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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.

For updating printed manuals, page numbers indicating portions of the manual that are to be removed and replaced are shown below.

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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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Approved By

Signature

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Engineering and Regional Operations
State Materials Laboratory

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Hot Mix Asphalt				
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Concrete				
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Geotechnical – Soils				
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T 307	AASHTO		✓	Determining the Resilient Modulus of Soils and Aggregate Materials
T 310	WSDOT	✓	✓	FOP for AASHTO for In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
T 606	WSDOT		✓	Method of Test for Compaction Control of Granular Materials
T 610	WSDOT		✓	Method of Test for the Capillary Rise of Soils
SOP 615	WSDOT	✓	✓	Determination of the % Compaction for Embankment & Untreated Surfacing Materials Using the Nuclear Moisture-Density Gauge
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Standard Practice				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
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QC 2	WSDOT		✓	Standard Practice for Asphalt Suppliers That Certify Performance Graded and Emulsified Asphalts
QC 3	WSDOT		✓	Quality System Laboratory Review
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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	WSDOT	✓	✓	FOP for AASHTO for Standard Practice for Sampling Aggregates
TM 2	WAQTC	✓	✓	FOP for WAQTC for 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	WSDOT	✓	✓	FOP for AASHTO for Making and Curing Concrete Test Specimens in the Field
T 27	AASHTO			Sieve Analysis of Fine and Coarse Aggregates
T 27/T 11	WSDOT	✓	✓	FOP for WAQTC/AASHTO for 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 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
T 48	AASHTO			Flash and Fire Points by Cleveland Cup
T 49	AASHTO			Penetration of Bituminous Materials

Numerical Order				
Procedure Number	Owner	Field Use	In Manual	Test Method
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	WSDOT	✓	✓	FOP for WAQTC/AASHTO for Sampling Bituminous Materials
E 70	ASTM			pH of Aqueous Solutions With the Glass Electrode
T 72	AASHTO			Saybolt Viscosity
R 76	AASHTO			Reducing Samples of Aggregate to Testing Size
R 76	WSDOT	✓	✓	FOP for AASHTO for 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 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 Checklist
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	WSDOT	✓	✓	FOP for AASHTO for Standard Test Method for Slump of Hydraulic-Cement Concrete
T 121	AASHTO	✓	✓	Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete (Checklist Only)
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

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
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	WSDOT	✓	✓	FOP for WAQTC for 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	WSDOT	✓	✓	FOP for AASHTO for Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
T 168	AASHTO			Sampling Bituminous Paving Mixtures
T 168	WSDOT	✓	✓	FOP for WAQTC/AASHTO for 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	WSDOT	✓	✓	FOP for AASHTO for Plastic Fines in Graded Aggregates and Soils by 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 Checklist
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
T 209	AASHTO			Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)
T 209	WSDOT	✓	✓	FOP for AASHTO for Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures
T 215	AASHTO			Permeability of Granular Soils (Constant Head)
T 216	AASHTO			One-Dimensional Consolidation Properties of Soils
T 217	WSDOT	✓	✓	FOP for AASHTO for Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester
T 228	AASHTO			Specific Gravity of Semi-Solid Bituminous Material

Numerical Order				
Procedure Number	Owner	Field Use	In Manual	Test Method
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	WSDOT	✓	✓	FOP for AASHTO for 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 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			Family of Curves – One Point Method
T 272	WSDOT	✓	✓	FOP for AASHTO for Family of Curves – One Point Method
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
T 308	WSDOT	✓	✓	FOP for AASHTO for 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	WSDOT	✓	✓	FOP for AASHTO for Temperature of Freshly Mixed Portland Cement Concrete
T 310	WSDOT	✓	✓	FOP for AASHTO for In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
T 312	WSDOT	✓	✓	FOP for AASHTO for Preparing Hot-Mix Asphalt (HMA) 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)

Numerical Order				
Procedure Number	Owner	Field Use	In Manual	Test Method
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 712	WSDOT	✓	✓	Standard Method of Reducing Hot Mix Asphalt Paving Mixtures
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
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

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
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
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)

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
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
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

Numerical Order				
Procedure Number	**Owner**	**Field Use**	**In Manual**	**Test Method**
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)

WSDOT Standard Practice for QC 8

Standard Practice for Approval of Hot Mix Asphalt Mix Designs for the Qualified Products List

1. Scope

1.1. This standard specifies requirements and procedures for approval of 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

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

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

3.3. ASA – Aggregate Source Approval

3.4. ASTM – American Society of Testing and Materials

3.5. HMA – Hot Mix Asphalt

3.6. PG – Performance Graded asphalt binder

3.7. QPL – Qualified Products List

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

3.9. 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 350-042
- 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*.

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 1.5% 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 350-041 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

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

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

WSDOT FOP for AASHTO T 310[1]

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

1. Scope

1.1 This test method describes the procedure for determining the in-place density and moisture of soil and soil-aggregate by use of nuclear equipment. The density of the material may be determined by direct transmission, backscatter, or backscatter/air-gap ratio method. The WSDOT standard method for determining density is by direct transmission.

1.2 Density – The total or wet density of soil and soil-rock mixtures is determined by the attenuation of gamma radiation where the source or detector is placed at a known depth up to 12 in (300 mm) while the detector(s) or source remains on the surface (Direct Transmission Method) or the source and detector(s) remain on the surface (Backscatter Method).

1.2.1 The density in mass per unit volume of the material under test is determined by comparing the detected rate of gamma radiation with previously established calibration data.

1.3 Moisture – The moisture content of the soil and soil-rock mixtures is determined by thermalization or slowing of fast neutrons where the neutron source and the thermal neutron detector both remain at the surface.

1.3.1 The water content in mass per unit volume of the material under test is determined by comparing the detection rate of thermalized or slow neutrons with previously established calibration data.

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

1.5 This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use (see Section 6).

2. Referenced 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
T 180	Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18 in (457 mm) Drop
T 191	Density of Soil In-Place by the Sand-Cone Method
T 217	Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester
T 255	Total Evaporable Moisture Content of Aggregate by Drying
T 265	Laboratory Determination of Moisture Content of Soils
T 272	Family of Curves – One-Point Method

[1]This FOP is based on AASHTO 310-11 and has been modified per WSDOT standards. To view the redline modifications, contact the WSDOT Quality Systems Manager at 360-709-5412.

2.2 ASTM Test Method

D 2216	Laboratory Determination of Moisture Content of Soil
D 2487	Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D 2488	Description and Identification for Soils (Visual-Manual Procedure)
D 2937	Density of Soil in Place by the Drive-Cylinder Method
D 4253	Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
D 4254	Maximum Index Density and Unit Weight of Soils and Calculation of Relative Density
D 7013	Standard Guide for Nuclear Surface Moisture and Density Gauge Calibration Facility Setup

2.3 WSDOT Standards

T 606	Method of Test for Compaction Control of Granular Materials
SOP 615	Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge

3. Significance

3.1 The test method described is useful as a rapid, nondestructive technique for the in-place determination of the wet density and water content of soil and soil-aggregate.

3.2 The test method is used for quality control and acceptance testing of compacted soil and rock for construction and for research and development. The non-destructive nature allows repetitive measurements at a single test location and statistical analysis of the results.

3.3 Density – The fundamental assumptions inherent in the methods are that Compton scattering is the dominant interaction and that the material under test is homogeneous.

3.4 Moisture – The fundamental assumptions inherent in the test method are that the hydrogen present is in the form of water as defined by ASTM D 2216, and that the material under test is homogeneous.

3.5 Test results may be affected by chemical composition, sample heterogeneity, and, to a lesser degree, material density and the surface texture of the material being tested. The technique also exhibits spatial bias in that the gauge is more sensitive to water contained in the material in close proximity to the surface and less sensitive to water at deeper levels.

4. Interferences

4.1 In-Place Density Interferences

4.1.1 The chemical composition of the sample may affect the measurement, and adjustments may be necessary.

4.1.2 The gauge is more sensitive to the density of the material in close proximity to the surface in the Backscatter Method.

Note 1: The nuclear gauge density measurements are somewhat biased to the surface layers of the soil being tested. This bias has largely been corrected out of the Direct Transmission Method and any remaining bias is insignificant. The Backscatter Method is still more sensitive to the material within the first several inches from the surface. Density measurements with direct transmission is the WSDOT standard method for soil and soil aggregate.

4.1.3 Oversize rocks or large voids in the source-detector path may cause higher or lower density determination. Since there is lack of uniformity in the soil due to layering, rock, or voids the test site beneath the gauge will be excavated and a representative sample will be taken to determine the gradation per WSDOT SOP 615.

4.1.4 Keep all other radioactive sources at least the minimum distance recommended by the manufacture away from the gauge to avoid affecting the measurement.

4.2 In-Place Moisture Content Interferences

4.2.1 The chemical composition of the sample may dramatically affect the measurement and adjustments may be necessary. Hydrogen in forms other than water, as defined by ASTM D 2216, and carbon will cause measurements in excess of the true value. Some chemical elements such as boron, chlorine, and minute quantities of cadmium will cause measurements lower than the true value.

4.2.2 The water content determined by this test method is not necessarily the average water within the volume of the sample involved in the measurement. The measurement is heavily influenced by the water content of the material closest to the surface. The volume of soil and rock represented in the measurement is indeterminate and will vary with the water content of the material. In general, the greater the water content of the material, the smaller the volume involved in the measurement. At 10 lbs/ft^3 (160 kg/m^3), approximately 50 percent of the typical measurement results from the water content of the upper 2 to 3 in (50 to 75 mm).

4.2.3 Keep all other neutron sources at least the minimum distance recommended by the manufacture away from the gauge to avoid affecting the measurement.

5. Apparatus

5.1 Nuclear Density/Moisture Gauge – While exact details of construction of the gauge may vary, the system shall consist of:

5.1.1 A sealed source of high energy gamma radiation such as cesium or radium.

5.1.2 Gamma Detector – Any type of gamma detector such as a Geiger-Mueller tube(s).

5.2 Fast Neutron Source – A sealed mixture of a radioactive material such as americium, radium, or californium-252 and a target material such as beryllium.

5.3 Slow Neutron Detector – Any type of slow neutron detector such as boron trifluoride or helium-3 proportional counter.

5.4 Reference Standard – A block of material used for checking instrument operation, correction of source decay, and to establish conditions for a reproducible reference count rate.

5.5 Site Preparation Device – A plate, straightedge, or other suitable leveling tool which may be used for planing the test site to the required smoothness, and in the Direct Transmission Method, guiding the drive pin to prepare a perpendicular hole.

5.6 Drive Pin – A pin not to exceed the diameter of the rod in the Direct Transmission Gauge by more than ¼ in (6 mm) or as recommended by the gauge manufacturer used to prepare a hole in the material under test for inserting the rod.

5.7 Hammer – Hand-held hammer of sufficient size and weight to drive the drive pin into the material being tested. A slide hammer with an attached drive pin is an acceptable alternate to the Drive Pin, Hammer, and Drive Pin Extractor.

5.8 Drive Pin Extractor – A tool that may be used to remove the drive pin in a vertical direction so that the pin will not distort the hole in the extraction process.

6. Hazards

6.1 This gauge utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of this gauge must become familiar with applicable safety procedures and government regulations.

6.2 Effective user instructions together with routine safety procedures, such as source leak tests, recording, and evaluation of film badge data, etc., are a recommended part of the operation and storage of this gauge.

7. Calibration

Nuclear gauges used for the purpose of acceptance testing, independent assurance testing, or dispute resolution shall be calibrated

WSDOT-owned nuclear density gauges will be calibrated by WSDOT using the manufacturer's recommended procedures or may be calibrated by an external calibration facility that has been approved by the State Materials Engineer.

Nuclear gauges that are not owned by WSDOT shall be calibrated in accordance with AASHTO T 310 Annexes A1, A 2, and A3.

8. Standardization

8.1 Turn the gauge on and allow it to stabilize for a minimum of 45 minutes prior to standardization. Leave the power on during the day's testing.

Note 2: If for any reason the gauge loses power or is turned off during the work period, the Standard Count must be re-established prior to use.

8.2 Standardize the gauge 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. Compare the daily Standard Count to the Density Standard Decay Sheet (Note 3) to ensure the Standard Count falls within acceptable limits. If the daily variations are exceeded after repeating the standardization procedure or if the daily Standard Count is outside the range of the Standard Decay Sheet, the gauge should be repaired and or recalibrated.

8.3 Record the Standard Count for both density and moisture in the Daily Standard Count Log. The exact procedure for standard count is listed in the manufacturer's operators manual.

Note 3: The Density Standard Decay Sheet is located in the calibration documentation. This sheet shows the anticipated Standard Count range based on the calculated decay rate of the gauges radioactive source over the passage of time.

9. Procedure

9.1 Select a test location per WSDOT SOP 615.

9.2 Prepare the test site in the following manner:

9.2.1 Remove all loose and disturbed material and additional material as necessary to expose the top of the material to be tested.

Note 4: The spatial bias should be considered in determining the depth at which the gauge is to be seated.

9.2.2 Select a horizontal area sufficient in size to accommodate four gauge readings that will be 90° to each other. Plane the area to a smooth condition so as to obtain maximum contact between the gauge and the material being tested.

9.2.3 The maximum void beneath the gauge shall not exceed ⅛ in (3 mm). Use native fines or fine sand to fill the voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler shall not exceed approximately ⅛ in (3 mm).

9.3 This section has been deleted because WSDOT does not use this method.

9.4 Direct Transmission Method of In-Place Nuclear Density and Moisture Content

9.4.1 When selecting a test location, the tester shall visually select a site where the least compactive effort has been applied. Select a test location where the gauge will be at least 6 in (150 mm) away from any vertical mass. If closer than 24 in (600 mm) to a vertical mass, such as in a trench, follow gauge manufacturer correction procedures.

The test location should be at least 33 ft (10 m) away from other sources of radioactivity and at least 10 ft (3 m) away from large objects or the minimum distance recommended by the manufacturer, whichever is the greater distance.

9.4.2 Make a hole perpendicular to the prepared surface using the guide and the hole-forming device (Section 5). The hole shall be a minimum of 2 in (50 mm) deeper than the desired measurement depth and of an alignment that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

9.4.3 Mark the test area to allow the placement of the gauge over the test site and to allow the alignment of the source rod to the hole. Follow manufacturer recommendations if applicable.

Note 5: For alignment purposes, the user may expose the source rod for a maximum of ten seconds.

9.4.4 Remove the hole forming device carefully to prevent the distortion of the hole, damage to the surface, or loose material to fall into the hole.

Note 6: If the hole cannot be maintained, contact the Regional Materials Laboratory for directions on how to proceed.

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

9.4.6 Lower the source rod into the hole to the desired test depth. Pull gently on the gauge in the direction that will bring the side of the probe to face the center of the gauge so that the probe is in intimate contact with the side of the hole in the gamma measurement path.

9.4.7 If the gauge is so equipped, set the depth selector to the same depth as the probe before recording the automated (gauge computed densities, moisture contents, and weights) values.

9.4.8 Secure and record one, one minute dry density and moisture content readings, then turn the gauge 90º and perform another set of readings. If the two dry density readings are not within 3 lbs/cf (50 kg/m^3) of each other, see Note 7.

Note 7: If two readings are not within tolerances stated, rotate gauge 90º and retest. Again compare both 90º readings. If after four readings the results are not within the tolerances stated, rotate gauge 90º and retest. Again compare both readings. If these reading are still not within tolerances stated, move to another location to perform test.

10. Calculation of Results

10.1 If dry density is required, the in-place water content may be determined by using the nuclear methods described herein, gravimetric samples and laboratory determination, or other approved instrumentation.

10.1.1 If the water content is determined by nuclear methods, use the gauge readings directly.

10.1.2 If the water content is determined by other methods and is in the form of percent, proceed as follows:

$$d = \frac{100}{100+W}(m)$$

where:

d = dry density in lb/ft^3 (kg/m^3)
m = wet density in lb/ft^3 (kg/m^3)
W = water as a percent of dry mass

10.2. Percent Compaction

WSDOT has deleted this section. Refer to WSDOT SOP 615 for determining the percent compaction.

11. Report

WSDOT has deleted this section. Refer to WSDOT SOP 615 for reporting.

12. Precision and Bias

WSDOT has deleted this section. Refer to AASHTO T 310 for precision and bias information.

Appendix

WSDOT has deleted this section. WSDOT uses the manufacturer's software to calibrate the gauge.

Performance Exam Checklist

In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
FOP for AASHTO T 310

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. Gauge turned on and allowed to stabilize?	☐	☐
4. Gauge standardized and standard count recorded?	☐	☐
5. Test location selected per WSDOT SOP 615?	☐	☐
6. Loose, disturbed material removed?	☐	☐
7. Flat, smooth area prepared?	☐	☐
8. Surface voids filled with native fines (⅛ in (3 mm) maximum thickness)?	☐	☐
9. Hole driven 2 in (50 mm) deeper than material to be tested?	☐	☐
10. Gauge placed, probe placed, and source rod lowered without disturbing loose material?	☐	☐
11. For alignment purposes, did not expose the source rod for more than 10 seconds?.	☐	☐
12. Method B		
a. Gauge firmly seated and gently pulled back so that source rod is against hole?	☐	☐
b. A one-minute count taken; dry density and moisture data recorded?	☐	☐
c. Gauge turned 90° (180° in trench)?	☐	☐
d. Gauge firmly seated and gently pulled back so that source rod is against hole?	☐	☐
e. A second one-minute count taken; dry density and moisture data recorded?	☐	☐
f. Dry density counts within 3 lb/ft3 (50 kg/m3)?	☐	☐
g. Average of two tests?	☐	☐
13. A minimum 9 lbs (4 kg) sample obtained from below gauge?	☐	☐
14. Oversize determined following WSDOT SOP 615?	☐	☐
15. All calculations performed correctly?	☐	☐
16. Nuclear Gauge secured in a manner consistent with current DOH requirements?	☐	☐

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

Signature of Examiner ______________________

Comments:

Washington State
Department of Transportation

WSDOT FOP for AASHTO T 355

In-Place Density of Asphalt Mixtures Using the Nuclear Moisture-Density Gauge

Scope

This test method describes a procedure for determining the density of asphalt mixtures by means of a nuclear gauge using the backscatter or thin layer method in accordance with AASHTO T 355-15. 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

- WSDOT does not use filler material

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 (Standard Count)

1. Turn the gauge on and allow it to stabilize for a minimum of 45 minutes prior to taking a Standard Count. Leave the power on during the day's testing.

   Note 1: If for any reason the gauge loses power or is turned off during the work period, the Standard Count must be re-established prior to use.

2. Prior to any correlation of the nuclear gauge, perform a Stat Test in accordance with the gauge's operator manual. If the gauge passes the Stat Test, perform a Standard Count. If the gauge fails the Stat Test, run a second Stat Test. If the gauge fails the second Stat Test, it should be repaired or recalibrated.

3. Take a Standard Count 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. Compare the daily Standard Count to the Density Standard Decay Sheet (Note 2) to ensure the standard count falls within acceptable limits. If the daily variations in Standard Count are exceeded after repeating the Standard Count procedure or if the daily Standard Count is outside the range of the Standard Decay Sheet, the gauge should be repaired and or recalibrated.

4. Record the Standard Count for both density and moisture in the Daily Standard Count Log. Instructions for taking a Standard Count are found in the gauge's operator manual.

   Note 2: The Density Standard Decay Sheet is found in the calibration documentation packet. This sheet shows the anticipated standard count range based on the calculated decay rate of the gauges radioactive source over the passage of time.

Test Site Location

Select a test location(s) randomly and in accordance with WSDOT Test Method T 716. Test sites should be relatively smooth and flat and meet the following conditions:

a. At least 30 ft. (10 m) away from other sources of radioactivity.

b. At least 10 ft. (3 m) away from large objects.

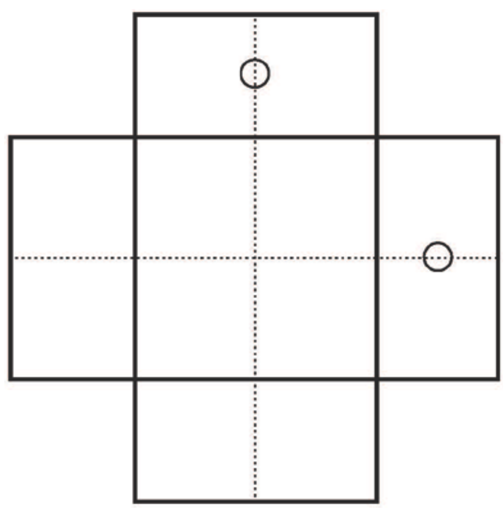
c. If the gauge will be closer than 24 in (600 mm) to any vertical mass, or less than 6 in (150 mm) from a vertical pavement edge, use the gauge manufacturer's correction procedure.

Procedure

Place the gauge on the test site. Using a crayon (not spray paint), mark the outline or footprint of the gauge. Extend the probe to the backscatter position.

Method 1 – Average of two one-minute tests WSDOT does not use Method 1

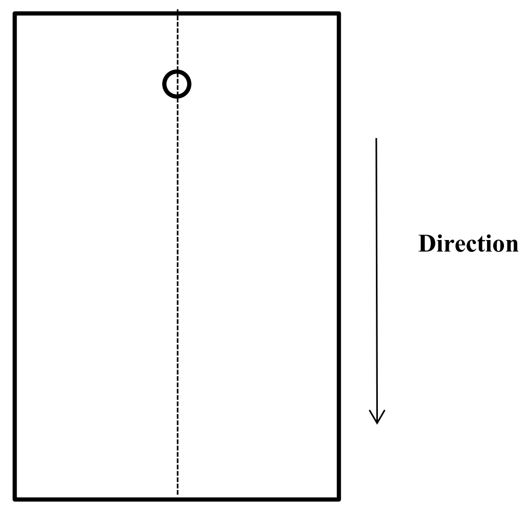
1. Take a one-minute test and record the wet density reading.
2. Rotate the gauge 90 degrees centered over the original footprint. Mark the outline or footprint of the gauge.
3. Take another one-minute test and record the wet density reading.
4. If the difference between the two one-minute tests is greater than 2.5 lb/ft^3 (40 kg/m^3), retest in both directions. If the difference of the retests is still greater than 2.5 lb/ft^3 (40 kg/m^3) test at 180 and 270 degrees.
5. 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
Method 1

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.*
3. Draw an outline around the entire gauge base for correlation coring.
4. Take one 4-minute test and record the wet density reading parallel to the direction of travel.



Footprint of The Gauge Test Site Parallel to Direction of Travel
Method 2

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 for Method 1 :

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

Example for Method 2:

Reading #1: 140.8 lb/ft^3

Core correction: +2.1 lb/ft^3

Corrected reading: 142.9 lb/ft^3

Example percent compaction:

From the FOP for AASHTO T 209:

$\mathbf{G_{mm}}$ = 2.466

Maximum Laboratory Dry Density = 153.5 lb/ft^3

$$\frac{Corrected\ Reading}{Maximum\ Density} \times 100 = \%\ compaction \qquad \frac{142.9\ lb/ft^3}{153.5\ lb/ft^3} \times 100 = 93.1\%$$

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)

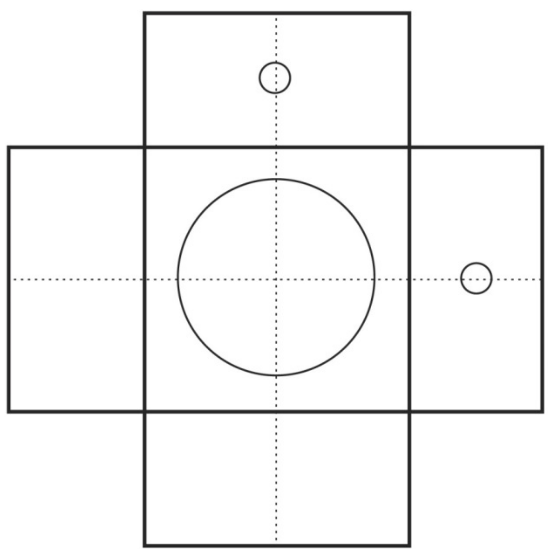
The Bulk Specific Gravity (G_{mb}) of the core is a physical measurement of the in-place HMA and can be compared with the nuclear density gauge readings. Comparing the core value to the corresponding gauge values, a correlation can be established.

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.

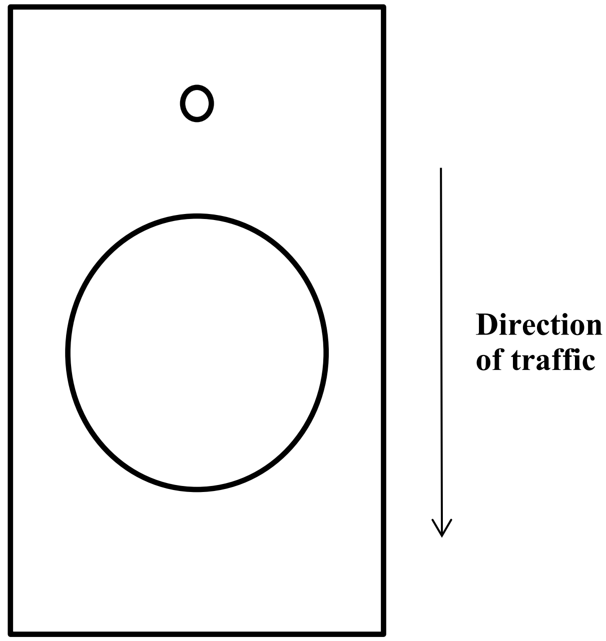
When density correlation with the FOP for AASHTO T 166 is required, correlation of the nuclear gauge with pavement cores shall be made on the first day's paving (within 24 hours) or from a test strip constructed prior to the start of paving. Cores must be taken before traffic is allowed on the pavement.

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 WSDOT SOP 734. The core should be taken from the center of the nuclear gauge footprint.



Footprint of The Gauge Test Site
Method 1



Footprint of The Gauge Test Site
Method 2

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 0.1 lb/ft^3 (1 kg/m^3). Calculate the average difference and standard deviation of the differences for the entire data set to the nearest 0.1 lb/ft^3 (1 kg/m^3).
   b. If the standard deviation of the differences is equal to or less than 2.5 lb/ft^3 (40 kg/m^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 2.5 lb/ft^3 (40 kg/m^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:	**English Average Gauge Reading:**	**Difference:**	**X**	**X²**
1	144.9 lb/ft³	142.1 lb/ft³	2.8 lb/ft³	-0.7	0.49
2	142.8 lb/ft³	140.9 lb/ft³	1.9 lb/ft³	0.2	0.04
3	143.1 lb/ft³	140.7 lb/ft³	2.4 lb/ft³	-0.3	0.09
4	140.7 lb/ft³	138.9 lb/ft³	1.8 lb/ft³	0.3	0.09
5	145.1 lb/ft³	143.6 lb/ft³	1.5 lb/ft³	0.6	0.36
6	144.2 lb/ft³	142.4 lb/ft³	1.8 lb/ft³	0.3	0.09
7	143.8 lb/ft³	141.3 lb/ft³	2.5 lb/ft³	-0.4	0.16
8	142.8 lb/ft³	139.8lb/ft³	3.0 lb/ft³	0.9	0.81
9	144.8 lb/ft³	143.3 lb/ft³	1.5 lb/ft³	-0.6	0.36
10	143.0 lb/ft³	141.0 lb/ft³	2.0 lb/ft³	-0.1	0.01
		Average Difference:	+2.1 lb/ft³		

$$\sqrt{\frac{\sum x^2}{n-1}}$$

Where:

$\sum$ = Sum

x = Difference from the average Difference

n-1 = number of data sets minus 1

Example: 10 – 1 = 9

$$\sqrt{\frac{2.5}{9}} = 0.53$$

The Sum of X^2 = 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

In-Place Density of Asphalt Mixtures Using The Nuclear Moisture-Density Gauge FOP For AASHTO T 355

Participant Element ____________________

Procedure Element	**Trial 1**	**Trial 2**
1. Does the tester have 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. Gauge turned on?	____	____
4. Gauge standardized and Standard Count recorded?	____	____
5. Standard Count compared with Density Standard Decay sheet?	____	____
6. Test location selected appropriately?	____	____
7. Test location selected appropriately [24 in (600 mm) from vertical projections or 30 ft (10 m) from any other radioactive sources]?	____	____
8. Procedure:		
a. Gauge placed on pavement surface and footprint of gauge marked?	____	____
b. Probe extended to backscatter position?	____	____
c. Does measurement depth match planned pavement depth (Thin Layer Mode Only)	____	____
d. Was a four-minute count taken?	____	____
e. Core correlation applied if required?	____	____
9. Percent compaction calculated correctly?	____	____
10. Nuclear Gauge secured in a manner consistent with current DOH requirements?	____	____

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 potable 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:

% passing = 100 – % 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:

WSDOT Test Method T 716

Method of Random Sampling for Locations of Testing and Sampling Sites

A. Scope

1. This method outlines the procedure for selecting sampling and testing sites in accordance with accepted random sampling techniques. It is intended that all testing and sampling locations be selected in an unbiased manner based entirely on chance.
2. Testing and sampling locations and procedures are as important as testing. For test results or measurements to be meaningful, it is necessary that the sampling locations be selected at random, typically by use of a table of random numbers. Other techniques yielding a system of randomly selected locations are also acceptable.

B. Summary of Method for Selecting Random Test Location

- Method A – Determining a Random Location for Hot Mixture Asphalt (HMA) Density Tests
- Method B – Determining Random Test Location for Sampling HMA Mix, Aggregates, and Miscellaneous Materials
- Method C – Determining Random Test Location for Portland Cement Concrete
- Appendix A – Hot Mix Asphalt Density Test Locations for Irregular Paving Areas

C. Procedure for Determining Random Test/Sampling Location

Method A – Selection of Random Location for HMA Density

1. Stationing

   This method outlines the procedure for determining the random location of HMA Density testing sites using stationing.

   Calculate the linear foot distance for tons specified per sublot (i.e. 80 or 100 ton sublots).

   Equations:

$$Sublot\ length\ (ft) = \frac{Sublot\ quantity\ (tons)}{\left(\frac{width\ (ft)\ x\ depth\ (ft)\ x\ 2.05\ tons}{27}\right)}$$

   a. Use a random number generator (i.e. calculator, computer) or a random number determined by a stopwatch (See Note 1) to enter Table 1. Use the corresponding X value to determine the test station. A new X value is required for every test.

      Note 1: To use the stopwatch method, randomly start and stop the stopwatch 10 or more times, then use the decimal part of the seconds as your entry point.

b. Determine the test station as follows:

Test Station = (sublot length × "X" multiplier) + beginning station of paving (round to the nearest foot)

c. Use a random number generator (i.e. calculator, computer) or a random number determined by a stopwatch (See Note 1) to enter Table 2. Use the corresponding "Y" multiplier to determine the offset. A new "Y" multiplier is required for every test.

d. Determine the offset as follows:

Offset = (width of pavement × "Y" multiplier) (round to the nearest 0.1 ft)

Offset may be figured from the right or left edge of pavement. Tester shall indicate in MATS or approved density form from which edge the offset is measured.

e. If a tester must move a testing location due to an obstruction of other interference, a new random number for the offset and station shall be picked and the location recalculate. Document the new location and the reason the testing location was changed.

Example for a 100 ton sublot:

Given:

Paving width = 12 ft
Paving depth = 0.15 ft
Beginning Station = 10 + 00
Offset from left edge of pavement

Calculations:

$$Sublot\ length\ = \frac{100}{\left(\frac{12\ x\ 0.15\ x\ 2.05}{27}\right)} = 731.7\ lf$$

Ending Station = (Beginning Station + Sublot length) = (1000 + 731.7) = 17 + 32
Random generated number = X=25, Y=10
Beginning Test Location
Enter Table 1 at (25): "X" multiplier = 0.080
Enter Table 2 at (10): "Y" multiplier 0.167
Testing Station = (732 × 0.080) + 1000 =1058.5 = 10 + 59 (round to the nearest ft)
Offset = (12 × 0.167) = 2.00 = 2.0 ft left of pavement edge (round to the nearest 0.1 ft)

2. Milepost

   This method outlines the procedure for determining the random location of HMA Density testing sites using mileposts.

   a. Convert to tons per mile using the roadway area based on the roadway width and depth.

      Equations:

$$Sublot\ length\ (mile) = \frac{Sublot\ quantity\ (tons)}{\left(\frac{width\ (ft) x\ depth\ (ft) x\ 2.05\ tons}{27}\right)\ x\ 5280\ lf}$$

      Round sublot length to the nearest thousandth (0.001) of a mile

      Calculate the location of the test site and offset using the same method as described in Method A Stationing except use tons per mile instead of the tons per *lf*.

      Test site = (sublot length × "X" multiplier) + beginning milepost

      Offset = (width × "Y" multiplier)

      Example for 100-ton sublot:

      Given:
      Paving width = 12 ft
      Paving depth = 0.15 ft
      Beginning Milepost (MP) = 1.00
      Offset determined from right side of pavement

Calculations:

$$Sublot\ length\ = \frac{100}{\left(\frac{12\ x\ 0.15\ x\ 2.05}{27}\right)\ x\ 5280} = 0.138$$

Ending MP = (Beginning MP + Sublot length) = (1.00 + 0.138) = 1.138
Random generated number = X=25, Y=90
Beginning Test Location
Enter Table 1 at (25): "X" multiplier = 0.080
Enter Table 2 at (90): "Y" multiplier = 0.060
Testing MP = (.138 × 0.080) + 1.00 = 1.011
Offset = (12 × 0.060) = 0.72 = 0.72 ft right of edge of pavement

Random #	X	Random #	X	Random #	X	Random #	X
1	0.794	26	0.526	51	0.304	76	0.617
2	0.500	27	0.519	52	0.167	77	0.584
3	0.393	28	0.446	53	0.308	78	0.591
4	0.427	29	0.219	54	0.570	79	0.563
5	0.165	30	0.780	55	0.322	80	0.482
6	0.821	31	0.574	56	0.491	81	0.499
7	0.562	32	0.730	57	0.349	82	0.227
8	0.284	33	0.435	58	0.681	83	0.476
9	0.704	34	0.338	59	0.858	84	0.258
10	0.988	35	0.515	60	0.716	85	0.227
11	0.692	36	0.751	61	0.521	86	0.364
12	0.491	37	0.063	62	0.568	87	0.186
13	0.769	38	0.269	63	0.168	88	0.791
14	0.675	39	0.357	64	0.460	89	0.985
15	0.205	40	0.555	65	0.708	90	0.562
16	0.187	41	0.837	66	0.453	91	0.753
17	0.238	42	0.699	67	0.778	92	0.097
18	0.400	43	0.456	68	0.484	93	0.723
19	0.263	44	0.730	69	0.609	94	0.214
20	0.545	45	0.314	70	0.949	95	0.215
21	0.230	46	0.179	71	0.575	96	0.428
22	0.700	47	0.152	72	0.263	97	0.647
23	0.616	48	0.334	73	0.192	98	0.794
24	0.179	49	0.284	74	0.845	99	0.154
25	0.080	50	0.819	75	0.095	100	0.964

Random Number - X
Table 1

Random #	Y	Random #	Y	Random #	Y	Random #	Y
1	0.823	26	0.755	51	0.068	76	0.298
2	0.646	27	0.922	52	0.709	77	0.217
3	0.928	28	0.299	53	0.742	78	0.662
4	0.247	29	0.855	54	0.704	79	0.709
5	0.742	30	0.270	55	0.230	80	0.634
6	0.666	31	0.875	56	0.584	81	0.245
7	0.624	32	0.076	57	0.663	82	0.672
8	0.553	33	0.393	58	0.727	83	0.620
9	0.311	34	0.366	59	0.559	84	0.580
10	0.167	35	0.860	60	0.907	85	0.452
11	0.198	36	0.605	61	0.311	86	0.141
12	0.814	37	0.239	62	0.665	87	0.937
13	0.876	38	0.349	63	0.134	88	0.228
14	0.356	39	0.201	64	0.241	89	0.225
15	0.898	40	0.650	65	0.384	90	0.060
16	0.141	41	0.822	66	0.268	91	0.820
17	0.913	42	0.157	67	0.629	92	0.883
18	0.384	43	0.799	68	0.227	93	0.528
19	0.815	44	0.340	69	0.187	94	0.749
20	0.761	45	0.479	70	0.167	95	0.441
21	0.370	46	0.925	71	0.127	96	0.221
22	0.156	47	0.494	72	0.288	97	0.863
23	0.397	48	0.833	73	0.436	98	0.082
24	0.416	49	0.128	74	0.913	99	0.467
25	0.705	50	0.294	75	0.665	100	0.828

Random Number - Y
Table 2

Method B – Hot Mix Asphalt (HMA) Pavement Mixture or Aggregates

1. Determine the sublot increment of the material.
2. Use a random number generator (i.e. calculator, computer, etc) or a random number determined by a stopwatch (See Note 1) to enter Table 1. Use the corresponding X multiplier to determine the offset.
3. A new X multiplier is required for every sublot.
4. Random sample tonnage may be adjusted per sublot to accommodate field testing. Adjustments to random sample tonnage must be documented.
5. Calculate the location of the sampling site as follows:

   Equations:

   First Sample Site = Sublot increment × "X" multiplier (Table 1)
   Subsequent Sites= (sublot increment + (Sublot increment × "X" multiplier)

   Aggregate Sample Example:

   Given: Crushed Surfacing Base Coarse
   Random sample frequency per 9-3.7 =1 per 2,000 tons.
   Calculate the location of the first random sample site as follows:

   The computer-generated number is 22.
   Sublot Increment (Frequency of sampling) = 2,000 tons
   Enter Table 1 at (22) "X" = 0.700
   Sampling Site = 2000 × 0.700= 1400 tons

   Calculate subsequent sample sites as follows:

   The computer-generated number is (53).
   Sublot Increment (Frequency of sampling) = 2,000 tons
   Enter Table 1at 53 "X" = 0.308
   Sampling Site = 2000 + (2000 × 0.308) = 2616 tons

Method C Portland Cement Concrete (PCC)

1. Determine subsequent random sampling locations as follows:

   a. Example for less than 100 cubic yards remaining after reducing frequency:

      (1) Determine amount of pour remaining this will be the sublot increment

      (2) Use a random number generator (i.e. calculator, computer) or a random number determined by a stopwatch (See Note 1) to enter Table 1. Use the corresponding X multiplier to determine the test station. A new X multiplier is required for every test.

      (3) Determine the sample location as follows:

      Sampling Location = Concrete remaining × “X” multiplier (Table 1)

      Given:

      Total cubic yards (cy) of concrete placement = 80 cy
      Truckload = 10 cy
      Given: First truck is in specification = 10 cy
      Remaining cubic yards = 80 cy - 10 cy = 70 cy < 100 cy
      Sublot increment = 70 cy
      Random number = 30 “X” = 0.780
      Sampling Location = 70 cy × 0.780 = 54.6 = 55 cy or 7th truck

   b. Example for greater than 100 cubic yards remaining after reducing frequency

      (1) ***Given:***

      Pour = 130 cy
      Each truck carries 8 cy of concrete
      First truck is in specification = 8 cy
      Remaining cubic yards = 130 - 8 = 122 > 100 cy
      Sublot Increment = 100 cy

      (2) Use a random number generator (i.e. calculator, computer) or a random number determined by a stopwatch (See Note 1) to enter Table 1. Use the corresponding X value to determine the test station. A new X value is required for every test.

      (3) Determine the sample location as follows:

      Sampling Location = Sublot increment × “X” multiplier (Table 1)

      Example:

      Random number = 15 “X”= 0.205
      Sample location = 100 cy × 0.205 = 20.5
      Determine where the first sample will be taken:
      Testing location = (accumulated cy of last truck sampled) + sample yardage

Example:

First Sample Location:
Accumulated cy first truck = 8
Sample location = 8 cy + 20.5 cy = 28.5 cy
Truck load = 28.5/8 = 4
Sampling = second half of 4th truck

Determine subsequent sampling locations as follows:

Sublot increment = total pour – (initial loads in specification)-(first sublot increment)
Sublot increment = 130 cy – (8 cy) – (100 cy) = 22 cy
Random number = 52 “X” = 0.167
Testing location = (initial load in specification) + (first sublot increment) + (testing location within the second sublot)
Testing location = (8 cy)+(100 cy)+(0.167 × 22 cy)
Testing location = 111.7 cy or 111.7/8 cy per truck = 14.0 = 14th truck

3. Report

   a. Report the random number used to determine station and offset

   b. Document any changes in station or offset of random testing location

   c. Use one of the following to report random location information:
      - Materials Testing System (MATS)
      - Form approved in writing by the State Materials Engineer

Appendix A

Hot Mix Asphalt Density Test Locations for Irregular Paving Areas

A. Track tonnage placed in the irregular shaped area until specified tons are placed, note the stationing.

B. Measure back to the beginning of the paving or end of the previous lot to obtain the length (this is also your beginning station).

C. Use a computer-generated random number or a random number determined by a stopwatch (See Note 1) to enter Table 1. Use the corresponding X value to determine the test station. A new X value is required for every test.

D. Multiply the length by the "X" value and add to the beginning station to locate your testing site.

E. Use a computer-generated random number or a random number determined by a stopwatch (See Note 1) to enter Table 2. Use the corresponding Y value to determine the offset. A new Y value is required for every test.

F. Measure the width at the testing station and multiply the width time the "Y" value to determine the offset of the testing site.

G. Make a sketch of the area to document the test location in the event a retest is required.

Example:

Paving began at Station 101 + 00.

The tester determined Station 105 + 75 was the end of the 100 ton lot.

The width of the pavement began at 0 and transitioned to 12.

Testing Station

Sta 105 + 75 – Sta 101 + 00 = 475 ft
Random number = 45, "X" value = 0.314
475 ft × 0.314= 149.15= 149 Testing station = 10100 + 149 =102 + 49

Testing Offset

Measure width at station 102 + 49
Width = 3.76
Random # 65 "Y" value = 0.384
Offset = 3.76 × 0.384 = 1.44 = 1.4 ft from right edge

WSDOT SOP 730

Correlation of Nuclear Gauge Densities With Hot Mix Asphalt (HMA) Cores

1. When evaluating HMA compaction:

   1.1 A gauge correlation is required:

   a. For each combination of gauge and HMA Mix Design (initial JMF).

   b. When gauge mode changes (i.e., back scatter to thin layer).

   c. When wearing course lift thickness changes per Note 1.

   d. When a gauge is recalibrated.

   Note 1: For density determined with "Thin Layer Mode," a layer thickness change of greater than 0.08 feet requires a new correlation. For density determined with "Back Scatter Mode," a layer thickness change of greater than 0.15 feet requires a new gauge correlation.

   1.2 A gauge correlation is not required but may be considered by the Regional Materials Engineer when:

   a. Base material changes from the original correlation base (i.e., from a surfacing base to an asphalt base).

   b. The same gauge HMA Mix Design (Reference Mix Design) combination are used on a different contract within the same construction year.

   c. When JMF has been adjusted in accordance with *Standard Specifications* Section 9-03.8(7)A.

2. Gauge correlation is based on ten in-place HMA densities and ten cores taken at the same location as the in-place density.

   2.1 In-place HMA densities shall be determined in accordance with WSDOT FOP for WAQTC T 355.

   2.2 Cores should be taken no later than the day following paving and before traffic has been allowed on roadway. Correlation cores are not required to be taken at record density locations. Therefore, a site outside the traveled way should be considered for worker safety, as long as the lift thickness matches that of the plan lift thickness of the record density locations.

   Note 2: If a core becomes damaged, it shall be eliminated from the average.

   Note 3: Cores may be taken sooner than the day after paving if the HMA is cooled to prevent damage during coring and removal of cores. Water, ice, or dry-ice may be used to cool the pavement. Another method of cooling that may be used is substitution of nitrogen gas or CO_2 for drilling fluids.

3. Obtain a pavement core from each of the test sites in accordance with WSDOT SOP 734. The core shall be taken in the nuclear gauge footprint.

   3.1 For either gauge mode, back scatter or thin layer, locate the core in the approximate center of the nuclear gauge footprint. If the core thickness exceeds the plan pavement thickness by more than 0.04 feet, then the core shall be saw cut to the plan thickness prior to performing density testing. If a core thickness is less than the plan thickness by more than 0.04 feet, it shall be eliminated from the average.

4. Bulk Specific Gravity (G_{mb}) of core shall be determined in conformance with WSDOT FOP for AASHTO T 166 Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens.

   Calculate core density as follows, round to the nearest 0.1 pcf:

   $$\text{Core Density} = G_{mb} \times 62.245 \text{ pcf}$$

   Calculate gauge correlation factor as follows:

   $$\text{Density Ratio} = \frac{\textit{(core density)}}{\textit{(nuclear gauge density)}}$$

   Round Density Ratio to the nearest 0.001

   $$\text{Gauge correlation factor} = \frac{\textit{(Sum of ratios)}}{\textit{(number of cores)}}$$

5. Gauge Correlation Factor shall be determined to 0.001.

6. Report the Gauge Correlation Factor using MATS or DOT Form 350-112.

WSDOT SOP 734

Sampling Hot Mix Asphalt After Compaction (Obtaining Cores)

1. **Scope**
   - This method describes the process for obtaining Hot Mix Asphalt test cores for Laboratory testing after compaction has been completed. Cores may range in size from 2 in to 12 in
2. **Significance and Use**
   - Samples obtained in accordance with the procedure given in this practice may be used for measuring pavement thickness, density, and acceptance testing.
   - When cores are used to determine nuclear gauge correlation, refer to WSDOT SOP 730.
   - When cores are used to determine pavement density, the Bulk Specific Gravity ($\mathbf{G_{mb}}$) is determined according to WSDOT FOP for AASHTO T 166.
   - When cores are used for forensic testing of HMA, refer to SOP 737 "Procedure for the Forensic Testing of HMA Field Cores" to determine the required number and size of cores.
3. **Apparatus**
   - Core Drill Machine –A Core Drill Machine of sufficient horsepower and depth to minimize distortion of the compacted cores of Hot Mix Asphalt.
   - Core Bit – The cutting edge of the core drill bit shall be of hardened steel or other suitable material with diamond chips embedded in the metal cutting edge or as recommended by the core drill bit manufacturer. Typically the core drill bit should have an inside diameter of 4" ± 0.25" (100 mm ± 6 mm) or 6" ± 0.25" (150 mm ± 6 mm), these core bit dimensions are agency preferred alternatives. Suitable larger and smaller diameter core bit alternatives shall be employed as required by the agency.
   - Tools – Core layers may be separated using a saw or other suitable device which provides a clean smooth surface and does not damage the core.
   - Retrieval Device (Optional) –The retrieval device used for removing core samples from holes must preserve the integrity of the core. The device may be a steel rod of suitable length and with a diameter that will fit into the space between the core and the pavement material. There may be a 90 degree bend at the top to form a handle and a 90 degree bend at the bottom, approximately 2 in (50 mm) long, forming a hook to assist in the retrieval of the core or other suitable device.
4. **Safety**

   This standard does not purport to address all of the safety concerns, associated with its use. It is the responsibility of the user of this standard operating procedure to establish a pre activity safety plan prior to use.

5. Test Site Location

- The quantity of cores to be obtained shall be determined by the test procedure to be performed or agency requirements. Refer to WSDOT SOP 730 when taking correlation cores.
- Determine the location of the core(s) as required by the agency.

6. Procedure

- For freshly placed Hot Mix Asphalt materials, the core shall be taken when the material has had sufficient amount of time to cool to prevent damage to the core.
- Pavement may be cooled to expedite the removal of the core by the following methods; water, ice water, ice, or dry ice or liquid nitrogen.
- Place the coring machine and core bit over the selected location.
- Keep the core bit perpendicular to the Hot Mix Asphalt surface during the coring process.

  Note 1: If any portion of the coring machine shifts during the operation, the core may break or distort.
- Constant downward pressure should be applied on the core bit. Failure to apply constant pressure, or too much pressure, may cause the bit to bind or distort the core.
- Continue the coring operation until the desired depth is achieved.
- If necessary, use a retrieval device to remove the core.
- Clearly identify the cores location and offset without causing damage (i.e., lumber crayon or grease pencil).

  Note 2: If the core is damaged to a point that it cannot be used for its intended purpose, a new core shall be obtained within 6 in of the original location.

7. Filling Core Holes

- When necessary, the hole made from the coring operation shall be filled with a material that will not separate from the surrounding material. If Hot Mix Asphalt is available and used, it shall be compacted into the hole. A ready mix concrete or fast set grout product may be used in lieu of a Hot Mix Asphalt. A black dye can be used to color the grout on driving surface.
- Prior to backfilling a core hole on a bridge deck, ensure that the hole and sidewalls are dry enough to bond with the sealant before applying.
- Acceptable sealants include; asphalt binder or any waterproof sealant designed for asphalt applications as stated by the manufacturer.
- Apply sealant to bottom surface and side walls of core hole as needed.
- Backfill the core hole with Hot Mix Asphalt, cold mix asphalt, ready mix concrete or grout and compact as needed.

8. Transporting Cores

- Transport cores in a suitable container(s) that prevents damage from jarring, rolling, hitting together, and/or impact with any object.
- Prevent cores from freezing or excessive heat above 130º F (54º C), during transport.

  Note 1: In extreme ambient temperature conditions, cores should be placed in water during transport.
- If the core is damaged in transport to a point it can not be utilized for its intended purpose the core will not be used.

9. Separate The Layers

- When necessary, separate the lifts or layers of pavement courses by using a water cooled saw to cut the core on the designated lift line or separate by other suitable methods that will not damage the lifts or layers to be tested.

  Note 4: Lift lines are often more visible by rolling the core on a flat surface and/or surface drying the core.

10. Length Determination

Measure the thickness of the designated lift to the nearest 0.01’ or ⅛” according to WSDOT Test Method 720.

11. Report

Core information shall be reported on standard agency forms and should include the following information.

- The date the cores were obtained
- Paving date
- Contract number
- Project title
- Location of test
- The lift being evaluated
- Type of material being evaluated
- Mix Design Lab Number
- Average thickness of each core (to the nearest 0.01’ or ⅛ “)
- Average Theoretical Maximum Density

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