

Or for $\mathbf{P_c}$:

$$P_c = 100 - P_f$$

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 fine particles
M_{DC} = mass of oversize particles

Optimum Moisture Correction Equation

1. Calculate the corrected moisture content as follows:

$$MC_T = \frac{\left(MC_F \times P_f\right) + \left(MC_c \times P_c\right)}{100} \qquad \frac{(13.2\% \times 73.0\%) + (2.1\% \times 27.0\%)}{100} = 10.2\%$$

Where:

MC_T = corrected moisture content of combined fines and oversized particles, expressed as a percent moisture
MC_f = moisture content of fine particles, as a percent moisture
MC_C = moisture content of oversized particles, as a percent moisture

Note 1: Moisture content of oversize material can be assumed to be two (2) percent for most construction applications.

Note 2: In some field applications agencies will allow the percentages of oversize and fine materials to be determined with the materials in the wet state.

Density Correction Equation

1. Calculate the corrected dry density of the total sample (combined fine and oversized particles) as follows:

$$D_d = \frac{100\%}{\left[\left(\frac{P_f}{D_f}\right) + \left(\frac{P_c}{k}\right)\right]}$$

Where:

D_d = corrected total dry density (combined fine and oversized particles) kg/m^3 (lb/ft^3)
D_f = dry density of the fine particles kg/m^3 (lb/ft^3), determined in the lab
P_c= percent of oversize particles, of sieve used, by weight.
P_f = percent of fine particles, of sieve used, by weight.
k = Metric: 1,000 * Bulk Specific Gravity (G_{sb}) (oven dry basis) of coarse particles (kg/m^3).
k = English: 62.4 * Bulk Specific Gravity (G_{sb}) (oven dry basis) of coarse particles (lb/ft^3)

Note 3: If the specific gravity is known, then this value will be used in the calculation. For most construction activities the specific gravity for aggregate may be assumed to be 2.600.

Calculation

Example

Metric:

Maximum laboratory dry density (D_f):	1890 kg/m^3
Percent coarse particles (P_c):	27 percent
Percent fine particles (P_f):	73 percent
Mass per volume coarse particles (k):	(2.697) (1000) = 2697 kg/m^3

$$D_d = \frac{100\%}{\left[\left(\frac{P_f}{D_f}\right) + \left(\frac{P_c}{k}\right)\right]}$$

$$D_d = \frac{100\%}{\left[\left(\frac{73\%}{1890\,kg/m^3}\right) + \left(\frac{27\%}{2697\,kg/m^3}\right)\right]}$$

$$D_d = \frac{100\%}{[0.03862\,kg/m^3 + 0.01001\,kg/m^3]}$$

$$D_d = 2056.3\,kg/m^3\ report\ \ 2056\,kg/m^3$$

English:

Maximum laboratory dry density (D_f):	117.0 lb/ft^3
Percent coarse particles (P_c):	27 percent
Percent fine particles (P_f):	73 percent
Mass per volume of coarse particles (k):	(2.697) (62.4) = 168.3 lb/ft^3

$$D_d = \frac{100\%}{\left[\left(\frac{P_f}{D_f}\right) + \left(\frac{P_c}{k}\right)\right]}$$

$$D_d = \frac{100\%}{\left[\left(\frac{73\%}{117.0\ lb/ft^3}\right) + \left(\frac{27\%}{168.3\ lb/ft^3}\right)\right]}$$

$$D_d = \frac{100\%}{[0.6239\ lb/ft^3 + 0.1604\ lb/ft^3]}$$

$$D_d = \frac{100\%}{0.7843\ lb/ft^3}$$

$$D_d = 127.50\ lb/ft^3 \quad Report\ 127.5\ lb/ft^3$$

Report

- Results on forms approved by the agency
- Sample ID
- Corrected maximum dry density to the closest 1 kg/m^3 (0.1 lb/ft^3)
- Corrected optimum moisture to the 0.1 percent

ANNEX B

Standardization of The Mold

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedure as described herein will produce inaccurate or unreliable test results.

Apparatus

- Mold and base plate
- Balance or scale – Accurate to within 45 g (0.1 lb) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- Cover plate – A piece of plate glass, at least 6 mm (1⁄4 in) thick and at least 25 mm (1 in) larger than the diameter of the mold.
- Thermometers – Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)

Procedure

1. Create a watertight seal between the mold and base plate.
2. Determine and record the mass of the dry sealed mold, base plate, and cover plate.
3. Fill the mold with water at a temperature between 16°C and 29°C (60°F and 85°F) and cover with the cover plate in such a way as to eliminate bubbles and excess water.
4. Wipe the outside of the mold, base plate, and cover plate dry, being careful not to lose any water from the mold.
5. Determine and record the mass of the filled mold, base plate, cover plate, and water.
6. Determine and record the mass of the water in the mold by subtracting the mass in Step 2 from the mass in Step 5.
7. Measure the temperature of the water and determine its density from Table B1, interpolating as necessary.
8. Calculate the volume of the mold, V_m, by dividing the mass of the water in the mold by the density of the water at the measured temperature.

Calculations

$$V_m = \frac{M}{D}$$

Where:

V_m = volume of the mold
M = mass of water in the mold
D = density of water at the measured temperature

Example

Mass of water in mold = 0.94061 kg (2.0737 lb)

Density of water at 23°C (73.4°F) = 997.54 kg/m^3 (62.274 lb/ft^3)

$$V_m = \frac{0.94061\ kg}{997.54\ kg/m^3} = 0.000943\ m^3 \qquad V_m = \frac{2.0737\ lb}{62.274\ lb/ft^3} = 0.0333\ ft^3$$

Table B1 Unit Mass of Water 15°C to 30°C

°C	(°F)	kg/m^3	(lb/ft^3)	°C	(°F)	kg/m^3	(lb/ft^3)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Report

- Mold ID
- Date Standardized
- Temperature of the water
- Volume, V_m, of the mold

Performance Exam Checklist

FOP for AASHTO T 99
MOISTURE-DENSITY RELATION OF SOILS

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	If damp, sample dried in air or drying apparatus, not exceeding 60°C (140°F)?		
2.	Sample broken up and an adequate amount sieved over the appropriate sieve (4.75 mm/No. 4 or 19.0 mm/ ¾ in) to determine oversize (coarse particle) percentage?		
3.	Sample passing the sieve has appropriate mass?		
4.	If soil is plastic (clay types):		
	a. Multiple samples mixed with water varying moisture content by 1 to 2 percent, bracketing the optimum moisture content?		
	b. Samples placed in covered containers and allowed to stand for at least 12 hours?		
5.	Sample determined to be 4 to 8 percent below expected optimum moisture content?		
6.	Mold placed on rigid and stable foundation?		
7.	Layer of soil (approximately one third compacted depth) placed in mold with collar attached, loose material lightly tamped?		
8.	Soil compacted with appropriate number of blows (25 or 56)?		
9.	Material adhering to the inside of the mold trimmed?		
10.	Layer of soil (approximately two thirds compacted depth) placed in mold with collar attached, loose material lightly tamped?		
11.	Soil compacted with appropriate number of blows (25 or 56)?		
12.	Material adhering to the inside of the mold trimmed?		
13.	Mold filled with soil such that compacted soil will be above the mold, loose material lightly tamped?		
14.	Soil compacted with appropriate number of blows (25 or 56)?		
15.	Collar removed without shearing off sample?		
16.	Approximately 6 mm (¼ in) of compacted material above the top of the mold (without the collar)?		
17.	Soil trimmed to top of mold with the beveled side of the straightedge?		
18.	Mass of mold and contents determined to appropriate precision?		
19.	Wet density calculated from the wet mass?		

Procedure Element	Trial 1	Trial 2
20. Soil removed from mold using a sample extruder if needed?	_____	_____
21. Soil sliced vertically through center (non-granular material)?	_____	_____
22. Moisture sample removed ensuring all layers are represented?	_____	_____
23. Moist mass determined immediately to 0.1 g?	_____	_____
24. Moisture sample mass of correct size?	_____	_____
25. Sample dried and water content determined according to the FOP for T 255/T 265?	_____	_____
26. Remainder of material from mold broken up until it will pass through the sieve, as judged by eye, and added to remainder of original test sample?	_____	_____
27. Water added to increase moisture content of the remaining sample in 1 to 2 percent increments?	_____	_____
28. Steps 2 through 26 repeated for each increment of water added?	_____	_____
29. If material is degradable: Multiple samples mixed with water varying moisture content by 1 to 2 percent, bracketing the optimum moisture content?	_____	_____
30. Process continued until wet density either decreases or stabilizes?	_____	_____
31. Moisture content and dry density calculated for each sample?	_____	_____
32. Dry density plotted on vertical axis, moisture content plotted on horizontal axis, and points connected with a smooth curve?	_____	_____
33. Moisture content at peak of curve recorded as optimum water content and recorded to nearest 0.1 percent?	_____	_____
34. Dry density at optimum moisture content reported as maximum density to nearest 1 kg/m^3 (0.1 lb/ft^3)?	_____	_____
35. Corrected for coarse particles if applicable?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

Washington State
Department of Transportation

WSDOT Test Method T 113

Method of Test for Determination of Degradation Value

1. Scope

a. This method covers the procedure for determining the susceptibility of an aggregate to degrade into plastic fines when abraded in the presence of water.

2. Apparatus

a. Balance – 5000 g capacity, sensitive to 0.1 g

b. Degradation Shaker – Tyler Portable Sieve Shaker CL-305 modified to provide 300 ± 5 oscillations per minute with a 1¾ in (44.5 mm) throw on the cam or a shaker with equivalent movement

c. Washing Canister – Shall be either Plastic or Steel meeting the following:
   - Plastic Canister – 7½ in ± ¼ in (190.5 mm ± 6.3 mm) diameter x 6 ± ½ in (152.4 mm ± 12.5 mm) high. Sidewalls of the plastic canister should meet the bottom at 90 degrees with little or no fillet
   - Steel Canister: Meeting the requirements of AASHTO T 210 (ASTM D 3744)

d. Sand equivalent graduated cylinder and rubber stopper

e. Sand equivalent stock solution

f. Sieves – ½ in (12.5 mm), ⅜ in (9.5 mm), ¼ in (6.3 mm), U.S. No. 10 (2.00 mm) and U.S. No. 200 (0.075 mm) sieves conforming to the requirement of ASTM E11

g. Graduates – 500 ml tall form, 100 ml

h. Interval timer

i. Funnel – Large enough to securely hold the nest of sieves and a mouth that fits into the 500 ml graduate

j. Sieve Shaker – Shaker that meets the requirements of AASHTO T-27

k. Oven – Sufficient size, capable of maintaining a uniform temperature of 230 ± 9°F (110 ± 5°C)

l. Sprayer – Water sprayer, device to produce a low volume stream of water. i.e. 500 ml wash bottle

m. Suitable Containers – Pans for washing and drying

3. Sample Preparation

a. If testing pit run material: dry at 230 ± 9°F (110 ± 5°C) to allow for clean separation from the fine material. Separate the material over the ½ in (12.5 mm) sieve and discard that finer than the ½ in (12.5 mm) and proceed to step 3d.

b. If testing crushed and stockpiled material: dry at 230 ± 9°F (110 ± 5°C) to allow for clean separation from the fine material and proceed to step 3e.

c. If testing quarry material: if necessary, separate the material over the ½ in (12.5 mm) sieve and discard that finer than the ½ in (12.5 mm).

d. Crush the material to be tested to pass the ½ in sieve (12.5 mm).

e. Split out an adequate amount of crushed material (approximately 5000 grams).

f. Sieve the approx. 5000 g split over a ½ in (12.5 mm), ⅜ in (9.5 mm), ¼ in (6.3 mm), and U.S. No. 10 (2.00 mm) screens in a sieve shaker. Steps should be taken to avoid overloading the sieves. Use shaking time determined to meet the requirement of AASHTO T 27 Section 8.2 for the shaker being used.

g. By splitting or quartering, obtain from the sieved material approximately 550 g of ½ -⅜ (12.5-9.5 mm), 550 g of ⅜-¼ (9.5-6.3 mm), and 1100 g of ¼ -#10 (6.3-2.00 mm).

h. Combine the ½-⅜ (12.5-9.5 mm) with the ⅜-¼ (9.5-6.3 mm).

i. Wash the ½-¼ (12.5-6.3 mm) and ¼-#10 (6.3-2.00 mm) portions separately by placing in a container and adding sufficient water to cover it. Agitate vigorously to ensure complete separation of the material finer than No. 200 (0.075 mm) from coarser particles and bring the fine material into suspension above the coarser material.

   Note 1: The use of a mechanical aggregate washer is NOT permitted in the washing procedure.

   Immediately pour the wash water containing the suspended and dissolved solids over a U.S. No. 10 (2.00 mm) sieve, being careful not to pour out the coarser particles. Add a second charge of water to the portion remaining in the container, agitate, and repeat the operation until the wash water is reasonably clear. Return all material retained on the sieve to the container. Repeat the process for the second portion.

j. Place washed portions into suitable containers and dry to a constant weight at 230 ± 9°F (110 ± 5°C).

k. Allow to cool to room temperature.

l. From the washed and dried material, prepare two - 1000 g test samples as follows:

   1. Quarter or split the ½-¼ (12.5-6.3 mm) to achieve two 500 ± 1 g portions; hand selection of up to 50 g to attain the 500 ± 1 grams is acceptable.

   2. Split the ¼-#10 (6.3-2.00 mm) to achieve two 500 ± 1 g portions; hand selection of up to 50 g to attain the 500 ± 1 grams is acceptable.

   3. Combine each of the ½-¼ (12.5-6.3 mm) portions with one of the ¼-#10 (6.3-2.00 mm) portions to create two - 1000 ± 2 g test samples consisting of ½-#10 (12.5-2.00 mm) material.

4. Procedure

a. Place one test sample in the washing canister, add 200 ± 5 ml of water, cover tightly and place in degradation shaker.

b. Immediately agitate the material for 20 minutes.

c. At the end of the shaking time, empty the washing canister into nested U.S. No. 10 (2.00 mm) and U.S. No. 200 (0.075 mm) sieves fitted into the funnel placed over a 500 ml graduate to catch all wash water.

Note 2: IMPORTANT! It is critical to the test result that material finer than the U.S. No. 200 (0.075 m) is washed off the larger particles into the 500 ml graduate. This process has to be completed using approximately 300 ml of water such that the total amount water used in the test is only 500 ml. (200 ml with shaking, plus the 20-50 ml used for rinsing the canister and lid, plus that remaining to wash the fines off the particles) The process should be slow and meticulous, utilizing a high pressure, low volume spray of water. Use of a 500 ml squeeze type wash bottle has been found to work well for this process. The washing process should take 5 - 10 minutes.

d. Rinse material finer than U.S. No. 200 (0.075 mm) off the lid into the washing canister and then from the washing canister into the nested sieves using minimal amount of water. (20-50 ml).

e. Shake the nested sieves to spread the sample evenly. (Note 3).

f. Wash the sample using only 20-50 ml. of water. (Note 2).

g. Shake the nested sieves to release any water and 200- that may be sitting on the U.S. No. 200 (0.075 mm) sieve. (Note 3).

h. Raise the funnel and tilt slightly, insure that the mouth of the funnel remains over the 500 ml graduate and catches all of the wash water, to allow the sieves to drain easier. Observe the liquid for clarity.

i. Lower the funnel back into the 500 ml graduate.

j. Repeat steps 4e. through 4i. until the liquid in the graduate reaches the 500 ml mark. Do not allow drainage above the 500 ml mark.

Note 3: Shaking should be vigorous enough to move the aggregate but with care such that no spillage of wash water or loss of aggregate occurs.

k. Measure 7 ± 1 ml of sand equivalent stock solution and pour into a sand equivalent cylinder.

l. Bring all solids in the 500 ml graduate into suspension by capping the top with the palm of the hand and turning it completely upside down and back as rapidly as possible, allowing the air bubble to traverse from end to end. Repeat this cycle 10 times, shaking the graduate on the first inversion to release sediment on the bottom.

m. After the tenth cycle, immediately pour the agitated liquid into the sand equivalent cylinder to the 15 ± 0.1 inch. (381 ± 2.5 mm) mark before any settling occurs. (Note 4.)

Note 4: The pour should be immediate and continuous without pause. Allowing the agitated liquid to flow back into the 500 ml graduate and then resuming the pour will allow settling and yield inconsistent results.

n. Insert rubber stopper into the sand equivalent cylinder and mix the contents by turning the cylinder completely upside down and back as rapidly as possible, allowing the bubble to traverse from end to end. Repeat this cycle 20 times.

o. Gently place the sand equivalent cylinder on the table, remove stopper, and immediately start timer. Allow to stand undisturbed for 20 minutes. After 20 minutes read and record the height of the sediment column to the nearest 0.1 in (2.5 mm).

p. Repeat steps 4a. thru 4o. for the second test sample.

5. Calculations

a. Calculate the degradation factors for the two test samples using the following formula:

$$D_1 = \frac{(15\text{-}H_1)}{(15 + 1.75H_1) \times 100} \qquad D_2 = \frac{(15\text{-}H_2)}{(15 + 1.75H_2) \times 100}$$

Note: Table 1 may be used to determine the values of D1and D2 by finding the corresponding H value.

b. Average the two degradation factors if they meet the requirements of Section 6, Repeatability:

$$D = \frac{(D_1+D_2)}{2}$$

Where:

D	=	Degradation Factor
D_1	=	Degradation Factor for the first test sample
D_2	=	Degradation Factor for the second test sample
H_1	=	Height of Sediment in first sand equivalent cylinder
H_2	=	Height of Sediment in second sand equivalent cylinder

c. Report the Degradation Factor (D) to the nearest whole number.

d. Degradation Factors range from 0 to 100, with higher values representing the best materials.

6. Repeatability

a. The two test samples, D_1 & D_2 must agree within 6 points.

b. Repeat the entire test if variation between the test samples exceeds 6 points, see following calculation:

Absolute Value $(D_1\text{-}D_2) > 6$

$$D = \frac{(15\text{-}H)}{(15 + 1.75H)} \times 100$$

H	D	H	D	H	D	H	D	H	D
0.0	100	3.1	58	6.1	35	9.1	19	12.1	8
0.1	98	3.2	57	6.2	34	9.2	19	12.2	8
0.2	96	3.3	56	6.3	33	9.3	18	12.3	7
0.3	95	3.4	55	6.4	33	9.4	18	12.4	7
0.4	93	3.5	54	6.5	32	9.5	17	12.5	7
0.5	91	3.6	54	6.6	32	9.6	17	12.6	6
0.6	90	3.7	53	6.7	31	9.7	17	12.7	6
0.7	88	3.8	52	6.8	30	9.8	16	12.8	6
0.8	87	3.9	51	6.9	30	9.9	16	12.9	6
0.9	85	4.0	50	7.0	29	10.0	15	13.0	5
1.0	84								
1.1	82	4.1	49	7.1	29	10.1	15	13.1	5
1.2	81	4.2	48	7.2	28	10.2	15	13.2	5
1.3	79	4.3	48	7.3	28	10.3	14	13.3	4
1.4	78	4.4	47	7.4	27	10.4	14	13.4	4
1.5	77	4.5	46	7.5	27	10.5	13	13.5	4
1.6	75	4.6	45	7.6	26	10.6	13	13.6	4
1.7	74	4.7	44	7.7	26	10.7	13	13.7	3
1.8	73	4.8	44	7.8	25	10.8	12	13.8	3
1.9	71	4.9	43	7.9	25	10.9	12	13.9	3
2.0	70	5.0	42	8.0	24	11.0	12	14.0	3
2.1	69	5.1	41	8.1	24	11.1	11	14.1	2
2.2	68	5.2	41	8.2	23	11.2	11	14.2	2
2.3	67	5.3	40	8.3	23	11.3	11	14.3	2
2.4	66	5.4	39	8.4	22	11.4	10	14.4	1
2.5	65	5.5	39	8.5	22	11.5	10	14.5	1
2.6	63	5.6	38	8.6	21	11.6	10	14.6	1
2.7	62	5.7	37	8.7	21	11.7	9	14.7	1
2.8	61	5.8	37	8.8	20	11.8	9	14.8	0
2.9	60	5.9	36	8.9	20	11.9	9	14.9	0
3.0	59	6.0	35	9.0	20	12.0	8	15.0	0

Degradation Value "D"
Table 1

Performance Exam Checklist

WSDOT TM 113
Method of Test for Determination of Degradation Value

Participant Name _____ Exam Date _____

Procedure Element	Yes	No
Equipment		
1. Balance - 5000g capacity, sensitive to 0.1g- Calibrated?	☐	☐
2. Degradation Shaker – 1¾" throw, 300 ± 5 oscillations per minute – Verified?	☐	☐
3. Canister – plastic, 7½ in diameter x 6 in high, walls meet floor at 90 deg with min fillet, or steel meeting AASHTO T210, or ASTM D 3744?	☐	☐
4. Sand Equivalent Cylinder & Rubber Stopper?	☐	☐
5. Sand Equivalent Stock Solution?	☐	☐
6. Sieves – ½, ⅜, ¼, No. 10, No. 200 – Verified?	☐	☐
7. Graduates – 500 ml tall form & 100 ml?	☐	☐
8. Interval Timer – Verified?	☐	☐
9. Funnel – Large enough to hold the sieves with a mouth that fits in the 500 ml graduate?	☐	☐
10. Sieve Shaker(s) – Verified?	☐	☐
11. Oven – verified at 230 ± 9°F.- Calibrated?	☐	☐
12. Sprayer – produces a low volume stream of water?	☐	☐
13. Containers – suitable for drying and washing?	☐	☐
Procedure		
1. a. Pit Run – Dried and separated over the ½ in, ½-discarded?	☐	☐
b. Processed material – Dried?	☐	☐
c. Quarry material – prepared for crushing?	☐	☐
2. Material crushed to pass the ½"?	☐	☐
3. Split out approx. 5000g?	☐	☐
4. Separate the material over the ½, ⅜, ¼, and No. 10?	☐	☐
5. Split or quarter approx. 550g ½-⅜, 550g ⅜-¼, & 1100g ¼-No. 10?	☐	☐
6. Combine the ½-⅜ with the ⅜-¼?	☐	☐
7. Hand wash the ½-¼ and ¼-No. 10 separately?	☐	☐
8. Dry the portions in suitable containers at 230 ± 9 to a constant weight?	☐	☐
9. Split of quarter the two sizes into two 500 ± 1g portions, hand selection ok to 50g?	☐	☐
10. Combine to create two 1000 ± 2g, ½ - No. 10 test samples?	☐	☐
11. Place one sample into a canister, cover with 200 ± 5 ml water, cover & shake for 20 min?	☐	☐

Procedure Element	Yes	No
12. Empty canister into the nested No. 10 & No. 200 fitted in the funnel over the 500 ml grad.?	☐	☐
13. Rinse the lid into the canister and then the canister into the nested sieves?	☐	☐
14. Shake the sieves to spread the sample?	☐	☐
15. Wash using only 20-50 ml.?	☐	☐
16. Shake the sieves to release trapped water and then lift observing liquid for clarity?	☐	☐
17. Repeat 14-16 until water reaches the 500 ml mark – water not to exceed 500 ml?	☐	☐
18. No loss of fines or liquid during the washing process?	☐	☐
19. Place 7 ± 1 ml of SE Stock Solution in a SE Graduated Cylinder?	☐	☐
20. Turn capped 500 ml upside down & back allowing bubble to traverse 10 cycles?	☐	☐
21. Immediately pour into a SE Cylinder to the 15 ± 0.1 mark – no settling allowed?	☐	☐
22. Rubber stopper inserted and SE Cylinder turned upside down & back 20 cycles?	☐	☐
23. Place gently, remove stopper, start timer, allow to sit undisturbed for 20 min?	☐	☐
24. Record height of column to nearest 0.1 in?	☐	☐
25. Repeat for second sample?	☐	☐
26. Calculations performed correctly?	☐	☐
27. Second sample must be within 6 points?	☐	☐

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

Signature of Examiner _____

Comments:

FOP for AASHTO T 119

Slump of Hydraulic Cement Concrete

Scope

This procedure provides instructions for determining the slump of hydraulic cement concrete in accordance with AASHTO T 119-13. It is not applicable to non-plastic and non-cohesive concrete.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Mold: A metal frustum of a cone provided with foot pieces and handles. The mold must be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections such as protruding rivets. The mold shall be free from dents. A mold that clamps to a rigid nonabsorbent base plate is acceptable provided the clamping arrangement is such that it can be fully released without movement of the mold.
- Mold: If other than metal, it must conform to AASHTO T 119, Sections 5.1.2.1 and 5.1.2.2.
- Tamping rod: 16 mm (⅝ in) diameter and 400 mm (16 in) to 600 mm (24 in) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Tape measure or ruler with at least 5 mm or ⅛ in graduations
- Base: Flat, rigid, non-absorbent moistened surface on which to set the slump mold

Procedure

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If the concrete mixture contains aggregate retained on the 37.5 mm (1½ in) sieve, the aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

   Note 1: Testing shall begin within five minutes of obtaining the sample.

2. Dampen the inside of the mold and place it on a dampened, rigid, nonabsorbent surface that is level and firm.
3. Stand on both foot pieces in order to hold the mold firmly in place.
4. Use the scoop to fill the mold ⅓ full by volume, to a depth of approximately 67 mm (2⅝ in) by depth.
5. 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.
6. For this bottom layer, incline the rod slightly and make approximately half the strokes near the perimeter, and then progress with vertical strokes, spiraling toward the center.

7. Use the scoop to fill the mold ⅔ full by volume, to a depth of approximately 155 mm (6⅛ in) by depth.
8. Consolidate this layer with 25 strokes of the tamping rod, penetrate approximately 25 mm (1 in) into the bottom layer. Distribute the strokes evenly.
9. Use the scoop to fill the mold to overflowing.
10. Consolidate this layer with 25 strokes of the tamping rod, penetrate approximately 25 mm (1 in) into the second layer. Distribute the strokes evenly. If the concrete falls below the top of the mold, stop, add more concrete, and continue rodding for a total of 25 strokes. Keep an excess of concrete above the top of the mold at all times. Distribute strokes evenly as before.
11. Strike off the top surface of concrete with a screeding and rolling motion of the tamping rod.
12. Clean overflow concrete away from the base of the mold.
13. Remove the mold from the concrete by raising it carefully in a vertical direction. Raise the mold 300 mm (12 in) in 5 ± 2 seconds by a steady upward lift with no lateral or torsional (twisting) motion being imparted to the concrete.
14. The entire operation from the start of the filling through removal of the mold shall be carried out without interruption and shall be completed within an elapsed time of 2½ minutes. Immediately measure the slump.
15. Invert the slump mold and set it next to the specimen.
16. Lay the tamping rod across the mold so that it is over the test specimen.
17. Measure the distance between the bottom of the rod and the displaced original center of the top of the specimen to the nearest 5 mm (¼ in).

    Note 2: If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and make a new test on another portion of the sample. 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 the plasticity and cohesiveness necessary for the slump test to be applicable.
18. Discard the tested sample.

Report

- Results on forms approved by the agency
- Sample ID
- Slump to the nearest 5 mm (¼ in).

Performance Exam Checklist

FOP for AASHTO T 119
Slump of Hydraulic Cement Concrete

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
First layer		
1. Mold and floor or base plate dampened?	_____	_____
2. Mold held firmly against the base by standing on the two foot pieces? Mold not allowed to move in any way during filling?	_____	_____
3. Representative sample scooped into the mold, moving a scoop around the perimeter of the mold to evenly distribute the concrete as discharged?	_____	_____
4. Mold approximately one third (by volume), 67 mm (2⅝ in) deep?	_____	_____
5. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	_____	_____
Second layer		
6. Representative samples scooped into the mold, moving a scoop around the perimeter of the mold to evenly distribute the concrete as discharged?	_____	_____
7. Mold filled approximately two thirds (by volume), 155 mm (6⅛ in), deep?	_____	_____
8. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes, penetrate approximately 25 mm (1 in) into the bottom layer?	_____	_____
Third layer		
9. Representative sample scooped into the mold, moving a scoop around the perimeter of the mold to evenly distribute the concrete as discharged??	_____	_____
10. Mold filled to just over the top of the mold?	_____	_____
11. Layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes, penetrate approximately 25 mm (1 in) into the second layer?	_____	_____
12. Excess concrete kept above the mold at all times while rodding?	_____	_____
13. Concrete struck off level with top of mold using tamping rod?	_____	_____
14. Concrete removed from around the outside bottom of the mold?	_____	_____
15. Mold lifted upward 300 mm (12 in) in one smooth motion, without a lateral or twisting motion of the mold, in 5 ± 2 seconds?	_____	_____
16. Test performed from start of filling through removal of the mold within 2½ minutes?	_____	_____
17. Slump immediately measured to the nearest 5 mm (¼ in) from the top of the mold to the displaced original center of the top surface of the specimen?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

This checklist is derived, in part, from copyrighted material printed in ACI CP-1, published by the American Concrete Institute.

Comments:

FOP for AASHTO T 121

Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

Scope

This procedure covers the determination of density, or unit weight, of freshly mixed concrete in accordance with AASHTO T 121-17. It also provides formulas for calculating the volume of concrete produced from a mixture of known quantities of component materials, and provides a method for calculating cement content and cementitious material content – the mass of cement or cementitious material per unit volume of concrete. A procedure for calculating water/cement ratio is also covered.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Measure: May be the bowl portion of the air meter used for determining air content under the FOP for AASHTO T 152. Otherwise, it shall be a metal cylindrical container meeting the requirements of AASHTO T 121. The capacity and dimensions of the measure shall conform to those specified in Table 1.
- Balance or scale: Accurate to within 45 g (0.1 lb) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- Tamping rod: 16 mm (⅝ in) diameter and 400 mm (16 in) to 600 mm (24 in) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Vibrator: 7000 vibrations per minute, 19 to 38 mm (¾ to 1½ in) in diameter, and the length of the shaft shall be at least 610 mm (24 in).
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Strike-off plate: A flat rectangular metal plate at least 6 mm (¼ in) thick or a glass or acrylic plate at least 12 mm (½ in) thick, with a length and width at least 50 mm (2 in) 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 1.5 mm (1/16 in).
- Mallet: With a rubber or rawhide head having a mass of 0.57 ± 0.23 kg (1.25 ± 0.5 lb) for use with measures of 0.014 m^3 (½ ft^3) or less, or having a mass of 1.02 ± 0.23 kg (2.25 ± 0.5 lb) for use with measures of 0.028 m^3 (1 ft^3).

Table 1 Dimensions of Measures*

Capacity m^3 (ft^3)	Inside Diameter mm (in)	Inside Height mm (in)	Minimum Thicknesses mm (in)		Nominal Maximum Size of Coarse Aggregate*** mm (in)
			Bottom	Wall	
0.0071 (¼)**	203 ± 2.54 (8.0 ± 0.1)	213 ± 2.54 (8.4 ± 0.1)	5.1 (0.20)	3.0 (0.12)	25 (1)
0.0142 (½)	254 ± 2.54 (10.0 ± 0.1)	279 ± 2.54 (11.0 ± 0.1)	5.1 (0.20)	3.0 (0.12)	50 (2)
0.0283 (1)	356 ± 2.54 (14.0 ± 0.1)	284 ± 2.54 (11.2 ± 0.1)	5.1 (0.20)	3.0 (0.12)	76 (3)

*__Note:__ The indicated size of measure shall be for aggregates of nominal maximum size equal to or smaller than that listed.

** Measure may be the base of the air meter used in the FOP for AASHTO T 152.

*** Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Procedure Selection

There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 75 mm (3 in), consolidation is by rodding. When the slump is 25 to 75 mm (1 to 3 in), 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 concrete with slump less than 25 mm (1 in), consolidate the sample by internal vibration. Do not consolidate self-consolidating concrete (SCC).

When using measures greater than 0.0142 m^3 (½ ft^3) see AASHTO T 121.

Procedure – Rodding

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. Testing may be performed in conjunction with the FOP for AASHTO T 152. When doing so, this FOP should be performed prior to the FOP for AASHTO T 152.

   Note 1: If the two tests are being performed using the same sample, this test shall begin within five minutes of obtaining the sample.

2. Determine the mass of the dry empty measure.
3. Dampen the inside of the measure.
4. Use the scoop to fill the measure approximately ⅓ full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
5. 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.
6. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.

7. Add the second layer, filling the measure about ⅔ full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
8. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in) into the bottom layer.
9. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
10. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
11. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in) into the second layer.
12. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.

    Note 2: The measure should be slightly over full, about 3 mm (⅛ in) above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure 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.
13. Strike off by pressing the strike-off plate flat against the top surface, covering approximately ⅔ of the measure. Withdraw the strike-off plate with a sawing motion to finish the ⅔ originally covered. Cover the original ⅔ again with the plate; finishing the remaining ⅓ with a sawing motion (do not lift the plate; continue the sawing motion until the plate has cleared the surface of the measure). Final finishing may be accomplished with several strokes with the inclined edge of the strike-off plate. The surface should be smooth and free of voids.
14. Clean off all excess concrete from the exterior of the measure including the rim.
15. Determine and record the mass of the measure and the concrete.
16. If the air content of the concrete is to be determined, proceed to Rodding Procedure Step 13 of the FOP for AASHTO T 152.

Procedure - Internal Vibration

1. Perform Steps 1 through 3 of the rodding procedure.
2. Use the scoop to fill the measure approximately ½ full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Insert the vibrator at three different points in each layer. Do not let the vibrator touch the bottom or side of the measure.

   Note 3: Remove the vibrator slowly, so that no air pockets are left in the material.

   Note 4: 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.
4. Slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
5. Insert the vibrator as in Step 3. Do not let the vibrator touch the side of the measure, but do penetrate the first layer approximately 25 mm (1 in).
6. Return to Step 13 of the rodding procedure and continue.

Procedure – Self Consolidating Concrete

1. Perform Steps 1 through 3 of the rodding procedure.
2. Use the scoop to slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Complete steps 13 thru 16 of the rodding procedure.

Calculations

Density

$$D = \frac{M_m}{V_m}$$

Where:

D = density of the concrete mix
M_m = mass of concrete in measure
V_m = volume of measure (Annex A)

Yield m^3

$$Y_{m^3} = \frac{W}{D}$$

Where:

$Y_m{}^3$ = yield (m^3 of the batch of concrete)
W = total mass of the batch of concrete

Yield yd^3

$$Y_{ft^3} = \frac{W}{D} \qquad Y_{yd^3} = \frac{Y_{ft^3}}{27ft^3/yd^3}$$

Where:

Yft^3 = yield (ft^3 of the batch of concrete)
Yyd^3 = yield (yd^3 of the batch of concrete)
W = total mass of the batch of concrete
D = density of the concrete mix

Note 5: The total mass, W, includes the masses of the cement, water, and aggregates in the concrete.

Cement Content

$$N = \frac{N_t}{Y}$$

Where:

N = actual cementitous material content per Ym^3 or Yyd^3
Nt = mass of cementitious material in the batch
Y = $Y_m{}^3$ or $Y_{yd}{}^3$

Note 6: Specifications may require Portland Cement content and supplementary cementitious materials content.

Water Content

The mass of water in a batch of concrete is the sum of:

- water added at batch plant
- water added in transit
- water added at jobsite
- free water on coarse aggregate*
- free water on fine aggregate*
- liquid admixtures (if required by the agency)

This information is obtained from concrete batch tickets collected from the driver. Use the Table 2 to convert liquid measures.

Table 2 Liquid Conversion Factors

To Convert From	To	Multiply By
Liters, L	Kilograms, kg	1.0
Gallons, gal	Kilograms, kg	3.785
Gallons, gal	Pounds, lb	8.34
Milliliters, mL	Kilograms, kg	0.001
Ounces, oz	Milliliters, mL	28.4
Ounces, oz	Kilograms, kg	0.0284
Ounces, oz	Pounds, lb	0.0625
Pounds, lb	Kilograms, kg	0.4536

***Mass of free water on aggregate**

$$Free\ Water\ Mass = CA\ or\ FC\ Aggregate - \frac{CA\ or\ FC\ Aggregate}{1 + (Free\ Water\ Percentage/100)}$$

Where:

Free Water Mass = on coarse or fine aggregate
FC or CA Aggregate = mass of coarse or fine aggregate
Free Water Percentage = percent of moisture of coarse or fine aggregate

Water/Cement Ratio

$$\frac{Water\ Content}{C}$$

Where:

Water Content = sum mass of water in the batch
C = sum mass of cementitious materials

Example

Mass of concrete in measure (Mm)	16.290 kg (36.06 lb)
Volume of measure (Vm)	0.007079 m^3 (0.2494 ft^3)
From batch ticket:	
Yards batched	4 yd^3
Cement	950 kg (2094 lb)
Fly ash	180 kg (397 lb)
Coarse aggregate	3313 kg (7305 lb)
Fine aggregate	2339 kg (5156 lb)
Water added at plant	295 L (78 gal)
Other	
Water added in transit	0
Water added at jobsite	38 L (10 gal)
Total mass of the batch of concrete (W)	7115 kg (15,686 lb)
Moisture content of coarse aggregate	1.7 percent
Moisture content of coarse aggregate	5.9 percent

Density

$$D = \frac{M_m}{V_m}$$

$$D = \frac{16.920\ kg}{0.007079\ m^3} = 2390\ \ kg/m^3 \quad D = \frac{36.06\ lb}{0.2494\ ft^3} = 144.6\ \ lb/ft^3$$

Given:

Mm = 16.920 kg (36.06 lb)
Vm = 0.007079 m^3 (0.2494 ft^3) (Annex A)

Yield m^3

$$Y_{m^3} = \frac{W}{D}$$

$$Y_{m^3} = \frac{7115\ kg}{2390\ kg/m^3} = 2.98\ m^3$$

Given:

Total mass of the batch of concrete (W), kg = 7115 kg

Yield yd³

$$Y_{ft^3} = \frac{W}{D} \qquad Y_{yd^3} = \frac{Y_{ft^3}}{27 ft^3/yd^3}$$

$$Y_{ft^3} = \frac{15{,}686\ lb}{144.6\ lb/ft^3} = 108.48\ ft^3 \qquad Y_{yd^3} = \frac{108.48\ ft^3}{27\ ft^3/yd^3} = 4.02\ yd^3$$

Given:

Total mass of the batch of concrete (W), lb = 15,686 lb

Cement Content

$$N = \frac{N_t}{Y}$$

$$N = \frac{950\ kg + 180\ kg}{2.98\ m^3} = 379\ kg/m^3 \quad N = \frac{2094\ lb + 397\ lb}{4.02\ yd^3} = 620\ lb/yd^3$$

Given:

N_t (cement) = 950 kg (2094 lb)
N_t (flyash) = 180 kg (397 lb)
Y = Ym^3 or Yyd^3

Note 6: Specifications may require Portland Cement content and supplementary cementitious materials content.

Free water

$$Free\ Water\ Mass = CA\ or\ FC\ Aggregate - \frac{CA\ or\ FC\ Aggregate}{1 + (Free\ Water\ Percentage/100)}$$

$$CA\ Free\ Water = 3313\ kg - \frac{3313\ kg}{1 + (1.7/100)} = 55\ kg$$

$$CA\ Free\ Water = 7305\ lb - \frac{7305\ lb}{1 + (1.7/100)} = 122\ lb$$

$$FA\ Free\ Water = 2339\ kg - \frac{2339\ kg}{1 + (5.9/100)} = 130\ kg$$

$$FA\ Free\ Water = 5156\ lb - \frac{5156\ lb}{1 + (5.9/100)} = 287\ lb$$

Given:

CA aggregate = 3313 kg (7305 lb)
FC aggregate = 2339 kg (5156 lb)
CA moisture content = 1.7 percent
FC moisture content = 5.9 percent

Water Content

Sum of all water in the mix.

$$Water\ Content = [(78\ gal + 10\ gal) * 3.785\ kg/gal] + 55\ kg + 130\ kg = 518\ kg$$

$$Water\ Content\ = [(78\ gal + 10\ gal) * 8.34\ lb/gal] + 130\ lb + 287\ lb = 1151\ lb$$

Given:

Water added at plant = 295 L (78 gal)
Water added at the jobsite = 38 L (10 gal)

Water/Cement Ratio

$$W/C = \frac{518\ kg}{950\ kg + 180\ kg} = 0.458 \quad W/C\ = \frac{1151\ lb}{2094\ lb + 397\ lb} = 0.462$$

Report 0.46

Report

- Results on forms approved by the agency
- Sample ID
- Density (unit weight) to 1 kg/m^3 (0.1 lb/ft^3)
- Yield to 0.01 m^3 (0.01 yd^3)
- Cement content to 1 kg/m^3 (1 lb/yd^3)
- Cementitious material content to 1 kg/m^3 (1 lb/yd^3)
- Water/Cement ratio to 0.01

ANNEX A

Standardization of Measure

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedures as described herein will produce inaccurate or unreliable test results.

Apparatus

- Listed in the FOP for AASHTO T 121
  - Measure
  - Balance or scale
  - Strike-off plate
- Thermometer: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)

Procedure

1. Determine the mass of the dry measure and strike-off plate.
2. Fill the measure with water at a temperature between 16°C and 29°C (60°F and 85°F) and cover with the strike-off plate in such a way as to eliminate bubbles and excess water.
3. Wipe the outside of the measure and cover plate dry, being careful not to lose any water from the measure.
4. Determine the mass of the measure, strike-off plate, and water in the measure.
5. Determine the mass of the water in the measure by subtracting the mass in Step 1 from the mass in Step 4.
6. Measure the temperature of the water and determine its density from Table A1, interpolating as necessary.
7. Calculate the volume of the measure, V_m, by dividing the mass of the water in the measure by the density of the water at the measured temperature.

Calculations

$$V_m = \frac{M}{D}$$

Where:

V_m = volume of the mold
M = mass of water in the mold
D = density of water at the measured temperature

Example

Mass of water in Measure = 7.062 kg (15.53 lb)

Density of water at 23°C (73.4°F) = 997.54 kg/m^3 (62.274 lb/ft^3)

Table A1 Unit Mass of Water 15°C to 30°C

°C	(°F)	kg/m^3	(lb/ft^3)	°C	(°F)	kg/m^3	(lb/ft^3)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Report

- Measure ID
- Date Standardized
- Temperature of the water
- Volume, V_m, of the measure

Performance Exam Checklist

FOP for AASHTO T 121
Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Mass and volume of empty measure determined?		
First Layer		
2. Dampened measure filled approximately one third full, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?		
3. Layer rodded throughout its depth 25 times, without forcibly striking the bottom of the measure, with hemispherical end of rod, uniformly distributing strokes?		
4. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding?		
Second layer		
5. Measure filled approximately two thirds full, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?		
6. Layer rodded throughout its depth, just penetrating the previous layer (approximately 25 mm (1 in) 25 times with hemispherical end of rod, uniformly distributing strokes?		
7. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding?		
Third layer		
8. Measure slightly overfilled, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?		
9. Layer rodded throughout its depth, just penetrating the previous layer (approximately 25 mm (1 in) 25 times with hemispherical end of rod, uniformly distributing strokes?		
10. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding each layer?		
11. Any excess concrete removed using a trowel or a scoop, or small quantity of concrete added to correct a deficiency, after consolidation of final layer?		
12. Strike-off plate placed flat on the measure covering approximately ⅔ of the surface, then sawing action used to withdraw the strike-off plate across the previously covered surface?		
13. Strike-off plate placed flat on the measure covering approximately ⅔ of the surface, then sawing action used to advance the plate across the entire measure surface?		
14. Strike off completed using the inclined edge of the plate creating a smooth surface?		

Procedure Element	Trial 1	Trial 2
15. All excess concrete cleaned off and mass of full measure determined?	_____	_____
16. Net mass calculated?	_____	_____
17. Density calculated correctly?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

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Comments:

Washington State
Department of Transportation

WSDOT Test Method T 123

Method of Test for Bark Mulch

1. Scope

a. This method covers a procedure for determining the sieve analysis and material finer than No. 4 sieve using a loose volume bucket.

2. Equipment

a. A mechanical sieve shaker.

b. Sieves – Sieves conforming to the requirements of ASTM E11. Breaker sieves may be used.

c. Volume Bucket – A container calibrated in 1 gal. increments from 1 to 5 gal. A 5-gal. bucket may be used when calibrated as follows:

On a level surface calibrate the container by gradually filling it with water in 1 gal. increments. Mark the inner wall of the container after the addition of each gallon

3. Procedure

a. Air dry (140°F max) the sample for 15 hours, ± 4 hours.

b. Reduce the sample to testing size per the FOP for AASHTO R 76.

c. Place the sample in the volume bucket and record the volume as the total volume.

d. Shake the sample over the 2 in and No. 4 sieves. Using breaker sieves inserted between the two specified sieves so the No. 4 sieve will not be **overloaded**. Use caution to avoid over sieving as the wood material breaks down.

e. The material retained on the 2 in sieve is measured in the volume bucket and recorded.

f. The material on the breaker sieves is added to the material retained on the No. 4 sieve and the volume measured in the volume bucket and recorded.

g. The percent passing is calculated as follows:

$$100 - \frac{(\text{Volume on sieve} \times 100)}{\text{Total Volume}} = \%\ \text{passing}$$

Performance Exam Checklist

WSDOT T 123
Method of Test for Bark Mulch

Participant Name _____ Exam Date _____

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

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

Signature of Examiner _____
Comments:

Washington State
Department of Transportation

WSDOT Test Method T 126

Determination of Fiber Length Percentages in Hydraulically-Applied Erosion Control Products

1. Scope

1.1 This method covers the procedure for measuring the fiber length of a Hydraulically-applied Erosion Control Product (HECP).

1.2 HECP is engineered and processed to specific length and width dimensions to facilitate the hydraulic application process. When the correct percentages of fiber lengths and widths exist within the HECP for hydraulic planting, the result will be a properly layered, interlocking mulch to hold seed and moisture.

1.3 This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (**Warning**- HECP's may be dusty, a dust mask is recommended when working with these products.

2. Terminology

2.1 Hydraulically applied - applied within a slurry, solution, or emulsion to the soil surface as a spray-on or dropped-on application through various means (e.g. nozzle, tower, aerially, etc.) formation of a compound by the combining of water with some other substance.

2.2 Hydraulically-applied Erosion Control Product (HECP) - A manufactured, degradable, pre-packaged fibrous material that is mixed with water and hydraulically applied as slurry, solution, or emulsion to reduce soil erosion and assist in the establishment and growth of vegetation.

3. Apparatus

3.1 Balance – shall have sufficient capacity, readable to 0.1 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231 for general-purpose balance required for the principle sample mass being tested.

3.2 Sieves – Meeting the requirements of ASTM E11

3.3 Mechanical sieve shaker – Meeting the requirements of AASHTO T 27

4. Sample Preparation

Obtain approximate 60 grams of material from a full, sealed bag or bale in the following manner:

Divide the bag or bale into thirds; top, middle and bottom of bag or bale.

Extract approximately 20 grams of material from the center of each portion (or the inside face of each ⅓ of a bale) taking care not to damage the extracted material.

Recombine the three samples and reduce the sample, in accordance with AASHTO 248 Method B, to approximately 15 grams. Place the sample in a large container and gently separate the compressed fiber.

5. Procedure

5.1 Select sieves with suitable openings to furnish data 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.

5.2 Place sieves in mechanical shaker and shake for a 5 minutes.

5.3 Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1g

6. Calculations

Calculate the percentage of fiber retained on each of the sieves using the following formula:

Percent Retained:

$$CPR = \frac{CMR}{M} x\ 100$$

Where:

CPR = Cumulative Percent Retained
CMR= Cumulative Mass Retained
M = Total Sample mass

7. Report

Results shall be reported as follows:

- Cumulative mass retained on each sieve
- Cumulative percent retained on each sieve
- Percent passing and retained on each sieve shall be reported to the nearest 1 percent

WSDOT Errata to FOP for AASHTO T 152

Air Content of Freshly Mixed Concrete by the Pressure Method

WAQTC FOP for AASHTO T 152 has been adopted by WSDOT with the following changes:

Apparatus

- Vibrator:

  Replace with details below:

  The vibrator frequency shall be at least 9000 vibrations per minute, 19 to 38 mm (0.75 to 1.50 in) in diameter, at least 75 mm (3 in) longer than the section being vibrated for use with low slump concrete

FOP for AASHTO T 152

Air Content of Freshly Mixed Concrete by the Pressure Method

Scope

This procedure covers determination of the air content in freshly mixed Portland Cement Concrete containing dense aggregates in accordance with AASHTO T 152-17, Type B meter. It is not for use with lightweight or highly porous aggregates. This procedure includes standardization of the Type B air meter gauge, Annex A.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

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 standardization only)
- Tamping rod: 16 mm (⅝ in) diameter and 400 mm (16 in) to 600 mm (24 in) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means "half a sphere"; the tip is rounded like half of a ball.)
- Vibrator: 9000 vibrations per minute, 19 to 38 mm (0.75 to 1.50 in) in diameter, at least 75 mm (3 in) longer than the section being vibrated for use with low slump concrete
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Container for water: rubber syringe (may also be a squeeze bottle)
- Strike-off bar: Approximately 300 mm x 22 mm x 3 mm (12 in x ¾ in × ⅛ in)
- Strike-off plate: A flat rectangular metal plate at least 6 mm (¼ in) thick or a glass or acrylic plate at least 12 mm (½ in) thick, with a length and width at least 50 mm (2 in) 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 1.5 mm (1/16 in).

  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 0.57 ± 0.23 kg (1.25 ± 0.5 lb)

Procedure Selection

There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 75 mm (3 in), consolidation is by rodding. When the slump is 25 to 75 mm (1 to 3 in), 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 concrete with slumps less than 25 mm (1 in), consolidate the sample by internal vibration. Do not consolidate self-consolidating concrete (SCC).

Procedure – Rodding

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If the concrete mixture contains aggregate retained on the 37.5mm (1½ in) sieve, the aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

   Note 2: Testing shall begin within five minutes of obtaining the sample.

2. Dampen the inside of the air meter measure and place on a firm level surface.
3. Use the scoop to fill the measure approximately ⅓ full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
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 around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.
6. Add the second layer, filling the measure about ⅔ full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
7. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in) into the bottom layer.
8. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
9. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
10. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in) into the second layer.
11. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.

    Note 3: The measure should be slightly over full, about 3 mm (⅛ in) above the rim. If there is a great excess of concrete, remove a portion with the trowel or scoop. If the measure 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 measure just full. The surface should be smooth and free of voids.
13. Clean the top flange of the measure 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 measure.
16. Inject water through a petcock on the cover until water emerges from the petcock on the other side.
17. Incline slightly and gently rock the air meter until no air bubbles appear to be coming out of the second petcock. The petcock expelling water should be higher than the petcock where water is being injected. Return the air meter to a level position and verify that water is present in both petcocks.

18. Close the air bleeder valve and pump air into the air chamber until the needle goes past the initial pressure determined for the gauge. Allow a few seconds for the compressed air to cool.
19. Tap the gauge gently with one hand while slowly opening the air bleeder valve until the needle rests on the initial pressure. Close the air bleeder valve.
20. Close both petcocks.
21. Open the main air valve.
22. Tap around the perimeter of the measure smartly with the mallet.
23. With the main air valve open, lightly tap the gauge to settle the needle, and then read the air content to the nearest 0.1 percent.
24. Release or close the main air valve.
25. Open both petcocks to release pressure, remove the concrete, and thoroughly clean the cover and measure with clean water.
26. Open the main air valve to relieve the pressure in the air chamber.

Procedure - Internal Vibration

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If any aggregate 37.5 mm (1½ in) or larger is present, aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.
2. Dampen the inside of the air meter measure and place on a firm level surface.
3. Use the scoop to fill the measure approximately 1/2 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
4. Insert the vibrator at three different points. Do not let the vibrator touch the bottom or side of the measure. Remove the vibrator slowly, so that no air pockets are left in the material. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
5. Use the scoop to fill the measure a bit over full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Insert the vibrator as in Step 4. Do not let the vibrator touch the side of the measure, and penetrate the first layer approximately 25 mm (1 in). Remove the vibrator slowly, so that no air pockets are left in the material. 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.
7. Return to Step 12 of the rodding procedure and continue.

Procedure – Self Consolidating Concrete

1. Obtain the sample in accordance with the FOP for WAQTC TM 2.
2. Dampen the inside of the air meter measure and place on a firm level surface.
3. Use the scoop to slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
4. Complete Steps 12 thru 26 of the rodding procedure.

Report

- Results on forms approved by the agency
- Sample ID
- Percent of air to the nearest 0.1 percent.
- Some agencies require an aggregate correction factor in order to determine total percent of entrained air.

  Total percent entrained air = Gauge reading – aggregate correction factor from mix design

  (See AASHTO T 152 for more information.)

ANNEX A—Standardization of Air Meter Gauge

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedures as described below will produce inaccurate or unreliable test results.

Standardization shall be performed at a minimum of once every three months. Record the date of the standardization, the standardization results, and the name of the technician performing the standardization in the log book kept with each air meter.

There are two methods for standardizing the air meter, mass or volume, both are covered below.

1. Screw the short piece of straight tubing into the threaded petcock hole on the underside of the cover.
2. Determine and record the mass of the dry, empty air meter measure and cover assembly (mass method only).
3. Fill the measure nearly full with water.
4. Clamp the cover on the measure with the tube extending down into the water. Mark the petcock with the tube attached for future reference.
5. 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.
6. Wipe off the air meter measure and cover assembly; determine and record the mass of the filled unit (mass method only).
7. 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.
8. Close both petcocks and immediately open the main air valve exhausting air into the measure. 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.
9. Determine which petcock has the straight tube attached to it. Attach the curved tube to external portion of the same petcock.
10. Pump air into the air chamber. Open the petcock with the curved tube attached to it. Open the main air valve for short periods of time until 5 percent of water by mass or volume has been removed from the air meter. Remember to open both petcocks to release the pressure in the measure and drain the water in the curved tube back into the measure. To determine the mass of the water to be removed, subtract the mass found in Step 1 from the mass found in Step 5. Multiply this value by 0.05. This is the mass of the water that must be removed. To remove 5 percent by volume, remove water until the external standardization vessel is level full.

    Note A1: Many air meters are supplied with a standardization vessel(s) of known volume that are used for this purpose. Standardization vessel must be protected from crushing or denting. If an external standardization vessel is used, confirm what percentage volume it represents for the air meter being used. Vessels commonly represent 5 percent volume, but they are for specific size meters. This should be confirmed by mass.

11. Remove the curved tube. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
12. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle is stabilized. The gauge should now read 5.0 ± 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 ± 0.1 percent when this standardization is run, or could involve moving the gauge needle to read 5.0 percent. Any adjustment should comply with the manufacturer's recommendations.
13. 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.
14. If an internal standardization vessel is used, follow steps 1 through 8 to set initial reading.
15. Release pressure from the measure and remove cover. Place the internal standardization vessel into the measure. This will displace 5 percent of the water in the measure. (See AASHTO T 152 for more information on internal standardization vessels.)
16. Place the cover back on the measure and add water through the petcock until all the air has been expelled.
17. Pump up the air pressure chamber to the initial pressure. 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.
18. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle stabilizes. The gauge should now read 5 percent.
19. Remove the extension tubing from threaded petcock hole in the underside of the cover before starting the test procedure.

Report

- Air Meter ID
- Date Standardized
- Initial Pressure (IP)

Performance Exam Checklist

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

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Representative sample selected?		
First Layer		
2. Dampened measure filled approximately one third full, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?		
3. Layer rodded throughout its depth 25 times, without forcibly striking the bottom of the measure, with hemispherical end of rod, uniformly distributing strokes?		
4. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding?		
Second layer		
5. Measure filled approximately two thirds full, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?		
6. Layer rodded throughout its depth, just penetrating the previous layer (approximately 25 mm (1 in) 25 times with hemispherical end of rod, uniformly distributing strokes?		
7. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding?		
Third layer		
8. Measure slightly overfilled, moving a scoop around the perimeter of the measure to evenly distribute the concrete as discharged?		
9. Layer rodded throughout its depth, just penetrating the previous layer (approximately 25 mm (1 in)) 25 times with hemispherical end of rod, uniformly distributing strokes?		
10. Perimeter of the measure tapped 10 to 15 times with the mallet after rodding each layer?		
11. Concrete struck off level with top of the measure using the bar or strike-off plate and rim cleaned off?		
12. Top flange of base cleaned?		
Using a Type B Meter:		
13. Both petcocks open?		
14. Air valve closed between air chamber and the measure?		
15. Inside of cover cleaned and moistened before clamping to base?		
16. Water injected through petcock until it flows out the other petcock?		
17. Water injection into the petcock continued while jarring and or rocking the meter to insure all air is expelled?		

Procedure Element	Trial 1	Trial 2
18. Air pumped up to just past initial pressure line?	_____	_____
19. A few seconds allowed for the compressed air to stabilize?	_____	_____
20. Gauge adjusted to the initial pressure?	_____	_____
21. Both petcocks closed?	_____	_____
22. Air valve opened between chamber and measure?	_____	_____
23. The outside of measure tapped smartly with the mallet?	_____	_____
24. With the main air valve open, gauge lightly tapped and air percentage read to the nearest 0.1 percent?	_____	_____
25. Air valve released or closed and then petcocks opened to release pressure before removing the cover?	_____	_____
26. Aggregate correction factor applied if required?	_____	_____
27. Air content recorded to 0.1 percent?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

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Comments:

WSDOT Errata to FOP for AASHTO T 166

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

WAQTC FOP for AASHTO T 166 has been adopted by WSDOT with the following changes:

Test Specimens

Include items below:

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

1. Place the specimen in a container that has a flat bottom surface to prevent deformation of the bottom of the specimen. ***Note:*** A flat piece of wood, rigid aluminum or reinforced cardboard may be used to create a flat surface in an HMA sample box.
2. Make sure the specimen is not deformed in handling.
3. Do not stack anything on top of the specimen container.
4. Transport the container in the cab of the vehicle or secure it in the vehicle bed to prevent movement during transit.

Procedure - Method A (Suspension)

Include step h. below:

1. Dry the specimen to constant mass, if required.
   a.
   b.
   c.
   d.
   e.
   f.
   g.
   h. As an alternative to oven drying to constant mass, drying the sample according to AASHTO R 79 may be used.

Replace step 2 with below:

2. Cool the specimen in air for a minimum of 15 hours and a maximum of 24 hours to 25 ± 5°C (77 ± 9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as “A.”

FOP for AASHTO T 166

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

Scope

This procedure covers the determination of bulk specific gravity (G_{mb}) of compacted asphalt mixtures using three methods – A, B, and C – in accordance with AASHTO T 166-16. This FOP is for use on specimens not having open or interconnecting voids or absorbing more than 2.00 percent water by volume, or both. When specimens have open or interconnecting voids or absorbing more than 2.00 percent water by volume, or both, AASHTO T 275 or AASHTO T 331 should be performed.

Overview

- Method A: Suspension
- Method B: Volumeter
- Method C: Rapid test for A or B

Test Specimens

Test specimens may be either laboratory-molded or from asphalt mixture pavement. For specimens it is recommended that the diameter be equal to four times the maximum size of the aggregate and the thickness be at least one and one half times the maximum size.

Test specimens from asphalt mixture pavement will be sampled according to AASHTO R 67.

Terminology

Constant Mass: The state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus - Method A (Suspension)

Balance or scale: 5 kg capacity, readable to 0.1 g, and fitted with a suitable suspension apparatus and holder to permit weighing the specimen while suspended in water, conforming to AASHTO M 231.

- Suspension apparatus: Wire of the smallest practical size and constructed to permit the container to be fully immersed.
- Water bath: For immersing the specimen in water while suspended under the balance or scale, and equipped with an overflow outlet for maintaining a constant water level.
- Towel: Damp cloth towel used for surface drying specimens.
- Oven: Capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F) for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Thermometer: Having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

Procedure - Method A (Suspension)

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

1. Dry the specimen to constant mass, if required.
   a. Initially dry overnight at 52 ± 3°C (125 ± 5°F).
   b. Determine and record the mass of the specimen (M_p).
   c. Return the specimen to the oven for at least 2 hours.
   d. Determine and record the mass of the specimen (M_n).
   e. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
   f. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
   g. Constant mass has been achieved, sample is defined as dry.

   Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.
2. Cool the specimen in air to 25 ± 5°C (77 ± 9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as "A."
3. Fill the water bath to overflow level with water at 25 ± 1°C (77 ± 1.8°F) and allow the water to stabilize.
4. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.
5. Immerse the specimen shaking to remove the air bubbles. Place the specimen on its side in the suspension apparatus. Leave it immersed for 4 ± 1 minutes.
6. Determine and record the submerged weight to the nearest 0.1 g. Designate this submerged weight as "C."
7. Remove the sample from the water and quickly surface dry with a damp cloth towel within 5 seconds.
8. Zero or tare the balance.
9. Immediately determine and record the mass of the SSD specimen to nearest 0.1 g. Designate this mass as "B." Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen. Do not to exceed 15 seconds performing Steps 7 through 9.

Calculations - Method A (Suspension)

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement, g
M_n = new mass measurement, g

Bulk specific gravity (G_{mb}) and percent water absorbed:

$$G_{mb} = \frac{A}{B - C}$$

$$Percent\ Water\ Absorbed\ (by\ volume) = \frac{B - A}{B - C} \times 100$$

Where:

A = Mass of dry specimen in air, g
B = Mass of SSD specimen in air, g
C = Weight of specimen in water at 25 ± 1°C (77 ± 1.8°F), g

Example:

$$G_{mb} = \frac{4833.6\ g}{4842.4\ g - 2881.3\ g} = 2.465$$

$$\%\ \boldsymbol{Water\ Absorbed\ (by\ volume)} = \frac{\mathbf{4842.4\ g - 4833.6\ g}}{\mathbf{4842.4\ g - 2881.3\ g}} \times \mathbf{100} = \mathbf{0.45}\%$$

Apparatus - Method B (Volumeter)

- Balance or scale: 5 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Water bath: Thermostatically controlled to 25 ± 0.5°C (77 ± 0.9°F).
- Thermometer: Range of 19 to 27°C (66 to 80°F), and graduated in 0.1°C (0.2°F) subdivisions.
- Volumeter: Calibrated to 1200 mL or appropriate capacity for test sample and having a tapered lid with a capillary bore.
- Oven: Capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F) for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Towel: Damp cloth towel used for surface drying specimens.

Procedure - Method B (Volumeter)

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

1. Dry the specimen to constant mass, if required.
   a. Initially dry overnight at 52 ± 3°C (125 ± 5°F).
   b. Determine and record the mass of the specimen (M_p).
   c. Return the specimen to the oven for at least 2 hours.
   d. Determine and record the mass of the specimen (M_n).
   e. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
   f. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
   g. Constant mass has been achieved, sample is defined as dry.

   Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.
2. Cool the specimen in air to 25 ± 5°C (77 ± 9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as "A."
3. Immerse the specimen in the temperature-controlled water bath for at least 10 minutes.
4. Fill the volumeter with distilled water at 25 ± 1°C (77 ± 1.8°F) making sure some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry. Determine the mass of the volumeter to the nearest 0.1 g. Designate this mass as "D."
5. At the end of the ten minute period, remove the specimen from the water bath and quickly surface dry with a damp cloth towel within 5 seconds.
6. Immediately determine and record the mass of the SSD specimen to the nearest 0.1g.
7. Designate this mass as "B." Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen.
8. Place the specimen in the volumeter and let stand 60 seconds.
9. Bring the temperature of the water to 25 ± 1°C (77 ± 1.8°F) and cover the volumeter, making sure some water escapes through the capillary bore of the tapered lid.
10. Wipe the volumeter dry.
11. Determine and record the mass of the volumeter and specimen to the nearest 0.1 g. Designate this mass as "E."

    Note 2: Method B is not acceptable for use with specimens that have more than 6 percent air voids.

Calculations - Method B (Volumeter)

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement, g
M_n = new mass measurement, g

Bulk specific gravity (Gmb) and percent water absorbed:

$$G_{mb} = \frac{A}{B + D - E}$$

$$Percent\ Water\ Absorbed\ (by\ volume) = \frac{B - A}{B + D - E} \times 100$$

Where:

A = Mass of dry specimen in air, g
B = Mass of SSD specimen in air, g
D = Mass of volumeter filled with water at 25 ± 1°C (77 ± 1.8°F), g
E = Mass of volumeter filled with specimen and water, g

Example:

$$G_{mb} = \frac{4833.6\ g}{4842.4\ g + 2924.4\ g - 5806.0\ g} = 2.465$$

$$\%\ Water\ Absorbed\ (by\ volume) = \frac{4842.4\ g - 4833.6\ g}{4842.4\ g + 2924.4\ g - 5806.0\ g} \times 100 = 0.45\%$$

Method C (Rapid Test for Method A or B)

See Methods A or B.

Note 3: This procedure can be used for specimens that are not required to be saved and contain substantial amounts of moisture. Cores can be tested the same day as obtained by this method.

Procedure - Method C (Rapid Test for Method A or B)

1. Start on Step 3 of Method A or B, and complete that procedure, then determine dry mass, "A," as follows.
2. Determine and record mass of a large, flat-bottom container.
3. Place the specimen in the container.
4. Place in an oven at a minimum of 105°C (221°F). Do not exceed the Job Mix Formula mixing temperature.
5. Dry until the specimen can be easily separated into fine aggregate particles that are not larger than 6.3 mm (¼ in).
6. Determine and record the mass of the specimen (M_p).
7. Return the specimen to the oven for at least 2 hours.
8. Determine and record the mass of the specimen (M_n).
9. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
10. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
11. Constant mass has been achieved, sample is defined as dry.
12. Cool in air to 25 ± 5°C (77 ± 9°F).
13. Determine and record the mass of the container and dry specimen to the nearest 0.1 g.
14. Determine and record the mass of the dry specimen to the nearest 0.1 g by subtracting the mass of the container from the mass determined in Step 13. Designate this mass as "A."

Calculations - Method C (Rapid Test for Method A or B)

Complete the calculations as outlined in Methods A or B, as appropriate.

Report

- Results on forms approved by the agency
- Sample ID
- G_{mb} to 0.001
- Absorption to 0.01 percent
- Method performed.

Performance Exam Checklist

FOP for AASHTO T 166
Bulk Specific Gravity (G_{mb}) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
Method A:		
1. Mass of dry sample in air determined.		
a. Dried overnight at 52 ± 3°C (125 ± 5°F) and at successive 2-hour intervals to constant mass?	_____	_____
b. Cooled in air to 25 ± 5°C (77 ± 9°F)?	_____	_____
c. Dry mass determined to 0.1g?	_____	_____
2. Water at the overflow?	_____	_____
3. Balance zeroed?	_____	_____
4. Immersed weight determined.		
a. Water at 25 ± 1°C (77 ± 1.8°F)?	_____	_____
b. Immersed, shaken, on side, for 4 ± 1 minutes?	_____	_____
c. Immersed weight determined to 0.1g?	_____	_____
5. Sample rapidly surface dried with damp towel and saturated surface dry (SSD) mass determined to 0.1 g (entire operation performed within 15 seconds)?	_____	_____
6. G_{mb} calculated to 0.001?	_____	_____
7. Absorption calculated to 0.01 percent	_____	_____
Method B:		
1. Specimen dried, cooled, and mass determined as in Method A?	_____	_____
2. Saturated surface dry (SSD) mass determined to 0.1g.		
a. Immersed at least 10 minutes at 25 ± 1°C (77 ± 1.8°F)?	_____	_____
b. Sample rapidly dried with damp towel?	_____	_____
c. Specimen mass determined to 0.1 g?	_____	_____
d. Any water that seeps from specimen included in mass?	_____	_____
3. Mass of volumeter filled with distilled water at 25 ± 1°C (77 ± 1.8°F) determined?	_____	_____
4. SSD specimen placed into volumeter and let stand for 1 minute?	_____	_____
5. Temperature of water brought to 25 ± 1°C (77 ± 1.8°F) and volumeter covered, allowing some water to escape through the capillary bore of the tapered lid?	_____	_____

Procedure Element	Trial 1	Trial 2
6. Volumeter wiped dry, and mass of volumeter and contents determined?		
7. G_{mb} calculated to 0.001?		
8. Absorption calculated to 0.01 percent?		
Method C/A:		
1. Immersed weight determined.		
a. Water at 25 ± 1°C (77 ± 1.8°F)?		
b. Immersed, shaken, on side, for 4 ± 1 minutes?		
c. Immersed weight determined to 0.1 g?		
2. Sample rapidly surface dried with damp cloth (within 5 seconds)?		
3. Saturated surface dry mass determined to 0.1 g?		
4. Dry mass determined by:		
a. Heating in oven at a minimum of 105°C (221°F)?		
b. Breaking down to 6.3 mm (¼ in) particles?		
c. Drying in oven to constant mass (change less than 0.05 percent in 2 hours of additional drying)?		
d. Cooled in air to 25 ± 5°C (77 ± 9°F) and mass determined to 0.1 g?		
5. G_{mb} calculated to 0.001?		
6. Absorption calculated to 0.01?		
Method C/B:		
1. Saturated surface dry (SSD) mass determined to 0.1g.		
a. Immersed at least 10 minutes at 25 ± 1°C (77 ± 1.8°F)?		
b. Sample rapidly dried with damp towel (within 5 seconds)?		
c. Specimen mass determined to 0.1g?		
d. Any water that seeps from specimen included in mass?		
2. Mass of volumeter filled with distilled water at 25 ± 1°C (77 ± 1.8°F) determined to 0.1 g?		
3. SSD specimen placed into volumeter and let stand for 1 minute?		
4. Temperature of water brought to 25 ± 1°C (77 ± 1.8°F) and volumeter covered, allowing some water to escape through the capillary pore of the tapered lid?		
5. Volumeter wiped dry, and mass of volumeter and contents determined to 0.1 g?		

Procedure Element	Trial 1	Trial 2
6. Dry mass determined by:		
a. Warming in oven at a minimum of 105°C (221°F)?	_____	_____
b. Breaking down to 6.3 mm (¼ in) particles?	_____	_____
c. Drying in oven to constant mass (change less than 0.05 percent in 2 hours of additional drying)?	_____	_____
d. Cooled in air to 25 ± 5°C (77 ± 9°F) and mass determined to 0.1 g?	_____	_____
7. G_{mb} calculated to 0.001?	_____	_____
8. Absorption calculated to 0.01 percent?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

WSDOT Errata to FOP for AASHTO T 168

Sampling of Bituminous Paving Mixtures

WAQTC FOP for AASHTO T 168 has been adopted by WSDOT with the following changes:

Sample Size

For Acceptance sampling and testing only: WSDOT requires a minimum of two times the amount required for testing. This should be 60 lbs.

For Acceptance and Conformation sampling and testing: WSDOT requires a minimum of four times the amount required for testing. This should be approximately 120 lbs. (See WSDOT *Construction Manual* Section 9-3.7 for Conformation sampling frequency)

Sampling

General

Include the steps below:

- Immediately upon obtaining a sample, using a verified thermometer, check and record temperature of the sample.
- The material shall be tested to determine variations. The supplier/contractor shall sample the HMA mixture in the presence of the Project Engineer. The supplier/contractor shall provide one of the following for safe and representative sampling:
  a. A mechanical sampling device installed between the discharge of the silo and the truck transport that is approved by the Regional Materials Engineer.
  b. Platforms or devices to enable sampling from the truck transport without entering the truck transport for sampling HMA.

Attached Sampling Devices

Sampling from Roadway Prior to Compaction (Plate Method)

Method 1 - Obtaining a Sample on Untreated Base: - *Method not recognized by WSDOT*.

Method 2 - Obtaining a Sample on Asphalt Surface: - *Method not recognized by WSDOT*.

FOP for AASHTO T 168

Sampling of Bituminous Paving Mixtures

Scope

This procedure covers the sampling of bituminous paving mixtures from HMA plants, haul units, and roadways in accordance with AASHTO T 168-03. Sampling is as important as testing, and every precaution must be taken to obtain a truly representative sample.

Apparatus

- Shovel
- Sample containers: such as cardboard boxes, metal cans, stainless steel bowls, or other agency-approved containers
- Scoops, trowels, or other equipment to obtain mix
- Sampling plate: Thick metal plate, minimum 8 gauge, sized to accommodate sample requirements, with a wire attached to one corner long enough to reach from the center of the paver to the outside of the farthest auger extension. Holes ¼ in in diameter should be provided in each corner.
- Cookie cutter sampling device: Formed steel angle with two 100 mm by 150 mm by 9 mm (4 in by 6 in by 3/8 in) handles, sized to accommodate sample requirements. Minimum 2 in smaller than the sampling plate when used together.

  Example: Sampling plate 380 mm (15 in) square and a cookie cutter sampling device 330 mm (13 in) square.
- Mechanical sampling device

Sample Size

Sample size depends on the test methods specified by the agency for acceptance. Check agency requirement for the size required.

Sampling

General

- The material shall be tested to determine variations. The supplier/contractor shall provide equipment for safe and appropriate sampling, including sampling devices on plants when required.
- For dense graded mixture samples use cardboard boxes, stainless steel bowls or other agency-approved containers.
- For hot open graded mixture samples use stainless steel bowls. Do not put open graded mixture samples in boxes until they have cooled to the point that bituminous material will not migrate from the aggregate.

Attached Sampling Devices

Some agencies require mechanical sampling devices for hot mix asphalt (HMA) and cold feed aggregate on some projects. These are normally permanently attached devices that allow a sample container to pass perpendicularly through the entire stream of material or divert the entire stream of material into the container. Operation may be hydraulic, pneumatic, or manual and allows the sample container to pass through the stream twice, once in each direction, without overfilling. Special caution is necessary with manually operated systems since a consistent speed is difficult to maintain and non-representative samples may result. Check agency requirements for the specifics of required sampling systems.

1. Lightly coat the container attached to the sampling device with an agency-approved release agent or preheat it, or both, to approximately the same discharge temperature of the mix.
2. Pass the container twice through the material perpendicularly without overfilling the container.
3. Repeat until proper sample size has been obtained.
4. Transfer the HMA to an agency-approved container without loss of material.

Sampling from Haul Units

1. Visually divide the haul unit into approximately four equal quadrants.
2. Identify one sampling location in each quadrant.
3. Dig down and remove approximately 0.3 m (1 ft) of material to avoid surface segregation. Obtain each increment from below this level.
4. Combine the increments to form a sample of the required size.

Sampling from Roadway Prior to Compaction (Plate Method)

Plate method using the “cookie cutter” sampling device.

There are two conditions that will be encountered when sampling hot mix asphalt (HMA) from the roadway prior to compaction. The two conditions are:

- Laying HMA on grade or untreated base material requires Method 1.
- Laying HMA on existing asphalt or laying a second lift of HMA requires Method 2.

SAFETY

Sampling is performed behind the paving machine and in front of the breakdown roller. For safety, the roller must remain at least 3 m (10 ft) behind the sampling operation until the sample has been taken and the hole filled with loose HMA.

Method 1 requires a plate to be placed in the roadway in front of the paving operation and therefore there is always concern with moving, operating equipment. It is safest to stop the paving train while a plate is installed in front of the paver. When this is not possible the following safety rules must be followed.

1. The plate placing operation must be at least 3 m (10 ft) in front of the paver or pickup device. The technician placing the plate must have eye contact and communication with the paving machine operator. If eye contact cannot be maintained at all time, a third person must be present to provide communication between the operator and the technician.

2. No technician is to be between the asphalt supply trucks and the paving machine. The exception to this rule is if the supply truck is moving forward creating a windrow, in which case the technician must be at least 3 m (10 ft) behind the truck.

If at any time the Engineer feels that the sampling technique is creating an unsafe condition, the operation is to be halted until it is made safe or the paving operation will be stopped while the plate is being placed.

Method 1 - Obtaining a Sample on Untreated Base:

1. Following the safety rules detailed above, the technician is to:
   a. Smooth out a location in front of the paver at least 0.5 m (2 ft) inside the edge of the mat.
   b. Lay the plate down diagonally with the direction of travel, keeping it flat and tight to the base with the lead corner facing the paving machine.
2. Secure the plate in place by driving a nail through the hole in the lead corner of the plate.
3. Pull the wire, attached to the outside corner of the plate, taut past the edge of the HMA mat and secure with a nail.
4. Let the paving operation proceed over the plate and wire. Immediately proceed with the sampling.
5. Using the exposed end of the wire, pull the wire up through the fresh HMA to locate the corner of the plate. Place the “cookie cutter” sample device, just inside the end of the wire; align the cutter over the plate. Press “cookie cutter” device down through the HMA to the plate.
6. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. Care shall be taken to prevent contamination of bituminous mixes by dust or other foreign matter, and to avoid segregation of aggregate and bituminous materials.
7. Remove the sample cutter and the plate from the roadway. The hole made from the sampling must be filled by the contractor with loose HMA.

Method 2 - Obtaining a Sample on Asphalt Surface:

1. After the paving machine has passed the sampling point, immediately place the “cookie cutter” sampling device on the location to be sampled. Push the cutter down through the HMA until it is flat against the underlying asphalt mat.
2. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. The hole made from the sampling must be filled by the contractor with loose HMA.

Identification and Shipping

1. Identify sample containers as required by the agency.
2. Ship samples in containers that will prevent loss, contamination, or damage.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

Performance Exam Checklist

FOP For AASHTO T 168
SAMPLING BITUMINOUS PAVING MIXTURES

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Was sample taken with an attached sampling device correctly?		
a. Container coated or preheated or both?		
b. Sampling device passed through stream twice perpendicular to material?		
c. Sampling device not over filled?		
2. Samples from truck transports taken from four quadrants at required depth of 300 mm (12 in)?		
3. Samples from roadway taken correctly with plate(s).		
a. When on untreated base plate placed well in front of paver?		
b. Wire pulled to locate plate corner?		
c. Cookie cutter placed on asphalt and pushed through to plate?		
d. All material removed from inside the cutter?		
4. Sample placed in appropriate container.		
5. Sample size meets agency requirements?		
6. Sample identified as required?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

WSDOT Errata to FOP for AASHTO T 176

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

WAQTC FOP for AASHTO T 176 has been adopted by WSDOT with the following changes:

Sample Preparation

Replace step 7 with below:

7. WSDOT requires two samples.

Include step 8 below:

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

Procedure

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

   c. Hand Method – Method not recognized by WSDOT.

10. Clay and sand readings:

Replace step d with below:

   d. If two Sand Equivalent (SE) samples are run on the same material and the second varies by more than ± 8, based on the first cylinder result, additional tests shall be run.

FOP for AASHTO T 176

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

Scope

This procedure covers the determination of plastic fines in accordance with AASHTO T 176-08. It serves as a rapid test to show the relative proportion of fine dust or clay-like materials in fine aggregates (FA) and soils.

Apparatus

See AASHTO T 176 for a detailed listing of sand equivalent apparatus. Note that the siphon tube and blow tube may be glass or stainless steel as well as copper.

- Graduated plastic cylinder.
- Rubber stopper.
- Irrigator tube.
- Weighted foot assembly: Having a mass of 1000 ± 5g. There are two models of the weighted foot assembly. The older model has a guide cap that fits over the upper end of the graduated cylinder and centers the rod in the cylinder. It is read using a slot in the centering screws. The newer model has a sand-reading indicator 254 mm (10 in) above this point and is preferred for testing clay-like materials.
- Bottle: clean, glass or plastic, of sufficient size to hold working solution
- Siphon assembly: The siphon assembly will be fitted to a 4 L (1 gal) bottle of working calcium chloride solution placed on a shelf 915 ± 25 mm (36 ± 1 in) above the work surface.
- Measuring can: With a capacity of 85 ± 5 mL (3 oz).
- Funnel: With a wide-mouth for transferring sample into the graduated cylinder.
- Quartering cloth: 600 mm (2 ft) square nonabsorbent cloth, such as plastic or oilcloth.
- Mechanical splitter: See the FOP for AASHTO R 76.
- Strike-off bar: A straightedge or spatula.
- Clock or watch reading in minutes and seconds.
- Manually-operated sand equivalent shaker: Capable of producing an oscillating motion at a rate of 100 complete cycles in 45 ± 5 seconds, with a hand assisted half stroke length of 127 ± 5 mm (5 ± 0.2 in). It may be held stable by hand during the shaking operation. It is recommended that this shaker be fastened securely to a firm and level mount, by bolts or clamps, if a large number of determinations are to be made.
- Mechanical shaker: See AASHTO T 176 for equipment and procedure.
- Oven: Capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F).
- Thermometer: Calibrated liquid-in-glass or electronic digital type designed for total immersion and accurate to 0.1°C (0.2°F).

Materials

- Stock calcium chloride solution: Obtain commercially prepared calcium chloride stock solution meeting AASHTO requirements.
- Working calcium chloride solution: Dilute one 3 oz. measuring can (85 ± 5 mL) of stock calcium chloride solution with 3.8 L (1 gal) distilled or demineralized water. Thoroughly mix the solution by filling the bottle with 2 L (½ gal) of water. Add the stock solution and agitate vigorously for 1 to 2 minutes. Add the remainder of the water, approximately 2 L (½ gal). Repeat the agitation process. The shelf life of the working solution is approximately 30 days. Label working solution with the date mixed. Discard working solutions more than 30 days old.

  Note 1: The graduated cylinder filled to 4.4 in contains 88 mL and may be used to measure the stock solution.

  Note 2: Tap water may be used if it is proven to be non-detrimental to the test and if it is allowed by the agency.

Control

The temperature of the working solution should be maintained at 22 ± 3°C (72 ± 5°F) during the performance of the test. If field conditions preclude the maintenance of the temperature range, reference samples should be submitted to the Central/Regional Laboratory, as required by the agency, where proper temperature control is possible. Samples that meet the minimum sand equivalent requirement at a working solution temperature outside of the temperature range need not be subject to reference testing.

Sample Preparation

1. Obtain the sample in accordance with the FOP for AASHTO T 2 and reduce in accordance with the FOP for AASHTO R 76.
2. Prepare sand equivalent test samples from the material passing the 4.75 mm (No. 4) sieve. If the material is in clods, break it up and re-screen it over a 4.75 mm (No. 4) sieve. All fines shall be cleaned from particles retained on the 4.75 mm (No. 4) sieve and included with the material passing that sieve.
3. Split or quarter 1000 to 1500 g of material from the portion passing the 4.75 mm (No. 4) sieve. Use extreme care to obtain a truly representative portion of the original sample.

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

   Note 4: All tests, including reference tests, will be performed utilizing Alternative Method No. 2 as described in AASHTO T 176, unless otherwise specified.
4. The sample must have the proper moisture content to achieve reliable results. This condition is determined by tightly squeezing a small portion of the thoroughly mixed sample in the palm of the hand. If the cast that is formed permits careful handling without breaking, the correct moisture content has been obtained.

   Note 5: Clean sands having little 75 µm (No. 200), such as sand for Portland Cement Concrete (PCC), may not form a cast.

If the material is too dry, the cast will crumble and it will be necessary to add water and remix and retest until the material forms a cast. When the moisture content is altered to provide the required cast, the altered sample should be placed in a pan, covered with a lid or with a damp cloth that does not touch the material, and allowed to stand for a minimum of 15 minutes. Samples that have been sieved without being air-dried and still retain enough natural moisture are exempted from this requirement.

If the material shows any free water, it is too wet to test and must be drained and air dried. Mix frequently to ensure uniformity. This drying process should continue until squeezing provides the required cast.

5. Place the sample on the quartering cloth and mix by alternately lifting each corner of the cloth and pulling it over the sample toward the diagonally opposite corner, being careful to keep the top of the cloth parallel to the bottom, thus causing the material to be rolled. When the material appears homogeneous, finish the mixing with the sample in a pile near the center of the cloth.
6. Fill the measuring can by pushing it through the base of the pile while exerting pressure with the hand against the pile on the side opposite the measuring can. As the can is moved through the pile, hold enough pressure with the hand to cause the material to fill the tin to overflowing. Press firmly with the palm of the hand, compacting the material and placing the maximum amount in the can. Strike off the can level full with the straightedge or spatula.
7. When required, repeat steps 5 and 6 to obtain additional samples.

Procedure

1. Start the siphon by forcing air into the top of the solution bottle through the tube while the pinch clamp is open. Siphon 101.6 ± 2.5 mm (4 ± 0.1 in) of working calcium chloride solution into the plastic cylinder.
2. Pour the prepared test sample from the measuring can into the plastic cylinder, using the funnel to avoid spilling.
3. Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the sample.
4. Allow the wetted sample to stand undisturbed for 10 ± 1 minutes.
5. At the end of the 10-minute period, stopper the cylinder and loosen the material from the bottom by simultaneously partially inverting and shaking the cylinder.
6. After loosening the material from the bottom of the cylinder, shake the cylinder and contents by any one of the following methods:

    a. Mechanical Method – Place the stoppered cylinder in the mechanical shaker, set the timer, and allow the machine to shake the cylinder and contents for 45 ± 1 seconds.

    Caution: Agencies may require additional operator qualifications for the next two methods.

b. Manually-operated Shaker Method – Secure the stoppered cylinder in the three spring clamps on the carriage of the manually-operated sand equivalent shaker and set the stroke counter to zero. Stand directly in front of the shaker and force the pointer to the stroke limit marker painted on the backboard by applying an abrupt horizontal thrust to the upper portion of the right hand spring strap.

   Remove the hand from the strap and allow the spring action of the straps to move the carriage and cylinder in the opposite direction without assistance or hindrance. Apply enough force to the right-hand spring steel strap during the thrust portion of each stroke to move the pointer to the stroke limit marker by pushing against the strap with the ends of the fingers to maintain a smooth oscillating motion. The center of the stroke limit marker is positioned to provide the proper stroke length and its width provides the maximum allowable limits of variation.

   Proper shaking action is accomplished when the tip of the pointer reverses direction within the marker limits. Proper shaking action can best be maintained by using only the forearm and wrist action to propel the shaker. Continue shaking for 100 strokes.

c. Hand Method – Hold the cylinder in a horizontal position and shake it vigorously in a horizontal linear motion from end to end. Shake the cylinder 90 cycles in approximately 30 seconds using a throw of 229 mm ± 25 mm (9 ± 1 in). A cycle is defined as a complete back and forth motion. To properly shake the cylinder at this speed, it will be necessary for the operator to shake with the forearms only, relaxing the body and shoulders.

7. Set the cylinder upright on the work table and remove the stopper.

8. Insert the irrigator tube in the cylinder and rinse material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while the working solution flows from the irrigator tip. Work the irrigator tube to the bottom of the cylinder as quickly as possible, since it becomes more difficult to do this as the washing proceeds. This flushes the fine material into suspension above the coarser sand particles.

   Continue to apply a stabbing and twisting action while flushing the fines upward until the cylinder is filled to the 381 mm (15 in) mark. Then raise the irrigator slowly without shutting off the flow so that the liquid level is maintained at about 381 mm (15 in) while the irrigator is being withdrawn. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 381 mm (15 in).

   Note 6: Occasionally the holes in the tip of the irrigator tube may become clogged by a particle of sand. If the obstruction cannot be freed by any other method, use a pin or other sharp object to force it out, using extreme care not to enlarge the size of the opening. Also, keep the tip sharp as an aid to penetrating the sample.

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

   Note 7: Any vibration or movement of the cylinder during this time will interfere with the normal settling rate of the suspended clay and will cause an erroneous result.

10. Clay and sand readings:

    a. At the end of the 20-minute sedimentation period, read and record the level of the top of the clay suspension. This is referred to as the clay reading.

       Note 8: If no clear line of demarcation has formed at the end of the 20-minute sedimentation period, allow the sample to stand undisturbed until a clay reading can be obtained, then immediately read and record the level of the top of the clay suspension and the total sedimentation time. If the total sedimentation time exceeds 30 minutes, rerun the test using three individual samples of the same material. Read and record the clay column height of the sample requiring the shortest sedimentation period only. Once a sedimentation time has been established, subsequent tests will be run using that time. The time will be recorded along with the test results on all reports.

    b. After the clay reading has been taken, place the weighted foot assembly over the cylinder and gently lower the assembly until it comes to rest on the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered. Subtract 254 mm (10 in) from the level indicated by the extreme top edge of the indicator and record this value as the sand reading.

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

    d. If two Sand Equivalent (SE) samples are run on the same material and the second varies by more than ± 4, based on the first cylinder result, additional tests shall be run.

    e. If three or more Sand Equivalent (SE) samples are run on the same material, average the results. If an individual result varies by more than ± 4, based on the average result, additional tests shall be run.

Calculations

Calculate the SE to the nearest 0.1 using the following formula:

$$SE = \frac{Sand\ Reading}{Clay\ Reading} \times 100$$

Example

Sand Reading = 3.3

Clay Reading = 8.0

$$SE = \frac{3.3}{8.0} \times 100 = 41.25\ or\ 41.3 \qquad \text{Report } 42$$

Note 9: This example reflects the use of equipment made with English units. At this time, equipment made with metric units is not available.

Report the SE as the next higher whole number. In the example above, the 41.3 would be reported as 42. An SE of 41.0 would be reported as 41.

When averaging two or more samples, raise each calculated SE value to the next higher whole number (reported value) before averaging.

Example

calculated value 1 = 41.3

calculated value 2 = 42.8

These values are reported as 42 and 43, respectively.

Average the two reported values:

$$Average\ SE = \frac{42 + 43}{2} = 42.5 \quad \text{Report } 43$$

If the average value is not a whole number, raise it to the next higher whole number.

Report

- Results on forms approved by the agency
- Sample ID
- Results to the whole number
- Sedimentation time if over 20 minutes

Performance Exam Checklist

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

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
Sample Preparation		
1. Sample passed through 4.75 mm (No. 4) sieve?		
2. Material in clods broken up and re-screened?		
3. Split or quarter 1,000 to 1,500g of material passing the 4.75 mm (No. 4) sieve? ***Note:*** If necessary, the material may be dampened before splitting to avoid segregation or loss of fines.		
4. No fines lost?		
5. Working solution dated?		
6. Temperature of working solution 22 ± 3°C (72 ± 5°F)?		
7. Working calcium chloride solution 915 ± 25 mm (36 ± 1in) above the work surface?		
8. 101.6 ± 2.5 mm (4 ± 0.1in) working calcium chloride solution siphoned into cylinder?		
9. Material checked for moisture condition by tightly squeezing small portion in palm of hand and forming a cast?		
10. Sample at proper water content?		
a. If too dry (cast crumbles easily) water added, re-mixed, covered, and allowed to stand for at least 15 minutes?		
b. If too wet (shows free water) sample drained, air dried and mixed frequently?		
11. Sample placed on splitting cloth and mixed by alternately lifting each corner of the cloth and pulling it over the sample toward diagonally opposite corner, causing material to be rolled?		
12. Is material thoroughly mixed?		
13. When material appears to be homogeneous, mixing finished with sample in a pile near center of cloth?		
14. Fill the 85 mL (3 oz) tin by pushing through base of pile with other hand on opposite side of pile?		
15. Material fills tin to overflowing?		
16. Material compacted into tin with palm of hand?		
17. Tin struck off level full with spatula or straightedge?		
18. Prepared sample funneled into cylinder with no loss of fines?		

Procedure Element	Trial 1	Trial 2
19. Bottom of cylinder tapped sharply on heel of hand several times to release air bubbles?	_____	_____
20. Wetted sample allowed to stand undisturbed for 10 min. ± 1 min?	_____	_____
21. Cylinder stoppered and material loosened from bottom by shaking?	_____	_____
22. Stoppered cylinder placed properly in mechanical shaker and cylinder shaken 45 ± 1 seconds?	_____	_____
23. Following shaking, cylinder set vertical on work surface and stopper removed?	_____	_____
24. Irrigator tube inserted in cylinder and material rinsed from cylinder walls as irrigator is lowered?	_____	_____
25. Irrigator tube forced through material to bottom of cylinder by gentle stabbing and twisting action?	_____	_____
26. Stabbing and twisting motion applied until cylinder filled to 381 mm (15 in) mark?	_____	_____
27. Liquid raised and maintained at 381 mm (15 in) mark while irrigator is being withdrawn?	_____	_____
28. Liquid at the 381 mm (15 in) mark?	_____	_____
29. Contents let stand 20 minutes ± 15 seconds?	_____	_____
30. Timing started immediately after withdrawal of irrigator?	_____	_____
31. No vibration or disturbance of the sample?	_____	_____
32. Readings taken at 20 minutes or up to 30 minutes, when a definite line appears?	_____	_____
33. Clay level correctly read, rounded, and recorded?	_____	_____
34. Weighted foot assembly lowered into cylinder without hitting mouth of cylinder?	_____	_____
35. Sand level correctly read, rounded, and recorded?	_____	_____
36. Calculations performed correctly?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

MOISTURE-DENSITY RELATIONS OF SOILS:

FOP for AASHTO T 99

USING A 2.5 kg (5.5 lb) RAMMER AND A 305 mm (12 in) DROP

FOP for AASHTO T 180

USING A 4.54 kg (10 lb) RAMMER AND A 457 mm (18 in) DROP

Scope

This procedure covers the determination of the moisture-density relations of soils and soil-aggregate mixtures in accordance with two similar test methods:

- AASHTO T 99-17: Methods A, B, C, and D
- AASHTO T 180-17: Methods A, B, C, and D

This test method applies to soil mixtures having 40 percent or less retained on the 4.75 mm (No. 4) sieve for methods A or B, or, 30 percent or less retained on the 19 mm (¾ in) with methods C or D. The retained material is defined as oversize (coarse) material. If no minimum percentage is specified, 5 percent will be used. Samples that contain oversize (coarse) material that meet percent retained criteria should be corrected by using *Annex A*, *Correction of Maximum Dry Density and Optimum Moisture for Oversized Particles*. Samples of soil or soil-aggregate mixture are prepared at several moisture contents and compacted into molds of specified size, using manual or mechanical rammers that deliver a specified quantity of compactive energy. The moist masses of the compacted samples are multiplied by the appropriate factor to determine wet density values. Moisture contents of the compacted samples are determined and used to obtain the dry density values of the same samples. Maximum dry density and optimum moisture content for the soil or soil-aggregate mixture is determined by plotting the relationship between dry density and moisture content.

Apparatus

- Mold – Cylindrical mold made of metal with the dimensions shown in Table 1 or Table 2. If permitted by the agency, the mold may be of the "split" type, consisting of two half-round sections, which can be securely locked in place to form a cylinder. Determine the mold volume according to *Annex B*, *Standardization of the Mold*.
- Mold assembly – Mold, base plate, and a detachable collar.
- Rammer –Manually or mechanically-operated rammers as detailed in Table 1 or Table 2. A manually-operated rammer shall be equipped with a guide sleeve to control the path and height of drop. The guide sleeve shall have at least four vent holes no smaller than 9.5 mm (⅜ in) in diameter, spaced approximately 90 degrees apart and approximately 19 mm (¾ in) from each end. A mechanically-operated rammer will uniformly distribute blows over the sample and will be calibrated with several soil types, and be adjusted, if necessary, to give the same moisture-density results as with the manually operated rammer. For additional information concerning calibration, see the FOP for AASHTO T 99 and T 180.
- Sample extruder – A jack, lever frame, or other device for extruding compacted specimens from the mold quickly and with little disturbance.

- Balance(s) or scale(s) of the capacity and sensitivity required for the procedure used by the agency.

  A balance or scale with a capacity of 11.5 kg (25 lb) and a sensitivity of 1 g for obtaining the sample, meeting the requirements of AASHTO M 231, Class G 5.

  A balance or scale with a capacity of 2 kg and a sensitivity of 0.1 g is used for moisture content determinations done under both procedures, meeting the requirements of AASHTO M 231, Class G 2.
- Drying apparatus – A thermostatically controlled drying oven, capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F) for drying moisture content samples in accordance with the FOP for AASHTO T 255/T 265.
- Straightedge – A steel straightedge at least 250 mm (10 in) long, with one beveled edge and at least one surface plane within 0.1 percent of its length, used for final trimming.
- Sieve(s) – 4.75 mm (No. 4) and/or 19.0 mm (¾ in), meeting the requirements of FOP for AASHTO T 27/T 11.
- Mixing tools – Miscellaneous tools such as a mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device, for mixing the sample with water.
- Containers with close-fitting lids to prevent gain or loss of moisture in the sample.

Table 1 Comparison of Apparatus, Sample, and Procedure – Metric

	T 99	T 180
Mold Volume, m^3	Methods A, C: 0.000943 ± 0.000014	Methods A, C: 0.000943 ± 0.000014
	Methods B, D: 0.002124 ± 0.000025	Methods B, D: 0.002124 ± 0.000025
Mold Diameter, mm	Methods A, C: 101.60 ± 0.40	Methods A, C: 101.60 ± 0.4
	Methods B, D: 152.40 ± 0.70	Methods B, D: 152.40 ± 0.70
Mold Height, mm	116.40 ± 0.50	116.40 ± 0.50
Detachable Collar Height, mm	50.80 ± 0.64	50.80 ± 0.64
Rammer Diameter, mm	50.80 ± 0.25	50.80 ± 0.25
Rammer Mass, kg	2.495 ± 0.009	4.536 ± 0.009
Rammer Drop, mm	305	457
Layers	3	5
Blows per Layer	Methods A, C: 25	Methods A, C: 25
	Methods B, D: 56	Methods B, D: 56
Material Size, mm	Methods A, B: 4.75 minus	Methods A, B: 4.75 minus
	Methods C, D: 19.0 minus	Methods C, D: 19.0 minus
Test Sample Size, kg	Method A: 3 Method B: 7 Method C: 5 (1) Method D: 11(1)	
Energy, kN-m/m^3	592	2,693

(1) This may not be a large enough sample depending on your nominal maximum size for moisture content samples.

Table 2 Comparison of Apparatus, Sample, and Procedure – English

	T 99	T 180
Mold Volume, ft^3	Methods A, C: 0.0333 ± 0.0005	Methods A, C: 0.0333 ± 0.0005
	Methods B, D: 0.07500 ± 0.0009	Methods B, D: 0.07500 ± 0.0009
Mold Diameter, in	Methods A, C: 4.000 ± 0.016	Methods A, C: 4.000 ± 0.016
	Methods B, D: 6.000 ± 0.026	Methods B, D: 6.000 ± 0.026
Mold Height, in	4.584 ± 0.018	4.584 ± 0.018
Detachable Collar Height, in	2.000 ± 0.025	2.000 ± 0.025
Rammer Diameter, in	2.000 ± 0.025	2.000 ± 0.025
Rammer Mass, lb	5.5 ± 0.02	10 ± 0.02
Rammer Drop, in	12	18
Layers	3	5
Blows per Layer	Methods A, C: 25	Methods A, C: 25
	Methods B, D: 56	Methods B, D: 56
Material Size, in	Methods A, B: No. 4 minus	Methods A, B: No.4 minus
	Methods C, D: ¾ minus	Methods C, D: ¾ minus
Test Sample Size, lb	Method A: 7 Method B: 16 Method C: 12(1) Method D: 25(1)	
Energy, lb-ft/ft^3	12,375	56,250

(1) This may not be a large enough sample depending on your nominal maximum size for moisture content samples.

Sample

If the sample is damp, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus maintained at a temperature not exceeding 60°C (140°F). Thoroughly break up aggregations in a manner that avoids reducing the natural size of individual particles.

Obtain a representative test sample of the mass required by the agency by passing the material through the sieve required by the agency. See Table 1 or Table 2 for test sample mass and material size requirements.

In instances where the material is prone to degradation, i.e., granular material, a compaction sample with differing moisture contents should be prepared for each point.

Note 1: Both T 99 and T 180 have four methods (A, B, C, D) that require different masses and employ different sieves.

Note 2: If the sample is plastic (clay types), it should stand for a minimum of 12 hours after the addition of water to allow the moisture to be absorbed. In this case, several samples at different moisture contents should be prepared, put in sealed containers and tested the next day.

Procedure

During compaction, rest the mold firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process.

1. Determine the mass of the clean, dry mold. Include the base plate, but exclude the extension collar. Record the mass to the nearest 1 g (0.005 lb).
2. Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 to 8 percentage points below optimum moisture content. See Note 2. For many materials, this condition can be identified by forming a cast by hand.
3. Form a specimen by compacting the prepared soil in the mold assembly in approximately equal layers. For each layer:
   a. Spread the loose material uniformly in the mold.

      Note 3: It is recommended to cover the remaining material with a non-absorbent sheet or damp cloth to minimize loss of moisture.

   b. Lightly tamp the loose material with the manual rammer or other similar device, this establishes a firm surface.
   c. Compact each layer with uniformly distributed blows from the rammer. See Table 1 for mold size, number of layers, number of blows, and rammer specification for the various test methods. Use the method specified by the agency.
   d. Trim down material that has not been compacted and remains adjacent to the walls of the mold and extends above the compacted surface.
4. Remove the extension collar. Avoid shearing off the sample below the top of the mold. The material compacted in the mold should not be over 6 mm (¼ in) above the top of the mold once the collar has been removed.
5. Trim the compacted soil even with the top of the mold with the beveled side of the straightedge.
6. Determine and record the mass of the mold, base plate, and wet soil to the nearest 1 g (0.005 lb) or better.
7. Determine and record the wet mass (M_w) of the sample by subtracting the mass in Step 1 from the mass in Step 6.
8. Calculate the wet density, in kg/m^3 (lb/ft^3), by dividing the wet mass by the measured volume (V_m).
9. Extrude the material from the mold. For soils and soil-aggregate mixtures, slice vertically through the center and take a representative moisture content sample from one of the cut faces, ensuring that all layers are represented. For granular materials, a vertical face will not exist. Take a representative sample. This sample must meet the sample size requirements of the test method used to determine moisture content.

   Note 4: When developing a curve for free-draining soils such as uniform sands and gravels, where seepage occurs at the bottom of the mold and base plate, taking a representative moisture content from the mixing bowl may be preferred in order to determine the amount of moisture available for compaction.

10. Determine and record the moisture content of the sample in accordance with the FOP for AASHTO T 255/T 265.
11. Thoroughly break up the remaining portion of the molded specimen until it will again pass through the sieve, as judged by eye, and add to the remaining portion of the sample being tested. See Note 2.
12. Add sufficient water to increase the moisture content of the remaining soil by 1 to 2 percentage points and repeat steps 3 through 11.
13. Continue determinations until there is either a decrease or no change in the wet mass. There will be a minimum of three points on the dry side of the curve and two points on the wet side. For non-cohesive, drainable soils, one point on the wet side is sufficient.

Calculations

Wet Density

$$D_w = \frac{M_w}{V_m}$$

Where:

D_w = wet density, kg/m^3 (lb/ft^3)
M_w = wet mass
V_m = volume of the mold, Annex B

Dry Density

$$D_d = \left(\frac{D_w}{w + 100}\right) \times 100 \quad or \quad D_d = \frac{D_w}{\left(\frac{w}{100}\right) + 1}$$

Where:

D_d = dry density, kg/m^3 (lb/ft^3)
w = moisture content, as a percentage

Example for 4-inch mold, Methods A or C

Wet mass, M_w	= 1.944 kg (4.25 lb)
Moisture content, w	= 11.3 percent
Measured volume of the mold, V_m	= 0.000946 m^3 (0.0334 ft^3)

Wet Density

$$D_w = \frac{1.944\ kg}{0.000946\ m^3} = 2055\ kg/m^3 \quad D_w = \frac{4.25\ lb}{0.0334\ ft^3} = 127.2\ lb/ft^3$$

Dry Density

$$D_d = \left(\frac{2055\ kg/m^3}{11.3 + 100}\right) \times 100 = 1846\ kg/m^3 \quad D_d = \left(\frac{127.2\ lb/ft^3}{11.3 + 100}\right) \times 100 = 114.3\ lb/ft^3$$

Or

$$D_d = \left(\frac{2055\ kg/m^3}{\frac{11.3}{100} + 1}\right) = 1846\ kg/m^3 \quad D_d = \left(\frac{127.2\ lb/ft^3}{\frac{11.3}{100} + 1}\right) = 114.3\ lb/ft^3$$

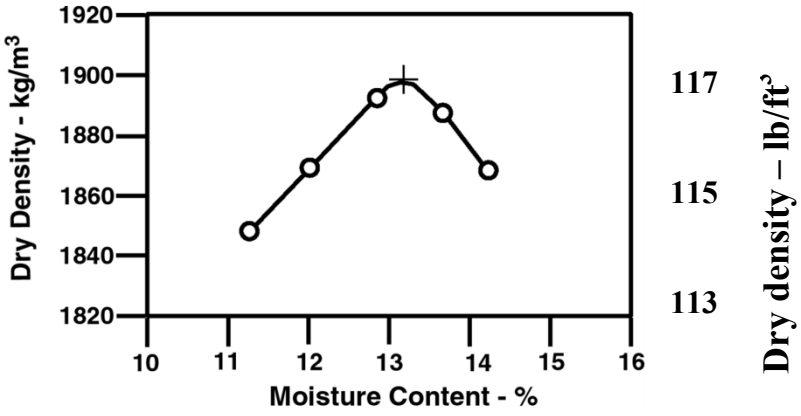
Moisture-Density Curve Development

When dry density is plotted on the vertical axis versus moisture content on the horizontal axis and the points are connected with a smooth line, a moisture-density curve is developed. The coordinates of the peak of the curve are the maximum dry density, or just "maximum density," and the "optimum moisture content" of the soil.

Example

Given the following dry density and corresponding moisture content values develop a moisture-density relations curve and determine maximum dry density and optimum moisture content.

Dry Density		Moisture Content, %
kg/m³	lb/ft³	
1846	114.3	11.3
1868	115.7	12.1
1887	116.9	12.8
1884	116.7	13.6
1871	115.9	14.2



In this case, the curve has its peak at:

Maximum dry density = 1890 kg/m³ (117.0 lb/ft³)

Optimum moisture content = 13.2 percent

Note that both values are approximate, since they are based on sketching the curve to fit the points.

Report

- Results on forms approved by the agency
- Sample ID
- Maximum dry density to the closest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the closest 0.1 percent

ANNEX A

Correction of Maximum DRY Density and Optimum Moisture for Oversized Particles

This section corrects the maximum dry density and moisture content of the material retained on the 4.75 mm (No. 4) sieve, Methods A and B; or the material retained on the 19 mm (¾ in) sieve, Methods C and D. The maximum dry density, corrected for oversized particles and total moisture content, are compared with the field-dry density and field moisture content.

This correction can be applied to the sample on which the maximum dry density is performed. A correction may not be practical for soils with only a small percentage of oversize material. The agency shall specify a minimum percentage below which the method is not needed. If not specified, this method applies when more than 5 percent by weight of oversize particles is present.

Bulk specific gravity (G_{sb}) of the oversized particles is required to determine the corrected maximum dry density. Use the bulk specific gravity as determined using the FOP for AASHTO T 85 in the calculations. For construction activities, an agency established value or specific gravity of 2.600 may be used.

This correction can also be applied to the sample obtained from the field while performing in-place density.

1. Use the sample from this procedure or a sample obtained according to the FOP for AASHTO T 310.
2. Sieve the sample on the 4.75 mm (No. 4) sieve for Methods A and B or the 19 mm (¾ in) sieve, Methods C and D.
3. Determine the dry mass of the oversized and fine fractions (M_{DC} and M_{DF}) by one of the following:
    a. Dry the fractions, fine and oversized, in air or by use of a drying apparatus that is maintained at a temperature not exceeding 60°C (140°F).
    b. Calculate the dry masses using the moisture samples.

To determine the dry mass of the fractions using moisture samples.

1. Determine the moist mass of both fractions, fine (M_{Mf}) and oversized (M_{Mc}):
2. Obtain moisture samples from the fine and oversized material.
3. Determine the moisture content of the fine particles (MC_f) and oversized particles (MC_C) of the material by FOP for AASHTO T 255/T 265 or agency approved method.
4. Calculate the dry mass of the oversize and fine particles.

$$M_D = \frac{M_m}{1 + \mathrm{MC}}$$

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, expressed as a decimal

5. Calculate the percentage of the fine (P_f) and oversized (P_c) particles by dry weight of the total sample as follows: See Note 2.

$$P_f = \frac{100 \times M_{DF}}{M_{DF} + M_{DC}} \qquad \frac{100 \times 15.4\ lb}{15.4\ lbs + 5.7\ lb} = 73\% \qquad \frac{100 \times 6.985\ kg}{6.985\ kg + 2.602\ kg} = 73\%$$

And

$$P_c = \frac{100 \times M_{DC}}{M_{DF} + M_{DC}} \qquad \frac{100 \times 5.7\ lb}{15.4\ lbs + 5.7\ lb} = 27\% \qquad \frac{100 \times 2.585 kg}{6.985\ kg + 2.585\ kg} = 27\%$$

Or for $\mathbf{P_c}$:

$$P_c = 100 - P_f$$

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 fine particles
M_{DC} = mass of oversize particles

Optimum Moisture Correction Equation

1. Calculate the corrected moisture content as follows:

$$MC_T = \frac{(MC_F \times P_f) + (MC_c \times P_c)}{100} \qquad \frac{(13.2\% \times 73.0\%) + (2.1\% \times 27.0\%)}{100} = 10.2\%$$

Where:

MC_T = corrected moisture content of combined fines and oversized particles, expressed as a percent moisture
MC_f = moisture content of fine particles, as a percent moisture
MC_C = moisture content of oversized particles, as a percent moisture

Note 1: Moisture content of oversize material can be assumed to be two (2) percent for most construction applications.

Note 2: In some field applications agencies will allow the percentages of oversize and fine materials to be determined with the materials in the wet state.

Density Correction Equation

1. Calculate the corrected dry density of the total sample (combined fine and oversized particles) as follows:

$$D_d = \frac{100\%}{\left[\left(\frac{P_f}{D_f}\right) + \left(\frac{P_c}{k}\right)\right]}$$

Where:

D_d = corrected total dry density (combined fine and oversized particles) kg/m^3 (lb/ft^3)
D_f = dry density of the fine particles kg/m^3 (lb/ft^3), determined in the lab
P_c= percent of oversize particles, of sieve used, by weight.
P_f = percent of fine particles, of sieve used, by weight.
k = Metric: 1,000 * Bulk Specific Gravity (G_{sb}) (oven dry basis) of coarse particles (kg/m^3).
k = English: 62.4 * Bulk Specific Gravity (G_{sb}) (oven dry basis) of coarse particles (lb/ft^3)

Note 3: If the specific gravity is known, then this value will be used in the calculation. For most construction activities the specific gravity for aggregate may be assumed to be 2.600.

Calculation

Example

Metric:

Maximum laboratory dry density (D_f):	1890 kg/m^3
Percent coarse particles (P_c):	27 percent
Percent fine particles (P_f):	73 percent
Mass per volume coarse particles (k):	(2.697) (1000) = 2697 kg/m^3

$$D_d = \frac{100\%}{\left[\left(\frac{P_f}{D_f}\right) + \left(\frac{P_c}{k}\right)\right]}$$

$$D_d = \frac{100\%}{\left[\left(\frac{73\%}{1890\,kg/m^3}\right) + \left(\frac{27\%}{2697\,kg/m^3}\right)\right]}$$

$$D_d = \frac{100\%}{[0.03862\,kg/m^3 + 0.01001\,kg/m^3]}$$

$$D_d = 2056.3\,kg/m^3\ report\ \ 2056\,kg/m^3$$

English:

Maximum laboratory dry density (D_f):	117.0 lb/ft^3
Percent coarse particles (P_c):	27 percent
Percent fine particles (P_f):	73 percent
Mass per volume of coarse particles (k):	(2.697) (62.4) = 168.3 lb/ft^3

$$D_d = \frac{100\%}{\left[\left(\frac{P_f}{D_f}\right) + \left(\frac{P_c}{k}\right)\right]}$$

$$D_d = \frac{100\%}{\left[\left(\frac{73\%}{117.0\ lb/ft^3}\right) + \left(\frac{27\%}{168.3\ lb/ft^3}\right)\right]}$$

$$D_d = \frac{100\%}{[0.6239\ lb/ft^3 + 0.1604\ lb/ft^3]}$$

$$D_d = \frac{100\%}{0.7843\ lb/ft^3}$$

$$D_d = 127.50\ lb/ft^3 \quad Report\ 127.5\ lb/ft^3$$

Report

- Results on forms approved by the agency
- Sample ID
- Corrected maximum dry density to the closest 1 kg/m^3 (0.1 lb/ft^3)
- Corrected optimum moisture to the 0.1 percent

ANNEX B

Standardization of The Mold

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedure as described herein will produce inaccurate or unreliable test results.

Apparatus

- Mold and base plate
- Balance or scale – Accurate to within 45 g (0.1 lb) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- Cover plate – A piece of plate glass, at least 6 mm (1⁄4 in) thick and at least 25 mm (1 in) larger than the diameter of the mold.
- Thermometers – Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)

Procedure

1. Create a watertight seal between the mold and base plate.
2. Determine and record the mass of the dry sealed mold, base plate, and cover plate.
3. Fill the mold with water at a temperature between 16°C and 29°C (60°F and 85°F) and cover with the cover plate in such a way as to eliminate bubbles and excess water.
4. Wipe the outside of the mold, base plate, and cover plate dry, being careful not to lose any water from the mold.
5. Determine and record the mass of the filled mold, base plate, cover plate, and water.
6. Determine and record the mass of the water in the mold by subtracting the mass in Step 2 from the mass in Step 5.
7. Measure the temperature of the water and determine its density from Table B1, interpolating as necessary.
8. Calculate the volume of the mold, V_m, by dividing the mass of the water in the mold by the density of the water at the measured temperature.

Calculations

$$V_m = \frac{M}{D}$$

Where:

V_m = volume of the mold
M = mass of water in the mold
D = density of water at the measured temperature

Example

Mass of water in mold = 0.94061 kg (2.0737 lb)

Density of water at 23°C (73.4°F) = 997.54 kg/m^3 (62.274 lb/ft^3)

$$V_m = \frac{0.94061\ kg}{997.54\ kg/m^3} = 0.000943\ m^3 \qquad V_m = \frac{2.0737\ lb}{62.274\ lb/ft^3} = 0.0333\ ft^3$$

Table B1 Unit Mass of Water 15°C to 30°C

°C	(°F)	kg/m^3	(lb/ft^3)	°C	(°F)	kg/m^3	(lb/ft^3)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Report

- Mold ID
- Date Standardized
- Temperature of the water
- Volume, V_m, of the mold

Performance Exam Checklist

FOP for AASHTO T 180
Moisture-Density Relation of Soils

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		Trial 1	Trial 2
1.	If damp, sample dried in air or drying apparatus, not exceeding 60°C (140°F)?		
2.	Sample broken up and an adequate amount sieved over the appropriate sieve (4.75 mm/No. 4 or 19.0 mm/3/4 in) to determine oversize (coarse particle) percentage?		
3.	Sample passing the sieve has appropriate mass?		
4.	If soil is plastic (clay types):		
	a. Multiple samples mixed with water varying moisture content by 1 to 2 percent, bracketing the optimum moisture content?		
	b. Samples placed in covered containers and allowed to stand for at least 12 hours?		
5.	Sample determined to be 4 to 8 percent below expected optimum moisture content?		
6.	Mold placed on rigid and stable foundation?		
7.	Layer of soil (approximately one fifth compacted depth) placed in mold with collar attached, loose material lightly tamped?		
8.	Soil compacted with appropriate number of blows (25 or 56)?		
9.	Material adhering to the inside of the mold trimmed?		
10.	Layer of soil (approximately two fifths compacted depth) placed in mold with collar attached, loose material lightly tamped?		
11.	Soil compacted with appropriate number of blows (25 or 56)?		
12.	Material adhering to the inside of the mold trimmed?		
13.	Layer of soil (approximately three fifths compacted depth) placed in mold with collar attached, loose material lightly tamped?		
14.	Soil compacted with appropriate number of blows (25 or 56)?		
15.	Material adhering to the inside of the mold trimmed?		
16.	Layer of soil (approximately four fifths compacted depth) placed in mold with collar attached, loose material lightly tamped?		
17.	Soil compacted with appropriate number of blows (25 or 56)?		
18.	Material adhering to the inside of the mold trimmed?		
19.	Mold filled with soil such that compacted soil will be above the mold, loose material lightly tamped?		
20.	Soil compacted with appropriate number of blows (25 or 56)?		

Procedure Element	Trial 1	Trial 2
21. Collar removed without shearing off sample?		
22. Approximately 6 mm (¼ in) of compacted material above the top of the mold (without the collar)?		
23. Soil trimmed to top of mold with the beveled side of the straightedge?		
24. Mass of mold and contents determined to appropriate precision?		
25. Wet density calculated from the wet mass?		
26. Soil removed from mold using a sample extruder if needed?		
27. Soil sliced vertically through center (non-granular material)?		
28. Moisture sample removed ensuring all layers are represented?		
29. Moist mass determined immediately to 0.1 g?		
30. Moisture sample mass of correct size?		
31. Sample dried and water content determined according to the FOP for T 255/T 265?		
32. Remainder of material from mold broken up until it will pass through the sieve, as judged by eye, and added to remainder of original test sample?		
33. Water added to increase moisture content of the remaining sample in 1 to 2 percent increments?		
34. Steps 2 through 20 repeated for each increment of water added?		
35. If soil is plastic (clay types):		
a. Samples mixed with water varying moisture content by 1 to 2 percent, bracketing the optimum moisture content?		
b. Samples placed in covered containers and allowed to stand for at least 12 hours?		
36. If material is degradable:		
Multiple samples mixed with water varying moisture content by 1 to 2 percent, bracketing the optimum moisture content?		
37. Process continued until wet density either decreases or stabilizes?		
38. Moisture content and dry density calculated for each sample?		
39. Dry density plotted on vertical axis, moisture content plotted on horizontal axis, and points connected with a smooth curve?		
40. Moisture content at peak of curve recorded as optimum water content and recorded to nearest 0.1 percent?		
41. Dry density at optimum moisture content reported as maximum density to nearest 1 kg/m^3 (0.1 lb/ft^3)?		
42. Corrected for coarse particles if applicable?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

FOP for AASHTO T 209

Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (Hma) Paving Mixtures

Scope

This procedure covers the determination of the maximum specific gravity (G_{mm}) of uncompacted hot mix asphalt (HMA) paving mixtures in accordance with AASHTO T 209-12. Two methods using different containers – bowl and pycnometer/volumetric flask– are covered.

Specimens prepared in the laboratory shall be cured according to agency standards.

Apparatus

- Balance or scale: 10,000 g capacity, readable to 0.1 g
- Container: A glass, metal, or plastic bowl, pycnometer or volumetric flask between 2000 and 10,000 mL as required by the minimum sample size requirements in Table 1 sample and capable of withstanding a partial vacuum
- Pycnometer/volumetric flask cover: A glass plate or a metal or plastic cover with a vented opening
- Vacuum lid: A transparent lid with a suitable vacuum connection, with a vacuum opening to be covered with a fine wire mesh
- Vacuum pump or water aspirator: Capable of evacuating air from the container to a residual pressure of 4.0 kPa (30 mm Hg)
- Residual pressure manometer or vacuum gauge: Traceable to NIST and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less
- Manometer or vacuum gauge: Capable of measuring the vacuum being applied at the source of the vacuum
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)
- Bleeder valve to adjust vacuum
- Timer

Standardization of Pycnometer or Volumetric Flask

Use a pycnometer/volumetric flask that is standardized to accurately determine the mass of water, at 25 ± 0.5°C (77 ± 1°F), in the pycnometer/volumetric flask. The pycnometer/volumetric flask shall be standardized periodically in conformance with procedures established by the agency.

Test Sample Preparation

Obtain samples in accordance with the FOP for AASHTO T 168 and reduce according to the FOP for AASHTO R 47.

Test sample size shall conform to the requirements of Table 1. Samples larger than the capacity of the container may be tested in two or more increments. Results will be combined and averaged. If the increments have a specific gravity difference greater than 0.014 the test must be re-run.

Table 1 Test Sample Size for G_{mm}

Nominal Maximum* Aggregate Size mm (in)		Minimum Mass g
37.5 or greater	(1½)	4000
19 to 25	(¾ to 1)	2500
12.5 or smaller	(½)	1500

*Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained.

Procedure – General

Two procedures – bowl and pycnometer/volumetric flask – are covered. The first 11 steps are the same for both.

1. Separate the particles of the sample, taking care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 6.3 mm (¼ in). If the mixture is not sufficiently soft to be separated manually, place it in a large flat pan and warm in an oven only until it is pliable enough for separation.
2. Cool the sample to room temperature.
3. Determine and record the mass of the dry container to the nearest 0.1 g.
4. Place the sample in the container.
5. Determine and record the mass of the dry container and sample to the nearest 0.1 g.
6. Determine and record the mass of the sample by subtracting the mass determined in Step 3 from the mass determined in Step 5. Designate this mass as “A”.
7. Add sufficient water at approximately 25° C (77° F) to cover the sample by about 25 mm (1 in).

   Note 1: The release of entrapped air may be facilitated by the addition of a wetting agent. Check with the agency to see if this is permitted and, if it is, for a recommended agent.
8. Place the lid on the container and attach the vacuum line. To ensure a proper seal between the container and the lid, wet the O-ring or use a petroleum gel.
9. Remove entrapped air by subjecting the contents to a partial vacuum of 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg) residual pressure for 15 ± 2 minutes.

10. Agitate the container and contents, either continuously by mechanical device or manually by vigorous shaking, at 2 minute intervals. This agitation facilitates the removal of air.

11. Release the vacuum, increasing the pressure to atmospheric pressure in 10 to 15 seconds, turn off the vacuum pump, and remove the lid. When performing the pycnometer/volumetric flask method, complete steps 12B through 16B within 10 ± 1 minutes.

Procedure – Bowl

12A. Fill the water bath to overflow level with water at 25 ± 1°C (77 ± 2°F) and allow the water to stabilize.

13A. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.

14A. Suspend and immerse the bowl and contents in water at 25 ± 1°C (77 ± 2°F) for 10 ± 1 minutes. The holder shall be immersed sufficiently to cover both it and the bowl.

15A. Determine and record the submerged weight of the bowl and contents to the nearest 0.1 g.

16A. Refill the water bath to overflow level.

17A. Empty and re-submerge the bowl following Step 12A to determine the submerged weight of the bowl to the nearest 0.1 g.

18A. Determine and record the submerged weight of the sample to the nearest 0.1 g by subtracting the submerged weight of the bowl from the submerged weight determined in Step 15A. Designate this submerged weight as “C”.

Procedure – Pycnometer or Volumetric Flask

12B. Immediately fill the pycnometer/volumetric flask with water without reintroducing air.

13B. Stabilize the temperature of the pycnometer/volumetric flask and contents so that the final temperature is within 25 ± 1°C (77 ± 2°F).

14B. Finish filling the pycnometer/volumetric flask with water that is 25 ± 1°C (77 ± 2°F), place the cover or a glass plate on the pycnometer/volumetric flask, and eliminate all air.

Note 2: When using a metal pycnometer and cover, place the cover on the pycnometer and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling the pycnometer to avoid reintroducing air into the water.

15B. Towel dry the outside of the pycnometer/volumetric flask and cover.

16B. Determine and record the mass of the pycnometer/volumetric flask, cover, de-aired water, and sample to the nearest 0.1 g. within 10 ± 1 minutes of completion of Step 11. Designate this mass as “E.”

Procedure – Mixtures Containing Uncoated Porous Aggregate

If the pores of the aggregates are not thoroughly sealed by a bituminous film, they may become saturated with water during the vacuuming procedure, resulting in an error in maximum density. To determine if this has occurred, complete the general procedure and then:

1. Carefully drain water from sample through a towel held over the top of the container to prevent loss of material.
2. Spread sample in a flat shallow pan and place before an electric fan to remove surface moisture.
3. Determine the mass of the sample when the surface moisture appears to be gone.
4. Continue drying and determine the mass of the sample at 15-minute intervals until less than a 0.5 g loss is found between determinations.
5. Record the mass as the saturated surface dry mass to the nearest 0.1 g. Designate this mass as "A_{SSD}".
6. Calculate, as indicated below, G_{mm}, using "A" and "A_{SSD}", and compare the two values.

Calculation

Calculate the G_{mm} to three decimal places as follows:

Bowl Procedure

$$G_{mm} = \frac{A}{A - C} \qquad or \qquad G_{mm} = \frac{A}{A_{SSD} - C}$$

(for mixes containing uncoated aggregate materials)

where:

A = mass of dry sample in air, g
A_{SSD} = Mass of saturated surface dry sample in air, g
C = submerged weight of sample in water, g

Example:

A = 1432.7 g

A_{SSD} = 1434.2 g

C = 848.6 g

$$G_{mm} = \frac{1432.7\ g}{1432.7\ g - 848.6\ g} = 2.453 \qquad or \qquad G_{mm} = \frac{1432.7\ g}{1434.2\ g - 848.6\ g} = 2.447$$

Pycnometer/Volumetric Flask Procedure

$$G_{mm} = \frac{A}{A + D - E} \qquad or \qquad G_{mm} = \frac{A}{A_{SSD} + D - E}$$

(for mixtures containing uncoated materials)

where:

A = Mass of dry sample in air, g
A_{SSD} = Mass of saturated surface-dry sample in air, g
D = Mass of pycnometer/volumetric flask filled with water at 25°C (77°F), g, determined during the Standardization of Pycnometer/Volumetric Flask procedure
E = Mass of pycnometer/volumetric flask filled with water and the test sample at test temperature, g

Example (in which two increments of a large sample are averaged):

Increment 1	**Increment 2**
A = 2200.3 g	A = 1960.2 g
D = 7502.5 g	D = 7525.5 g
E = 8812.0 g	E = 8690.8 g
Temperature = 26.2°C	Temperature = 25.0°C

$$G_{mm_1} = \frac{2200.3\ g}{2200.3\ g + 7502.5\ g - 8812.0\ g} = 2.470$$

$$G_{mm_2} = \frac{1960.2\ g}{1960.2\ g + 7525.5\ g - 8690.8\ g} = 2.466$$

Allowable variation is: 0.014

2.470 - 2.466 = 0.004, which is < 0.014, so they can be averaged.

Average

2.470 + 2.466 = 4.936 4.936 ÷ 2 = 2.468

Theoretical Maximum Density

To calculate the theoretical maximum density at 25°C (77°F) use one of the following formulas. The density of water at 25°C (77°F) is 997.1 in Metric units or 62.245 in English units.

Theoretical maximum density kg/m^3 = G_{mm} × 997.1 kg/m^3

2.468 × 997.1 kg/m^3 = 2461 kg/m^3

or

Theoretical maximum density lb/ft^3 = G_{mm} × 62.245 lb/ft^3

2.468 × 62.245 lb/ft^3 = 153.6 lb/ft^3

Report

- Results on forms approved by the agency
- Sample ID
- G_{mm} to three decimal places
- Theoretical maximum density to1 kg/m^3 (0.1 lb/ft^3)

Performance Exam Checklist

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

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		Trial 1	Trial 2
1.	Sample reduced to correct size?		
2.	Particles carefully separated insuring that aggregate is not fractured?		
3.	After separation, fine aggregate particles not larger than 6.3 mm (¼ in)?		
4.	Sample at room temperature?		
5.	Mass of container determined to 0.1 g?		
6.	Mass of sample and container determined to 0.1 g?		
7.	Mass of sample calculated and conforms to required size?		
8.	Water at approximately 25°C (77°F) added to cover sample?		
9.	Entrapped air removed using partial vacuum for 15 ± 2 min?		
10.	Container and contents agitated continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes?		
11.	Bowl determination:		
	a. Water bath filled to the overflow level?		
	b. Bowl and contents suspended in water at 25 ± 1°C (77 ± 2°F) for 10 ± 1 minutes?		
	c. Submerged weight of bowl and contents determined to 0.1 g?		
	d. Submerged weight of empty bowl determined to 0.1 g?		
	e. Net submerged weight of contents calculated?		

Procedure Element	Trial 1	Trial 2
12. Pycnometer/Volumetric Flask determination:		
a. Pycnometer/volumetric flask filled with water without reintroducing air into the sample?	_____	_____
b. Contents stabilized at 25 ± 1°C (77 ± 2°F)	_____	_____
c. Pycnometer/volumetric flask completely filled with water that is 25 ± 1°C (77 ± 2°F)?	_____	_____
d. Mass of filled pycnometer/volumetric flask and cover determined to 0.1 g, 10 ± 1 minutes after removal of entrapped air completed?	_____	_____
e. Mass of pycnometer/volumetric flask, cover, and water obtained from the Standardization of Pycnometer or Volumetric Flask procedure?	_____	_____
13. G_{mm} calculated correctly and reported to 0.001?	_____	_____
14. Density calculated correctly and reported to 1 kg/m^3 (0.1 lb/ft^3)?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

FOP for AASHTO T 255

Total Evaporable Moisture Content of Aggregate by Drying

WAQTC FOP for AASHTO T 255 has been adopted by WSDOT with the following changes:

Sample Preparation

TABLE 1 Sample Sizes for Moisture Content of Aggregate – *Shall include the note below.*

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 percent of the materials.

FOP for AASHTO T 255

Total Evaporable Moisture Content of Aggregate by Drying

WAQTC FOP for AASHTO T 255 has been adopted by WSDOT with the following changes:

Sample Preparation

TABLE 1 Sample Sizes for Moisture Content of Aggregate – *Shall include the note below.*

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 percent of the materials.

WSDOT Errata to FOP for AASHTO T 255

Total Evaporable Moisture Content of Aggregate by Drying

Scope

This procedure covers the determination of moisture content of aggregate in accordance with AASHTO T 255-00. It may also be used for other construction materials.

Overview

Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

Constant mass – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus

- Balance or scale: Capacity sufficient for the principle sample mass, accurate to 0.1 percent of sample mass or readable to 0.1 g, meeting the requirements of AASHTO M 231.
- Containers: clean, dry and capable of being sealed
- Suitable drying containers
- Microwave safe container with ventilated lids
- Heat source, controlled
  - Forced draft oven
  - Ventilated oven
  - Convection oven
- Heat source, uncontrolled
  - Infrared heater, hot plate, fry pan, or any other device/method that will dry the sample without altering the material being dried
  - Microwave oven (900 watts minimum)
- Hot pads or gloves
- Utensils such as spoons

Sample Preparation

In accordance with the FOP for AASHTO T 2 obtain a representative sample in its existing condition. The representative sample size is based on Table 1 or other information that may be specified by the agency.

Table 1 Sample Sizes for Moisture Content of Aggregate

Nominal Maximum Size* mm (in)		Minimum Sample Mass g (lb)	
150	(6)	50,000	(110)
100	(4)	25,000	(55)
90	(3½)	16,000	(35)
75	(3)	13,000	(29)
63	(2½)	10,000	(22)
50	(2)	8000	(18)
37.5	(1½)	6000	(13)
25.0	(1)	4000	(9)
19.0	(¾)	3000	(7)
12.5	(½)	2000	(4)
9.5	(⅜)	1500	(3.3)
4.75	(No. 4)	500	(1.1)

*One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Immediately seal or cover samples to prevent any change in moisture content or follow the steps in "Procedure."

Procedure

Determine all masses to the nearest 0.1 percent of the sample mass or to the nearest 0.1 g.

When determining the mass of hot samples or containers or both, place and tare a buffer between the sample container and the balance. This will eliminate damage to or interference with the operation of the balance or scale.

1. Determine and record the mass of the container (and lid for microwave drying).
2. Place the wet sample in the container.
   a. For oven(s), hot plates, infrared heaters, etc.: Spread the sample in the container.
   b. For microwave oven: Heap sample in the container; cover with ventilated lid.
3. Determine and record the total mass of the container and wet sample.
4. Determine and record the wet mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 3.

5. Place the sample in one of the following drying apparatus:
   a. Controlled heat source (oven): at 110 ± 5°C (230 ± 9°F).
   b. Uncontrolled heat source (Hot plate, infrared heater, etc.): Stir frequently to avoid localized overheating.
6. Dry until sample appears moisture free.
7. Determine mass of sample and container.
8. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 7.
9. Return sample and container to the heat source for additional drying.
   a. Controlled (oven): 30 minutes
   b. Uncontrolled (Hot plate, infrared heater, etc.): 10 minutes
   c. Uncontrolled (Microwave oven): 2 minutes

Caution: Some minerals in the sample may cause the aggregate to overheat, altering the aggregate gradation.

10. Determine mass of sample and container.
11. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 10.
12. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
13. Continue drying, performing steps 9 through 12, until there is less than a 0.10 percent change after additional drying time.
14. Constant mass has been achieved, sample is defined as dry.
15. Allow the sample to cool. Determine and record the total mass of the container and dry sample.
16. Determine and record the dry mass of the sample by subtracting the mass of the container determined in Step 1 from the mass of the container and sample determined in Step 15.
17. Determine and record percent moisture by subtracting the final dry mass determination (M_D) from the initial wet mass determination (M_W) divide by the final dry mass determination (M_D) multiply by 100.

Table 2 Methods of Drying

Heat Source	Specific Instructions	Drying intervals to achieve constant mass (minutes)
Controlled: Forced Draft Oven (preferred), Ventilated Oven, or Convection Oven	110 ± 5°C (230 ± 9°F)	30
Uncontrolled:		
Hot plate, Infrared heater, etc.	Stir frequently	10
Microwave	Heap sample and cover with ventilated lid	2

Calculation

Constant Mass:

Calculate constant mass using the following formula:

$$\frac{M_p - M_n}{M_p} \times 100 = \%\ \text{Change}$$

Where:

M_p = previous mass measurement
M_n = new mass measurement

Example:

Mass of container: 1232.1 g

Mass of container after first drying cycle: 2637.2 g

Mass, M_p, of possibly dry sample: 2637.2 g - 1232.1 g = 1405.1 g

Mass of container and dry sample after second drying cycle: 2634.1 g

Mass, M_n, of dry sample: 2634.1 g - 1232.1 g = 1402.0 g

$$\frac{1405.1\ \text{g} - 1402.0\ \text{g}}{1405.1\ \text{g}} \times 100 = 0.22\%$$

0.22 percent is not less than 0.10 percent, so continue drying

Mass of container and dry sample after third drying cycle: 2633.0 g

Mass, M_n, of dry sample: 2633.0 g - 1232.1 g = 1400.9 g

$$\frac{1402.0\ \text{g} - 1400.9\ \text{g}}{1402.0\ \text{g}} \times 100 = 0.08\%$$

0.08 percent is less than 0.10 percent, so constant mass has been reached

Moisture Content:

Calculate the moisture content, w, as a percent, using the following formula:

$$\frac{M_W - M_D}{M_D} \times 100 = \%\ Moisture\ Content$$

Where:

M_W = wet mass
M_D = dry mass

Example:

Mass of container: 1232.1 g

Mass of container and wet sample: 2764.7 g

Mass, M_W, of wet sample: 2764.7 g - 1232.1 g = 1532.6 g

Mass of container and dry sample (COOLED): 2633.0 g

Mass, M_D, of dry sample: 2633.0 g - 1232.1 g = 1400.9 g

$$w = \frac{1532.6\text{g} - 1400.9\text{g}}{1400.9\text{g}} \times 100 = \frac{131.7\text{g}}{1400.9\text{g}} = 9.40\%\ \text{rounded to}\ 9.4\%$$

Report

- Results on forms approved by the agency
- Sample ID
- M_W, wet mass
- M_D, dry mass
- w, moisture content to nearest 0.1 percent

FOP for AASHTO T 255

Total Evaporable Moisture Content of Aggregate by Drying

FOP for AASHTO T 265

Laboratory Determination of Moisture Content of Soils

Scope

This procedure covers the determination of moisture content of aggregate and soil in accordance with AASHTO T 255-00 and AASHTO T 265-15. It may also be used for other construction materials.

Overview

Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

Constant mass – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus

- Balance or scale: capacity sufficient for the principle sample mass, accurate to 0.1 percent of sample mass or readable to 0.1 g, and meeting the requirements of AASHTO M 231
- Containers, clean, dry and capable of being sealed
- Suitable drying containers
- Microwave safe container with ventilated lid
- Heat source, controlled:
  - Forced draft oven
  - Ventilated oven
  - Convection oven
- Heat source, uncontrolled:
  - Infrared heater/heat lamp, hot plate, fry pan, or any other device/method that will dry the sample without altering the material being dried
  - Microwave oven (900 watts minimum)
- Utensils such as spoons
- Hot pads or gloves

Sample Preparation

In accordance with the FOP for AASHTO T 2 obtain a representative sample in its existing condition.

For aggregates the representative sample size is based on Table 1 or other information that may be specified by the agency.

Table 1 Sample Sizes for Moisture Content of Aggregate

Nominal Maximum Size* mm (in)		Minimum Sample Mass g (lb)	
4.75	(No. 4)	500	(1.1)
9.5	(⅜)	1500	(3.3)
12.5	(½)	2000	(4)
19.0	(¾)	3000	(7)
25.0	(1)	4000	(9)
37.5	(1½)	6000	(13)
50	(2)	8000	(18)
63	(2½)	10,000	(22)
75	(3)	13,000	(29)
90	(3½)	16,000	(35)
100	(4)	25,000	(55)
150	(6)	50,000	(110)

*One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum.

For soils the representative sample size is based on Table 2 or other information that may be specified by the agency.

Table 2 Sample Sizes for Moisture Content of Soil

Maximum Particle Size mm (in)		Minimum Sample Mass g (lb)
0.425	(No. 40)	10
4.75	(No. 4)	100
12.5	(½)	300
25.0	(1)	500
50	(2)	1000

Immediately seal or cover samples to prevent any change in moisture content or follow the steps in “Procedure.”

Procedure

Determine and record the sample mass as follows:

- For aggregate, determine and record all masses to the nearest 0.1 percent of the sample mass or to the nearest 0.1 g.
- For soil, determine and record all masses to the nearest 0.1 g.

When determining the mass of hot samples or containers or both, place and tare a buffer between the sample container and the balance. This will eliminate damage to or interference with the operation of the balance or scale.

1. Determine and record the mass of the container (and lid for microwave drying).
2. Place the wet sample in the container.
    a. For oven(s), hot plates, infrared heaters, etc.: Spread the sample in the container.
    b. For microwave oven: Heap sample in the container; cover with ventilated lid.
3. Determine and record the total mass of the container and wet sample.
4. Determine and record the wet mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 3.
5. Place the sample in one of the following drying apparatus:
    a. For aggregate –
        i. Controlled heat source (oven): at 110 ± 5°C (230 ± 9°F).
        ii Uncontrolled heat source (Hot plate, infrared heater, etc.): Stir frequently to avoid localized overheating.
    b. For soil – controlled heat source (oven): at 110 ± 5°C (230 ± 9°F).

    Note 1: Soils containing gypsum or significant amounts of organic material require special drying. For reliable moisture contents dry these soils at 60°C (140°F). For more information see AASHTO T 265, Note 2.
6. Dry until sample appears moisture free.
7. Determine mass of sample and container.
8. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 7.
9. Return sample and container to the heat source for additional drying.
    a. For aggregate –
        i. Controlled heat source (oven): 30 minutes
        ii. Uncontrolled heat source (Hot plate, infrared heater, etc.): 10 minutes
        iii. Uncontrolled heat source (Microwave oven): 2 minutes

        Caution: Some minerals in the sample may cause the aggregate to overheat, altering the aggregate gradation.
    b. For soil – controlled heat source (oven): 1 hour

10. Determine mass of sample and container.
11. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 10.
12. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
13. Continue drying, performing steps 9 through 12, until there is less than a 0.10 percent change after additional drying time.
14. Constant mass has been achieved, sample is defined as dry.
15. Allow the sample to cool. Immediately determine and record the total mass of the container and dry sample.
16. Determine and record the dry mass of the sample by subtracting the mass of the container determined in Step 1 from the mass of the container and sample determined in Step 15.
17. Determine and record percent moisture by subtracting the final dry mass determination (M_D) from the initial wet mass determination (M_W) divide by the final dry mass determination (M_D) multiply by 100.

Table 3 Methods of Drying

Aggregate		
Heat Source	**Specific Instructions**	**Drying intervals to achieve constant mass (minutes)**
Controlled: Forced draft (preferred), ventilated, or convection oven	110 ± 5°C (230 ± 9°F)	30
Uncontrolled: Hot plate, infrared heater, etc.	Stir frequently	10
Microwave	Heap sample and cover with ventilated lid	2
Soil		
Heat Source	**Specific Instructions**	**Drying increments (minutes)**
Controlled: Forced draft (preferred), ventilated, or convection oven	110 ± 5°C (230 ± 9°F)	1 hour

Calculation

Constant Mass:

Calculate constant mass using the following formula:

$$\frac{M_p - M_n}{M_p} \times 100 = \%\ \text{Change}$$

Where:

M_p = previous mass measurement
M_n = new mass measurement

Example:

Mass of container: 1232.1 g

Mass of container and sample after first drying cycle: 2637.2 g

Mass, M_p, of possibly dry sample: 2637.2 g - 1232.1 g = 1405.1 g

Mass of container and dry sample after second drying cycle: 2634.1 g

Mass, M_n, of dry sample: 2634.1 g - 1232.1 g = 1402.0 g

$$\frac{1405.1\ g - 1402.0\ g}{1405.1\ g} \times 100 = 0.22\%$$

0.22 percent is not less than 0.10 percent, so continue drying

Mass of container and dry sample after third drying cycle: 2633.0 g

Mass, M_n, of dry sample: 2633.0 g - 1232.1 g = 1400.9 g

$$\frac{1402.0\ g - 1400.9\ g}{1402.0\ g} \times 100 = 0.08\%$$

0.08 percent is less than 0.10 percent, so constant mass has been reached.

Moisture Content:

Calculate the moisture content, as a percent, using the following formula:

$$w = \frac{M_W - M_D}{M_D} \times 100$$

Where:

w = moisture content, percent
M_W = wet mass
M_D = dry mass

Example:

Mass of container: 1232.1 g

Mass of container and wet sample: 2764.7 g

Mass, M_W, of wet sample: 2764.7 g - 1232.1 g = 1532.6 g

Mass of container and dry sample (COOLED): 2633.5 g

Mass, M_D, of dry sample: 2633.5 g - 1232.1 g = 1401.4 g

$$w = \frac{1532.6\ g - 1401.4\ g}{1401.4\ g} \times 100 = \frac{131.2 g}{1401.4\ g} \times 100 = 9.36\% \quad report\ 9.4\%$$

Report

- Results on forms approved by the agency
- Sample ID
- M_W, wet mass
- M_D, dry mass
- w, moisture content to nearest 0.1 percent

Performance Exam Checklist

FOP for AASHTO T 265
Laboratory Determination of Moisture Content of Soils

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	Representative sample of appropriate mass obtained?		
2.	Mass of container determined to 0.1 g?		
3.	Sample placed in container and mass determined to 0.1 g?		
4.	Test sample mass conforms to the required mass?		
5.	Wet sample mass determined to 0.1 g?		
6.	Loss of moisture avoided prior to mass determination?		
7.	Sample dried by a suitable heat source?		
8.	If aggregate heated by means other than a controlled oven, is sample stirred to avoid localized overheating?		
9.	For aggregate: Is aggregate heated for the additional, specified time (forced draft, ventilated, convection – 30 minutes; microwave – 2 minutes; other 10 minutes) and then mass determined and compared to previous mass showing less than 0.10 percent loss?		
10.	For soil: Is soil heated for at least 1hour additional drying time and then mass determined and compared to previous mass - showing less than 0.10 percent loss?		
11.	Sample cooled, dry mass determined and recorded to the nearest 0.1 percent?		
12.	Moisture content calculated correctly and recorded to the nearest 0.1 percent?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

FOP for AASHTO T 272

One-Point Method For Determining Maximum Dry Density And Optimum Moisture

Scope

This procedure provides for a rapid determination of the maximum dry density and optimum moisture content of a soil sample, using a one-point determination in accordance with AASHTO T 272-16. This procedure is related to the FOPs for AASHTO T 99/T 180 and R 75.

One-point determinations are made by compacting the soil in a mold of a given size with a specified rammer dropped from a specified height and then compared to an individual moisture/density curve (FOP for AASHTO T 99 or T 180) or a family of curves (FOP for AASHTO R 75). Four alternate methods – A, B, C, and D – are used and correspond to the methods described in the FOP for AASHTO T 99/T 180. The method used in AASHTO T 272 must match the method used for the reference curve or to establish the family of curves. For example, when moisture-density relationships as determined by T 99 - Method C are used to form the family of curves or an individual moisture density curve, then T 99 - Method C must be used to for the one-point determination.

Apparatus

See the FOP for AASHTO T 99/T 180. Use the method matching the individual curve or Family of Curves. Refer to Table 1 of the FOP for AASHTO T 99/T 180 for corresponding mold size, number of layers, number of blows, and rammer specification for the various test methods.

Sample

Sample size determined according to the FOP for AASHTO T 310. In cases where the existing individual curve or family cannot be used a completely new curve will need to be developed and the sample size will be determined by the FOP for AASHTO T 99/T 180.

If the sample is damp, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus maintained at a temperature not exceeding 60°C (140°F). Thoroughly break up aggregations in a manner that avoids reducing the natural size of individual particles.

Procedure

1. Determine the mass of the clean, dry mold. Include the base plate, but exclude the extension collar. Record the mass to the nearest 1 g (0.005 lb).
2. Thoroughly mix the sample with sufficient water to adjust moisture content to 80 to 100 percent of the anticipated optimum moisture.
3. Form a specimen by compacting the prepared soil in the mold (with collar attached) in approximately equal layers. For each layer:
   a. Spread the loose material uniformly in the mold.

      Note 1: It is recommended to cover the remaining material with a non-absorbent sheet or damp cloth to minimize loss of moisture.

   b. Lightly tamp the loose material with the manual rammer or other similar device, this establishes a firm surface.
   c. Compact each layer with uniformly distributed blows from the rammer.
   d. Trim down material that has not been compacted and remains adjacent to the walls of the mold and extends above the compacted surface.
4. Remove the extension collar. Avoid shearing off the sample below the top of the mold. The material compacted in the mold should not be over 6 mm (¼ in) above the top of the mold once the collar has been removed.
5. Trim the compacted soil even with the top of the mold with the beveled side of the straightedge.
6. Determine the mass of the mold and wet soil to the nearest 1 g (0.005 lb) or better.
7. Determine the wet mass of the sample by subtracting the mass in Step 1 from the mass in Step 6.
8. Calculate the wet density as indicated below under “Calculations.”
9. Extrude the material from the mold. For soils and soil-aggregate mixtures, slice vertically through the center and take a representative moisture content sample from one of the cut faces, ensuring that all layers are represented. For granular materials, a vertical face will not exist. Take a representative sample. This sample must meet the sample size requirements of the test method used to determine moisture content.
10. Determine the moisture content of the sample in accordance with the FOP for AASHTO T 255/T 265.

Calculations

1. Calculate the wet density, in kg/m^3 (lb/ft^3), by dividing the wet mass by the measured volume of the mold (T 19).

   Example – Methods A or C mold:

   Wet mass = 2.0055 kg (4.42 lb)

   Measured volume of the mold = 0.0009469 m^3 (0.03344 ft^3)

$$Wet\ Density = \frac{2.0055\ kg}{0.0009469\ m^3} = 2118\ kg/m^3$$

$$Wet\ Density = \frac{4.42\ lb}{0.03344\ ft^3} = 132.2\ lb/ft^3$$

2. Calculate the dry density as follows.

$$\rho_d = \left(\frac{\rho_w}{w + 100}\right) \times 100 \quad or \quad \rho_d = \frac{\rho_w}{\left(\frac{w}{100}\right) + 1}$$

Where:

ρ_d = Dry density, kg/m^3 (lb/ft^3)
ρ_w = Wet density, kg/m^3 (lb/ft^3)
w = Moisture content, as a percentage

Example:

ρ_w = 2118 kg/m^3 (132.2 lb/ft^3)
w = 13.5%

$$\rho_d = \left(\frac{2118\ kg/m^3}{13.5 + 100}\right) \times 100 = 1866\ kg/m^3 \quad \rho_d = \left(\frac{132.2\ lb/ft^3}{13.5 + 100}\right) \times 100 = 116.5\ lb/ft^3$$

or

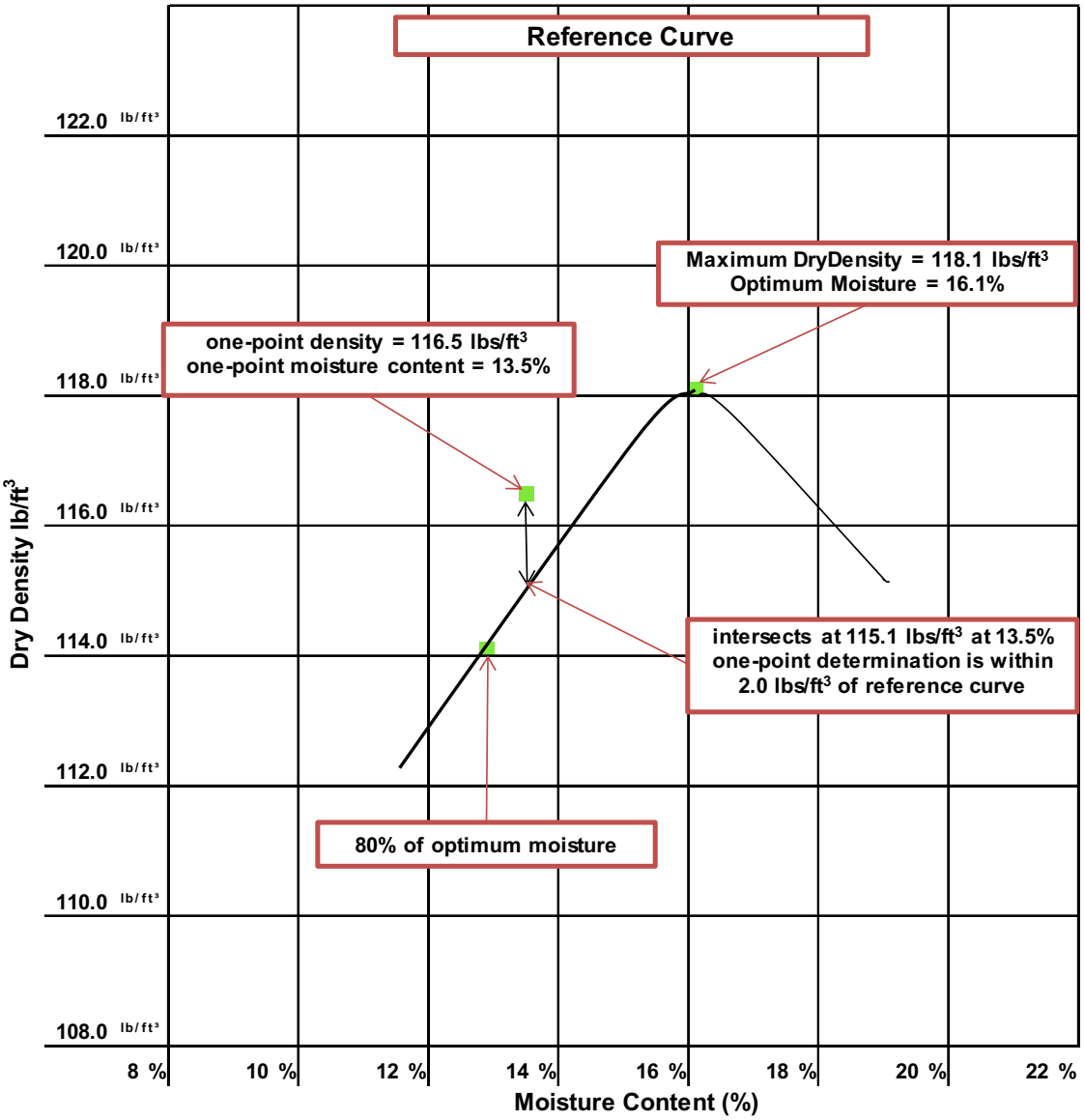
$$\rho_d = \left(\frac{2118\ kg/m^3}{\frac{13.5}{100} + 1}\right) = 1866\ kg/m^3 \quad \rho_d = \left(\frac{132.2\ lb/ft^3}{\frac{13.5}{100} + 1}\right) = 116.5\ lb/ft^3$$

Maximum Dry Density and Optimum Moisture Content Determination Using an Individual Moisture / Density Curve

1. The moisture content must be within 80 to 100 percent of optimum moisture of the reference curve. Compact another specimen, using the same material, at an adjusted moisture content if the one-point does not fall in the 80 to 100 percent of optimum moisture range.
2. If the moisture content of the one-point determination is not within 80 to 100 percent of the optimum moisture content, compact another specimen, using the same material, at adjusted moisture content.
3. Plot the one-point, dry density on the vertical axis and moisture content on the horizontal axis, on the reference curve graph.

4. If the one-point falls on the reference curve or within ± 2.0 lbs/ft^3, then the maximum dry density and optimum moisture content determined by the curve can be used.
5. Perform a full moisture-density relationship if the one-point does not fall on or within ± 2.0 lbs/ft^3 of the reference curve at 80 to 100 percent optimum moisture.

Example



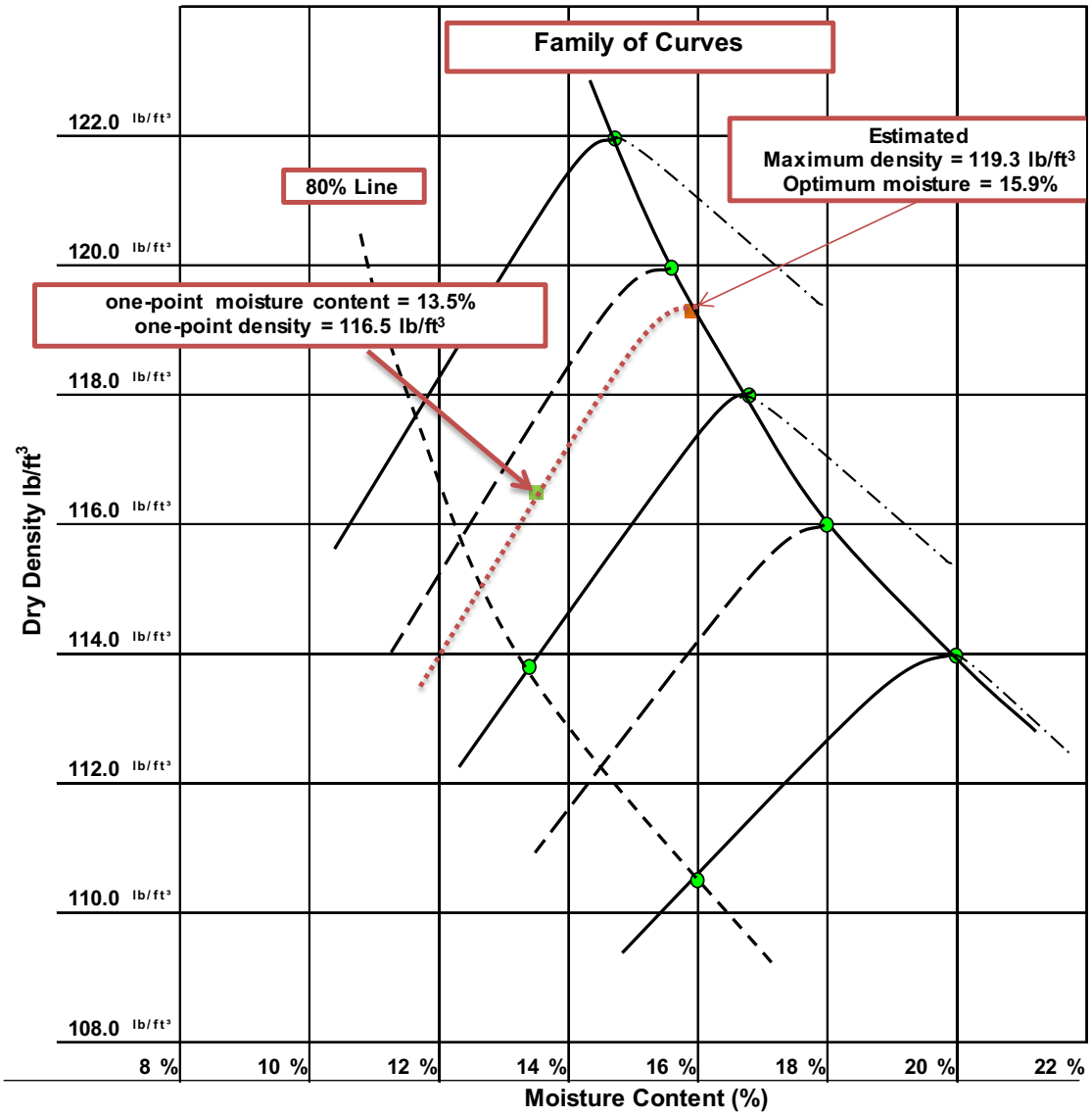
The results of a one-point determination were 116.5 lb/ft^3 at 13.5 percent moisture. The point was plotted on the reference curve graph. The one-point determination is within 2.0 lb/ft^3 of the point on the curve that corresponds with the moisture content.

Maximum Dry Density and Optimum Moisture Content Determination Using a Family of Curves

1. If the moisture-density one-point falls on one of the curves in the family of curves, the maximum dry density and optimum moisture content defined by that curve is used.
2. If the moisture-density one-point falls within the family of curves but not on an existing curve, draw a new curve through the plotted single point, parallel and in character with the nearest existing curve in the family of curves. Use the maximum dry density and optimum moisture content as defined by the new curve.
3. The one-point must fall either between or on the highest or lowest curves in the family. If it does not, then a full curve must be developed.
4. If the one-point plotted within or on the family of curves does not fall in the 80 to 100 percent of optimum moisture content, compact another specimen, using the same material, at an adjusted moisture content that will place the one point within this range.
5. If the new curve through a one-point is not well defined or is in any way questionable, perform a full moisture-density relationship to correctly define the new curve and verify the applicability of the family of curves.

   Note 2: New curves drawn through plotted single point determinations shall not become a permanent part of the family of curves until verified by a full moisture-density procedure following the FOP for AASHTO T 99/T 180.

Example



The results of a one-point determination were 116.5 lb/ft^3 at 13.5 percent moisture. The point was plotted on the reference curve graph. The point was plotted on the appropriate family between two previously developed curves near and intermediate curve.

The "dotted" curve through the moisture-density one-point was sketched between the existing curves. A maximum dry density of 119.3 lb/ft^3 and a corresponding optimum moisture content of 15.9 percent were estimated.

Report

- Results on forms approved by the agency
- Sample ID
- Maximum dry density to the closest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the closest 0.1 percent
- Reference curve or Family of Curves used

Performance Exam Checklist

FOP for AASHTO T 272 (T 99)
One-Point Method

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		Trial 1	Trial 2
1.	One-point determination of dry density and corresponding moisture content made in accordance with the FOP for AASHTO T 99?		
	a. Correct size (4.75 mm/No. 4 or 19.0 mm / ¾ in) material used?		
2.	If necessary, sample dried until friable in air or drying apparatus, not exceeding 60°C (140°F)?		
3.	Sample broken up and an adequate amount sieved over the appropriate sieve (4.75 mm / No. 4 or 19.0 mm / ¾ in) to determine oversize (coarse particle) percentage?		
4.	Sample passing the sieve has appropriate mass?		
5.	Layer of soil (approximately one third compacted depth) placed in mold with collar attached, loose material lightly tamped?		
6.	Soil compacted with appropriate number of blows (25 or 56)?		
7.	Material adhering to the inside of the mold trimmed?		
8.	Layer of soil (approximately two thirds compacted depth) placed in mold with collar attached, loose material lightly tamped?		
9.	Soil compacted with appropriate number of blows (25 or 56)?		
10.	Material adhering to the inside of the mold trimmed?		
11.	Mold filled with soil such that compacted soil will be above the mold, loose material lightly tamped?		
12.	Soil compacted with appropriate number of blows (25 or 56)?		
13.	Collar removed without shearing off sample?		
14.	Approximately 6 mm (¼ in) of compacted material above the top of the mold (without the collar)?		
15.	Soil trimmed to top of mold with the beveled side of the straightedge?		
16.	Mass of mold and contents determined to appropriate precision?		
17.	Wet density calculated from the wet mass?		
18.	Soil removed from mold using a sample extruder if needed?		
19.	Soil sliced vertically through center (non-granular material)?		
20.	Moisture sample removed ensuring all layers are represented?		
21.	Moist mass determined immediately to 0.1 g?		
22.	Moisture sample mass of correct size?		

Procedure Element	Trial 1	Trial 2
23. Sample dried and water content determined according to the FOP for T 255/T 265?	_____	_____
24. One-point plotted on family of curves supplied?	_____	_____
25. One-point falls within 80 to 100 percent of optimum moisture content in order to be valid?	_____	_____
26. If one-point does not fall within 80 to 100 percent of optimum moisture content, another one-point determination with an adjusted water content is made?	_____	_____
27. Maximum dry density and corresponding optimum moisture content correctly estimated?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

Performance Exam Checklist

ONE-POINT METHOD
FOP FOR AASHTO T 272 (T 180)

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		Trial 1	Trial 2
1.	One-point determination of dry density and corresponding moisture content made in accordance with the FOP for AASHTO T 180?		
	a. Correct size (4.75 mm / No. 4 or 19.0 mm / ¾ in.) material used?		
2.	If necessary, sample dried until friable in air or drying apparatus, not exceeding 60°C (140°F)?		
3.	Sample broken up and an adequate amount sieved over the appropriate sieve (4.75 mm / No. 4 or 19.0 mm / ¾ in.) to determine oversize (coarse particle) percentage?		
4.	Sample passing the sieve has appropriate mass?		
5.	Mold placed on rigid and stable foundation?		
6.	Layer of soil (approximately one fifth compacted depth) placed in mold with collar attached, loose material lightly tamped?		
7.	Soil compacted with appropriate number of blows (25 or 56)?		
8.	Material adhering to the inside of the mold trimmed?		
9.	Layer of soil (approximately two fifths compacted depth) placed in mold with collar attached, loose material lightly tamped?		
10.	Soil compacted with appropriate number of blows (25 or 56)?		
11.	Material adhering to the inside of the mold trimmed?		
12.	Layer of soil (approximately three fifths compacted depth) placed in mold with collar attached, loose material lightly tamped?		
13.	Soil compacted with appropriate number of blows (25 or 56)?		
14.	Material adhering to the inside of the mold trimmed?		
15.	Layer of soil (approximately four fifths compacted depth) placed in mold with collar attached, loose material lightly tamped?		
16.	Soil compacted with appropriate number of blows (25 or 56)?		
17.	Material adhering to the inside of the mold trimmed?		
18.	Mold filled with soil such that compacted soil will be above the mold, loose material lightly tamped?		
19.	Soil compacted with appropriate number of blows (25 or 56)?		
20.	Collar removed without shearing off sample?		

Procedure Element	Trial 1	Trial 2
21. Approximately 6 mm (¼ in) of compacted material above the top of the mold (without the collar)?	_____	_____
22. Soil trimmed to top of mold with the beveled side of the straightedge?	_____	_____
23. Mass of mold and contents determined to appropriate precision?	_____	_____
24. Wet density calculated from the wet mass?	_____	_____
25. Soil removed from mold using a sample extruder if needed?	_____	_____
26. Soil sliced vertically through center (non-granular material)?	_____	_____
27. Moisture sample removed ensuring all layers are represented?	_____	_____
28. Moist mass determined immediately to 0.1 g?	_____	_____
29. Moisture sample mass of correct size?	_____	_____
30. Sample dried and water content determined according to the FOP for T 255/T 265?	_____	_____
31. One-point plotted on family of curves supplied?	_____	_____
32. One-point falls within 80 to 100 percent of optimum moisture content in order to be valid?	_____	_____
33. If one-point does not fall within 80 to 100 percent of optimum moisture content, another one-point determination with an adjusted water content is made?	_____	_____
34. Maximum dry density and corresponding optimum moisture content correctly estimated?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

WSDOT Errata to FOP for AASHTO T 308

Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

WAQTC FOP for AASHTO T 308 has been adopted by WSDOT with the following changes:

Procedure – Method B (External Balance) – *Method not recognized by WSDOT.*

Annex – Correction Factors

Asphalt Binder and Aggregate

Asphalt binder correction factor – *Shall read as below:*

A correction factor must be established by testing a set of correction specimens for each Job Mix Formula (JMF).

Aggregate correction factor - *Method not recognized by WSDOT.*

Procedure

Steps 9 – 13 not recognized by WSDOT.

FOP for AASHTO T 308

Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

Scope

This procedure covers the determination of asphalt binder content of hot mix asphalt (HMA) by ignition of the binder in accordance with AASHTO T 308-16.

Overview

The sample is heated in a furnace at 538°C (1000°F) or less; samples may be heated by convection or direct infrared irradiation (IR). The aggregate remaining after burning can be used for sieve analysis using the FOP for AASHTO T 30.

Some agencies allow the use of recycled HMA. When using recycled HMA, check with the agency for specific correction procedures.

Asphalt binder in the HMA is ignited in a furnace. Asphalt binder content is calculated as the percentage difference between the initial mass of the HMA and the mass of the residual aggregate, with the asphalt binder correction factor, and moisture content subtracted. The asphalt binder content is expressed as percent of moisture-free mix mass.

Two methods, A and B, are presented.

Apparatus

Note 1: The apparatus must be calibrated for the specific mix design. See "Correction Factors" at the end of this FOP.

There are two methods – A and B. The apparatus for the two methods are the same except that the furnace for Method A has an internal balance.

- Ignition Furnace: A forced-air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The convection-type furnace must be capable of maintaining the temperature at 538 ± 5°C (1000 ± 9°F).

  For Method A, the furnace will be equipped with an internal scale thermally isolated from the furnace chamber and accurate to 0.1 g. The scale shall be capable of determining the mass of a 3500 g sample in addition to the sample baskets. A data collection system will be included so that mass can be automatically determined and displayed during the test. The furnace shall have a built-in computer program to calculate the change in mass of the 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 binder content, test time, and test temperature. 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. Perform lift test according to manufacturer's instructions weekly during use.

  Note 2: The furnace shall be designed to permit the operator to change the ending mass loss percentage from 0.01 percent to 0.02 percent.

For both Method A and Method B, the furnace chamber dimensions shall be adequate to accommodate a 3500 g sample. The furnace door shall be equipped so that it cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided and the furnace shall be vented so that no emissions escape into the laboratory. The furnace shall have a fan to pull air through the furnace to expedite the test and to eliminate the escape of smoke into the laboratory.

- Sample Basket Assembly: consisting of sample basket(s), catch pan, and basket guards. Sample basket(s) will be of appropriate size allowing samples to be thinly spread and allowing air to flow through and around the sample particles. Sets of two or more baskets shall be nested. A 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. Basket guards will completely enclose the basket and be made of screen mesh, perforated stainless steel plate, or other suitable material.
- Thermometer, or other temperature measuring device, with a temperature range of 10 -260°C (50-500°F).
- Oven capable of maintaining 110 ± 5°C (230 ± 9°F).
- Balance or scale: Capacity sufficient for the sample mass and conforming to the requirements of M 231, Class G2.
- **Safety equipment:** Safety glasses or face shield, high temperature gloves, long sleeved jacket, a heat resistant surface capable of withstanding 650°C (1202°F), a protective cage capable of surrounding the sample baskets during the cooling period, and a particle mask for use during removal of the sample from the basket assembly.
- Miscellaneous equipment: A pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls, and wire brushes.

Sampling

1. Obtain samples of HMA in accordance with the FOP for AASHTO T 168.
2. Reduce HMA samples in accordance with the FOP for AASHTO R 47.
3. If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan in an oven at 110 ± 5°C (230 ± 9°F) until soft enough.
4. Test sample size shall conform to the mass requirement shown in Table 1.

   Note 3: When the mass of the test specimen exceeds the capacity of the equipment used or for large samples of fine mixes, the test specimen may be divided into suitable increments, tested, and the results appropriately combined through a weighted average for calculation of the asphalt binder content.

Table 1

Nominal Maximum Aggregate Size* mm (in)		Minimum Mass Specimen g	Maximum Mass Specimen g
37.5	(1½)	4000	4500
25.0	(1)	3000	3500
19.0	(¾)	2000	2500
12.5	(½)	1500	2000
9.5	(⅜)	1200	1700
4.75	(No. 4)	1200	1700

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Procedure – Method A (Internal Balance)

1. For the convection-type furnace, preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or to the temperature determined in the "Correction Factor" section, Step 9 of this method. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically. For the direct IR irradiation-type furnace, use the same burn profile as used during the correction factor determination.
2. Dry the sample to constant mass, according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.
3. Determine and record the mass to the nearest 0.1 g of the sample basket assembly.
4. Evenly distribute the sample in the sample basket assembly, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.
5. Determine and record the total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as (Mi).
6. Record the correction factor or input into the furnace controller for the specific HMA.
7. Input the initial mass of the sample (Mi) into the ignition furnace controller. Verify that the correct mass has been entered.

   CAUTION: Operator should wear safety equipment – high temperature gloves, face shield, fire-retardant shop coat – when opening the door to load or unload the sample.
8. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Close the chamber door and verify that the sample mass displayed on the furnace scale equals the total mass of the sample and sample basket assembly recorded in Step 5 within ± 5 g.

Note 4: Furnace temperature will drop below the set point when the door is opened, but will recover when the door is closed and ignition begins. Sample ignition typically increases the temperature well above the set point – relative to sample size and asphalt binder content.

9. Initiate the test by pressing the start button. This will lock the sample chamber and start the combustion blower.

   Safety note: **Do not attempt to open the furnace door until the asphalt binder has been completely burned off.**

10. Allow the test to continue until the stable light and audible stable indicator indicate that the change in mass does not exceed 0.01 percent for three consecutive minutes. Press the 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 used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.

11. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 minutes).

12. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as M_f.

13. Use the asphalt binder content percentage from the printed ticket. Subtract the moisture content from the printed ticket asphalt binder content and report the difference as the corrected asphalt binder content.

14. Asphalt binder content percentage can also be calculated using the formula from "Method B" Step 16.

Calculation

Corrected asphalt binder content:

$$P_b = BC - MC - C_f$$

(if not input in the furnace controller)

where:

P_b = the corrected asphalt binder content as a percent by mass of the HMA
BC = asphalt binder content shown on printed ticket
MC = moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, MC=0)
C_f = correction factor as a percent by mass of the HMA sample

Procedure – Method B (External Balance)

1. Preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or to the temperature determined in the "Correction Factor" section, Step 9 of this method. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.
2. Dry the sample to constant mass, according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.
3. Determine and record the mass of the sample basket assembly to the nearest 0.1 g.
4. Place the sample basket(s) in the catch pan. Evenly distribute the sample in the sample basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.
5. Determine and record the total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as (M_i).
6. Record the correction factor for the specific HMA.
7. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Burn the HMA sample in the furnace for 45 minutes or the length of time determined in the "Correction Factors" section.
8. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample and allow it to cool to room temperature (approximately 30 min).
9. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.
10. Place the sample basket assembly back into the furnace.
11. Burn the sample for at least 15 minutes after the furnace reaches the set temperature.
12. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 min).
13. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.
14. Repeat Steps 10 through 13 until the change in measured mass of the sample after ignition does not exceed 0.01 percent of the previous sample mass after ignition.

    Note 6: An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.

15. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as M_f.
16. Calculate the asphalt binder content of the sample.

Calculations

Calculate the asphalt binder content of the sample as follows:

$$P_b = \frac{M_i - M_f}{M_i} \times 100 - MC - C_f$$

Where:
P_b = the corrected asphalt binder content as a percent by mass of the HMA sample
M_f = the final mass of aggregate remaining after ignition
M_i = the initial mass of the HMA sample prior to ignition
MC = moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, MC=0).
C_f = correction factor as a percent by mass of the HMA sample

Example

Correction Factor	= 0.42 percent
Moisture Content	= 0.04 percent
Initial Mass of Sample and Basket	= 5292.7 g
Mass of Basket Assembly	= 2931.5 g
M_i	= 2361.2 g
Total Mass after First ignition + basket	= 5154.4 g
Sample Mass after First ignition	= 2222.9 g
Sample Mass after additional 15 min ignition	= 2222.7 g

$$\frac{2222.9\ g - 2222.7\ g}{2222.9\ g} \times 100 = 0.009\%$$

Not greater than 0.01 percent, so **M_f** = 2222.7 g

$$P_b = \frac{2361.2\ g - 2222.7\ g}{2361.2\ g} \times 100 - 0.42\% - 0.04\% = 5.41\%$$

P_b= 5.41 percent

Gradation

1. Empty contents of the basket(s) into a flat pan, being careful to capture all material. Use a small wire brush to ensure all residual fines are removed from the baskets.

   Note 7: Particle masks are a recommended safety precaution.

2. Perform the gradation analysis in accordance with the FOP for AASHTO T 30.

Report

- Results on forms approved by the agency
- Sample ID
- Method of test (A or B)
- Corrected asphalt binder content, Pb, per agency standard
- Correction factor, Cf , to 0.01 percent
- Temperature compensation factor (if applicable)
- Total percent loss
- Sample mass
- Moisture content to 0.01 percent
- Test temperature

Attach the original printed ticket with all intermediate values (continuous tape) to the report for furnaces with internal balances.

Annex – Correction Factors

(Mandatory Information)

Asphalt Binder and Aggregate

Asphalt binder content results may be affected by the type of aggregate in the mixture and by the ignition furnace. Asphalt binder and aggregate correction factors must, therefore, be established by testing a set of correction specimens for each Job Mix Formula (JMF) mix design. Each ignition furnace will have its own unique correction factor determined in the location where testing will be performed.

This procedure must be performed before any acceptance testing is completed, and repeated each time there is a change in the mix ingredients or design. Any changes greater than 5 percent in stockpiled aggregate proportions should require a new correction factor.

Historical data or scientific studies may be used to determine the correction factor(s) in lieu of using this testing procedure if the testing agency provides reference to the studies/data.

All correction samples will be prepared by a central/regional laboratory unless otherwise directed.

Asphalt binder correction factor: A correction factor must be established by testing a set of correction specimens for each Job Mix Formula (JMF). Certain aggregate types may result in unusually high correction factors (> 1.00 percent). Such mixes should be corrected and tested at a lower temperature as described below.

Aggregate correction factor: Due to potential aggregate breakdown during the ignition process, a correction factor will need to be determined for the following conditions:

a. Aggregates that have a proven history of excessive breakdown

b. Aggregate from an unknown source.

This correction factor will be used to adjust the acceptance gradation test results obtained according to the FOP for AASHTO T 30.

Procedure

1. Obtain samples of aggregate in accordance with the FOP for AASHTO T 2.
2. Obtain samples of asphalt binder in accordance with the FOP for AASHTO R 66.

   Note 8: Include other additives that may be required by the JMF.
3. Prepare an initial, or “butter,” mix at the design asphalt binder content. Mix and discard the butter mix prior to mixing any of the correction specimens to ensure accurate asphalt content.
4. Prepare two correction specimens at the JMF design asphalt binder content. Aggregate used for correction specimens shall be sampled from material designated for use on the project. An agency approved method will be used to combine aggregate. An additional “blank” specimen shall be batched and tested for aggregate gradation in accordance with the FOP for AASHTO T 30. The gradation from the “blank” shall fall within the agency specified mix design tolerances.

5. Place the freshly mixed specimens directly into the sample basket assembly. If mixed specimens are allowed to cool prior to placement in the sample basket assembly, the specimens must be dried to constant mass according to the FOP for AASHTO T 329. Do not preheat the sample basket assembly.
6. Test the specimens in accordance with Method A or Method B of the procedure.
7. Once both of the correction specimens have been burned, determine the asphalt binder content for each specimen by calculation or from the printed oven tickets, if available.
8. If the difference between the asphalt binder contents of the two specimens exceeds 0.15 percent, repeat with two more specimens and, from the four results, discard the high and low result. Determine the correction factor from the two original or remaining results, as appropriate. Calculate the difference between the actual and measured asphalt binder contents for each specimen to 0.01 percent. The asphalt binder correction factor, C_f, is the average of the differences expressed as a percent by mass of HMA.
9. If the asphalt binder correction factor exceeds 1.00 prcent, the test temperature must be lowered to 482 ± 5°C (900 ± 9°F) and new samples must be burned. The temperature for determining the asphalt binder content of HMA samples by this procedure shall be the same temperature determined for the correction samples.
10. For the direct IR irradiation-type burn furnaces, the **default** burn profile should be used for most materials. The operator may select burn-profile Option 1 or Option 2 to optimize the burn cycle. The burn profile for testing HMA samples shall be the same burn profile selected for correction samples.

    Option 1 is designed for aggregate that requires a large asphalt binder correction factor (greater than 1.00 percent) – typically very soft aggregate (such as dolomite).

    Option 2 is designed for samples that may not burn completely using the default burn profile.
11. Perform a gradation analysis on the residual aggregate in accordance with the FOP for AASHTO T 30, if required. The results will be utilized in developing an “Aggregate Correction Factor” and should be calculated and reported to 0.1 percent.
12. From the gradation results subtract the percent passing for each sieve, for each sample, from the percent passing each sieve of the “Blank” specimen gradation results from Step 4.
13. Determine the average difference of the two values. If the difference for any single sieve exceeds the allowable difference of that sieve as listed in Table 2, then aggregate gradation correction factors (equal to the resultant average differences) for all sieves shall be applied to all acceptance gradation test results determined by the FOP for AASHTO T 30. If the 75 µm (No. 200) is the only sieve outside the limits in Table 2, apply the aggregate correction factor to only the 75 µm (No. 200) sieve.

Table 2 Permitted Sieving Difference

Sieve	Allowable Difference
Sizes larger than or equal to 2.36 mm (No.8)	± 5.0%
Sizes larger than to 75 µm (No.200) and smaller than 2.36 mm (No.8)	± 3.0%
Sizes 75 µm (No.200) and smaller	± 0.5%

Examples

Sieve Size mm (in)		Correction Factor Blank Sample % Passing	Correction Factor Sample #1 % Passing	Correction Factor Sample #2 % Passing	Difference ½	Avg. Diff.	Sieves to adjust
19.0	(¾)	100	100	100	0/0	0.0	
12.5	(½)	86.3	87.4	86.4	-1.1/-0.1	-0.6	
9.5	(⅜)	77.4	76.5	78.8	+0.9/-1.4	-0.3	
4.75	(No. 4)	51.5	53.6	55.9	-2.1/-4.4	-3.3	
2.36	(No. 8)	34.7	36.1	37.2	-1.4/-2.5	-2.0	
01.18	(No. 16)	23.3	25.0	23.9	-1.7/-0.6	-1.2	
0.600	(No. 30)	16.4	19.2	18.1	-2.8/-1.7	-2.3	
0.300	(No. 50)	12.0	11.1	12.7	+0.9/-0.7	+0.1	
0.150	(No. 100)	8.1	9.9	6.3	-1.8/+1.8	0.0	
75 µm	(No. 200)	5.5	5.9	6.2	-0.4/-0.7	-0.6	- 0.6

In this example, all gradation test results performed on the residual aggregate (FOP for AASHTO T 30) would have an aggregate correction factor applied to the percent passing the 75 µm (No. 200) sieve. The correction factor must be applied because the average difference on the 75 µm (No. 200) sieve is outside the tolerance from Table 2.

In the following example, aggregate correction factors would be applied to each sieve because the average difference on the 4.75 mm (No. 4) is outside the tolerance from Table 2.

Sieve Size mm (in)		Correction Factor Blank Sample % Passing	Correction Factor Sample #1 % Passing	Correction Factor Sample #2 % Passing	Difference ½	Avg. Diff.	Sieves to adjust
19.0	(¾)	100	100	100	0/0	0.0	0.0
12.5	(½)	86.3	87.4	86.4	-1.1/-0.1	-0.6	-0.6
9.5	(⅜)	77.4	76.5	78.8	+0.9/-1.4	-0.3	-0.3
4.75	(No. 4)	51.5	55.6	57.9	-4.1/-6.4	-5.3	-5.3
2.36	(No. 8)	34.7	36.1	37.2	-1.4/-2.5	-2.0	-2.0
01.18	(No. 16)	23.3	25.0	23.9	-1.7/-0.6	-1.2	-1.2
0.600	(No. 30)	16.4	19.2	18.1	-2.8/-1.7	-2.3	-2.3
0.300	(No. 50)	12.0	11.1	12.7	+0.9/-0.7	+0.1	+0.1
0.150	(No. 100)	8.1	9.9	6.3	-1.8/+1.8	0.0	0.0
75 µm	(No. 200)	5.5	5.9	6.2	-0.4/-0.7	-0.6	-0.6

Performance Exam Checklist

FOP for AASHTO T 308
Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	Oven at correct temperature 538 ± 5°C (1000 ± 9°F) or correction factor temperature?		
	Or: for IR ovens, correct burn profile applied?		
2.	Sample reduced to correct size?		
3.	HMA sample or companion moisture sample taken and dried per FOP for AASHTO T 329?		
4.	Mass of sample basket assembly recorded to 0.1 g?		
5.	With pan below basket(s) sample evenly distributed in basket(s)?		
6.	Sample conforms to the required mass and mass recorded to 0.1 g?		
7.	Method A		
	a. Initial mass entered into furnace controller?		
	b. Sample correctly placed into furnace?		
	c. Test continued until stable indicator signals?		
	d. Uncorrected asphalt binder content obtained on printed ticket?		
	e. Sample mass determined to nearest 0.1 g.?		
8.	Method B		
	a. Sample correctly placed into furnace?		
	b. Sample burned for 45 min or time determined by correction process?		
	c. Sample cooled to room temperature?		
	d. Sample burned to constant mass?		
	e. Sample mass determined to nearest 0.1 g.?		
	f. Uncorrected asphalt binder content calculated correctly and recorded?		
9.	Asphalt binder content corrected for Correction Factor if needed?		
10.	Asphalt binder content corrected for moisture per the FOP for AASHTO T 329 if needed?		

Procedure Element	Trial 1	Trial 2
11. Corrected asphalt binder content recorded?	_____	_____
12. Contents of the basket(s) carefully emptied into a pan?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

FOP for AASHTO T 309

Temperature of Freshly Mixed Portland Cement Concrete

Scope

This procedure covers the determination of the temperature of freshly mixed Portland Cement Concrete in accordance with AASHTO T 309-15.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Container — The container shall be made of non-absorptive material and large enough to provide at least 75 mm (3 in) of concrete in all directions around the sensor; concrete cover must also be a least three times the nominal maximum size of the coarse aggregate.
- Temperature measuring device — The temperature measuring device shall be calibrated and capable of measuring the temperature of the freshly mixed concrete to ± 0.5°C (± 1°F) throughout the temperature range likely to be encountered. 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.
- Reference temperature measuring device — The reference temperature measuring device shall be a thermometric device readable to 0.2°C (0.5°F) 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.

Calibration of Temperature Measuring Device

Each temperature measuring device shall be verified for accuracy annually and whenever there is a question of accuracy. Calibration shall be performed by comparing readings on the temperature measuring device with another calibrated instrument at two temperatures at least 15°C or 27°F apart.

Sample Locations and Times

The temperature of freshly mixed concrete may be measured in the transporting equipment, in forms, or in sample containers, provided the sensor of the temperature measuring device has at least 75 mm (3 in) of concrete cover in all direction around it.

Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.

Concrete containing aggregate of a nominal maximum size greater than 75 mm (3 in) may require up to 20 minutes for the transfer of heat from the aggregate to the mortar after batching.

Procedure

1. Dampen the sample container.
2. Obtain the sample in accordance with the FOP for WAQTC TM 2.
3. Place sensor of the temperature measuring device in the freshly mixed concrete so that it has at least 75 mm (3 in) of concrete cover in all directions around it.
4. Gently press the concrete in around the sensor of the temperature measuring device at the surface of the concrete so that air cannot reach the sensor.
5. Leave the sensor of the temperature measuring device in the freshly mixed concrete for a minimum of two minutes, or until the temperature reading stabilizes.
6. Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.
7. Read and record the temperature to the nearest 0.5°C (1°F).

Report

- Results on forms approved by the agency
- Sample ID
- Measured temperature of the freshly mixed concrete to the nearest 0.5°C (1°F).

Performance Exam Checklist

FOP for AASHTO T 309
Temperature of Freshly Mixed Concrete

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	Obtain sample of concrete large enough to provide a minimum of 75 mm (3 in) of concrete cover around sensor in all directions?		
2.	Place temperature measuring device in sample with a minimum of 75 mm (3 in) cover around sensor?		
3.	Gently press concrete around thermometer?		
4.	Read temperature after a minimum of 2 minutes or when temperature reading stabilizes?		
5.	Complete temperature measurement within 5 minutes of obtaining sample?		
6.	Record temperature to nearest 0.5°C (1°F)?		

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

Signature of Examiner _____ WAQTC #:_____

This checklist is derived, in part, from copyrighted material printed in ACI CP-1, published by the American Concrete Institute.

Comments:

WSDOT Errata to FOP for AASHTO T 310

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

WAQTC FOP for AASHTO T 310 has been adopted by WSDOT with the following changes:

Procedure

Replace step 1 with below:

1. WSDOT requires test location selected per WSDOT SOP 615.

6. Place the gauge on the prepared surface so the source rod can enter the hole without disturbing loose material.

Include note below:

Note: For alignment purposes, the user may expose the source rod for a maximum of ten seconds.

10. Perform one of the following methods, per agency requirements:

    a. Method A Single Direction: - Method not recognized by WSDOT.

11. Step not required by WSDOT.

Percent Compaction

Determined using WSDOT SOP 615.

FOP for AASHTO T 310

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

Scope

This procedure covers the determination of density, moisture content, and relative compaction of soil, aggregate, and soil-aggregate mixes in accordance with AASHTO T 310-13. This field operating procedure is derived from AASHTO T 310. The nuclear moisture-density gauge is used in the direct transmission mode.

Apparatus

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

Radiation Safety

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

Calibration

Calibrate the nuclear gauge as required by the agency. This calibration may be performed by the agency using manufacturer's recommended procedures or by other facilities approved by the agency. Verify or re-establish calibration curves, tables, or equivalent coefficients every 12 months.

Standardization

1. Turn the gauge on and allow it to stabilize (approximately 10 to 20 minutes) prior to standardization. Leave the power on during the day's testing.
2. Standardize the nuclear gauge at the construction site at the start of each day's work and as often as deemed necessary by the operator or agency. Daily variations in standard count shall not exceed the daily variations established by the manufacturer of the gauge. If the daily variations are exceeded after repeating the standardization procedure, the gauge should be repaired and/or recalibrated.
3. Record the standard count for both density and moisture in the Daily Standard Count Log. The exact procedure for standard count is listed in the manufacturer's Operator's Manual.

   Note 1: New standard counts may be necessary more than once a day. See agency requirements.

Overview

There are two methods for determining in-place density of soil/soil aggregate mixtures. See agency requirements for method selection.

- Method A Single Direction
- Method B Two Direction

Procedure

1. Select a test location(s) randomly and in accordance with agency requirements. Test sites should be relatively smooth and flat and meet the following conditions:
   a. At least 10 m (30 ft) away from other sources of radioactivity
   b. At least 3 m (10 ft) away from large objects
   c. The test site should be at least 150 mm (6 in) away from any vertical projection, unless the gauge is corrected for trench wall effect.
2. Remove all loose and disturbed material, and remove additional material as necessary to expose the top of the material to be tested.
3. Prepare a flat area sufficient in size to accommodate the gauge. Plane the area to a smooth condition so as to obtain maximum contact between the gauge and the material being tested. For Method B, the flat area must be sufficient to permit rotating the gauge 90 or 180 degrees about the source rod.
4. Fill in surface voids beneath the gauge with fines of the material being tested passing the 4.75 mm (No. 4) sieve or finer. Smooth the surface with the guide plate or other suitable tool. The depth of the filler should not exceed approximately 3 mm (⅛ in).
5. Make a hole perpendicular to the prepared surface using the guide plate and drive pin. The hole shall be at least 50 mm (2 in) deeper than the desired probe depth, and shall be aligned such that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area. Remove the drive pin by pulling straight up and twisting the extraction tool.
6. Place the gauge on the prepared surface so the source rod can enter the hole without disturbing loose material.

7. Insert the probe in the hole and lower the source rod to the desired test depth using the handle and trigger mechanism.
8. Seat the gauge firmly by partially rotating it back and forth about the source rod. Ensure the gauge is seated flush against the surface by pressing down on the gauge corners, and making sure that the gauge does not rock.
9. Pull gently on the gauge to bring the side of the source rod nearest to the scaler/detector firmly against the side of the hole.
10. Perform one of the following methods, per agency requirements:
    a. Method A Single Direction: Take a test consisting of the average of two, one-minute readings, and record both density and moisture data. The two wet density readings should be within 32 kg/m^3 (2.0 lb/ft^3) of each other. The average of the two wet densities and moisture contents will be used to compute dry density.
    b. Method B Two Direction: Take a one-minute reading and record both density and moisture data. Rotate the gauge 90 or 180 degrees, pivoting it around the source rod. Reseat the gauge by pulling gently on the gauge to bring the side of the source rod nearest to the scaler/detector firmly against the side of the hole and take a one-minute reading. (In trench locations, rotate the gauge 180 degrees for the second test.) Some agencies require multiple one-minute readings in both directions. Analyze the density and moisture data. A valid test consists of wet density readings in both gauge positions that are within 50 kg/m^3 (3.0 lb/ft^3). If the tests do not agree within this limit, move to a new location. The average of the wet density and moisture contents will be used to compute dry density.
11. If required by the agency, obtain a representative sample of the material, 4 kg (9.0 lb) minimum, from directly beneath the gauge full depth of material tested. This sample will be used to verify moisture content and/or identify the correct density standard. Immediately seal the material to prevent loss of moisture.

    The material tested by direct transmission can be approximated by a cylinder of soil approximately 300 mm (12 in) in diameter directly beneath the centerline of the radioactive source and detector. The height of the cylinder will be approximately the depth of measurement. When organic material or large aggregate is removed during this operation, disregard the test information and move to a new test site.
12. To verify the moisture content from the nuclear gauge, determine the moisture content with a representative portion of the material using the FOP for AASHTO T 255/T 265 or other agency approved methods. If the moisture content from the nuclear gauge is within ± 1 percent, the nuclear gauge readings can be accepted. Moisture content verification is gauge and material specific. Retain the remainder of the sample at its original moisture content for a one-point compaction test under the FOP for AASHTO T 272, or for gradation, if required.

    Note 2: Example: A gauge reading of 16.8 percent moisture and an oven dry of 17.7 percent are within the ± 1 percent requirements. Moisture correlation curves will be developed according to agency guidelines. These curves should be reviewed and possibly redeveloped every 90 days.

13. Determine the dry density by one of the following.

    a. From nuclear gauge readings, compute by subtracting the mass (weight) of the water (kg/m^3 or lb/ft^3) from the wet density (kg/m^3 or lb/ft^3) or compute using the percent moisture by dividing wet density from the nuclear gauge by 1 + moisture content expressed as a decimal.

    b. When verification is required and the nuclear gauge readings cannot be accepted, the moisture content is determined by the FOP for AASHTO T 255/T 265 or other agency approved methods. Compute dry density by dividing wet density from the nuclear gauge by 1 + moisture content expressed as a decimal.

Percent Compaction

- Percent compaction is determined by comparing the in-place dry density as determined by this procedure to the appropriate agency density standard. For soil or soil-aggregate mixes, these are moisture-density curves developed using the FOP for AASHTO T 99/T 180. When using maximum dry densities from the FOP for AASHTO T 99/T 180 or FOP for AASHTO T 272, it may be necessary to use the Annex in the FOP for T 99/T 180 to determine corrected maximum dry density and optimum moisture content.

  For coarse granular materials, the density standard may be density-gradation curves developed using a vibratory method such as AKDOT&PF's ATM 212, ITD's T 74, WSDOT's TM 606, or WFLHD's Humphres.

See appropriate agency policies for use of density standards.

Calculation

Wet density readings from gauge: 1963 kg/m^3 (121.6 lb/ft^3)
1993 kg/m^3 (123.4 lb/ft^3)

Avg: 1978 kg/m^3 (122.5 lb/ft^3)

Moisture readings from gauge: 14.2% and 15.4% = Avg 14.8%

Moisture content from the FOP's for AASHTO T 255/ T 265: 15.9%

Moisture content is greater than 1 percent different so the gauge moisture cannot be used.

Calculate the dry density as follows:

$$\rho_d = \left(\frac{\rho_w}{w + 100}\right) \times 100 \quad or \quad \rho_d = \left(\frac{\rho_w}{\frac{w}{100} + 1}\right)$$

Where:

ρ_d = Dry density, kg/m^3 (lb/ft^3)
ρ_w = Wet density, kg/m^3 (lb/ft^3)
w = Moisture content from the FOP's for AASHTO T 255/T 265, as a percentage

$$\rho_d = \left(\frac{1978\,kg/m^3\ or\ 122.5\ lb/ft^3}{15.9 + 100}\right) \times 100 \quad \rho_d = \left(\frac{1978\,kg/m^3\ or\ 122.5\ lb/ft^3}{\frac{15.9}{100} + 1}\right)$$

Corrected for moisture Dry Density: 1707 kg/m^3 (105.7 lb/ft^3)

Calculate percent compaction as follows:

$$\% \text{ Compaction} = \frac{\rho_d}{Agency\ density\ standard} \times 100$$

Example:

$$\% \ Compaction = \frac{105.7\ lb/ft^3}{111.3\ lb/ft^3} \times\ 100 = 95\%$$

Where:

ρ_d = Dry density, kg/m^3 (lb/ft^3)

Agency density standard = Corrected maximum dry density from the FOP from T 99/T 180 Annex

Report

- Results on forms approved by the agency
- Sample ID
- Location of test, elevation of surface, and thickness of layer tested.
- Visual description of material tested.
- Make, model and serial number of the nuclear moisture-density gauge.
- Wet density to 0.1 lb/ft^3.
- Moisture content as a percent, by mass, of dry soil mass to 0.1 percent.
- Dry density to 0.1 lb/ft^3.
- Density standard to 0.1 lb/ft^3.
- Percent compaction.
- Name and signature of operator.

Performance Exam Checklist

FOP for AASHTO T 310
In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		Trial 1	Trial 2
1.	Gauge turned on 10 to 20 minutes before use?		
2.	Calibration verified?		
3.	Standard count taken and recorded in accordance with manufacturer's instructions?		
4.	Test location selected appropriately 10 m (30 ft) from other radioactive sources, 3 m (10 ft) from large objects, 150 mm (6 in) away from vertical projections?		
5.	Loose, disturbed material removed?		
6.	Flat, smooth area prepared?		
7.	Surface voids filled with native fines (-No. 4) to 3 mm (⅛ in) maximum thickness?		
8.	Hole driven 50 mm (2 in) deeper than probe depth?		
9.	Gauge placed, probe placed, and source rod lowered without disturbing loose material?		
10.	Method A:		
	a. Gauge firmly seated, and gently pulled back so that the source rod is against the side of the hole toward the scaler/detectors?		
	b. Two, one-minute reading taken; wet density within 32 kg/m^3 (2.0 lb/ft^3)?		
	c. Density and moisture data averaged?		
11.	Method B:		
	a. Gauge firmly seated, and gently pulled back so that the source rod is against the side of the hole toward the scaler/detectors?		
	b. A minimum of a one-minute reading taken; density and moisture data recorded?		
	c. Gauge turned 90° or 180° (180° in trench)?		
	d. Gauge firmly seated, and gently pulled back so that the source rod is against the side of the hole toward the scaler/detectors?		
	e. A minimum of a one-minute reading taken; density and moisture data recorded?		
	f. Wet densities within 50 kg/m^3 (3.0 lb/ft^3)?		
	g. Density and moisture data averaged?		

Procedure Element	Trial 1	Trial 2
12. Representative sample (4 kg or 9 lb) obtained from test location?	_____	_____
13. Sample sealed immediately to prevent moisture loss?	_____	_____
14. Moisture content correctly determined using other means than the nuclear density gauge reading?	_____	_____
15. Dry Density calculated using proper moisture content?	_____	_____
16. Percent compaction calculated correctly?	_____	_____

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

Signature of Examiner _____ WAQTC #:_____

Comments:

WSDOT Errata to FOP for AASHTO T 312

Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

WAQTC FOP for AASHTO T 312 has been adopted by WSDOT with the following changes:

Sample Preparation

Plant Produced Asphalt Mixtures

Replace step 3 with below:

3. Place in the oven set no more than 25° F above the compaction temperature range until the material is within the compaction temperature range.

Compaction Procedure

Replace step 3 with below:

3. Remove the pan of HMA from the oven and in one motion invert the pan onto the construction paper, vinyl mat, etc. Quickly remove any material that remains in the pan and include it with the HMA sample to be compacted. Grasp opposing edges of the paper and roll them together to form the HMA into a cylindrical shape. Insert one end of the paper roll into the bottom of the compaction mold and remove the paper as the HMA slides into the mold. This process needs to be accomplished in approximately 60 seconds. Place the mixture into the mold in one lift. Care should be taken to avoid segregation in the mold.

FOP for AASHTO T 312

Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

Scope

This procedure covers preparing specimens, using samples of plant produced asphalt mixtures, for determining the mechanical and volumetric properties of asphalt mixtures in accordance with AASHTO T 312-15.

Apparatus

- Superpave Gyratory Compactor (SGC) meeting the requirements of AASHTO T 312
- Molds meeting the requirements of AASHTO T 312
- Chute, mold funnel or both (Optional)
- Scale meeting the requirements of AASHTO M 231 Class G 5
- Oven, thermostatically controlled, capable of maintaining set temperature within ± 3°C (± 5°F)
- Thermometers accurate to ± 1°C (± 2°F) between 10 and 232°C (50 - 450°F)

  Note 1: Non-Contact thermometers are not acceptable.
- Miscellaneous pans, spoons, spatulas, hot pads, gloves, paper discs, markers, etc.

Equipment Requirements

The calibration shall be performed on the SGC per the Manufacturer's instructions. See agency requirements for the calibration frequency.

The mold and base plate dimensions shall be checked every twelve months or 80 hours of operation to determine that they are within the tolerances listed in AASHTO T 312.

Equipment Preparation

Prepare the equipment in accordance with manufacturer's recommendations. At a minimum preparation includes:

- Warm-up gyratory compactor
- Verify machine settings
- Internal Angle: 1.16 ± 0.02°
- Ram Pressure: 600 kPa ± 18 kPa
- Number of gyrations

  Note 2: The number of gyrations (N_{des}) is obtained from the Job Mix Formula (JMF).
- Lubricate bearing surfaces
- Prepare recording device as required
- Pre-heat molds and plates at the compaction temperature range (minimum of 30 min) or before reuse reheat (minimum of 5 min)

  Note 3: The use of multiple molds will speed up the compaction process.
- Pre-heat chute, mold funnel, spatulas, and other apparatus (not to exceed the maximum compaction temperature)

Sample Preparation

Laboratory Prepared Asphalt Mixtures

This is a sample produced during the Mix Design process using aggregate and binder that is combined in the laboratory. When designing asphalt mixtures using the gyratory compactor refer to AASHTO T 312.

Plant Produced Asphalt Mixtures

- Determine initial sample size, number of gyrations (N_{des}), and compaction temperature range from the Job Mix Formula (JMF).
- Obtain the sample in accordance with the FOP for AASHTO T 168.
- Reduce the sample in accordance with the FOP for AASHTO R 47.
- The sample size should be such that it results in a compacted specimen that is 115 ± 5mm at the desired number of gyrations.

Note 4: Replicate specimens are generally prepared. Refer to agency requirements.

If the material is not in the compaction temperature range:

1. Place the appropriate sample mass into a container.
2. Spread to a depth of 1 to 2 in for even heating of mixture.
3. Place in the oven until the material is within the compaction temperature range.

Note 5: The material properties may be altered when the times of delivery of the test sample and the placement of the material on the roadway are different.

Compaction Procedure

Follow the manufacturer's recommended loading procedure. This may require the steps below to be performed in a different order. Steps 1 through 8 must be performed before the sample and mold cools below minimum compaction temperature.

1. Remove pre-heated mold and plate(s) from the oven (verify mold and plate(s) has been cleaned if previously used).
2. Place the base plate and paper disc in bottom of mold.
3. Place the mix into the mold in a single lift (care should be taken to avoid segregation or loss of material).
4. Level the mix in the mold.
5. Place a paper disc and the heated upper plate (if required) on top of the leveled sample.
6. Load the mold into the compactor; check settings.
7. Start the compaction process.
    a. Check the pressure (600 ± 18 kPa).
    b. Check the angle (1.16 ± 0.02°).
8. Upon completion of the compaction process, record the number of gyrations and specimen height.

Note 6: If the specimen is not 115 ± 5mm follow agency requirements.

9. Extrude the specimen from the mold; a brief cooling period may be necessary before fully extruding some specimens to ensure the specimens are not damaged.

   Note 7: Clean molds after each use.

10. Carefully remove the paper discs.
11. Cool the compacted specimen to room temperature.
12. Identify the specimen with chalk or other marker.

Report

- On forms approved by the agency
- Sample ID
- Number of gyrations
- Specimen height

Performance Exam Checklist

FOP for AASHTO T 312
Gyratory Compaction of Asphalt Mixtures

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	Angle, pressure and number of gyrations set?		
2.	Bearing surfaces, rotating base surface, and rollers lubricated?		
3.	Representative sample obtained according to the FOP for AASHTO T 168?		
4.	Sample reduced according to FOP AASHTO R 47?		
5.	Asphalt mixture heated to compaction temperature range?		
6.	Mold, base plate, and upper plate heated to compaction temperature range?		
7.	Mold, base plate, and upper plate (if required) removed from oven and paper disk placed on bottom of mold?		
8.	Mix placed into mold in one lift without segregation?		
9.	Paper disk placed on top of the asphalt mixture?		
10.	Mold placed into compactor and upper plate clamped into place?		
11.	Pressure applied at 600 kPa ± 18 kPa?		
12.	Specified number of gyrations applied?		
13.	Proper angle confirmed from display?		
14.	Compacted specimen removed from mold, paper disc(s) removed, and allowed to cool to room temperature?		
15.	Asphalt mixture sample measured to a height of 115 ± 5 mm at required gyrations?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

FOP for AASHTO T 329

Moisture Content of Asphalt Mixtures by Oven Method

Scope

This procedure covers the determination of moisture content of asphalt mixtures in accordance with AASHTO T 329-15.

Overview

Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

Constant mass – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus

- Balance or scale: 2 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Forced draft, ventilated, or convection oven: Capable of maintaining the temperature surrounding the sample at 163 ± 14°C (325 ± 25°F).
- Sample Container: Clean, dry, not affected by heat and of sufficient size to contain a test sample without danger of spilling.
- Thermometer or other suitable device with a temperature range of 10-260°C (50-500°F).

Sample

The test sample shall be obtained in accordance with the FOP for AASHTO T 168, and reduced in accordance with the FOP for AASHTO R 47. The size of the test sample shall be a minimum of 1000 g.

Procedure

1. Preheat the oven to the Job Mix Formula (JMF) mixing temperature range. If the mixing temperature is not supplied, a temperature of 163 ± 14°C (325 ± 25°F) is to be used.

   Note 1: For repeatability between laboratories, the preferred practice is to dry the sample at no less than 9° C (15° F) below the JMF mixing temperature.

2. Determine and record the mass of the sample container, including release media, to the nearest 0.1 g.

   Note 2: When using paper or other absorptive material to line the sample container ensure it is dry before determining initial mass of sample container.

3. Place the test sample in the sample container.
4. Determine and record the temperature of the test sample.
5. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

6. Calculate the initial, moist mass (M_i) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 5.
7. The test sample shall be initially dried for 90 ± 5 minutes, and its mass determined. Then it shall be dried at 30 ± 5 min intervals until further drying does not alter the mass by more than 0.05 percent.
8. Cool the sample container and test sample to ± 9°C (± 15°F) of the temperature determined in Step 4.
9. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

   Note 3: Do not attempt to remove the test sample from the sample container for the purposes of determining mass.
10. Calculate the final, dry mass (M_f) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 9.

    Note 4: 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

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement
M_n = new mass measurement

Example:

Mass of container: 232.6 g

Mass of container and sample after first drying cycle: 1361.8 g

Mass, M_p, of possibly dry sample: 1361.8 g – 232.6 g = 1129.2 g

Mass of container and possibly dry sample after second drying cycle: 1360.4 g

Mass, M_n, of possibly dry sample: 1360.4 g – 232.6 g = 1127.8 g

$$\frac{1129.2\ g - 1127.8\ g}{1129.2\ g} \times 100 = 0.12\%$$

0.12 percent is not less than 0.05 percent, so continue drying the sample.

Mass of container and possibly dry sample after third drying cycle: 1359.9 g

Mass, M_n, of dry sample: 1359.9 g – 232.6 g = 1127.3 g

$$\frac{1127.8\ g - 1127.3\ g}{1127.8\ g} \times 100 = 0.04\%$$

0.04 percent is less than 0.05 percent, so constant mass has been reached.

Moisture Content:

Calculate the moisture content, as a percent, using the following formula.

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

Where:

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

Example:

$$Moisture\ Content = \frac{1134.9\ g - 1127.3\ g}{1127.3\ g} \times 100 = 0.674, \text{say } 0.67\%$$

Where:

M_i = 1134.9 g
M_f = 1127.3 g

Report

- Results on forms approved by the agency
- Sample ID
- Moisture content to 0.01 percent

Performance Exam Checklist

FOP for AASHTO T 329
Moisture Content of Asphalt Mixtures by Oven Method

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	Mass of clean dry container including release media determined to 0.1 g?		
2.	Representative sample obtained; 1000 g minimum?		
3.	Initial temperature taken and recorded?		
4.	Mass of sample determined to 0.1 g?		
5.	Sample placed in drying oven for 90 ± 5 minutes?		
6.	Sample dried at a temperature not to exceed the JMF mixing temp?		
7.	Constant mass checked at 30 ± 5 minute intervals and reached?		
8.	Sample and container cooled to ± 9°C (15°F) of the initial temperature before final mass determined to 0.1 g?		
9.	Calculation of moisture content performed correctly to 0.01 percent?		

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

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

Signature of Examiner _____ WAQTC #:_____

Comments:

WSDOT Errata to FOP for AASHTO T 335

Determining the Percent Fracture in Coarse Aggregate

WAQTC FOP for AASHTO T 335 has been adopted by WSDOT with the following changes:

Sampling and Sample Preparation

4. Method 2 – Individual Sieve Fracture Determination – *Method not recognized by WSDOT.*

FOP for AASHTO T 335

Determining the Percent Fracture in Coarse Aggregate

Scope

This procedure covers the determination of the percentage, by mass, of a coarse aggregate (CA) sample that consists of fractured particles meeting specified requirements in accordance with AASHTO T 335-09.

In this FOP, a sample of aggregate is screened on the sieve separating CA and fine aggregate (FA). This sieve will be identified in the agency's specifications, but might be the 4.75 mm (No. 4) sieve. CA particles are visually evaluated to determine conformance to the specified fracture. The percentage of conforming particles, by mass, is calculated for comparison to the specifications.

Apparatus

- Balance or scale: Capacity sufficient for the principle sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g, and meeting the requirements of AASHTO M 231.
- Sieves: Meeting requirements of the FOP for AASHTO T 27/T 11.
- Splitter: Meeting the requirements of FOP for AASHTO R 76.

Terminology

1. Fractured Face: An angular, rough, or broken surface of an aggregate particle created by crushing or by other means. A face is considered a "fractured face" whenever one-half or more of the projected area, when viewed normal to that face, is fractured with sharp and well defined edges. This excludes small nicks.
2. Fractured particle: A particle of aggregate having at least the minimum number of fractured faces specified. (This is usually one or two.)

Sampling and Sample Preparation

1. Sample and reduce the aggregate in accordance with the FOPs for AASHTO T 2 and R 76.
2. When the specifications list only a total fracture percentage, the sample shall be prepared in accordance with Method 1. When the specifications require that the fracture be counted and reported on each sieve, the sample shall be prepared in accordance with Method 2.
3. Method 1 - Combined Fracture Determination
    a. Dry the sample sufficiently to obtain a clean separation of FA and CA material in the sieving operation.
    b. Sieve the sample in accordance with the FOP for AASHTO T 27/T 11 over the 4.75 mm (No. 4) sieve, or the appropriate sieve listed in the agency's specifications for this material.

        Note 1: Where necessary, wash the sample over the sieve designated for the determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with the FOP for AASHTO T 255.

c. Reduce the sample using Method A – Mechanical Splitter, in accordance with the FOP for AASHTO R 76, to the appropriate test size. This test size should be slightly larger than shown in Table 1, to account for loss of fines through washing if necessary.

Table 1 Sample Size
Method 1 (Combined Sieve Fracture)

Nominal Maximum Size* mm (in)		Minimum Cumulative Sample Mass Retained on 4.75 mm (No. 4) Sieve g (lb)	
37.5	(1½)	2500	(6)
25.0	(1)	1500	(3.5
19.0	(¾)	1000	(2.5)
12.5	(½)	700	(1.5)
9.5	(⅜)	400	(0.9)
4.75	(No. 4)	200	(0.4)

*One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

4. Method 2 – Individual Sieve Fracture Determination

a. Dry the sample sufficiently to obtain a clean separation of FA and CA material in the sieving operation. A washed sample from the gradation determination (the FOP for T 27/T 11) may be used.

b. If not, sieve the sample in accordance with the FOP for AASHTO T 27 over the sieves listed in the specifications for this material.

Note 2: If overload (buffer) sieves are used the material from that sieve must be added to the next specification sieve.

c. The size of test sample for each sieve shall meet the minimum size shown in Table 2. Utilize the total retained sieve mass or select a representative portion from each sieve mass by splitting or quartering in accordance with the FOP for AASHTO R 76.

Note 3: Where necessary, wash the sample over the sieves designated for the determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with the FOP for AASHTO T 255.

Table 2 Sample Size
Method 2 (Individual Sieve Fracture)

Sieve Size mm (in)		Minimum Sample Mass g (lb)	
31.5	(1¼)	1500	(3.5)
25.0	(1)	1000	(2.2)
19.0	(¾)	700	(1.5)
16.0	(⅝)	500	(1.0)
12.5	(½)	300	(0.7)
9.5	(⅜)	200	(0.5)
6.3	(¼)	100	(0.2)
4.75	(No. 4)	100	(0.2)
2.36	(No. 8)	25	(0.1)
2.00	(No. 10)	25	(0.1)

Note 4: If fracture is determined on a sample obtained for gradation, use the mass retained on the individual sieves, even if it is less than the minimum listed in Table 2. If less than 5 percent of the total mass is retained on a single specification sieve, include that material on the next smaller specification sieve. If a smaller specification sieve does not exist, this material shall not be included in the fracture determination.

Procedure

1. After cooling, spread the dried sample on a clean, flat surface.
2. Examine each particle face and determine if the particle meets the fracture criteria.
3. Separate the sample into three categories:
   - Fractured particles meeting the criteria
   - Particles not meeting the criteria
   - Questionable or borderline particles
4. Determine the dry mass of particles in each category to the nearest 0.1 g.
5. Calculate the percent questionable particles.
6. Resort the questionable particles when more than 15 percent is present. Continue sorting until there is no more than 15 percent in the questionable category.
7. Calculate the percent fractured particles meeting criteria to nearest 0.1 percent. Report to 1 percent.

Calculation

Calculate the mass percentage of questionable particles to the nearest 1 percent using the following formula:

$$\%Q = \frac{Q}{F + Q + N} \times 100$$

Where:

%Q	=	Percent of questionable fractured particles
F	=	Mass of fractured particles
Q	=	Mass of questionable or borderline particles
N	=	Mass of unfractured particles

Example:

Mass of unfractured particles	= 632.6 g
Mass of questionable particles	= 97.6 g
Mass of unfractured particles	= 352.6 g

$$\%Q = \frac{97.6\ g}{632.6\ g + 97.6\ g + 352.6\ g} \times 100 = 9.0\%$$

Calculate the mass percentage of fractured faces to the nearest 0.1 percent using the following formula:

$$\mathrm{P} = \frac{\frac{Q}{2} + F}{F + Q + N} \times 100$$

where:

P	=	Percent of fracture
F	=	Mass of fractured particles
Q	=	Mass of questionable particles
N	=	Mass of unfractured particles

Example:

Mass of fractured particles	= 632.6 g,
Mass of questionable particles	= 97.6 g
Mass of unfractured particles	= 352.6 g

$$\mathrm{P} = \frac{\frac{97.6\ g}{2} + 632.6\ \mathrm{g}}{632.6\ g + 97.6\ g + 352.6\ g} \times 100 = 62.9\% \qquad \text{Report } 63\%$$

Report

- Results on forms approved by the agency
- Sample ID
- Fractured particles to the nearest 1 percent.

Performance Exam Checklist

FOP for AASHTO T 335
Determining The Percentage of Fracture in Coarse Aggregate

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

	Procedure Element	Trial 1	Trial 2
1.	Sample properly sieved through specified sieve(s)?		
2.	Sample reduced to correct size?		
3.	Sample dried and cooled, if necessary?		
4.	Particles separated into fractured, unfractured, and questionable categories?		
5.	Dry mass of each category determined to nearest 0.1 g?		
6.	Questionable category resorted if more than 15 percent of total mass falls in that category?		
7.	Fracture calculation performed correctly?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

WSDOT Errata to FOP for AASHTO T 355

In-Place Density of Asphalt Mixtures by Nuclear Method

WAQTC FOP for AASHTO T 355 has been adopted by WSDOT with the following changes:

Material

- Filler material: Not used by WSDOT.

Test Site Location

Replace step 1 with below:

1. WSDOT requires test location selected per WSDOT Test Method 716.

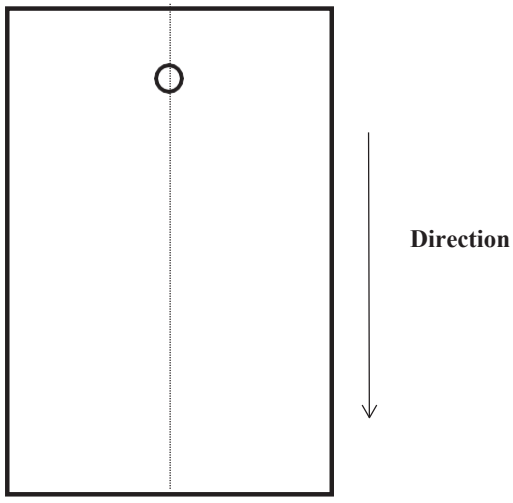
Procedure

Steps 1 – 7 not recognized by WSDOT use Method 2 Below:

Method 2 – One four minute test

1. For Thin Layer Mode (Use with Troxler 3450 only) ensure the depth entered into the gauge matches the pavement depth and the depth at which the gauge was correlated or set the gauge depth to Backscatter.
   - *Thin Layer or Backscatter are different modes of measurement, ensure that the correct form of measurement is utilized.*
2. Draw an outline around the entire gauge base for correlation coring.
3. Take one 4-minute test and record the wet density reading parallel to the direction of travel.

Method 2 Footprint of The Gauge Test Site Parallel to Direction of Travel



APPENDIX – CORRELATION WITH CORES

Correlation with Cores

Replace step 2 with below:

1. Obtain a pavement core from each of the test sites according to WSDOT SOP 734. The core should be taken from the center of the nuclear gauge footprint.

FOP for AASHTO T 355

IN-PLACE DENSITY OF ASPHALT MIXTURES by Nuclear Method

Scope

This test method describes a procedure for determining the density of asphalt mixtures by means of a nuclear gauge using the backscatter method in accordance with AASHTO T 355-16. Correlation with densities determined under the FOP for AASHTO T 166 is required by some agencies.

Apparatus

- Nuclear density gauge with the factory-matched standard reference block.
- Transport case for properly shipping and housing the gauge and tools.
- Instruction manual for the specific make and model of gauge.
- Radioactive materials information and calibration packet containing:
  - Daily standard count log
  - Factory and laboratory calibration data sheet
  - Leak test certificate
  - Shippers' declaration for dangerous goods
  - Procedure memo for storing, transporting and handling nuclear testing equipment
  - Other radioactive materials documentation as required by local regulatory requirements

Material

- Filler material: Fine-graded sand from the source used to produce the asphalt pavement or other agency approved materials.

Radiation Safety

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

Calibration

Calibrate the nuclear gauge as required by the agency. This calibration may be performed by the agency using the manufacturer's recommended procedures or by other facilities approved by the agency. Verify or re-establish calibration curves, tables, or equivalent coefficients every 12 months.

Standardization

1. Turn the gauge on and allow it to stabilize (approximately 10 to 20 minutes) prior to standardization. Leave the power on during the day's testing.
2. Standardize the nuclear gauge at the construction site at the start of each day's work and as often as deemed necessary by the operator or agency. Daily variations in standard count shall not exceed the daily variations established by the manufacturer of the gauge. If the daily variations are exceeded after repeating the standardization procedure, the gauge should be repaired, recalibrated, or both.
3. Record the standard count for both density and moisture in the daily standard count log. The exact procedure for standard count is listed in the manufacturer's Operator's Manual.

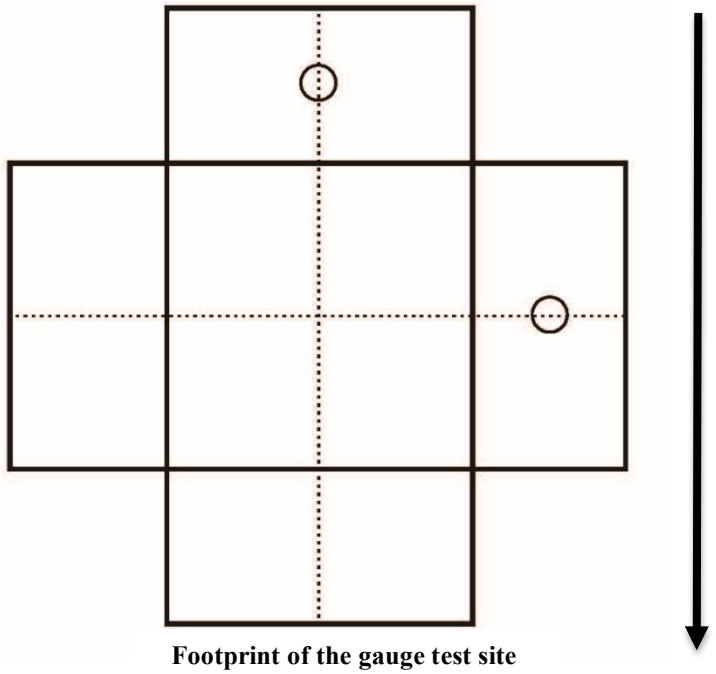
   Note 1: New standard counts may be necessary more than once a day. See agency requirements.

Test Site Location

1. Select a test location(s) randomly and in accordance with agency requirements. Test sites should be relatively smooth and flat and meet the following conditions:
   a. At least 10 m (30 ft) away from other sources of radioactivity.
   b. At least 3 m (10 ft) away from large objects.
   c. If the gauge will be closer than 600 mm (24 in) to any vertical mass, or less than 300 mm (12 in) from a vertical pavement edge, use the gauge manufacturer's correction procedure.

Procedure

1. Maintain maximum contact between the base of the gauge and the surface of the material under test. Use filler material to fill surface voids. Spread a small amount of filler material over the test site surface and distribute it evenly. Strike off the surface with a straightedge (such as a lathe or flat-bar steel) to remove excess material.
2. Place the gauge on the test site, perpendicular to the roller passes. Using a crayon (not spray paint), mark the outline or footprint of the gauge. Extend the probe to the backscatter position.
3. Take a one-minute test and record the wet density reading.
4. Rotate the gauge 90 degrees centered over the original footprint. Mark the outline or footprint of the gauge.
5. Take another one-minute test and record the wet density reading.
6. If the difference between the two one-minute tests is greater than 40 kg/m^3 (2.5 lb/ft^3), retest in both directions. If the difference of the retests is still greater than 40 kg/m^3 (2.5 lb/ft^3) test at 180 and 270 degrees.
7. The density reported for each test site shall be the average of the two individual one-minute wet density readings.



Footprint of the gauge test site
Arrow indicates the direction of the roller pass

Calculation of Results

Percent compaction is determined by comparing the in-place wet density as determined by this method to the appropriate agency density standard. See appropriate agency policy for use of density standards.

Example:

Reading #1:	141.5 lb/ft^3
Reading #2:	140.1 lb/ft^3 Are the two readings within the tolerance? (YES)
Reading average:	140.8 lb/ft^3
Core correction:	+2.1 lb/ft^3
Corrected reading:	142.9 lb/ft^3
From the FOP for AASHTO T 209:	G_{mm} = 2.466

$$\boldsymbol{Maximum\ Laboratory\ Dry\ Density} = 2.466 \times 62.245 lb/ft^3 = 153.5 lb/ft^3$$

$$\boldsymbol{Percent\ compaction} = \frac{142.9\ lb/ft^3}{153.5\ lb/ft^3} \times 100 = 93.1\%$$

Report

- Results on forms approved by the agency
- Test ID
- Location of test and thickness of layer tested
- Mixture type
- Make, model and serial number of the nuclear moisture-density gauge
- Calculated wet density of each measurement and any adjustment data
- Density standard
- Compaction 0.1 percent
- Name and signature of operator

APPENDIX – CORRELATION WITH CORES

(Nonmandatory Information)

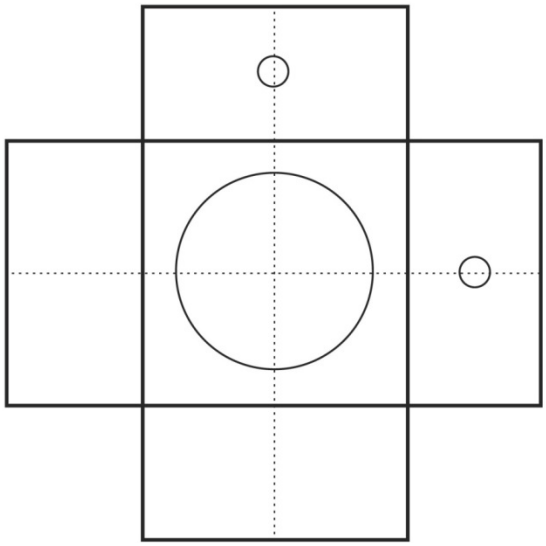
The Bulk Specific Gravity (Gmb) of the core is a physical measurement of the in-place HMA and can be compared with the nuclear density gauge readings. Comparing the core value to the corresponding gauge values, a correlation can be established.

The correlation can then be used to adjust the gauge readings to the in-place density of the cores. The core correlation is gauge specific and must be determined without traffic allowed on the pavement between nuclear density gauge readings and obtaining the core. When using multiple nuclear density gauges each gauge should be correlated to the core locations prior to removal of the core.

When density correlation with the FOP for AASHTO T 166 is required, correlation of the nuclear gauge with pavement cores shall be made on the first day's paving (within 24 hours) or from a test strip constructed prior to the start of paving. Cores must be taken before traffic is allowed on the pavement.

Correlation with Cores

1. Determine the number of cores required for correlation from the agency's specifications. Cores shall be located on the first day's paving or on the test strip. Locate the test sites in accordance with the agency's specifications. Follow the "Procedure" section above to establish test sites and obtain densities using the nuclear gauge.
2. Obtain a pavement core from each of the test sites according to AASHTO R 67. The core should be taken from the center of the nuclear gauge footprint.



Footprint of the gauge test site. Core location in the center of the footprint.

3. Determine the density of the cores by the FOP for AASHTO T 166, Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface Dry Specimens.

4. Calculate a correlation factor for the nuclear gauge reading as follows:

   a. Calculate the difference between the core density and the average nuclear gauge density at each test site to the nearest 1 kg/m^3 (0.1 lb/ft^3). Calculate the average difference and standard deviation of the differences for the entire data set to the nearest 1 kg/m^3 (0.1 lb/ft^3).

   b. If the standard deviation of the differences is equal to or less than 40 kg/m^3 (2.5 lb/ft^3), the correlation factor applied to the average nuclear gauge density shall be the average difference calculated above in 4.a.

   c. If the standard deviation of the differences is greater than 40 kg/m^3 (2.5 lb/ft^3), the test site with the greatest variation from the average difference shall be eliminated from the data set and the data set properties and correlation factor recalculated following 4.a and 4.b.

   d. If the standard deviation of the modified data set still exceeds the maximum specified in 4.b, additional test sites will be eliminated from the data set and the data set properties and correlation factor recalculated following 4.a and 4.b. If the data set consists of less than five test sites, additional test sites shall be established.

   Note A1: The exact method used in calculating the nuclear gauge correlation factor shall be defined by agency policy.

   Note A2: The above correlation procedure must be repeated if there is a new job mix formula. Adjustments to the job mix formula beyond tolerances established in the contract documents will constitute a new job mix formula. A correlation factor established using this procedure is only valid for the particular gauge and at the probe depth used in the correlation procedure. If another gauge is brought onto the project, it shall be correlated using the same procedure. Multiple gauges may be correlated from the same series of cores if done at the same time.

   Note A3: For the purpose of this procedure, a job mix formula is defined as the percent and grade of paving asphalt used with a specified gradation of aggregate from a designated aggregate source. A new job mix formula may be required whenever compaction of the wearing surface exceeds the agency's specified maximum density or minimum air voids.

Core Correlation Example:

	Core results from T 166:	Average Gauge reading:	Difference:	X	X2
1	144.9 lb/ft^3	142.1 lb/ft^3	2.8 lb/ft^3	-0.7	0.49
2	142.8 lb/ft^3	140.9 lb/ft^3	1.9 lb/ft^3	0.2	0.04
3	143.1 lb/ft^3	140.7 lb/ft^3	2.4 lb/ft^3	-0.3	0.09
4	140.7 lb/ft^3	138.9 lb/ft^3	1.8 lb/ft^3	0.3	0.09
5	145.1 lb/ft^3	143.6 lb/ft^3	1.5 lb/ft^3	0.6	0.36
6	144.2 lb/ft^3	142.4 lb/ft^3	1.8 lb/ft^3	0.3	0.09
7	143.8 lb/ft^3	141.3 lb/ft^3	2.5 lb/ft^3	-0.4	0.16
8	142.8 lb/ft^3	139.8lb/ft^3	3.0 lb/ft^3	0.9	0.81
9	144.8 lb/ft^3	143.3 lb/ft^3	1.5 lb/ft^3	-0.6	0.36
10	143.0 lb/ft^3	141.0 lb/ft^3	2.0 lb/ft^3	-0.1	0.01
	Average Difference:		+2.1 lb/ft^3		

$$\sqrt{\frac{\sum x^2}{n-1}}$$

Where:

∑ = Sum
x = Difference from the average Difference
n-1 = number of data sets minus 1

Example: 10 – 1 = 9

$$\sqrt{\frac{2.5}{9}} = 0.53$$

X1.1.1.

The Sum of X2 = 2.5 and the number of data sets = 9 for a computed standard deviation of 0.53. This is within the allowable 2.5 therefore no cores are eliminated, use the average difference from all ten cores.

Performance Exam Checklist

FOP for AASHTO T 355
In-Place Density of Asphalt Mixtures by Nuclear Method

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element		Trial 1	Trial 2
1.	Gauge turned on approximately 10 to 20 minutes before use?		
2.	Gauge calibrated and standard count recorded?		
3.	Test location selected appropriately [600 mm (24 in) from vertical projections or 10 m (30 ft) from any other radioactive sources]?		
4.	Procedure:		
	a. Filler spread evenly over test site?		
	b. Excess filler material removed by striking off the surface?		
	c. Gauge placed on pavement surface and footprint of gauge marked?		
	d. Probe extended to backscatter position?		
	e. One-minute count taken; gauge rotated 90°, reseated, and another one-minute count taken?		
	f. Densities averaged?		
	g. If difference of the wet densities is greater than 40 kg/m3 (2.5 lb/ft3), retest conducted in both directions?		
5.	Core correlation applied if required?		
6.	Percent compaction calculated correctly?		

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

Signature of Examiner _____ WAQTC #:_____

Comments:

Washington State
Department of Transportation

WSDOT Test Method T 606

Method of Test for Compaction Control of Granular Materials

1. Scope

This test method is used to establish the theoretical maximum density of granular materials and non-granular materials with more than 30 percent by weight of the original specimen is retained on the No. 4 sieve or more than 30 percent by weight of the original specimen is retained on the ¾ in sieve.

2. Reference Documents

2.1 AASHTO Standards

T 99	Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop (Method A only)
M 92	Standard Specification for Wire-Cloth Sieves for Testing Purposes
M 231	Standard Specification for Weighing Devices Used in the Testing of Materials

2.2 WSDOT Standards

T 2	FOP for AASHTO Standard Practice for Sampling Aggregates
R 76	FOP for AASHTO Reducing Samples of Aggregate to Testing Size
T 255	FOP for AASHTO Total Moisture Content of Aggregate by Drying

3. Definitions

3.1 Fine Aggregate Portion – Material passing the No. 4 Sieve.

3.2 Coarse Aggregate Portion – Material retained on the No. 4 Sieve.

4. Significance and Use

This test method consists of three separate tests which present a method for establishing the proper theoretical maximum density values to be used for controlling the compaction of granular materials. In general, this test method is applicable to granular materials having 30 to 70 percent of the material passing the No. 4 (4.75 mm) sieve. These methods account for variations of maximum obtainable density of a given material for a given compactive effort, due to fluctuations in gradation.

5. Apparatus

5.1 A vibratory spring-loaded compactor. Information on where to obtain this equipment will be provided by the State Materials Laboratory.

5.2 Small Mold height = 8 in ± 0.1 internal diameter = 6 in ± 0.15, a piston to fit inside the mold with a maximum 1⁄16 in clearance between piston and mold.

5.3 Large Mold- Approximately ½ ft^3 (internal height 85-150 percent of diameter) with a piston to fit inside mold having a maximum 1⁄16 in clearance between piston and mold.

5.3.1 The molds and pistons will be constructed of metal of such dimensions as to remain rigid and inflexible under test conditions.

5.4 Spacer blocks of varying heights compatible with the compactor and pistons.

5.5 Measuring device, accurate and readable to 0.01 in with a minimum 6 in length.

5.6 Pycnometer calibrated at the test temperature having a capacity of at least 1 quart (100 ml). Glass pycnometers shall be used to determine the specific gravity of the fine particles. The glass pycnometer shall have a companion glass plate large enough to cover the jar's opening when calibrating or weighing the pycnometer.

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

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

5.8 One vacuum pump or aspirator (pressure not to exceed 100 mm mercury).

5.9 One balance accurate to 0.1 g.

5.10 3 in (75 mm), ¾ in (19 mm), and a No. 4 (4.75 mm) sieve conforming to ASTM E11 requirements.

5.11 Balance or Scale – Capacity sufficient for the principle sample mass, readable to 0.1 percent or 0.1 g, and meeting the requirements of AASHTO M 231.

5.12 Manually Operated Metal Rammer – As specified in AASHTO T 99, Apparatus.

5.13 Tamping rod of straight steel, ⅝ in (16 mm) in diameter and approximately 24 in (400 mm) long having at least one end rounded to a hemispherical tip.

5.14 Graduated cylinder.

5.15 A stopwatch or timer readable to 1 second.

6. Selection of T 606 Test and Procedure

To select the proper method for determining the maximum density of the fine aggregate portion of the sample, refer to the Fine Aggregate Split of Original Sample section of Table 1.

To select the proper procedure in Test 2 for determining the maximum density of the coarse aggregate portion of the sample, refer to the Coarse Aggregate Split of Original Sample section of Table 1.

Fine Aggregate Split of Original Sample	
Soil Type	**Test Method**
Sandy, non-plastic, permeable soils or non-cohesive soils.	T 606, Test 1
Silt, some plasticity, low permeability.	T 99, Method A
Sandy/silt, some plasticity, permeable.	T 606, Test 1/T 99, Method A (use highest results)
Coarse Aggregate Split of Original Sample	
No more than 15 percent by weight of the original aggregate specimen exceeds ¾ in	T 606, Test 2, Procedure 1
15 percent or more by weight of the original aggregate specimen is greater than ¾ in (19 mm), but does not exceed 3 in (76 mm).	T 606, Test 2, Procedure 2

Test Selection
Table 1

7. Sampling Material

7.1 Sample the material in accordance with WSDOT FOP for AASHTO T 2.

7.2 Native soils within the contract limits to be used for embankment construction and/or backfill material do not require sampling by a qualified tester.

7.3 For material that requires gradation testing such as but not limited to manufactured aggregates and gravel borrow, sampling shall be performed by a qualified testers.

8. Sample Preparation

8.1 Prepare the field sample by splitting out a representative portion in accordance with WSDOT FOP for AASHTO R 76.

8.2 Dry the compaction sample in accordance with WSDOT FOP for AASHTO T 255.

8.3 Scalp the plus 75 mm (3 in) material from the compaction sample and discard, if not required for other tests.

8.4 Separate the remainder of the compaction sample into coarse and fine aggregate fractions as follows:

8.4.1 Fine Aggregate (No. 4 minus) – Minimum of three portions approximately 13 lb (6 kg) each.

8.4.2 Coarse Aggregate

8.4.2.1 Procedure 1 (Aggregate Size: No. 4 to ¾ in (19 mm) – Separate a representative specimen of 10 to 11 lbs (4.5 to 5 kg) and weigh to 0.01 lbs (5 g) or less if using a balance that is more accurate than 0.1 lbs.

8.4.2.2 Procedure 2 (Aggregate Size: No. 4 to 3 in (76 mm) – Separate a representative specimen of 45 lbs (20 kg) and weigh to 0.1 lbs (50 g) or less if using a balance that is more accurate than 0.1 lbs.

9. Procedure

9.1 Test No. 1 – Compaction Test of the Fine Fraction (No. 4 Minus Material)

9.1.1 Assemble the small mold and determine its mass, along with the piston, to the nearest 0.01 lb (5 g). Record this as the Mass of Mold Assembly.

9.1.2 Using one of the fine aggregate portions, add an amount of water estimated to produce a saturated sample (see Note 1). Mix the water and aggregate until the sample is homogenous.

Note 1: The sample is considered saturated when one to two drops of free water are visible at the base of the mold at the end of the first 2-minute cycle. Do not over saturate the material.

9.1.3 Set the piston aside and place the sample in the mold in three approximately equal layers. Consolidate each lift by 25 strokes of the tamping rod followed by 25 blows of the manually operated metal rammer. The surface of the top lift should be finished as level as possible.

9.1.4 Place the piston on top of the sample and mount the mold on the jack platform in the compactor. Spacers between the load spring and piston must be used to adjust the elevation of the mold so the hammers strike the mold in the center of the lift area.

9.1.5 Elevate the mold until the loading head seats on top of the piston. Apply an initial seating load of approximately 100 lbs on the sample.

9.1.6 Start the compactor hammers and, by elevating the jack, begin the loading procedure. The load is gradually applied over the time stated in the table below.

Load Application Rate	
Load	**Time**
0 to 500 lb	1 minute
500 lb to 1,000 lb	30 sec
1000 lb to 2,000 lb	30 sec

9.1.7 Upon reaching the 2,000 lb load at the end of the 2-minute cycle, stop the hammers, release the load on the jack, return to zero pressure, and check for free water.

Note 2: If dirty water is flooding off the base of the mold or excessive material is pumping around the sides of the top piston, the sample is beyond the saturation point. Stop the test, remove the material from the mold, prepare a new sample at lower moisture content, and begin the test again.

9.1.8 Repeat Steps 9.1.5 through 9.1.7 four additional times (excluding check for free water). After the last run, remove the mold from the compactor.

9.1.9 Measure the height of the compacted sample to the nearest 0.01 in (0.1 mm) and record as the “Depth.”

9.1.10 Determine the mass of the specimen in the mold to the nearest 0.01 lb (5 g). Record this as: Mass of Mold + Sample.

9.1.11 Remove the specimen from the mold and determine the moisture content in accordance with WSDOT FOP for AASHTO T 255.

9.1.12 Vertically slice through the center of the specimen, take a representative specimen (at least 1.1 lbs (500 g)) of the materials from one of the cut faces (using the entire specimen is acceptable), weigh immediately, dry in accordance with AASHTO T 255 to determine the moisture content, and record the results.

9.1.13 Calculate and record the dry density of fine fraction.

9.2 Test No. 2 – Compaction Test of the Coarse Fraction

9.2.1 Procedure 1 – ¾ in (19 mm) to No. 4 (4.75 mm) Aggregates

9.2.1.1 Determine the mass of the coarse aggregate to the nearest 0.01 lb (5 g).

9.2.1.2 Add 2.5 percent moisture to the sample, mix thoroughly.

9.2.1.3 Place in 0.1 ft^3 (0.0028 m^3) mold in approximately three equal lifts. Tamp each lift lightly to consolidate material and achieve a level surface. Avoid the loss of any material during placement.

9.2.1.4 Follow steps 9.1.5 through 9.1.8.

9.2.1.5 Measure the height of the compacted sample to the nearest 0.01 in (0.1 mm) and record as the "Depth."

9.2.1.6 Calculate and record the dry density of coarse fraction.

9.2.2 Procedure 2 – 3 in (76 mm) to No. 4 Aggregates

9.2.2.1 Determine the mass of the coarse aggregate to the nearest 0.01 lb (5 g) or better.

9.2.2.2 Divide the sample into five representative, approximately equal portions.

9.2.2.3 Place one of the portions into the ½ ft^3 (0.014 m^3) mold and level the surface.

9.2.2.4 Position the piston on the material, mount the mold in the compactor, and compact as described in steps 9.1.5 through 9.1.7.

Note 3: Spacers may be needed between the load spring and piston to adjust the elevation of the mold to the height of the lift being compacted.

9.2.2.5 Repeat 9.2.2.3 and 9.2.2.4 for the remaining four portions of material.

9.2.2.6 After the final portion is compacted, determine the height of the compacted sample to the nearest 0.01 in (0.1 mm) and record as the "Depth."

9.2.2.7 Calculate and record the dry density of coarse fraction (see Calculations section).

9.3 Test No. 3 – Specific Gravity Determination for Maximum Density Test

9.3.1 Material

9.3.1.1 Fine fraction No. 4 (4.75 mm) minus 1.1 lbs (500 g) minimum.

9.3.1.2 Coarse fraction No. 4 (4.75 mm) plus 2.2 lbs (1,000 g) minimum.

9.3.2 Procedure

9.3.2.1 Place dry materials, either fine or coarse fraction, in pycnometer.

9.3.2.2 Fill the pycnometer approximately ¾ full with 68°F (20°C) water.

9.3.2.3 Connect the pycnometer to the vacuum system. Apply a partial vacuum of 30 mm Hg or less absolute pressure for a period of 20 minutes.

9.3.2.4 Agitate container either continuously by mechanical device or manually by vigorous shaking at 2-minute intervals.

9.3.2.5 Release vacuum and disconnect the hoses.

9.3.2.6 Fill pycnometer with water. Water temperature during test should be maintained as close to 68° ± 1°F (20° ± 0.5°C) as possible.

Note 4: It may be necessary to place the pycnometer in a water bath for 10 minutes, after release of vacuum, to bring the water temperature back to 68° ± 1°F (20° ± 0.5°C).

9.3.2.6.1 Metal Pycnometer (Coarse Specific Gravity Only) – Fill the vessel, according to the manufacturer's instructions, with 68° ± 1°F (20° ± 0.5°C) water. Dry the outside of the vessel and weigh to the nearest 0.1g. Record the weight.

9.3.2.6.2 Glass Pynometer (Fine or Coarse Specific Gravity) – Completely fill the pycnometer with 68° ± 1°F (20° ± 0.5°C) water, then slide the calibrated glass plate over the mouth of the jar making sure air bubbles are not trapped under the glass plate. Dry the outside of the pycnometer and glass plate and weigh to the nearest 0.1g. Record the weight.

Calculations

10. Determine the dry density of each of the fine aggregate points as follows:

10.1 Calculate Specific Gravity as follows:

$$\text{Sp. Gr.} = = \frac{a}{(a + b - c)}$$

Where:

a = Weight of dry material, grams
b = Weight of pycnometer + water, grams
c = Weight of pycnometer + material + water, grams

10.2 Calculate the wet sample weight:

$$e = c - d$$

Where:

e = Wet sample weight, g
c = mold and wet sample weight
d = Tare of mold assembly

10.3 Calculate the wet density by:

$$g = \frac{e}{b \times f}$$

Where:

g = wet density, lb/ft^3
e = wet sample weight, lbs
b = mold constant, ft^3/in
f = height of sample, in (height constant-depth)

10.4 Calculate the dry density of each of the fine fraction specimens as follows:

$$h = \frac{g}{1 + n}$$

Where:

h = dry density, lb/ft^3
g = wet density, lb/ft^3
n = moisture content, expressed as a decimal

11. Reports

11.1 Enter information into the WSDOT Materials Testing System (MATS) or other form approved in writing by the State Materials Engineer to obtain the theoretical maximum density curve.

Performance Exam Checklist

WSDOT Test Method T 606
Method of Test for Compaction Control of Granular Materials

Participant Name _____ Exam Date _____

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	☐	☐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	☐	☐
Fine Fraction – 100% Passing the No. 4 (4.75 mm) Sieve		
Specimen Preparation		
1. Has the specimen been oven-dried?	☐	☐
2. Has the specimen been separated on the No. 4 (4.75 mm) sieve?	☐	☐
3. Is the specimen weight approximately 13 lbs?	☐	☐
Procedure		
1. Is specimen saturated when compacted?	☐	☐
2. Has specimen been placed in three layers, rodded 25, and tamped 25 times, each layer?	☐	☐
3. Is the hammer blow approximately a 12 in free fall to prevent severe displacement of the specimen?	☐	☐
4. The specimen is as level as possible?	☐	☐
5. Has piston been placed on top of the specimen?	☐	☐
6. Has the mold been mounted on the jack in the compactor?	☐	☐
7. Has the mold been elevated until the load-spring retainer sits on top of the piston?	☐	☐
8. Has the initial load been set at 100 lbs?	☐	☐
9. Is the loading rate applied as specified in the test procedure?	☐	☐
10. Has the hammer been stopped, jack released, and pressure returned to zero when 2,000 lbs pressure was reached?	☐	☐
11. Are one to two drops of free water visible at the base of the mold at the end of the first 2-minute cycle?	☐	☐
12. Steps 7 through 10 repeated four additional times?	☐	☐
13. The mold removed from the compactor?	☐	☐
14. Has the height of the specimen been determined?	☐	☐
15. Has specimen been weighed?	☐	☐
16. Has specimen been removed from mold and a representative portion immediately weighted and the moisture percentage determined?	☐	☐
17. Moisture content, dry density determined and entered on the testing sheet?	☐	☐
18. Theoretical maximum density determined by testing fresh specimens, as necessary, at different moisture contents and entered on the testing sheets?	☐	☐

Procedure Element	Yes	No
Aggregate Size: No. 4 to ¾ in (19 mm)		
Specimen Preparation		
1. Has the specimen been oven-dried?	☐	☐
2. Has the specimen been separated on the No. 4 (4.75 mm) sieve?	☐	☐
3. Does more than 85 percent of the material pass the ¾ in (19 mm) sieve?	☐	☐
Procedure		
1. Weight and record specimen weight?	☐	☐
2. Has the specimen been dampened to 2½ percent and placed in three lifts in a 0.1 ft^3 mold?	☐	☐
3. Specimen lightly tamped to archive a level surface?	☐	☐
4. Piston placed on top of specimen and mold mounted on jack in compactor?	☐	☐
5. Mold elevated until the load-spring retainer sits on top of the piston?	☐	☐
6. Initial load of 100 lbs set prior to starting machine?	☐	☐
7. Is the load rate applied as specified in the test procedure?	☐	☐
8. Hammers stopped, jack released, and pressure returned to zero when 2,000 lb load has been reached?	☐	☐
9. Steps 5 through 8 repeated four additional times?	☐	☐
10. The mold removed from the compactor and the height measured?	☐	☐
11. Dry density calculated and entered on the testing sheets?	☐	☐
Aggregate Size: No. 4 to 3 in		
Specimen Preparation		
1. Has the specimen been oven-dried?	☐	☐
2. Has the specimen been separated on the No. 4 (4.75 mm) sieve?	☐	☐
3. Is the specimen weight approximately 45 lbs?	☐	☐
4. Does the specimen contain 15 percent or more ¾ + material?	☐	☐
5. Has material greater than 3 in (76 mm) been removed?	☐	☐
6. Specimen separated into five approximately equal parts?	☐	☐
Procedure		
1. Specimen placed in the mold in five separate lifts?	☐	☐
2. The specimen is as level as possible?	☐	☐
3. After each lift, mold placed in compactor and compacted according to test procedure?	☐	☐
4. After compacting final lift, specimen removed from compactor and volume determined?	☐	☐
5. Dry density determined calculated and entered onto testing sheet?	☐	☐

Procedure Element	**Yes**	**No**
Specific Gravity Determination for Theoretical Maximum Density Test		
Specimen Preparation		
1. Has the specimen been oven-dried?	☐	☐
2. Has the specimen been separated on the No. 4 (4.75 mm) sieve?	☐	☐
3. Weight of fine fraction approximately 500 g?	☐	☐
4. Weight of coarse fraction approximately 1000 g?	☐	☐
Procedure		
1. Material placed in pycnometer and 68°F water added?	☐	☐
2. Vacuum applied for at least 20 minutes?	☐	☐
3. Container and contents agitated manually by shaking at intervals of 2 minutes?	☐	☐
4. Pycnometer filled with water at 68°F?	☐	☐
5. Pycnometer dried, weighted, and recorded on testing sheet?	☐	☐
6. Specific Gravity calculated and entered onto testing sheet?	☐	☐

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

Signature of Examiner _____

Comments:

Washington State
Department of Transportation

WSDOT Standard Operating Procedure SOP 615

Determination of the % Compaction for Embankment & Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge

1. Scope

This procedure covers the procedures for determining the in-place density, moisture content, gradation analysis, oversize correction, and determination of maximum density of compacted soils and untreated surfacing materials using a nuclear density device in the direct transmission mode.

2. References

a. AASHTO T 99 for Method of Test for Moisture-Density Relations of Soils

b. AASHTO T 180 for Method of Test for Moisture-Density Relations of Soils

c. T 255 – WSDOT FOP for AASHTO for Total Moisture Content of Aggregate by Drying

d. T 272 – WSDOT FOP for AASHTO for Family of Curves – One Point Method

e. T 310 – WSDOT FOP for AASHTO 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. 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.

When retesting is required due to a failing test; retest within a 10-foot radius of the original station and offset.

4. Nuclear Density Test

Determine the dry density and moisture content of soils and untreated surfacing materials using the nuclear moisture-density gauge in accordance with WSDOT FOP for AASHTO T 310, and record in the Materials Testing System (MATS), WSDOT Form 350-074, Field Density Test, or other form approved in writing by the State Materials Engineer.

5. Oversize Determination

a. AASHTO T 99 and WSDOT T 606

A sample weighing a minimum of 4.08 kg (9 lbs) will be taken from beneath the gauge. Care shall be taken to select material that is truly representative of where the moisture density gauge determined the dry density and moisture content.

There are two methods for determining the percentage of material retained on the No. 4 sieve:

1. Method 1 – material that allows for the easy separation of fine and coarse aggregate.
    a. Dry the sample until no visible free moisture is present (material may still appear damp but will not be shiny).
    b. Determine and record the mass of the sample to the nearest 0.1 percent of the total mass or better.
    c. Shake the sample by hand over a verified No. 4 (4.75 mm) sieve taking care not to overload the sieve. Overloading for a No. 4 (4.75 mm) sieve is defined as; A retained mass of more than 800 g (1.8 lbs), on a 12 inch sieve, or 340 g, (0.75 lbs); on an 8 inch sieve after sieving is complete.

        Note 1: If the tester suspects a sieve will be overloaded the sample can be separated into smaller increments and recombined after sieving.
    d. Determine and record the mass of the material retained on the No. 4 (4.75 mm) sieve to the nearest 0.1 percent of the total mass or better and record.
2. Method 2 – recommended for crushed surfacing materials, materials with high clay content, or other granular materials that are at or near the optimum moisture content for compaction.
    a. Determine and record the mass of the sample to the nearest 0.1 percent of the total mass or better and record.
    b. Shake sample by hand over a verified No. 4 (4.75 mm) sieve. Do not overload the sieve. (See Section 1a and Note 1 for overload definition and information on how to prevent overloading of a sieve)
    c. Shake material until no particles are observed passing the No. 4 (4.75 mm) sieve
    d. Rinse the sample with water
    e. Continue rinsing the material until it is visibly free of any coating or minus No. 4 material.
    f. Place the washed material, retained on the No. 4 (4.75 mm) sieve, into a tared container and blot until no visible free moisture is present on the material (material may still appear damp but will not appear shiny).
    g. Determine and record the mass of the material retained on the No. 4 (4.75 mm) sieve to the nearest 0.1 percent of the total mass or better.

b. AASHTO T 180

1. Follow either Method 1 or Method 2 in 5 a. with the following exception; sieve the material over a ¾ in (19.0 mm) sieve.
2. Do not overload the ¾" (19.0 mm) sieve. Overloading of a ¾" (19.0 mm) sieve is defined as: A retained mass of more than 3.2 kg (7.04 pounds) on a 12 inch sieve or 1.4 kg (3.08 pounds) on an 8 inch sieve after sieving is complete.

6. Calculations

a. Calculate the percent retained as follows:

$$\% \text{ retained (Pc)} = 100 \times \frac{\text{mass retained on sieve}}{\text{original mass}} \text{ (round to nearest percent)}$$

b. Calculate percent passing as follows:

$$\% \text{ passing} = 100 - \% \text{ retained}$$

c. Calculate the dry density as follows:

$$d = \frac{100}{100 + W} (m)$$

Where:

d = dry field density of total sample, pcf
m = total field wet density, pcf
W = moisture content of total field sample

d. Calculate the corrected theoretical maximum density as follows:

$$D_d = \frac{100 \times (D_f) \times (k)}{[(D_f) \times (P_c) + (k) \times (P_f)]}$$

Where:

D_d = corrected dry density of combined fine and oversized particles, expressed as lbs/ft^3.
D_f = dry density of fine particles expressed as lbs/ft^3, determined in lab.
P_c = percent of coarse particles, by weight.
P_f = percent of fine particles, by weight.
k = 62.4 x Bulk Specific Gravity.

Calculate in-place dry density to the nearest 0.1 lbs/ft^3.

Note 2: If the specific gravity of the coarse particles has been determined, use this value in the calculation for the "k" value. If the specific gravity is unknown then use 2.67. Either AASHTO T 85 or WSDOT T 606 Test 3 may be used to determine the specific gravity of the coarse particles.

e. Calculate the percent of compaction using the following equation:

$$\% \text{ compaction} = \frac{\text{Dry Density (lbs/ft}^3\text{)}}{\text{corrected theoretical maximum density (lbs/ft}^3\text{)}}$$

7. Density Curve Tables

The Materials Testing System (MATS) Density Curve Tables is the WSDOT preferred method for determining the corrected theoretical maximum density.

a. MATS calculates the corrected theoretical maximum density in accordance with AASHTO T 99 and T 180 ANNEX A1. (Correction of Maximum Dry Density and Optimum Moisture for Oversized Particles) and reports the results in the Density Curve Table.

b. To determine the corrected theoretical maximum density using the Density Curves Table enter the Table at the line corresponding to the % passing or % retained (T 99 & T 180 requires percent retained, T 606 requires percent passing), read across to the column labeled Max this number is the Corrected Theoretical Maximum Density.

8. Report

a. Report the results using one or more of the following:
   - Materials Testing System (MATS)
   - WSDOT Form 350-074 and 351-015
   - Form approved in writing by the State Materials Engineer

b. Report the percent of compaction to the nearest whole number.

Performance Exam Checklist

WSDOT Standard Operating Procedure SOP 615
Determination of the % Compaction for Embankment &
Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge

Participant Name _____ Exam Date _____

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	☐	☐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	☐	☐
Gradation Analysis		
3(A) Method 1		
1. Sample Dried to a SSD condition (dried until no visible free moisture present) and mass recorded?	☐	☐
2. Sample allowed to cool sufficiently prior to sieving?	☐	☐
3. Sample was shaken by hand through the appropriate sieve for a sufficient period of time?	☐	☐
4. Recorded mass of material retained on the appropriate sieve?	☐	☐
5. Calculated and recorded percent of material retained and passing the appropriate sieve?	☐	☐
3(B) Method 2		
1. Mass of sample determined prior to washing?	☐	☐
2. Material charged with water in suitable container and agitated to suspend fines?	☐	☐
3. Sample decanted over required sieve for a sufficient amount of time without overloading sieve?	☐	☐
4. Retained material dried to SSD condition and mass determined?	☐	☐
5. Recorded mass of material retained on appropriate sieve?	☐	☐
6. Calculated and recorded percent of material retained and passing appropriate sieve?	☐	☐
Correction for Coarse Particles		
7. Appropriate MATS Density Curve Table used to determine the corrected theoretical maximum density, based on the percent passing or retained on the appropriate sieve?	☐	☐
8. All calculations performed correctly?	☐	☐

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

Signature of Examiner _____

Comments: