Washington State
Department of Transportation

# Publications Transmittal

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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 April 2018 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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Washington State Department of Transportation
Materials Laboratory
PO Box 47365
Olympia, WA 98504-7365
www.wsdot.wa.gov/business/materialslab/default.htm

Approved By

Signature

Washington State
Department of Transportation

# Materials Manual

**M 46-01.31**

September 2018

**Engineering and Regional Operations**
State Materials Laboratory

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Washington State Department of Transportation
Engineering and Regional Operations
State Materials Laboratory
PO Box 47365
Olympia, WA 98504-7365

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| Aggregate | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| T 2 | AASHTO | | | Sampling of Aggregates |
| T 2 | WAQTC | ✓ | ✓ | FOP for AASHTO T 2, Sampling of Aggregates |
| T 11 | AASHTO | | | Materials Finer Than 0.075 mm (No. 200) Sieve in Mineral Aggregates by Washing |
| 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 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 |
| T 37 | AASHTO | | | Sieve Analysis of Mineral Filler for Hot Mix Asphalt (HMA) |
| R 76 | AASHTO | | | Standard Practice for Reducing Samples of Aggregate to Testing Size |
| R 76 | WAQTC | ✓ | ✓ | FOP for AASHTO R 76, Reducing Samples of Aggregate to Testing Size |
| T 84 | AASHTO | | | Specific Gravity and Absorption of Fine Aggregates |
| T 85 | AASHTO | | | Specific Gravity and Absorption of Coarse Aggregate |
| T 85 | WAQTC | ✓ | ✓ | FOP for AASHTO T 85, Specific Gravity and Absorption of Coarse Aggregate |
| T 96 | AASHTO | | | Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine |
| T 112 | AASHTO | | ✓ | Clay Lumps and Friable Particles in Aggregate |
| T 113 | WSDOT | | ✓ | Method of Test for Determination of Degradation Value |
| 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 |
| SOP 128 | WSDOT | ✓ | ✓ | Sampling for Aggregate Source Approval |
| T 176 | AASHT0 | | | 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 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 288 | AASHTO | | ✓ | Determining Minimum Laboratory Soil Resistivity (Checklist Only) |
| T 289 | AASHTO | | | Determining pH of Soil for Use in Corrosion Testing |
| T 304 | AASHTO | | | Uncompacted Void Content of Fine Aggregate |
| T 304 | WSDOT | ✓ | ✓ | FOP for AASHTO T 304, Uncompacted Void Content of Fine Aggregate |
| 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 417 | WSDOT | | ✓ | Method of Test for Determining Minimum Resistivity and pH of Soil and Water |
| T 716 | WSDOT | ✓ | ✓ | Method of Random Sampling for Locations of Testing and Sampling Sites |

| Bituminous Cement | | | | |
|---|---|---|---|---|
| Procedure Number | Owner | Field Use | In Manual | Test Method |
| R 28 | AASHTO | | | Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel |
| R 29 | AASHTO | | | Standard Practice for Grading or Verifying the Performance Grade (PG) of an Asphalt Binder |
| T 44 | AASHTO | | | Solubility of Bituminous Materials |
| T 48 | AASHTO | | | Flash and Fire Points by Cleveland Open Cup |
| T 49 | AASHTO | | | Penetration of Bituminous Materials |
| T 50 | AASHTO | | | Float Test for Bituminous Materials |
| T 51 | AASHTO | | | Ductility of Asphalt Materials |
| T 53 | AASHTO | | | Softening Point of Bitumen (Ring-and-Ball Apparatus) |
| T 59 | AASHTO | | | Emulsified Asphalts |
| R 66 | AASHTO | | | Standard Practice for Sampling Asphalt Materials |
| 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 |
| T 228 | AASHTO | | | Specific Gravity of Semi-Solid Asphalt Materials |
| T 240 | AASHTO | | | Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test) |
| T 301 | AASHTO | | | Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer |
| T 313 | AASHTO | | | Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR) |
| 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 426 | WSDOT | | ✓ | Pull-Off Test for Hot Melt Traffic Button Adhesive |
| D 3111 | ASTM | | | Flexibility Determination of Hot-Melt Adhesives by Mandrel Bend Test Method |

| Hot Mix Asphalt | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| R 30 | AASHTO | | | Standard Practice for Mixture Conditioning 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 of Hot Mix Asphalt (HMA) |
| R 47 | AASHTO | | | Standard Practice for Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size |
| R 47 | WAQTC | ✓ | ✓ | FOP for AASHTO R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size |
| R 79 | AASHTO | | | Standard Practice for Vacuum Drying Compacted Asphalt Specimens |
| T 166 | AASHTO | | | Bulk Specific Gravity ($G_{mb}$) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens |
| T 166 | WAQTC | ✓ | ✓ | FOP for AASHTO T 166, Bulk Specific Gravity ($G_{mb}$) 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 209 | AASHTO | | | Theoretical Maximum Specific Gravity ($G_{mm}$) and Density of Hot Mix Asphalt (HMA) |
| T 209 | WAQTC | ✓ | ✓ | FOP for AASHTO T 209, Theoretical Maximum Specific Gravity ($G_{mm}$) and Density of Hot Mix Asphalt (HMA) Paving Mixtures |
| T 269 | AASHTO | | | Percent Air Void in Compacted Dense and Open Asphalt Mixtures |
| T 308 | AASHTO | | | Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method |
| T 308 | WAQTC | ✓ | ✓ | FOP for AASHTO T 308, Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method |
| T 312 | AASHTO | | | Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor |
| T 312 | WSDOT | ✓ | ✓ | FOP for AASHTO T 312, Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor |
| T 324 | AASHTO | | ✓ | Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures |
| T 329 | AASHTO | | | Moisture Content of Asphalt Mixtures by Oven Method |
| T 329 | WAQTC | ✓ | ✓ | FOP for AASHTO T 329, Moisture Content of Asphalt Mixtures by Oven Method |
| T 331 | AASHTO | | ✓ | Bulk Specific Gravity ($G_{mb}$) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method |
| T 355 | AASHTO | | | In-Place Density of Asphalt Mixtures by Nuclear Methods |
| T 355 | WAQTC | ✓ | ✓ | FOP for AASHTO T 355, In-Place Density of Asphalt Mixtures by Nuclear Method |
| 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) |

| Hot Mix Asphalt | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| 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 | WSDOT | | ✓ | Procedure for the Forensic Testing of HMA Field Cores |
| D 6931 | ASTM | | ✓ | Indirect Tensile (IDT) Strength of Asphalt Mixtures |

| Cement | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| T 105 | AASHTO | | | Chemical Analysis of Hydraulic Cement |
| T 106 | AASHTO | | | Compressive Strength of Hydraulic Cement Mortars (Using 50-mm or 2-in. 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 129 | AASHTO | | | Amount of Water Required for Normal Consistency of Hydraulic Cement Paste |
| 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 |
| 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 260 | AASHTO | | | Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials |
| T 303 | AASHTO | | | Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction |
| T 313 | WSDOT | | ✓ | Method of Test for Cement-Latex Compatibility |
| 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 |
| 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 |
| C 939 | WSDOT | ✓ | ✓ | FOP for ASTM for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method) |

| Chemical | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| T 65 | AASHTO | | | Mass (Weight) of Coating on Iron and Steel Articles With Zinc or Zinc-Alloy Coatings |
| T 267 | AASHTO | | | Determination of Organic Content in Soils by Loss on Ignition |
| T 420 | WSDOT | ✓ | ✓ | Test Method for Determining the Maturity of Compost (Solvita Test) |
| C 881 | ASTM | | | Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete |
| C 882 | ASTM | | ✓ | Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear (Checklist Only) |
| C 1218 | ASTM | | | Water-Soluble Chloride in Mortar and Concrete |
| D 1429 | ASTM | | | Specific Gravity of Water and Brine |
| D 1475 | ASTM | | | Density of Liquid Coatings, Inks, and Related Products |
| D 2628/ M 220 | ASTM | | ✓ | Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements |
| D 4758 | ASTM | | | Nonvolatile Contents of Latexes |
| D 5329 | ASTM | | | Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphalt Pavements and Portland Cement Concrete Pavements |
| D 7091 | ASTM | ✓ | ✓ | Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals (Checklist Only) |

| Concrete | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| TM 2 | WAQTC | ✓ | ✓ | FOP for WAQTC TM 2, Sampling Freshly Mixed Concrete |
| T 22 | AASHTO | | | Compressive Strength of Cylindrical Concrete Specimens |
| T 22 | WSDOT | ✓ | ✓ | FOP for AASHTO T 22, 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 |
| R 39 | AASHTO | | | Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory |
| T 106 | AASHTO | | | Compressive Strength of Hydraulic Cement Mortars (Using 50-mm or 2-in. Cube Specimens) |
| T 106 | WSDOT | ✓ | ✓ | FOP for AASHTO for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens) |
| T 119 | AASHTO | | | Slump of Hydraulic Cement Concrete |
| T 119 | WAQTC | ✓ | ✓ | FOP for AASHTO T 119, Slump of Hydraulic Cement Concrete |
| T 121 | WAQTC | ✓ | ✓ | FOP for AASHTO T 121, Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete |
| C 140 | ASTM | | | Sampling and Testing Concrete Masonry Units and Related Units |
| T 141 | AASHTO | | | Sampling Freshly Mixed Concrete |
| 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 196 | AASHTO | | ✓ | Air Content of Freshly Mixed Concrete by the 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 231 | AASHTO | | | Capping Cylindrical Concrete Specimens |
| T 231 | WSDOT | ✓ | ✓ | FOP for AASHTO T 231, Capping Cylindrical Concrete Specimens |
| T 260 | AASHTO | | | Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials |
| T 277 | AASHTO | | | Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration |
| T 309 | AASHTO | | | Temperature of Freshly Mixed Portland Cement Concrete |
| T 309 | WAQTC | ✓ | ✓ | FOP for AASHTO T 309, Temperature of Freshly Mixed Portland Cement Concrete |
| C 457 | ASTM | | | Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete |
| C 495 | ASTM | | | Compressive Strength of Lightweight Insulated Concrete |
| T 716 | WSDOT | ✓ | ✓ | Method of Random Sampling for Locations of Testing and Sampling Sites |
| T 802 | WSDOT | ✓ | ✓ | Method of Test for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading) |
| C 805 | ASTM | | | Rebound Number of Hardened Concrete |

| Concrete | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| C 805 | WSDOT | ✓ | ✓ | Rebound Hammer Determination of Compressive Strength of Hardened Concrete |
| 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 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 939 | ASTM | | | Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method) |
| C 939 | WSDOT | ✓ | ✓ | FOP for ASTM C 939. Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method) |
| C 1218 | ASTM | | | Water-Soluble Chloride in Mortar and Concrete |
| D 1429 | ASTM | | | Specific Gravity of Water and Brine |
| 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 |

| Electrical and Traffic | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| IP 78-16 | FHWA | | | Signal Controller Evaluation |
| T 257 | AASHTO | | | Instrumental Photometric Measurements of Retroreflective Materials and Retroreflective Devices |
| T 314 | WSDOT | | ✓ | Method of Test for Photovolt Reflectance |
| 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 |
| 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 |
| DMCT 700 | ATSI | | | Manual on Signal Controller Evaluation |
| PCMZ 2000 | TS | | | Manual on Signal Controller Evaluation |
| D 4956 | ASTM | | | Standard Specification for Retroreflective Sheeting for Traffic Control |
| TS1 | NEMA | | | Signal Controller Evaluation |

| Geotechnical – Soils | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| R 58 | AASHTO | | | Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test |
| R 75 | AASHTO | | | Standard Practice for Developing a Family of Curves |
| R 75 | WAQTC | ✓ | ✓ | FOP for AASHTO R 75, Developing a Family of Curves |
| T 88 | AASHTO | | | Particle Size Analysis of Soils |
| T 89 | AASHTO | | ✓ | Determining the Liquid Limit of Soils (Checklist Only) |
| T 90 | AASHTO | | ✓ | Determining the Plastic Limit and Plasticity Index of Soils (Checklist Only) |
| T 99 | AASHTO | | | Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in) 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 Soils |
| T 180 | AASHTO | | | Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in) 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 |
| 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 265, 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 |
| T 501 | WSDOT | | ✓ | Test Method to Determine Durability of Very Weak Rock |
| D 2487 | ASTM | | | Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) |
| D 2488 | ASTM | | | Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) |
| D 4186 | ASTM | | | One-Dimensional Consolidation Properties of Saturated Cohesive Soils Using Controlled-Strain Loading |
| D 4644 | ASTM | | | Slake Durability of Shales and Similar Weak Rocks |
| D 5084 | ASTM | | | Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter |
| D 5311 | ASTM | | | Load Controlled Cyclic Triaxial Strength of Soil |
| D 5731 | ASTM | | | Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications |
| D 6467 | ASTM | | | Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils |
| D 6528 | ASTM | | | Consolidated Undrained Direct Simple Shear Testing of Cohesive Soils |
| D 7012 | ASTM | | ✓ | Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Verying States of Stress and Temperatures |

| Geotextile and Steel | | | | |
|---|---|---|---|---|
| Procedure Number | Owner | Field Use | In Manual | Test Method |
| E 18 | ASTM | | | Rockwell Hardness of Metallic Materials |
| 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 | | | Definitions for Mechanical Testing of Steel Products |
| F 606 | ASTM | | | Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets |
| 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 | | | Failure in Sewen Seams of Woven Fabrics |
| D 4354 | ASTM | | ✓ | Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing |
| D 4355 | ASTM | | | Deterioration of Geotextiles From Exposure to Light, Moisture and Heat in a Xenon-Arc-Type Apparatus |
| D 4491 | ASTM | | | Water Permeability of Geotextiles by permittivity |
| D 4533 | ASTM | | | Trapezoid Tearing Strength of Geotextiles |
| D 4595 | ASTM | | | Tensile Properties of Geotextiles by the Wide-Width Strip Method |
| D 4632 | ASTM | | | Grab Breaking Load and Elongation of Geotextiles |
| D 4751 | ASTM | | | Determining Apparent Opening Size of a Geotextiles |
| D 6241 | ASTM | | | Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe |

| Paint | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| D 185 | ASTM | | | Coarse Particles in Pigments |
| T 314 | WSDOT | | ✓ | Method of Test for Photovolt Reflectance |
| D 562 | ASTM | | | Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer |
| D 1208 | ASTM | | | Common Properties of Certain Pigments |
| D 1210 | ASTM | | | Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage |
| D 1475 | ASTM | | | Density of Liquid Coatings, Inks, and Related Products |
| D 2244 | ASTM | | | Standard Practice for Calculation of Color Tolerances and Color Differences From Instrumentally Measured Color Coordinates |
| D 2369 | ASTM | | | Volatile Content of Coatings |
| D 2371 | ASTM | | | Pigment Content of Solvent-Reducible Paints (Centrifuge) |
| D 2621 | ASTM | | | Infrared Identification of Vehicle Solids From Solvent-Reducible Paints |
| D 2697 | ASTM | | | Volume Nonvolatile Matter in Clear or Pigmented Coatings |
| 3011 | FTMS | | | Method for Determination of Condition in Container |
| D 3723 | ASTM | | | 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 Retroreflective Pavement Marking Tape for Extended Service Life |

| Pavement Soils | | | | |
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| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| T 242 | AASHTO | | | Frictional Properties of Paved Surfaces Using a Full-Scale 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 | AASHTO | | | In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth) |
| 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 |
| SOP 738 | WSDOT | ✓ | ✓ | Establishing Maximum Field Density for Recycled Concrete Aggregates by Test Point Evaluation |
| T 807 | WSDOT | ✓ | ✓ | Method of Operation of California Profilograph and Evaluation of Profiles |
| D 4694 | ASTM | | | Deflections with a Falling-Weight-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 |
| QC 9 | WSDOT | | ✓ | Standard Practice for Approval of Recycled Materials Facilities of WSDOT Recycled Concrete and Returned Concrete |
| QC 10 | WSDOT | | ✓ | Standard Practice for Approval of Recycled Materials Facilities from Stockpiles of Unknown Sources |

| 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 |
| QC 9 | WSDOT | | ✓ | Standard Practice for Approval of Recycled Materials Facilities of WSDOT Recycled Concrete and Returned Concrete |
| QC 10 | WSDOT | | ✓ | Standard Practice for Approval of Recycled Materials Facilities from Stockpiles of Unknown Sources |
| TS1 | NEMA | | | Signal Controller Evaluation |
| T 2 | AASHTO | | | Sampling of Aggregates |
| 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 | | | 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 T 22, 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 | | | Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel |
| R 29 | AASHTO | | | Standard Practice for Grading or Verifying the Performance Grade (PG) of an Asphalt Binder |
| R 30 | AASHTO | | | Standard Practice for Mixture Conditioning 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 for Hot Mix Asphalt (HMA) |

| Numerical Order | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| R 39 | AASHTO | | | Standard Practice for Making and curing Concrete Test Specimens in the Laboratory |
| T 44 | AASHTO | | | Solubility of Bituminous Materials |
| R 47 | AASHTO | | | Standard Practice for Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size |
| 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 Open Cup |
| T 49 | AASHTO | | | Penetration of Bituminous Materials |
| T 50 | AASHTO | | | Float Test for Bituminous Materials |
| T 51 | AASHTO | | | Ductility of Asphalt Materials |
| T 53 | AASHTO | | | Softening Point of Bitumen (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 | AASHTO | | | Standard Practice for Sampling Asphalt Materials |
| 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 | AASHTO | | | Standard Practice for Developing a Family of Curves |
| R 75 | WAQTC | | | FOP for AASHTO R 75, Developing a Family of Curves |
| R 76 | AASHTO | | | Standard Practice for 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 | | | Standard Practice for 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 (Checklist Only) |
| 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 2.5-kg (5.5-lb) Rammer and a 305 mm (12-in) 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 Soils |
| T 105 | AASHTO | | | Chemical Analysis of Hydraulic Cement |
| T 106 | AASHTO | | | Compressive Strength of Hydraulic Cement Mortars (Using 50-mm or 2-in Cube Specimens) |
| T 106 | WSDOT | ✓ | ✓ | FOP for AASHTO for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens) |

| Numerical Order | | | | |
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| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| 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 |
| 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 Effluents |
| SOP 128 | WSDOT | ✓ | ✓ | Sampling for Aggregate Source Approval |
| T 129 | AASHTO | | | Amount of Water Required for Normal Consistency of Hydraulic Cement Paste |
| 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 | | | 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 ($G_{mb}$) 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 4.54-kg (10-lb) Rammer and an 457-mm (18-in) 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 | | | Coarse Particles in Pigments |

| Numerical Order | | | | |
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| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| T 196 | AASHTO | | ✓ | Air Content of Freshly Mixed Concrete by the (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 ($G_{mm}$) and Density of Hot Mix Asphalt (HMA) |
| T 209 | WAQTC | ✓ | ✓ | FOP for AASHTO T 209, Theoretical Maximum Specific Gravity ($G_{mm}$) 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 Asphalt Materials |
| T 231 | AASHTO | | | Capping Cylindrical Concrete Specimens |
| T 231 | WSDOT | ✓ | ✓ | FOP for AASHTO T 231, 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-Scale 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 Photometric Measurements of Retroreflectivie Materials and Retroreflective Devices |
| 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 265, 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 Testing |
| 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 |

| Numerical Order | | | | |
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| Procedure Number | Owner | Field Use | In Manual | Test Method |
| T 304 | AASHTO | | | Uncompacted Void Content of Fine Aggregate |
| T 304 | WSDOT | ✓ | ✓ | FOP for AASHTO T 304, 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 | 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 | AASHTO | | | In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth) |
| 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 | | ✓ | Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures |
| 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 | AASHTO | | ✓ | 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 | AASHTO | | | In-Place Density of Asphalt Mixtures by Nuclear Methods |
| T 355 | WAQTC | ✓ | ✓ | FOP for AASHTO T 355, In-Place Density of Asphalt Mixtures by Nuclear Method |
| A 370 | ASTM | | | 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 |

| Numerical Order | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| 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 |
| 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 | | | Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete |
| C 495 | ASTM | | | Compressive Strength of Lightweight Insulated Concrete |
| T 501 | WSDOT | | ✓ | Test Method to Determine Durability of Very Weak Rock |
| D 562 | ASTM | | | Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer |
| F 606 | ASTM | | | 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 |
| SOP 734 | WSDOT | ✓ | ✓ | Standard Operating Procedure for Sampling Hot Mix Asphalt After Compaction (Obtaining Cores) |

| Numerical Order | | | | |
|---|---|---|---|---|
| Procedure Number | Owner | Field Use | In Manual | Test Method |
| SOP 735 | WSDOT | ✓ | ✓ | Standard Operating Procedure for Longitudinal Joint Density |
| SOP 736 | WSDOT | | ✓ | In-Place Density of Bituminous Mixes Using Cores |
| SOP 737 | WSDOT | | ✓ | Procedure for the Forensic Testing of HMA Field Cores |
| SOP 738 | WSDOT | ✓ | ✓ | Establishing Maximum Field Density for Recycled Concrete Aggregates by Test Point Evaluation |
| T 802 | WSDOT | ✓ | ✓ | Method of Test for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading) |
| C 805 | ASTM | | | 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 of Epoxy-Resin Systems Used With Concrete By Slant 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 | | | 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 | | | Common Properties of Certain Pigments |
| D 1210 | ASTM | | | Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage |
| C 1218 | ASTM | | | Water-Soluble Chloride in Mortar and Concrete |
| D 1429 | ASTM | | | Specific Gravity of Water and Brine |
| C 1437 | ASTM | | | Standard Test Method for Flow of Hydraulic Cement Mortar |
| D 1475 | ASTM | | | Density of Liquid Coatings, Inks, 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 | | | Failure in Sewn Seams of Woven Fabrics |

| Numerical Order | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| 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 | | | Volatile Content of Coatings |
| D 2371 | ASTM | | | Pigment Content of Solvent-Reducible Paints (Centrifuge) |
| D 2487 | ASTM | | | Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) |
| D 2488 | ASTM | | | Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) |
| D 2621 | ASTM | | | Infrared Identification of Vehicle Solids From Solvent-Reducible Paints |
| D 2628/ M 220 | ASTM | ✓ | ✓ | Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements |
| D 2697 | ASTM | | | Volume Nonvolatile Matter in Clear or Pigmented Coatings |
| 3011 | FTMS | | | Method for Determination of Condition in Container |
| D 3111 | ASTM | | | Flexibility Determination of Hot-Melt Adhesives by Mandrel Bend Test Method |
| D 3723 | ASTM | | | 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 | | | One-Dimensional Consolidation Properties of Saturated Cohesive Soils Using Controlled-Strain Loading |
| D 4354 | ASTM | | ✓ | Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing |
| D 4355 | ASTM | | | Deterioration of Geotextiles From Exposure to Light, Moisture and Heat in a Xenon-Arc-Type Apparatus |
| D 4491 | ASTM | | | Water Permeability of Geotextiles by Permittivity |
| D 4505 | ASTM | | | Standard Specification for Preformed Retroreflective Pavement Marking Tape for Extended Service Life |
| D 4533 | ASTM | | | Trapezoid Tearing Strength of Geotextiles |
| D 4595 | ASTM | | | Tensile Properties of Geotextiles by the Wide-Width Strip Method |
| D 4632 | ASTM | | | Grab Breaking Load and Elongation of Geotextiles |
| D 4644 | ASTM | | | Slake Durability of Shales and Similar Weak Rocks |
| D 4694 | ASTM | | | Deflections with Falling-Weight-Type Impulse Load Device |
| D 4751 | ASTM | | | Determining Apparent Opening Size of a Geotextile |
| D 4758 | ASTM | | | Nonvolatile Contents of Latexes |
| D 4956 | ASTM | | | Standard Specification for Retroreflective Sheeting for Traffic Control |
| D 5084 | ASTM | | | Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter |
| D 5311 | ASTM | | | Load Controlled Cyclic Triaxial Strength of Soil |
| D 5329 | ASTM | | | Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphalt Pavements and Portland Cement Concrete Pavements |
| D 5731 | ASTM | | | Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classifications |

| Numerical Order | | | | |
|---|---|---|---|---|
| **Procedure Number** | **Owner** | **Field Use** | **In Manual** | **Test Method** |
| D 6241 | ASTM | | | Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe |
| D 6467 | ASTM | | | Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils |
| D 6528 | ASTM | | | Consolidated Undrained Direct Simple Shear Testing of Cohesive Soils |
| D 6931 | ASTM | | ✓ | Indirect Tensile (IDT) Strength of Asphalt Mixtures |
| D 7012 | ASTM | | ✓ | Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Verying States of Stress and Temperatures |
| D 7091 | ASTM | ✓ | ✓ | Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals (Checklist Only) |

# 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**

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*. All communication from the State Materials Laboratory will be to the Contractor's/Producer's contact as specified on WSDOT Form 350-042.

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 350-041 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 *Standard Specifications* Section 5-04.3(11)F.
- 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.

Washington State
Department of Transportation

# WSDOT Standard Practice QC 9

## *Standard Practice for Approval of Recycled Materials Facilities of WSDOT Recycled Concrete and Returned Concrete*

**1. Scope**

This standard specifies the requirements for all Recycled Materials Facilities of WSDOT recycled concrete and returned concrete. Recycled concrete aggregate (RCA) from Recycled Materials Facilities that comply with this standard will not require evaluation of LA Wear, and WSDOT Degradation Value. Certification of toxicity characteristics will be required, when requested.

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

**2. Reference Documents**

2.1 WSDOT Standards

M 41-01 *Construction Manual*

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

M 46-01 *Materials Manual*

**3. Terminology**

3.1 AASHTO – American Association of State Highway and Transportation Officials

3.2 ASTM – American Society of Testing and Materials

3.3 ASA Database – The ASA (Aggregate Source Approval) is a database containing results of WSDOT preliminary testing of aggregate sources.

3.4 QC – Quality Control, the Recycled Materials Facility's activities that are performed or conducted to fulfill the contract requirements.

3.5 QPL – Washington State Department of Transportation, Qualified Products List.

3.6 RCA – Recycled concrete aggregate.

3.7 Recycled Returned Concrete – Recycled concrete aggregates that are produced from concrete returned to the plant, that was produced from a WSDOT approved aggregate source.

3.8 Returned Concrete – Concrete that was returned to the plant that was produced from a WSDOT approved aggregate source.

3.9 Recycled Materials Facility – The facility and location of the plant that produces recycled concrete aggregate materials.

3.10 WAQTC – Western Alliance for Quality Transportation Construction

3.11 WSDOT – Washington State Department of Transportation.

3.12 WSDOT Concrete – Concrete taken from WSDOT roadways and structures.

3.13 WSDOT Recycled Concrete – Recycled concrete aggregates that are produced from concrete taken from WSDOT roadways and structures.

## 4. Significance and Use

This standard practice specifies processes for approving the Recycled Materials Facilities that produce/supply RCA from either returned concrete and/or WSDOT concrete. This is accomplished by a system that evaluates the QC processes of Recycled Materials Facilities and determines if these QC processes will ensure non-contaminated quality RCA. Recycled Materials Facilities that meet this standard will be listed on the QPL as an approved supplier of Tier 2 Recycled Materials for either returned concrete and/or WSDOT concrete.

## 5. Recycled Concrete Aggregate Quality Control Plan

The Recycled Materials Facility shall have quality control plan on how the facility will ensure that returned concrete and WSDOT concrete are not blended with other recycled materials. This quality control plan should at the minimum include following;

5.1 Recycled Materials Facility

5.1.1 Facility Type

5.1.2 Facility Address

5.1.3 Name, email address, and telephone number of the contact person responsible for the quality control of the facility.

5.2 Prevention of Contamination, Segregation, and Degradation

The handling and storage of RCA shall be in such manner to minimize any segregation or degradation and to prevent contamination by foreign materials. When stockpiles of RCA cannot be stored sufficiently remote from each other to prevent mixing, baffles shall be provided which will prevent intermingling of the different stockpiles.

5.3 Returned Concrete

5.3.1 Shall provide a plan on how returned concrete will be cured, stored, crushed, stockpiled, and segregated from other materials.

5.3.2 Identify what processes will be used to ensure that no contamination will occur with other materials.

5.3.3 Shall provide ASA reports for the aggregate source(s).

5.4 WSDOT Concrete

5.4.1 Shall provide a plan on how WSDOT concrete is identified, for example;

5.4.1.1 Provide a contract number from WSDOT administered contract that the concrete is reclaimed from.

5.4.1.2 Provide the State Route or Interstate Route along with what the concrete is from, such as;

5.4.1.2.1 Cement Concrete Pavement Panel(s).

5.4.1.2.2 Structure(s)

5.4.1.2.3 Barrier

5.4.1.2.4 Precast units

5.4.1.2.5 Sidewalks

5.4.1.2.6 Other application not identified here, but must be approved by the Engineer/Agency.

5.4.2 Shall provide a plan on how the WSDOT concrete will be stored,crushed, stockpiled, and segregated from other materials.

5.4.3 Identify what processes will be used to ensure that no contamination will occur with other materials.

5.4.4 A new quality control plan shall be required whenever changes occur that causes the existing quality control plan to become inaccurate or invalid.

5.4.5 In order to ensure these quality control plans are occurring, WSDOT reserves the right to visit these facilities within one day notice to ensure the Recycled Materials facility is following their approved quality control plans.

## 6. Documentation Requirements

Each Recycled Materials Facility shall provide manufacturer's certification compliance in accordance with Section 1-06.3 of the *Standard Specifications* for the RCA from either returned concrete and/or WSDOT concrete. This certification shall represent a lot of processed RCA which is a maximum of 10,000 tons. The certification shall be in English and include the following;

6.1 Name of Recycled Materials Facility

6.2 Identification of RCA, WSDOT concrete and/or Returned Concrete

6.2.1 For returned concrete, include the ASA report for the aggregate source.

6.2.2 For WSDOT concrete, provide the following;

6.2.2.1 Contract number from where the concrete was reclaimed from or,

6.2.2.2 Identify the State route or Interstate route and what item the concrete was reclaimed from.

6.3 List the applicable standard specification the RCA is to be used for. See table in *Standard Specifications* Section 9-03.21(1)1.

6.4 Quantity of RCA

6.5 Unique identification number traceable to the date of production, 10,000 tons maximum. Production dates of the RCA

6.6 A certification report shall be provided for each lot of RCA.

## 7. Revocation of Qualification

7.1 A Recycled Materials Facility may have its qualification status revoked and be removed from the QPL if found in non-conformance with the Standard Specification or this Standard. Causes for removal from the QPL may include, but are not limited to, the following:

7.1.1 Failure to comply with the requirements of This Standard Practice.

7.1.2 Failure to notify WSDOT of changes in QC plan

7.1.3 Producing materials that fails to meet specification requirements.

## 8. Requalification

8.1 Once a Recycled Materials Facility has been removed from the QPL, the Recycled Materials Facility may request reinstatement by providing the following written information to WSDOT:

8.1.1 The root cause and corrective action taken to prevent future occurrences of the problem that cause removal from the QPL.

8.1.2 Updated quality control plan.

8.1.3 Other information and test data as determined by WSDOT.

8.2 Provided there is a satisfactory resolution of the initial problem, at WSDOT's discretion the Recycled Materials Facility may either be reinstated into the QPL, or the Recycled Materials Facility may be required to reapply to the QPL. All costs of the QPL process shall be borne by the Recycled Materials Facility.

Washington State
Department of Transportation

# WSDOT Standard Practice QC 10

## *Standard Practice for Approval of Recycled Materials Facilities from Stockpiles of Unknown Sources*

### 1. Scope

This standard specifies the requirements for all Recycled Materials Stockpiles for recycled materials identified in Section 9-03.21 of the *Standard Specifications* from unknown sources. Recycled Materials Facilities that comply with this standard will require evaluation of LA Wear, Modified WSDOT Degradation test, and certification of toxicity characteristics.

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

### 2. Reference Documents

2.1 AASHTO Standards

2.1.1 M 80 Standard Specification for Coarse Aggregate for Hydraulic Cement Concrete

2.1.2 R 18 Standard Recommended Practice for Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories

2.1.3 R 76 Reducing Samples of Aggregate to Testing Size

2.1.4 T 2 Standard Method of Test for Sampling of Aggregates

2.1.5 T 11 Standard Method of Test for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

2.1.6 T 27 Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregate

2.1.7 T 84 Standard Method of Test for Specific Gravity and Absorption of Fine Aggregate

2.1.8 T 85 Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate

2.1.9 T 96 Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

2.1.10 T 176 Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

2.1.11 T 304 Standard Method of Test for Uncompacted Void Content of Fine Aggregate

2.1.12 T 335 Standard Method of Test for Determining the Percentage of Fracture in Coarse Aggregate

2.2 ASTM Standards

2.2.1 D 75 Standard Practice for Sampling Aggregates

2.2.2 C 117 Standard Test Method for Materials Fine than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

2.2.3 C 127 Standard Test Method for Relative Density (Specific Gravity)and Absorption of Coarse Aggregate

2.2.4 C 128 Standard Test Method for Relative Density (Specific Gravity)and Absorption of Fine Aggregate

2.2.5 C 131 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

2.2.6 C 136 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate

2.3 WAQTC Standards

2.3.1 FOP for AASHTO T 2, Sampling Aggregates

2.3.2 FOP for AASHTO T 27_T11, Sieve Analysis of Fine and Coarse Aggregate

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

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

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

2.3.6 FOP for AASHTO T 335, Determining the Percentage of Fracture in Coarse Aggregate

2.4 WSDOT Standards

2.4.1 M 41-01 *Construction Manual*

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

2.4.3 M 46-01 *Materials Manual*

2.4.4 WSDOT Test Method T 113 Method of Test for Determination of Degradation Value

2.4.5 WSDOT Test Method T 304 FOP for Uncompacted Void Content of Fine Aggregate

2.4.6 WSDOT QC 3 Quality System Laboratory Review

## 3. Terminology

3.1 AASHTO – American Association of State Highway and Transportation Officials

3.2 ACI – American Concrete Institute

3.3 ASTM – American Society of Testing and Materials

3.4 ASA Database – The ASA (Aggregate Source Approval) is a database containing results of WSDOT preliminary testing of aggregate sources

3.5 Modified Degradation Test- WSDOT Test Method T 113 run with ½ - ⅜ inch and ⅜ - ¼ inch portions in step g and replacing the ¼ - #10 portion with ¼ - #4 material of the Recycled Concrete Aggregate

3.6 Stockpiles – stockpiles that are composed recycled concrete from which aggregate sources are unknown

3.7 QC – Quality Control, the Recycled Materials Facility's operational techniques and activities that are performed or conducted to fulfill specification compliance

3.8 QCP – Quality Control Plan

3.9 QPL – Washington State Department of Transportation, Qualified Products List

3.10 Recycling Materials Facility – The facility and location of the plant that produces recycled materials

3.11 WAQTC – Western Alliance for Quality Transportation Construction

3.12 WSDOT – Washington State Department of Transportation

## 4. Significance and Use

This standard practice specifies processes for approving Recycling Materials Facilities. This is accomplished by a system that evaluates the quality control processes of Recycling Materials Facilities and determines if these quality control processes will ensure that non- contaminated quality materials are produced to meet the specified materials quality.

## 5. Recycled Materials Quality Control Plan

The Recycling Materials Facility shall have QCP on how the facility will ensure that required quality levels are obtained. This QCP should at the minimum include following;

5.1 Recycling Materials Facility

5.1.1 Facility Type

5.1.2 Facility Address

5.1.3 Name, email address, and telephone number of the contact person responsible for the quality control of the facility.

5.2 Prevention of Contamination, Segregation, and Degradation

The handling and storage of recycled materials shall be in such manner to minimize any segregation or degradation and to prevent contamination by foreign materials or deleterious materials in accordance with Section 9-03 of the *Standard Specifications*.

5.2.1 Identify what processes will be used to ensure that no contamination will occur with other materials.

5.2.2 A new QCP shall be required whenever changes occur that causes the existing QCP to become inaccurate or invalid.

5.2.3 In order to ensure these quality control plans are occurring, WSDOT reserves the right to visit these facilities with a one day notice to ensure the Recycling Materials facility is following their approved quality control plans and perform sampling and testing.

5.3 Testing Requirements

5.3.1 Each Recycling Materials Facility must designate either its own personal or a commercial laboratory for the performance of QC testing. QC testing facility and personnel performing test for submittal to WSDOT must be equipped to run all applicable tests with equipment and technicians meeting the following requirements:

5.3.1.1 Materials testers shall be either WAQTC certified Aggregate Testing Technicians (AgTT) or ACI Aggregate Testing Technician level 1 and 2, as appropriate.

5.3.1.2 The QC laboratory and testing equipment shall be compliant with WSDOT QC 3 "Standard Practice for Quality System Laboratory Review" or hold a current AASHTO Accreditation with a scope of Aggregates.

5.3.2 Documentation of personnel qualifications and the equipment certification/standardization/checked records shall be maintained and available for inspection.

5.4 Analysis and Recording of Data

5.4.1 The QCP shall include a procedure that will review and analyze test data, so as to effectively evaluate control of the process.

5.4.2 The producer shall monitor its own data for compliance with the current Washington State Department of Transportation *Standard Specifications*. When there is an indication that the process is not being adequately controlled in compliance with the QCP, the producer shall immediately take the necessary steps to adjust the process

5.5 QC Tests

The maximum QC testing frequency is shown in Table 1:

**Table 1** Minimum Quality Control testing

| **All Aggregates per *Standard Specification* 9-03** | |
|---|---|
| **Test** | **Frequency** |
| Toxicity per 9-03.21(1) | Once every 90 days |
| Modified Degradation | Once every 3 Months |
| SPG | Once every 3 Months |
| Absorption | Once every 3 Months |
| LA wear | Once every 3 Months |
| Gradation | Once every 10,000 tons |
| SE | Once every 10,000 tons |
| Dust Ratio | Once every 10,000 tons |

The QCP may utilize other testing frequencies, but shall not exceed the frequencies shown in Table 1.

## 6. Documentation Requirements

A manufacturer's certification compliance in accordance with Section 1-06.3 of the WSDOT *Standard Specifications* shall be provide to Project Engineer. This certification shall represent a lot of processed recycled materials, not to exceed the frequencies shown in Table 1. The manufacture's certification of compliance shall be in English and include the following;

6.1 Name of Recycling Materials Facility

6.2 WSDOT Standard Specification that the recycled aggregate meets

6.3 Quantity of recycled material

6.4 Identify the percentage(s) of recycled materials and natural aggregate in the final blended aggregate product

6.5 Unique identification number traceable to the production dates of the recycled materials

6.6 Certification shall be provided for each lot of recycled materials, with the maximum lot size not exceeding 10,000 tons

6.7 Copy of test reports for items listed in Table 1 for each lot , including most current toxicity test, Modified WSDOT Degradation, LA wear test, Specific Gravity and Absorption results

## 7. Revocation of Qualifications

7.1 A Recycling Materials Facility may have its qualification status revoked and be removed from the QPL if found in non-conformance with the Standard Specification or this Standard. Causes for removal from the QPL may include, but are not limited to, the following;

7.1.1 Failure to comply with the requirements of this Standard Practice

7.1.2 Failure to notify WSDOT of changes in QC plan

7.1.3 Producing materials that fails to meet specification requirements

## 8. Requalification

8.1 Once a Recycling Materials Facility has been removed from the QPL, the Recycling Materials Facility may request reinstatement by providing the following written information to WSDOT:

8.1.1 The root cause and corrective action taken to prevent future occurrences of the problem that cause removal from the QPL

8.1.2 Updated QCP

8.1.3 Other information and test data as determined by WSDOT

8.2 Provided there is a satisfactory resolution of the initial problem, at WSDOT's discretion, the Recycling Materials Facility may either be reinstated into the QPL, or the Recycling Materials Facility may be required to reapply to the QPL. All costs of the QPL process shall be borne by the Recycling Materials Facility.

# 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) |

*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:*** 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:

## Performance Exam Checklist (Oral)

### *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 |
|---|---|---|
| 1. How is a sample obtained from a conveyor belt using Method A? | ______ | ______ |
| a) Stop the belt. | ______ | ______ |
| b) Set the sampling template on belt, avoiding intrusion of adjacent material. | ______ | ______ |
| c) All the material is removed from belt including all fines. | ______ | ______ |
| d) Take at least approximately three equal increments. | ______ | ______ |
| 2. How is a sample obtained from a conveyor belt using Method B? | ______ | ______ |
| a) Pass the sampling device through a full stream of material as it runs off the end of the belt. | ______ | ______ |
| b) The device must be passed through at least twice (once in each direction). | ______ | ______ |
| 3. How is a sample obtained from a Transport Unit? | ______ | ______ |
| a) Divide the unit into four quadrants. | ______ | ______ |
| b) Dig 0.3 m (1 ft.) below surface. | ______ | ______ |
| c) Obtain an increment from each quadrant. | ______ | ______ |
| 4. Describe the procedure for sampling from roadways Method A (Berm or Windrow). | ______ | ______ |
| a) Sample prior to spreading | ______ | ______ |
| b) Sample the material full depth without obtaining underlying material. | ______ | ______ |
| c) Take at least three approximately equal increments. | ______ | ______ |
| 5. Describe the procedure for sampling from roadway Method B (In-place). | ______ | ______ |
| a) Sample after spreading, prior to compaction. | ______ | ______ |
| b) Sample the material full depth without obtaining underlying material. | ______ | ______ |
| c) Take at least three approximately equal increments. | ______ | ______ |
| 6. Describe the procedure for sampling a stockpile Method A (Loader Sampling). | ______ | ______ |
| a) Loader creates sampling pile with a flat surface. | ______ | ______ |
| b) Divide the flat surface into four quadrants. | ______ | ______ |
| c) Take an approximately equal increment from each quadrant, excluding the underlying material. | ______ | ______ |

| Procedure Element | Trial 1 | Trial 2 |
|---|---|---|
| 7. Describe the procedure for sampling a stockpile Method B (Stockpile Face Sampling). | ______ | ______ |
| a) Create horizontal surfaces with vertical faces and at least one increment taken from each of the top, middle, and bottom thirds of the stockpile. | ______ | ______ |
| 8. Describe the procedure for sampling a stockpile Method C – Alternate Tube Method (Fine Aggregate). | ______ | ______ |
| a) Remove the outer layer and increments taken from at least five locations. | ______ | ______ |
| 9. After obtaining the increments what should you do before performing R 76? | ______ | ______ |
| a) Increments mixed thoroughly to form sample. | ______ | ______ |

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**

***Quartering Method***

***Note:*** If this method is being used for Initial Reduction of Field Sample, step 4 “turning the entire sample over a minimum of 4 times” for safety reasons is not required.

**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 110°C (230°F).
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

# WSDOT FOP for AASHTO T 90

## *Determining the Plastic Limit and Plasticity Index of Soils*

WSDOT has adopted AASHTO T 90.

## Performance Exam Checklist

### *AASHTO T 90*
### *Determining the Plastic Limit and Plasticity Index of Soils*

Participant Name ________________________ Exam Date ________________

| **Preparation** | **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. Sample obtained using AASHTO R 58? | ☐ | ☐ |
| 4. Minimum sample mass meets requirement of AASHTO T 90? | ☐ | ☐ |
| 5. Sample mixed with distilled, demineralized, or de-ionized water until plastic enough to be easily shaped into a ball? | ☐ | ☐ |
| 6. 10 g portion of ball taken from the moist sample material? | ☐ | ☐ |

| **Procedure** | **Yes** | **No** |
|---|---|---|
| 1. 1.5-2 g portion taken and formed into ellipsoidal mass? | ☐ | ☐ |
| 2. Mass rolled at between 80-90 strokes per minute (using one of the techniques described in T 90) for no more than 2 minutes to form a 3 mm diameter thread? | ☐ | ☐ |
| 3. Thread broken into six or eight pieces and pieces squeezed together into ellipsoidal shape and rerolled until thread crumbles and soil can no longer be rolled into a thread? | ☐ | ☐ |
| 4. Tested material placed in a tared covered container and procedure steps 1-6 repeated until all 10 g of material is tested? | ☐ | ☐ |
| 5. Sample dried in accordance with T 265 to determine moisture content? | ☐ | ☐ |
| 6. Were all calculations performed correctly? | ☐ | ☐ |

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

Signature of Examiner ____________________________

Comments:

## WSDOT Errata to FOP for AASHTO T 99

### *Moisture-Density Relations of Soils*

WAQTC FOP for AASHTO T 99 has been adopted by WSDOT with the following changes:

**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 30 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 perfcentage 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 com-pacted 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.

# 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<br>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<br>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

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

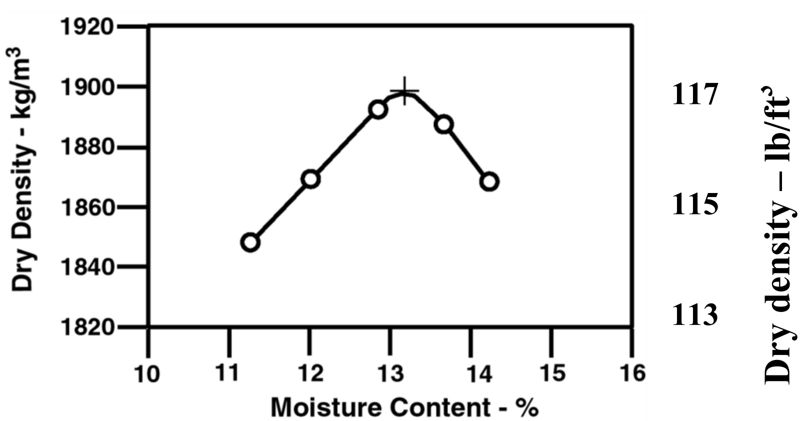
## Moisture-Density Curve Development

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 kg/m³ | Dry Density lb/ft³ | Moisture Content, % |
|---|---|---|
| 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/m³ (62.274 lb/ft³)

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

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

| °C | (°F) | kg/m³ | (lb/ft³) | °C | (°F) | kg/m³ | (lb/ft³) |
|---|---|---|---|---|---|---|---|
| 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:

# 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.

   ***Note 1:*** When performing this test for Recycled Concrete Aggregate (RCA) the final sieve for the 5000 g split is the U.S. No. 4 instead of the U.S. No. 10.

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 2:*** When performing this test for RCA use the ¼" - #4 instead of the ¼" - #10.

   ***Note 3:*** 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.

   ***Note 4:*** When performing this test for RCA use the ¼" - #4 instead of the ¼" - #10.

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:

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

**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 $(D_1-D_2) > 6$

**Table 1** Degradation Value "D"

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

| 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 |

## 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:

# WSDOT Errata to FOP for AASHTO T 180

## *Moisture-Density Relations of Soils*

WAQTC FOP for AASHTO T 180 has been adopted by WSDOT with the following changes:

**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 30 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 perfcentage 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 com-pacted 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.

# 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<br>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<br>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/m³ (lb/ft³)
$M_w$ = 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/m³ (lb/ft³)
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 m³ (0.0334 ft³) |

### *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

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

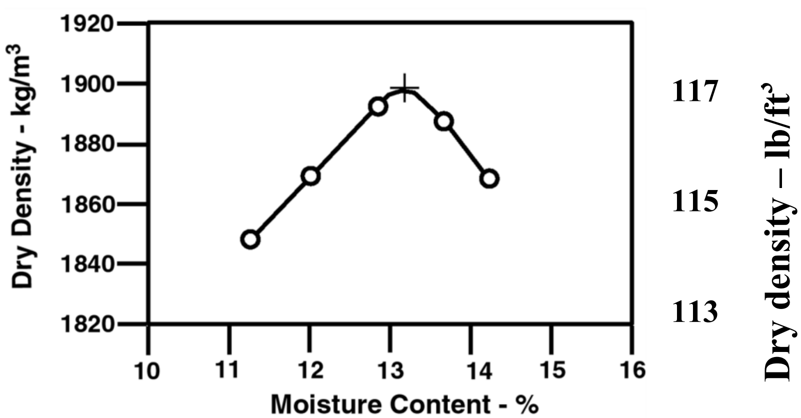
## Moisture-Density Curve Development

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, % |
|---|---|---|
| $kg/m^3$ | $lb/ft^3$ | |
| 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 $kg/m^3$ (117.0 $lb/ft^3$)

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:

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

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/m³ (62.274 lb/ft³)

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

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

| °C | (°F) | kg/m³ | (lb/ft³) | °C | (°F) | kg/m³ | (lb/ft³) |
|---|---|---|---|---|---|---|---|
| 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:

Washington State
Department of Transportation

# WSDOT Test Method T 813

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

### 1. Scope

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

### 2. Equipment

a. **Specimen Molds** – Specimen molds for the 2 in (50 mm) cube specimens shall be tight fitting. The molds shall not have more than three cube compartments and shall not be separable into more than two parts. The parts of the molds, when assembled, shall be positively held together. The molds shall be made of hard metal not attacked by the cement mortar. For new molds, the Rockwell hardness number shall not be less than HRB 55. The sides of the molds shall be sufficiently rigid to prevent spreading or warping. The interior faces of the molds shall conform to the tolerances of Table 1.

| Parameter | 2 in Cube Molds | | 50 mm Cube Molds | |
|---|---|---|---|---|
| | New | In Use | New | In Use |
| Planeness of Sides | <0.001 in | <0.002 in | <0.025 mm | <0.05 mm |
| Distance Between Opposite Sides | 2 in ± 0.005 in | 2 in ± 0.02 in | 50 mm + 0.13 mm | 50 mm + 0.50 mm |
| Height of Each Compartment | 2 in + 0.001 in to -0.005 in | 2 in + 0.01 in to -0.015 in | 50 mm + 0.25 mm to -0.013 mm | 50 mm + 0.25 mm to -0.38 mm |
| Angle Between Adjacent Faces* | 90 + 0.5° | 90 + 0.5° | 90 + 0.5° | 90 + 0.5° |

*Measured at points slightly removed from the intersection. Measured separately for each compartment between all the interior faces and the adjacent face and between interior faces and top and bottom planes of the mold.

**Permissible Variations of Specimen Molds**
***Table 1***

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

c. **Cover Plates** – Cover plates shall be made of a hard metal or glass not attacked by cement mortar. The surface shall be relatively plane.

d. **Tamper** – The tamper shall be made of a nonabsorptive, nonabrasive, nonbrittle material such as a rubber compound having a Shore A durometer hardness of 80 + 10, or seasoned oak wood rendered nonabsorptive by immersion for 15 minutes in paraffin at approximately 392°F (200°C), and shall have a cross-section of ½ in × 1 in (13 mm × 25 mm) and a length of about 5 to 6 in (125 to 150 mm). The tamping face shall be flat and at right angles to the length of the tamper.

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

## 3. Field Procedure

a. Three or more specimens shall be made for each period of test specified.

b. All joints shall be water tight. If not water tight, seal the surfaces where the halves of the mold join by applying a coating of light cup grease. The amount should be sufficient to extrude slightly when the halves are tightened together. Repeat this process for attaching the mold to the base plate. Remove any excess grease.

c. Apply a thin coating of release agent to the interior faces of the mold and base plate. (WD-40 has been found to work well as a release agent.) Wipe the mold faces and base plate as necessary to remove any excess release agent and to achieve a thin, even coating on the interior surfaces. Adequate coating is that which is just sufficient to allow a distinct fingerprint to remain following light finger pressure.

d. Begin molding the specimens within an elapsed time of not more than 2½ minutes from completion of the mixing.

e. For plastic mixes, place a first layer of mortar about 1 in (25 mm) deep in all the cube compartments (about one-half the depth of the mold). Tamp the mortar in each cube compartment 32 times in about 10 seconds making four rounds, each round perpendicular to the other and consisting of eight adjoining strokes over the surface of the specimen, as illustrated in Figure 1, below. The tamping pressure should be just sufficient to ensure uniform filling of the molds. The four rounds of tamping (32 strokes) shall be completed in one cube before going on to the next. When the tamping of the first layer is completed, slightly over fill the compartments with the remaining mortar and then tamp as specified for the first layer. During tamping of the second layer, bring in the mortar forced out onto the tops of the molds after each round of tamping, by means of gloved fingers and the tamper, before starting the next round of tamping. On completion of tamping, the tops of all the cubes should extend slightly above the tops of the molds.

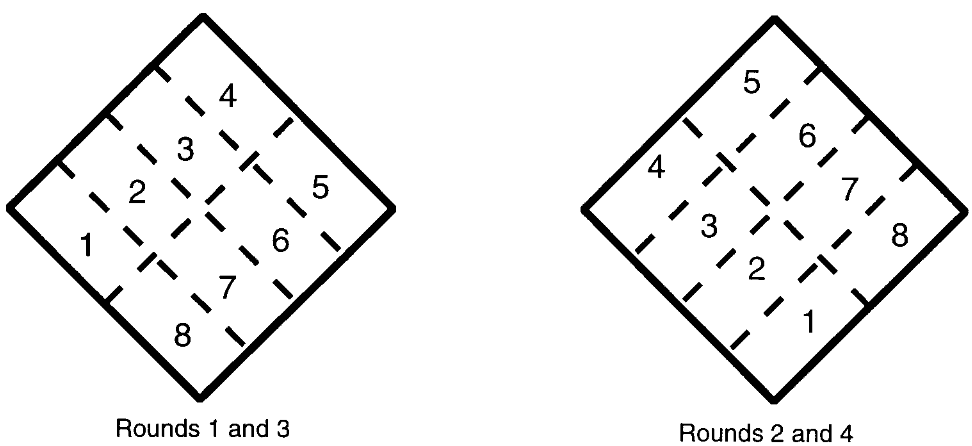



*Figure 1*

f. Bring in the mortar that has been forced out onto the tops of the molds with a trowel and smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube at right angles to the length of the mold. Then, for the purpose of leveling the mortar and making the mortar that protrudes above the top of the mold of more uniform thickness, draw the flat trailing edge of the trowel (with leading edge slightly raised) once lightly along the length of the mold. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion over the length of the mold.

g. When fabricating fluid mixes, steps e. and f. need not be followed. Instead, the cube mold is filled with mortar and cut off to a plane surface with a sawing motion over the length of the mold.

h. Immediately after molding, place cover plate on top of the mold, cover the sample with wet burlap, towels, or rags, seal it in a plastic sack in a level location out of direct sunlight, avoid freezing of cubes and record the time. Allow the sample to set undisturbed, away from vibration, for a minimum of four hours or as recommended by manufactures instructions before moving.

i. Deliver the sample to the Regional or State Materials Laboratory **in the mold** with the cover plate in wet burlap, towels or rags sealed in a plastic bag within 24 hours. **Time of molding MUST be recorded on the Concrete Transmittal.** If delivery within 24 hours is unachievable, contact the Laboratory for instructions on caring for the cubes.

j. Once received in the lab, the molded sample is to be immediately placed in a moist curing room, with the upper surfaces exposed to the moist air but protected from dripping until the sample is a minimum of 20 hours old or has cured sufficiently that removal from the mold will not damage the cube. If the specimens are removed from the mold before they are 24 hours old they are to be kept on the shelves of the moist curing room until they are 24 to 36 hours old.

k. When the specimens are 24 to 36 hours old, immerse them in a lime-saturated water storage tank (Note 1). The specimens are to remain in the storage tank until time of test. (Curing test specimens of material other than hydraulic cement shall be in conformance with the manufacturer's recommendations.)

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

## Performance Exam Checklist

### *Field Method of Fabrication of 2 in (50 mm) Cube Specimens for Compressive Strength Testing of Grouts and Mortars WSDOT Test Method T 813*

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. | Three cubes made for each time period of test? | ☐ | ☐ |
| 4. | All joints (mold halves, mold to base plate) shall be water tight? | ☐ | ☐ |
| 5. | Adequate coating of release agent applied to interior surfaces of the mold? | ☐ | ☐ |
| 6. | Molding began within 2½ minutes from completion of mixing? | ☐ | ☐ |
| 7. | Molding performed in two lifts? (Not necessary if mix is fluid.) | ☐ | ☐ |
| 8. | Lifts tamped 32 times, made up of 4 rounds of 8, each perpendicular to the other? (Not required if mix is fluid.) | ☐ | ☐ |
| 9. | For second layer, mortar forced out of the mold brought back in before each round? (Not required if mix is fluid.) | ☐ | ☐ |
| 10. | Mix extends slightly above the mold at the completion of tamping? | ☐ | ☐ |
| 11. | Mortar smoothed by drawing flat side of trowel across each cube at right angles? | ☐ | ☐ |
| 12. | Mortar leveled by drawing the flat side of trowel lightly along the length of mold? | ☐ | ☐ |
| 13. | Mortar cut off flush with mold with edge of trowel using sawing motion? | ☐ | ☐ |
| 14. | Time of molding recorded? | ☐ | ☐ |
| 15. | Cover plate placed on top of the mold and covered with wet burlap, towel or rag? | ☐ | ☐ |
| 16. | Covered sample sealed in a plastic sack in a level location out of sunlight? | ☐ | ☐ |
| 17. | Sample delivered to the laboratory in the mold within 24 hours? | ☐ | ☐ |
| 18. | Transmittal includes the time of molding? | ☐ | ☐ |

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

Signature of Examiner ______________________________

Comments: