### SUPERPAVE QC/QA CERTIFICATION COURSE ESTIMATED SCHEDULE 2023 Season

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<thead>
<tr>
<th>Day/Time</th>
<th>Module</th>
<th>Location</th>
<th>Topic</th>
<th>Instructor</th>
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<td><strong>Day 1</strong></td>
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<tr>
<td>8:00-8:15</td>
<td>Intro</td>
<td>Class Room</td>
<td>Introduction &amp; Welcome</td>
<td>Huffman</td>
</tr>
<tr>
<td>8:15-9:30</td>
<td>1</td>
<td>Class Room</td>
<td>Mix Design Overview</td>
<td>Huffman</td>
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<tr>
<td>9:30-10:15</td>
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<td>Class Room</td>
<td>QC/QA Overview</td>
<td>Huffman</td>
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<tr>
<td>10:15-10:30</td>
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<td>Break</td>
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<td>10:30-11:30</td>
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<td>Plant Operations Overview</td>
<td>Huffman</td>
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<tr>
<td>11:30-12:00</td>
<td>4</td>
<td>Class Room</td>
<td>Aggregate Testing Overview</td>
<td>Huffman</td>
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<tr>
<td>12:00-1:00</td>
<td>Lunch</td>
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<tr>
<td>1:00-2:15</td>
<td>5</td>
<td>Class Room</td>
<td>Asphalt Sampling</td>
<td>Huffman</td>
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<tr>
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<td>Random Numbers</td>
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<td>Loose Mix Sampling</td>
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<td>Density Cores</td>
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<td>2:15-2:30</td>
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<td>Break</td>
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<td>6</td>
<td>Lab</td>
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<td></td>
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<td></td>
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<td>Specimen Type/Size</td>
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<td></td>
<td></td>
<td>Reheat/Aging</td>
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<tr>
<td>3:00-3:30</td>
<td>7</td>
<td>Class Room</td>
<td>Gyratory Compactor</td>
<td>Huffman</td>
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<tr>
<td>3:30-4:00</td>
<td></td>
<td>Lab</td>
<td>Gyratory Demo</td>
<td>Huffman</td>
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<tr>
<td><strong>Day 2</strong></td>
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<tr>
<td>8:00-8:45</td>
<td>8</td>
<td>Class Room</td>
<td>Max. Specific Gravity (Rice)</td>
<td>Huffman</td>
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<tr>
<td>8:45-9:15</td>
<td></td>
<td>Lab</td>
<td>Rice Sp. Gravity (Demo)</td>
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<tr>
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<td>Binder Content: Ignition Oven</td>
<td>Huffman</td>
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<td>Break</td>
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<td>10:30-12:00</td>
<td>9,8,9</td>
<td>Lab</td>
<td>Ignition Oven demo</td>
<td>Huffman</td>
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<td>Practice: Gyro, Rice, Ignition</td>
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<td>1:30-2:45</td>
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<td>2:45-3:00</td>
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<td>3:00-3:30</td>
<td>12</td>
<td>Class Room</td>
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<td>Huffman</td>
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<tr>
<td>3:30-4:00</td>
<td>13</td>
<td>Class Room</td>
<td>Performance Testing</td>
<td>Huffman</td>
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</table>

### Day/Time   | Module | Location | Topic                                      | Instructor |
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<td><strong>Day 3</strong></td>
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<tr>
<td>8:00-9:00</td>
<td>MoDOT</td>
<td>Class Room</td>
<td>Contract Administration</td>
<td>MoDOT</td>
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<td>Lab</td>
<td>Individual Hands-on Proficiency Testing</td>
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SuperPave

2024 – Updates

- Module 5
  - Added slide on Truck procedure

- Module 8
  - Method update on vacuum to be 30 ± 5 mm Hg
  - Note on Glass vessels and Agitation use a rubber or plastic mat.

- Module 9
  - Updated slides for Moisture Content (AASHTO T329) to match BT.
  - Updated ovens slide 19, added image of an infrared Oven.
  - Added a classroom practice problem for T308, along with the key on a slide.

2023 - Updates

- Added updates page
- Added an Introduction to Superpave Module
- Module 5 – Asphalt Sampling Loose Mix and Cores - updates
  - Resources, added AASHTO R67 Sampling Asphalt Mixtures (Cores)
  - Lots and Sublots, Superlots now has a maximum of 28 sublots per lot.
  - AASHTO R67 steps for coring.
- Module 6 – Sample Reduction and Aging - updates
  - AASHTO R30 was updated on short-term and long-term conditioning.
- Module 7 – Gyratory Compactor AASHTO T312 - Updates
  - Thermometers for measuring temperature See Appendix Item #7 for more information on Thermometers.
• **Module 8 – Maximum Specific Gravity AASHTO T209 - Updates**
  o Thermometers for measuring temperature See Appendix Item #7 for more information on Thermometers.
  o Vacuum Measurement Device updated, see Appendix Item #7 for more information on Vacuum Measurement Device. Capable of measuring residual pressure down to 25mm Hg.

• **Module 9 – Binder Ignition Oven AASHTO T308- Updates**
  o Thermometers for measuring temperature See Appendix Item #7 for more information on Thermometers.
  o Ignition furnace updates on temperature control, see Appendix Item #7.

• **Appendix** - added Item #7 Equipment
# SUPERPAVE

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<td>Glossary</td>
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[MoDOT Logo]
Introduction to SuperPave
Superpave Certification

Introduction

Superpave Prerequisites

- Communication
- Developing Trust
- Joint Problem Solving
- Being Reasonable

Quality Control (QC) and
Quality Assurance (QA)

Working together for QUALITY of materials and testing for a superior pavement.
SUPERPAVE

- SUPERPAVE is the acronym for SUperiorPER forming asphalt PAVEments.
- It is the product of the Strategic Highway Research Program of LSA.
- It gives highway engineers and contractors the tools they need to design asphalt pavements that will perform better under extremes of temperature and heavy traffic loads.

This Certification Covers:

- An overview of the following
  - Mix Design
  - QC/QA
  - Plant Operations
  - Aggregate Testing
- Sample Preparation
  - Asphalt Sampling
  - Sample Reduction R47 and Aging R30
- AASHTO Test Methods Covered
  - T312 Gyratory Compactor Operations
  - T308 Asphalt Content by Ignition Oven
  - T299 Maximum Specific Gravity (Gmm)
- SUPERPAVE Items
  - Job Mix Formula (JMF)
  - Pay Factors
  - Quality Level Analysis (QLA)
  - Performance Testing
  - Contract Administration

SUPERPAVE LAYERS
Flexible Pavement = Asphalt (SUPERPAVE)
SUPERPAVE

- Superpave involves an improved mixture design and analysis system based on performance characteristics of the pavement.

- The Superpave system ties asphalt binder and aggregate selection into the mix design process and considers traffic and climate.

- The compaction devices from the Hveem and Marshall procedures have been replaced by a gyratory compactor and the compaction effort in mix design is tied to expected traffic.

Compacted Samples

<table>
<thead>
<tr>
<th>Marshall &amp; Hveem</th>
<th>Superpave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height 2.5 inches</td>
<td>Height 4.5 inches</td>
</tr>
<tr>
<td>Diameter 4 inches</td>
<td>Diameter 6 inches</td>
</tr>
</tbody>
</table>
SUPERPAVE Primarily addresses the following pavement distresses:

Permanent Deformation (Rutting) Which results from inadequate shear strength in the asphalt mix.

Low Temperature Cracking Is generated when an asphalt pavement shrinks, and the tensile stress exceeds the tensile strength.
Fatigue Cracking

Also known as alligator cracking, caused by load-related deterioration resulting from a weakened base course or subgrade, too little pavement thickness, overloading, or a combination of these factors.

Stripping

Is the separation of asphalt binder film from aggregate surfaces due primarily to the action of moisture and or moisture vapor.

First Steps...

• Collect maximum/minimum temperatures for both air and pavement, along with the current and anticipated traffic types and loads.

• Testing and selection criteria for PG binder, combined aggregate requirements, and mixture design are detailed in AASHTO M323.
OBJECTIVE OF A MIX DESIGN

- Sufficient flexibility to resist fatigue cracking.
- Sufficient strength or stability to resist traffic loading without permanent deformation. (rutting)
- Good workability to enable proper lay down and compaction.
- Moisture damage resistance. Did not degrade or strip due to adverse effect of water.
- Durable, to have the original good properties over the service life without unacceptable aging or water induced damages.
- Skid resistance, to have enough surface friction properties. (Safety)

SUPERPAVE PROCEDURE

1. Aggregate selection
2. Asphalt Binder selection
3. Sample preparation (Including compaction)
4. Performance Tests
5. Density and Voids calculations (volumetrics)
6. Optimum asphalt binder content selection
7. Moisture susceptibility evaluation

MIX DESIGN

1. Materials Selection
2. Design Aggregate Structure
3. Design Binder Content
4. Moisture Sensitivity
Types of Asphalt Mix

- **Hot Mix Asphalt (HMA)** – A combination of aggregates bound together by PG binder. Uses temperatures between 300 – 350°F.

- **Warm-Mix Asphalt (WMA)** – A combination of aggregates bound together by PG binder along with additives or a foam. Uses lower temperatures around 275°F.

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**What's NEW ???**

NOTE TO THE CLASS . . .

On the following few slides,
- Just a little information on WMA, since MODOT has been increasing the use of this product.

---

**Warm Mix Asphalt (WMA)**

"Warm mix asphalt is a relatively new technology that has taken the asphalt industry by storm in recent years.
Warm mix asphalt is a hybrid of sorts, combining all the qualities of traditional hot mix asphalt but drastically cutting the temperature of the asphalt.
On average, warm mix can shave anywhere from 50-100 degrees off production temperatures. This reduction results in less fuel consumption, lower emissions, and a reduced carbon footprint." MAPA

WMA is also used to incorporate higher percentages of reclaimed asphalt pavement (RAP) into the mix.
**Advantage of WMA**

- Lower production/construction temperatures
  - Up to 30% reduction in energy consumption
  - Up to 50% reduction in emissions
  - Lower odor
  - Increase haul distance
  - Extends paving season
  - Lower oxidation
  - Quicker return to traffic
- Decreased binder viscosity
  - Easier compaction
  - Higher RAP content
- Performance
  - Most projects have not seen a decrease in performance
  - Some have seen an increase
  - May need to add coating, workability, & compactability specifications

**WMA, how does it work?**

Warm Mix Asphalt technologies reduce the viscosity (the thickness) of the asphalt binder so that asphalt aggregates can be coated at lower temperatures. The key is the addition of additives (water-based, organic, or hybrids) to the asphalt mix.

The additives allow the asphalt binders and asphalt aggregates to be mixed at the lower temperatures. Reducing the viscosity also makes the mixture easier to manipulate and compact at the lower temperature.

**Different Types of WMA**

- Foam – addition of water
  - Mechanical – inject water/air, various proprietary configurations
  - Wet aggregate
  - Zeolites – Aspha-Min and Advera
- Organics and chemicals
  - Sasobit, Asphaltene, Licomont, RH, Thiothene, LEADCAP
  - Evotherm, Sasobit Redux, Rediset, Cecabase RT, Zycotherm, Sonnefamix
Even though WMA is gaining popularity, HOT MIX ASPHALT is the main topic discussed in this SUPERPAVE certification. So, on to Module 1 Mix Design Overview...
Module 1

Mix Design Overview
MIX DESIGN OVERVIEW

MoDOT SUPERPAVE CERTIFICATION COURSE

MODULE 1

1

AASHTO Test Methods

• R35 Volumetric Design Practice
• M323 Volumetric Mix Design Specifications
• R30 Mix Conditioning
• T 312 Gyratory Compactor Operation (Gyro)
• T 166 Bulk Specific Gravity of Compacted Specimens (Pucks)
• T 209 Maximum Specific Gravity of Voidless Mix (Rice)
• T 283 Moisture Sensitivity

2

MoDOT Specifications & Guides

• Missouri Standard Specifications
  • Sections: 403, 610, 1002, 1015 etc.
• Engineering Policy Guide (EPG)
  • Sections same as above.
  Other sections are referenced when applicable.
  • See Appendix Item #3 and #4 for information on Performance Graded (PG) Binder, RAP, Shingles, and testing.

3
**Superpave Language...**

- **Asphalt** - Is a mixture of fine and coarse aggregates, additives and bitumen. Also called: Asphaltic Concrete or Flexible pavement.
- **Bitumen** – Used as a binder to hold the asphalt mixture together. Also called: Asphalt Binder, PG Binder or Binder.

**PG Binder System**

- PG = Performance Grade, Example: PG 64-22H
  - See the Appendix Item #3 for more information.

  - Tests are directly related to *field performance*.
  - Criteria remain constant but tests are run at temperatures that reflect the design climate.
  - Tests are conducted at high, intermediate, and low temperatures.
  - Both short-term and long-term aging is employed.
  - Tests are suitable for modified binders.

**Typical Asphalt Mixture**

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>% by wt.</th>
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<tbody>
<tr>
<td>Aggregate (Coarse &amp; fine)</td>
<td>90%</td>
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<tr>
<td>Dust (Dust-of-fracture + mineral filler)</td>
<td>5%</td>
</tr>
<tr>
<td>Asphalt Binder</td>
<td>5%</td>
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</table>

Dust = less than -200 sieve
Hot Mix Asphalt Concrete (HMA) Mix Design Methods

- **Objective:**
  - Develop an economical blend of aggregates and asphalt that meet design requirements.

- **Mix design methods (Compaction):**
  - Superpave gyratory
  - Marshall hammer
  - Hveem

Requirements in Common

- Sufficient asphalt to ensure a **durable** pavement.
- Sufficient **stability** under traffic loads.
- Sufficient **air-voids**.
  - Upper limit to prevent consolidation rutting and excessive environmental damage.
  - Lower limit to prevent plastic distortion while allowing room for initial densification due to traffic.
- Sufficient **workability**.

Flexible Pavements MoDOT Standard Specs.

<table>
<thead>
<tr>
<th>Asphalt Mixture</th>
<th>EPG Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Mix (Bit Base, BP-1, BP-2, BP-3)</td>
<td>401</td>
</tr>
<tr>
<td>Surface Leveling</td>
<td>402</td>
</tr>
<tr>
<td>Asphalt Concrete (Superpave)</td>
<td>403</td>
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</tbody>
</table>

EPG = Engineering Policy Guide

[Engineering_Policy_Guide (modot.org)]
Superpave Nomenclature

"SPnnnyzz"
- SP = Superpave
- nnn = nominal max size
  - 048 = 4.75 mm (#4)
  - 095 = 9.5 mm (3/8 in)
  - 125 = 12.5 mm (1/2 in)
  - 190 = 19.0 mm (3/4 in)
  - 250 = 25.0 mm (1 in)
- y = Design Levels (ESAL's)
  - F = < 300,000
  - E = 300,000 to < 3,000,000
  - C = 3,000,000 to < 30,000,000
  - B = ≥ 30,000,000
- zz = Mixture Designations:
  - LP = Limestone Porphyry
  - SM = Stone Mastic Asphalt
  - SMR = SM Rural
  - NC = Non-Carbonate
  - LG = Lower Gyration

Superpave Mixture Names

- y = Design Levels (ESAL's)
  - F = < 300,000
  - E = 300,000 to < 3,000,000
  - C = 3,000,000 to < 30,000,000
  - B = ≥ 30,000,000
- zz = Mixture Designations:
  - LP = Limestone Porphyry
  - SM = Stone Mastic Asphalt
  - SMR = SM Rural
  - NC = Non-Carbonate
  - LG = Lower Gyration

Superpave Mixes in Missouri

- SP048 = #4 NMS surface course
- SP095 = 3/16" NMS surface course
- SP125 = ½" NMS surface course
- SP190 = ¾" NMS binder course
- SP250 = 1" NMS base course

Examples of Superpave names:
  - SP250C
  - SP125CLG
Material Standard Specs.

<table>
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<tr>
<th>Item</th>
<th>EPG Section</th>
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<tr>
<td>Aggregate for Asphaltic Concrete</td>
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<tr>
<td>Mineral Filler</td>
<td>1002</td>
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<td>Hydrated Lime</td>
<td>1002</td>
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<td>PG Binder</td>
<td>1015</td>
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<td>Fiber</td>
<td>1071</td>
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<td>Anti-Strip</td>
<td>1071</td>
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<td>RAP Reclaimed Asphalt Pavement</td>
<td>403</td>
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<td>RAS Reclaimed Asphalt Shingles</td>
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<tr>
<td>Asphalt Concrete Pavement</td>
<td>403</td>
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Types of Asphalt Mixes

- Dense-Graded (DGA)
  - Size evenly distributed from smallest to largest size (well-graded)
- Open-Graded - Friction Course (OGFC)
  - Primarily coarse aggregate with few fines
- Stone Mastic (Matrix) Asphalt (SMA)
  - Gap graded to achieve Stone – on – stone contact

Various Asphalt Mixes

SP = SuperPave
SMA = Stone Mastic (Matrix) Asphalt
Construction of SMA

- **What is Stone Mastic Asphalt?**
  - Mixture with a gap-graded aggregate skeleton that is filled with mastic.
  - Mastic comprised of fine aggregate, mineral filler, fibers and asphalt binder.
  - Minimum asphalt content of 6.0%.

MoDOT Determines Desired Mix Based on Design Traffic Data.

1. Determine traffic data for the project site.
2. Convert the traffic levels for the mix of vehicle types to **Equivalent Single Axle Load (ESAL)**'s.
3. Estimate growth over the design life.
4. Calculate the total design ESAL's:
   - Example: 12,000,000 ESAL's

13 MoDOT (AASHTO) Vehicle Classes

- [Diagram of vehicle classes]
<table>
<thead>
<tr>
<th>Class 1</th>
<th>Class 7</th>
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<tbody>
<tr>
<td>Motorcycles</td>
<td>Four or more axle, single unit</td>
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<table>
<thead>
<tr>
<th>Class 2</th>
<th>Class 8</th>
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</thead>
<tbody>
<tr>
<td>Passenger cars</td>
<td>Four or less axle, single trailer</td>
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<table>
<thead>
<tr>
<th>Class 3</th>
<th>Class 9</th>
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<tbody>
<tr>
<td>Four tire, single unit</td>
<td>5-Axle tractor semitrailer</td>
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<tr>
<th>Class 4</th>
<th>Class 10</th>
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<tbody>
<tr>
<td>Buses</td>
<td>Six or more axle, single trailer</td>
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<table>
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<th>Class 5</th>
<th>Class 11</th>
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<tbody>
<tr>
<td>Two axle, six tire, single unit</td>
<td>Five or less axle, multi trailer</td>
</tr>
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<table>
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<tr>
<th>Class 6</th>
<th>Class 12</th>
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</thead>
<tbody>
<tr>
<td>Three axle, single unit</td>
<td>Six axle, multi-trailer</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Class 6</th>
<th>Class 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three axle, single unit</td>
<td>Seven or more axle, multi-trailer</td>
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</table>
Trial Mix Design

**Aggregate (+ 4 Material) Tests:**
- Gradation
- Specific gravity & absorption
- Deleterious materials
- LA abrasion
- Coarse aggregate angularity
- Flat & elongated
- PI (as required)

**Aggregate (- 4 Material) Tests:**
- Gradation
- Specific gravity
- Deleterious materials
- LA abrasion
- Coarse aggregate angularity
- Flat & elongated
- PI (as required)

**Fine Aggregate Tests:**
- Gradation
- Specific gravity
- Clay lumps & shale
- Lightweight pieces
- Sand equivalent
- Coarse aggregate angularity
- PI (as required)

Blended aggregate must meet Superpave “Consensus” testing criteria:
- Fine aggregate angularity (FAA)
- Coarse aggregate (CA) fractured face count
- Coarse aggregate (CA) flat and elongated
- Sand equivalent (SE)

Selection of PG Binder Grade

Based on:
- Climate
- Depth in pavement
- Volume of traffic
- Vehicle speed
- Desired level of reliability
- RAS (Reclaimed Asphalt Shingles) content
- RAP (Reclaimed Asphalt Product) content
RAP/RAS Binders

- **RAP** - Has aged binder - stiffer than virgin binder.  
  *Virgin Asphalt*: Is a newly mixed/batched hot mix asphalt.

- **RAS** - Roofing binder is much stiffer, has a hardening effect on the binder.

- **Combined** - Virgin & recycled binder → stiffer

  Stiffer = Brittle and has a greater potential to crack during cold weather.

Example JMF Showing Substitution of purchased grade M 332 (PG 64V-22V) for contract grade M 320 (PG 76-22)

- SMA: No RAP/RAS allowed
- No additives, so in-line grade = PG 64-22V

What's My Grade?

- **"Contract Grade"** = the PG grade in the contract, e.g., PG 70-22.
- **"Purchased Grade"** = what contractor buys from supplier (terminal), e.g., PG 58-28 (if RAP/RAS will be used).
- **"In-line Grade"** = Purchased grade + additive (warm mix, anti-strip, etc.) e.g., PG 58-28.
- **"In-line Grade"** = Purchased grade + modifier (rejuvenator) e.g., PG 52-28.
Example JMF Showing Substitution of purchased grade M 332 (PG 64-22V) for contract grade M 320 (PG 76-22)

- SMA: No RAP/RAS allowed
- No additives, so in-line grade = PG 64-22V
**Volumetrics**

- "Volumetrics" involves the space (volume) between the aggregate particles.
- During mix design, several gradations are tried, and volumetrics are calculated until proper VMA, VFA, and Va (air voids) are obtained.
- Space is dependent on aggregate gradation, particle shape, aggregate toughness, and aggregate absorption.

**Aggregate Structure Selection**

- Aggregate Structure = gradation
  - The design gradation will be a blend of up to 8 different aggregate fractions plus mineral filler such as hydrated lime.
  - Vary the percentages of each fraction to make the total gradation blend.
  - The blend must meet the aggregate consensus test criteria.
Gradation is usually plotted on **0.45 power graph paper**.

The **maximum density line** represents the densest possible gradation for a given maximum aggregate size - it is just a reference line.
**Dust/Binder Ratio**

- Ratio of % minus #200 to % effective asphalt content.
- \( \frac{D}{P_{be}} \)  
  \( D = \text{Dust}, \ P_{be} = \text{Effective Asphalt Binder} \)
- Window: **0.8-1.6** (0.9-2.0 for SP048)
- Below 0.8: Insufficient dust in relation to binder—loss of cohesion.
- Above 1.6: Excessive dust:  
  * Gummy, hard to compact  
  * Loss of VMA

**Bag House Dust**

- Baghouse dust return should be closely regulated to:  
  * Preserve proper dust/asphalt ratio  
  * Preserve proper VMA

**VMA**

- “Voids in the Mineral Aggregate”  
- Space between the aggregate particles  
- Contains binder and air voids  
- Must have sufficient VMA to accommodate proper binder and air void contents

What happens if VMA is low?  
Lower VMA values = Intergranular space available for asphalt binder is reduced. This reduces the amount of effective asphalt binder that can be used in the mix, which in turn, leads to a lower binder film thickness around the aggregate particles, increasing the potential for cracking.
### How To Increase VMA

1. Use a more angular sand (manufactured sand).
2. Increase Crush Count
3. Lower the -#200 (dust)
4. Change the gradation to a Gap-grade, move away from the maximum density line.
5. Evaluate Flat and Elongated

---

### How to Lower Minus #200

*Reduce the % of the material that is the source of fines.*

- Replace some dusty screenings with a clean mfg. sand.
- Replace some dusty screenings with a natural sand.
- Replace some graded aggregate with a clean coarse fraction. (e.g., replace some ½” minus material with a clean ¾” chip).
- Replace some screenings with a less dusty graded fraction.
- Replace some of the source material that is breaking down with a harder aggregate.
- Wash the source material that is the source of fines.

---

### Aggregate Specific Gravity

*For each aggregate, there are three types of specific gravity:*

- Bulk specific gravity ($G_{sb}$)
- Apparent specific gravity ($G_{sa}$)
- Effective specific gravity ($G_{se}$)

**NOTES:**

- $G =$ Gravity
- $s =$ Aggregate
- $b =$ Bulk
- $a =$ Apparent
- $e =$ Effective
### Apparent Specific Gravity

\[ G_{sa} = \frac{\text{Mass of Aggregate, oven dry}}{\text{Vol. of agg. not including surface pores}} \]

### Effective Specific Gravity

\[ G_{se} = \frac{\text{Mass of Aggregate, oven dry}}{\text{Vol. of agg. not including pores not filled with AC}} \]

### Bulk Specific Gravity

\[ G_{sb} = \frac{\text{Mass of Aggregate, oven dry}}{\text{Vol. of agg. including surface pores}} \]

---

### Testing for Specific Gravity

- **Gsb and Gsa** from water displacement aggregate tests AASHTO T84 and AASHTO T85.
- **Gse** back-calculated from Maximum Specific Gravity test AASHTO T209 from an HMA mixture.

**Effective Specific Gravity**

\[ G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}} \]
<table>
<thead>
<tr>
<th>Mix Design and Field Verification</th>
<th>Air Void Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix Design and Field Verification</th>
<th>Voids in Mineral Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mix Design and Field Verification</th>
<th>Voids Filled with Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$VFA = \frac{VMA - V_a}{VMA} \times 100$</td>
</tr>
</tbody>
</table>
**Bulk Sp. Gravity of Compacted Mix**

- $G_{mb}$ is determined from the Bulk Specific Gravity of Compacted Bituminous Mixes test; AASHTO T166.

**Theoretical Maximum specific Gravity**

- $G_{mm}$ is determined from the Theoretical Maximum Specific Gravity (Rice) test; AASHTO T209.

  Creates:
  - NO Air Voids
  - Zero Air Voids

**Air Voids - Calculation**

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100$$

- $V_a = \%$ Air Voids
- $G_{mm}$ = maximum specific gravity of the Voidless mix (Rice sp gravity).
- $G_{mb}$ = sp. gravity of the compacted mix.
9 Steps to find Aggregate Structure and Optimum Target Asphalt Content (AC)%

1. Choose 3 or more trial aggregate gradations based on experience.
2. Estimate the required “initial” binder content based on experience or standard procedure.
3. Mix aggregate and binder. Condition for 2 hours at the compaction temperature. This allows binder to be absorbed.
4. Compact duplicate mixture specimens of each trial gradation at the initial binder content using the gyratory compactor.

- During design, specimens are compacted using the gyratory compactor. The number of gyrations applied is a function of design traffic level.
5. Measure compacted puck specific gravity.
6. Run Rice for maximum specific gravity (Gmm).
7. Calculate volumetrics (VMA, VFA, air voids) for each trial blend.
8. At $N_{des}$ adjust (calculate) % binder to achieve $V_a=4.0\%$. Calculate what VMA, VFA, and dust/effective asphalt would be.
9. Compared to criteria. Choose blend that best meets criteria, economy, and chance of success.

Selection of Design Asphalt Binder Content
Selection of Design Asphalt Binder Content

- Va vs %Binder
- VMA vs %Binder
- VFA vs %Binder
- DP vs %Binder
- %G_{mm} at N_{ini} vs %Binder
- %G_{mm} at N_{ini} vs %Binder

Blend 3
Binder Content Selection Steps

1. Using the winning blend, compact more specimens in duplicate to N\text{des}, this time varying binder content.
   Example: Use 3 different % of binder: -0.5, +0.5, and right on the initial %.

2. Again calculate volumetrics. Plot % binder vs. % air voids. Choose the design % binder that produces 4% air voids.

3. Check all other volumetric criteria.

4. Check %G_{\text{mm}} @ N_{\text{ri}}

5. Check dust/effective asphalt ratio, where "dust" = % minus #200 sieve material in the blend: 0.8-1.6

6. Compact more pucks at the design binder content to N_{\text{max}}; check criteria.

At this point, we have duplicate pucks at 3 trial Asphalt Contents (AC)

- AC 0.5% below target
- AC target %
- AC 0.5% above target

Example: SP 190 B

\[
\begin{array}{|c|c|}
\hline
\% \text{ AIR VOIDS} & \% \text{ ASPHALT BINDER} \\
\hline
4.0 & 4.0 \% \\
3.7 & 4.2 \\
4.2 & 4.7 \\
5.2 & 5.7 \\
5.7 & 6.2 \\
\hline
\end{array}
\]

Design AC @ 4.0\% Air
### Factor | Criteria | Reason
--- | --- | ---
Air voids, $N_{das}$ | 4.0% | Stability
VMA | $\geq 12, 13, 14, 15, 16, 17\%$ | Durability
VFA | 70-80 % 65-78% 65-75% | Stability
$\%G_{mn} @ N_{si}$ | $\leq 91.5\%$ $\leq 90.5\%$ $\leq 89.0\%$ | Tenderness
$\%G_{mn} @ N_{max}$ | $\leq 98.0\%$ | Stability
Dust/binder | 0.8-1.6 0.9-2.0 | Compaction Handling

Compare to criteria.

Choose the blend that best meets criteria, economy, and chance of success.
That’s the hard part!

- Now performance testing, design phase
- TSR
  - Moisture sensitivity, susceptibility, stripping
- Drain down (SMA, UBAWS)
  - Stability during the setting process
- Hamburg/IDT
  - Rutting
- Ideal CT/I-FIT
  - Cracking
Module 2

QC/QA
Overview

MoDOT
QC/QA OVERVIEW

1

QC/QA - What is it?

• Quality Control “QC”...Contractor provides control of the process.

• Quality Assurance “QA”...Owner provides assurance that control is working.

2

QC/QA - Who is?

• Quality Control:
  • Aggregate Producer
  • Paving Contractor

• Quality Assurance:
  • Owner (MoDOT)

3
Use of QC/QA

- QC/QA concept dates back over 40 years.
- Most DOT's use QC/QA.

QC/QA

- A way to get material producers and paving contractors more involved in the entire process, which includes:
  - Material selection
  - Mix design
  - Control of production
  - Control of construction

Flowchart, cont'd.

1. Paving contractor WRITES Bituminous QC plan; submits QC plan to MoDOT.
   - The mix design is often submitted at the same time.
2. MoDOT grants final approval of QC plan.
3. Paving Contractor contracts with Aggregate Producer.
   - Often aggregate samples for mix design are taken earlier.
4. Paving contractor submits mix design information (Job Mix Formula = JMF) to MoDOT through the district.

5. MoDOT Field Office handles JMF approval.

6. Aggregate production begins. 
   (actually, Superpave rock is more common now.)

7. Asphalt production begins.

**Specification Hierarchy**

- **Asphalt Mix Design Limits**
  - Limits controlling aspects of the mixture during the design phase.
    - Gradation, AC%, Dust limit, Aggregate quality, etc.

- **Production Limits**
  - Tolerances controlling production of asphalt.
    - Va, VMA, AC%, Density, Gradation, Consensus.

- **Comparison Limits**
  - Insure validity of QC/QA test results.

- **Removal Limits**
  - Specification limits requiring the removal and replacement of out of spec material.
### Asphalt Mix Design Limits

- Limits controlling aspects of the asphalt mixture during the design phase.
  - Gradation
  - AC%
  - Dust limit
  - Aggregate quality, etc.
  - Volumetrics
- **Based on . . .**
  - Anticipated traffic loads
  - Climate

### Production Limits

- Tolerances controlling production of asphalt.
  - Va
  - VMA
  - AC%
  - Density
  - Gradation
  - Consensus.
- Ranges set for each in order to keep the desired characteristics of the mixture.

### Comparison Limits

- Insuring validity of test of both QC and QA.
  - Tests are generally performed on a split sample with same equipment, separately by QC and QA personnel.
  - Limits are based on statistical data showing repeatability of a given test between operators.
Removal Limits

• Generally applied when test results fall outside of production limits.
• Example:
  - Air Voids (Va) specification tolerance is 4.0 ± 1.0%.
  - Removal limit is – 1.5%.
• Hope to stay away from this but it does happen.
• Many things to check before material is removed.

Aggregate Inspection

• QC and QA perform tests at the mixing facility, compare results to each other and:
  - Job Special Provisions
  - Standard specifications
  - Engineering Policy Guide (EPG) guidelines
  - Task Force (FAQ) guidelines, in EPG


Asphalt Inspection

• QC and QA perform tests, compare to each other and to:
  - Job Special Provisions
  - Standard Specifications
  - Engineering Policy Guide
• Must use spec. in force on contract date unless QC requests change.
• Pay factors are computed.
  ("Best Management Practice" says at the end of each lot).
**Quality Control**

- **QC** is the contractor’s responsibility to do the necessary testing during the production of the Asphalt pavement to ensure a durable, well performing product is achieved.

- **QC** involves comparing the contractor’s test results to the specifying agency's requirements and specifications; should use QC’s equipment for comparisons to work.

---

**Quality Control**

- The **contractor** provides control of all steps of the process: aggregate, binder, additives, mix design, asphalt production, and compaction.

- The **contractor** is responsible for providing properly trained personnel and testing equipment.

- **QC** must always perform tests diligently and in compliance with all specifications.

---

**Quality Assurance**

- **MoDOT** personnel assure that the quality controls are working properly.

- **QA** personnel must also be properly trained.

- **QA** must always perform tests diligently and in compliance with all specifications.
Asphalt Quality Control Plans

- Prior to the approval of the trial mix design, the Asphalt contractor will submit a QC Plan to the District which adds traffic and then sends to MoDOT Construction & Materials in Jefferson City.
- Generally, a “Short Form” QC plan is used once a companies’ standard practices are established.

QC PLAN

- Company name
- Contract name
- Contract #
- Job #
- Route
- Contractor rep. in charge of QC plus contact information.
- List Personnel conducting acceptance testing. **Lot & sublot sizes and how they will be designated.**
- Name, address, and phone number of the third-party testing lab that will be used for dispute resolution.

QC Plan cont.

- Information on which method will be used for %AC determination.
- Where the gradation will be sampled.
- Size and number of cores per sample.
Notes

• Lot sizes can be different for the same project. (e.g., 3000 tons first lot, 10,000 thereafter).

• Superlot – Up to 28 sublots, regardless of lot size.

• Third party cannot be the one that performed the mix design.

Example QC Plan

March 17, 2020

Quality Control Plan Supervisor SP10K3L3LP

Job: WTP5656  Contractor: CP-DEG/PLDR  Phase: 141  St. Louis and Jefferson Contracts

Feasibility Road – Arnold, MO

QC Personnel:

Quality Control Contact: Jan McDowell (314) 391-5712

Quality Control Inspector: Dan Weis (314) 391-2322

Quality Control Inspector: Mary Smith (314) 391-1702

Asphalt Testing

The quality control testing will be performed by taking samples from random sections for evaluations in accordance with the specifications. The sections of the project with a bonded binder, sampling will be performed using trueno-sampling methods.

Asphalt Content Determination

Asphalt content will be determined using the ignition oven, ASTM D 312-10. Gradations will be performed using the town-dried method.

Density Cores:

Density cores will be cut using a 3.5” diameter core saw. One core will constitute a sample.

Lot and Failures:

The failure with HD 44.22 will be one lot of 5845 tons in sub-lot of 750 tons. The entire lot must have a total of 5,845 tons and 750 tons with the remaining Lots of 10,000 tons in sub-lots of 10,000 tons.

Third Party Resolution

HOME Testing, LLC

Luis Nieto, 938-938-2987

Record Keeping Samples

• Contractor samples retained for the engineer:
  • Clean covered containers
  • Readily accessible

  *ID’d: Job mix no., sampler, sample location, time & date sampled.

• Stored until test results accepted.

• QC gradation samples: retain the portion of the QC sample not tested after reducing the sample to testing size.

  *All samples labeled
Record Keeping QC

• Record and maintain all test results
• Up-to-date test results
• Paper backup of results
• Maintain printouts from gyro and binder content devices
• Pay Factor records
• Maintain an inventory of major sampling, testing, & calibration equipment.

Documents On Hand

• Job mix
• QC plan
• Current copies of all test method procedures

Test Equipment & Plant Calibration/Verification Records

• Results of calibration
• Description of equipment calibrated
• Date of calibration
• Person calibrating
• Calibration procedure ID
• Next calibration due date
• ID of calibration device & trace ability of calibration
## Calibration

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Requirement</th>
<th>Interval (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyratory Compactor</td>
<td>Calibrate</td>
<td>12</td>
</tr>
<tr>
<td>Gyratory Compactor</td>
<td>Verify</td>
<td>Daily</td>
</tr>
<tr>
<td>Gyratory Compactor molds</td>
<td>Dimensions</td>
<td>12</td>
</tr>
<tr>
<td>Thermometer</td>
<td>Calibrate</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum</td>
<td>Pressure</td>
<td>12</td>
</tr>
<tr>
<td>Pycnometer</td>
<td>Calibrate</td>
<td>Daily</td>
</tr>
<tr>
<td>Ignition oven</td>
<td>Verify</td>
<td>12 or when moved</td>
</tr>
</tbody>
</table>

## Calibration, Cont’d.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Requirement</th>
<th>Interval (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear gage</td>
<td>Drift &amp; stability</td>
<td>1</td>
</tr>
<tr>
<td>Shakers</td>
<td>Sieving thoroughness</td>
<td>12</td>
</tr>
<tr>
<td>Sieves</td>
<td>Physical condition</td>
<td>12</td>
</tr>
<tr>
<td>Ovens</td>
<td>Standardize</td>
<td>12</td>
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<tr>
<td></td>
<td>Thermometric Device</td>
<td></td>
</tr>
<tr>
<td>Balances</td>
<td>Verify</td>
<td>12 or when moved</td>
</tr>
<tr>
<td>Timers</td>
<td>Accuracy</td>
<td>12</td>
</tr>
</tbody>
</table>

## QC Records

- Maintain 3 years from completion of project
- What:
  - test reports, including raw data
  - calibrations
  - technician training
  - personnel
# Exchange of Data

- QC furnishes raw data (including gyratory, and binder printouts) and test results to QA not later than the beginning of the next day following the test.
- QC data, control charts, etc., readily available to QA at all times.
- QA raw data & results made available to QC no later than the next working day.
- QA will make the Quality Level Analysis (QLA) within 24 hours of receipt of the QC test results.

---

## QC/QA Functions at the Asphalt Plant

### Engineering Policy Guide (EPG)

#### Aggregate

<table>
<thead>
<tr>
<th>Function</th>
<th>Location</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Gradation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate: 2 sizes:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 size smaller than NMS (not to exceed 82%)</td>
<td>QC: 1 per 2 sublots</td>
<td></td>
</tr>
<tr>
<td>40% not to exceed 20%</td>
<td>QA: 1 per 4 sublots</td>
<td></td>
</tr>
<tr>
<td>Residue: Optional T308 Residue</td>
<td></td>
<td>QA: QC retained: 1 per week</td>
</tr>
</tbody>
</table>

| Continuous Tests                   |                   |                    |
|--------------------------          |                   |                    |
| PA-like: 5%                 | QA: 1 per project |
| QA-like: 5%                 | QA: QC retained: 1 per project |
| FA-like: 2%                 | QA: 1 per project |
| QA: QC retained: 1 per project |

<table>
<thead>
<tr>
<th>Deleterious</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading (T308, T164 residue)</td>
<td></td>
<td>QC: 1 per day</td>
</tr>
<tr>
<td>Deleterious</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA-like</td>
<td>QA: 1 per 2 sublots</td>
<td></td>
</tr>
<tr>
<td>Binder</td>
<td>QA: 1 per 4 sublots</td>
<td></td>
</tr>
<tr>
<td>QA: QC retained: None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ground Shingles</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading</td>
<td></td>
<td>QC: 1 (sub lot)</td>
</tr>
</tbody>
</table>

#### Asphalt

<table>
<thead>
<tr>
<th>Function</th>
<th>Location</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtain Sample</td>
<td>Behind paver</td>
<td>QC: 1 per sublot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QA: 1 per 4 sublots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QA: QC retained: 1 per day, not necessary on days the QA independent sample is taken if favorable comparison of retained split has been achieved.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quarter Sample</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtain 2 gyro pucks at N&lt;sub&gt;mm&lt;/sub&gt;</td>
<td>QC lab</td>
<td></td>
</tr>
<tr>
<td>QC: 1 per sublot</td>
<td></td>
<td>QA: 1 per 4 sublots</td>
</tr>
<tr>
<td>QA: QC retained: None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asphalt content (P&lt;sub&gt;b&lt;/sub&gt;)</th>
<th>QC lab</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Either nuclear or ignition oven</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compared to spec: P&lt;sub&gt;b,JMF&lt;/sub&gt;±0.3%</td>
<td>QC lab</td>
<td></td>
</tr>
<tr>
<td>This is a pay factor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VMA</th>
<th>QC lab</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>V&lt;sub&gt;MA&lt;/sub&gt; 100&lt;sup&gt;x&lt;/sup&gt; = (P&lt;sub&gt;b&lt;/sub&gt; + G&lt;sub&gt;mm&lt;/sub&gt;) / (G&lt;sub&gt;mm&lt;/sub&gt; - G&lt;sub&gt;b&lt;/sub&gt;)</td>
<td>QC lab</td>
<td></td>
</tr>
<tr>
<td>G&lt;sub&gt;b&lt;/sub&gt; from JMF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compare to Spec: VMA design minimum [-0.5 to +0.0 %]</td>
<td>QC lab</td>
<td></td>
</tr>
<tr>
<td>This is a pay factor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Asphalt cont...

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run TSR</td>
<td>Trailway pavement</td>
<td>QC: 1 sample per sublot; QA: 1 sample per 4 sublots</td>
</tr>
<tr>
<td>Determine pavement core density ($G_{mc}$)</td>
<td>Trail</td>
<td>QC: 1 sample per sublot; QA: 1 sample per 4 sublots</td>
</tr>
</tbody>
</table>

### Additional Testing

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix Temperature</td>
<td>Roadway</td>
<td>QC: 1 per sublot; QA: 1 per mix</td>
</tr>
<tr>
<td>Temperature base &amp; air</td>
<td>Roadway</td>
<td>QC: 1 per 4 sublots; QA: 1 per day</td>
</tr>
<tr>
<td>Binder content of RAP/RAS</td>
<td>QC lab</td>
<td>QC: 1 per 4 sublots; QA: 1 per project</td>
</tr>
<tr>
<td>Calculable voids filled (VRA)</td>
<td>Roadway</td>
<td>QC: 1 per sublot; QA: 1 per 4 sublots</td>
</tr>
<tr>
<td>Void filled (VFA)</td>
<td>Roadway</td>
<td>QC: 1 sample per sublot; QA: 1 sample per 4 sublots</td>
</tr>
<tr>
<td>Drill unconfined joint cores</td>
<td>Roadway</td>
<td>QC: 1 sample per sublot; QA: 1 sample per 4 sublots</td>
</tr>
<tr>
<td>Drill longitudinal joint and shoulder cores</td>
<td>Roadway</td>
<td>QC: 1 sample per sublot; QA: 1 sample per 4 sublots</td>
</tr>
</tbody>
</table>

### Small Quantities

**Individual Asphalt Mixtures Less Than 4000 tons**

- **403.19.3.2.1 options:**
  1. Use all testing frequencies in 403.19.3 table.
  **OR**
  2. Do same tests as in 403.19.3 but:
     - No field lab required
     - **QC:** ≤750 tons/day: QC: 1/day
       >750 tons/day: QC: 2/day
     - **QA:** Independent & retained: 1/1500 tons
Small Quantities

- EPG section: 403.23.7.4.1
- QLA & PWL not required (no PF’s) but mix must be within spec
- Still have VMA, Va, Pb, density spec limits
- TSR still required
- Density: PF-adjustment table (See Specifications)
### QC/ QA Functions at the Hot Mix Plant

**Engineering Policy Guide (EPG)**

<table>
<thead>
<tr>
<th>Function</th>
<th>Location</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate Gradation:</td>
<td>Drum: Combined cold feed</td>
<td>QC: 1 per 2 sublots</td>
</tr>
<tr>
<td>3 sieves:</td>
<td>Batch: Hot bins</td>
<td>QA: 1 per 4 sublots</td>
</tr>
<tr>
<td></td>
<td>Optional: T308 Residue</td>
<td>QA: QC retained: 1 per week</td>
</tr>
<tr>
<td>#8: Not to exceed 2.0% beyond master spec.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#200: Within master spec.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consensus Tests:</td>
<td>Drum: Combined cold feed</td>
<td>QC: 1 per 10,000 tons</td>
</tr>
<tr>
<td>FAA&lt;sub&gt;spec&lt;/sub&gt; -2%</td>
<td>Batch: Combined cold feed</td>
<td>(min. 1 per project per mix type)</td>
</tr>
<tr>
<td>CAA&lt;sub&gt;spec&lt;/sub&gt; -5%</td>
<td></td>
<td>QA: 1 per project</td>
</tr>
<tr>
<td>SE&lt;sub&gt;spec&lt;/sub&gt; -5%</td>
<td></td>
<td>QA: QC retained: 1 per project</td>
</tr>
<tr>
<td>F&amp;E&lt;sub&gt;spec&lt;/sub&gt; +2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deleterious:</td>
<td>All plants: cold feed</td>
<td>QC: 1 per 2 sublots</td>
</tr>
<tr>
<td>RAP:</td>
<td></td>
<td>QA: 1 per 4 sublots</td>
</tr>
<tr>
<td>Gradation (T308 or T164 residue)</td>
<td></td>
<td>QA: QC retained: 1 per week</td>
</tr>
<tr>
<td>Deleterious</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro-Deval (if necessary)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Shingles:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gradation</td>
<td></td>
<td>QC: 1/10,000 tons</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Min. 1 per project)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QA: 1 per project</td>
</tr>
<tr>
<td>FUNCTION</td>
<td>LOCATION</td>
<td>FREQUENCY</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Obtain Sample               | Behind paver | QC: 1 per subplot  
|                             |              | QA: 1 per 4 sublots  
|                             |              | QA: QC retained, 1 per day; not necessary on days the QA independent sample is taken if favorable comparison of retained splits has been achieved. |
| Quarter Sample              | QC lab       | “                                                                                  |
| Compact 2 gyro pucks at N_{des} | QC lab   | “                                                                                  |
| Run pucks specific gravity  | QC lab       | “                                                                                  |
| Calculate average of the two (G_{mb}) | QC lab | “                                                                                  |
| Run Rice specific gravity (G_{mm}) | QC lab | “                                                                                  |
| Calculate % Air Voids (V_a): | QC lab       | “                                                                                  |
| \[ V_a = \left( \frac{G_{mm} - G_{mb}}{G_{mm}} \right) \times 100 \] | | “                                                                                  |
| Compare to spec: 4 ± 1.0% | | “                                                                                  |
| This is a pay factor        |              | “                                                                                  |
| Run asphalt content (P_b),  | QC lab       | “                                                                                  |
| Either nuclear or ignition oven.  | | “                                                                                  |
| Compare to spec: P_{b,JM} ± 0.3% | | “                                                                                  |
| This is a pay factor        |              | “                                                                                  |
| Calculate % aggregate (P_s): | QC lab       | “                                                                                  |
| \[ P_s = 100 - P_b \] | | “                                                                                  |
| Calculate VMA:              | QC lab       | “                                                                                  |
| \[ \text{VMA} = 100 - \left[ \frac{(G_{mb} \times P_s) + G_{sb}}{} \right] \] | | “                                                                                  |
| G_{sb} from JMFF            |              | “                                                                                  |
| Compare to Spec:            |              | “                                                                                  |
| VMA design minimum [ -0.5 to +2.0 %] | | “                                                                                  |
| This is a pay factor        |              | “                                                                                  |
### HMA cont...

<table>
<thead>
<tr>
<th>FUNCTION:</th>
<th>LOCATION:</th>
<th>FREQUENCY:</th>
</tr>
</thead>
</table>
| Run TSR  |           | QC: 1 per 10,000 T  
**Compare to spec**  
*This is a pay adjustment factor*  
QA: 1 per 50,000 T  
Minimum: 1 per mix (combination of projects) | |
| Drill pavement cores | Traveled way pavement | QC: 1 sample per subplot  
QA: 1 sample per 4 sublots | |
| Determine pavement core density \(G_{mc}\) | Trailer | QC: 1 sample per subplot  
QA: 1 sample per 4 sublots | |

### Additional Testing

<table>
<thead>
<tr>
<th>FUNCTION:</th>
<th>LOCATION:</th>
<th>FREQUENCY:</th>
</tr>
</thead>
</table>
| Mix Temperature | Roadway | QC: 1 per subplot  
QA: 1 per day | |
| Temperature base & air | RAP/RAS feed | As needed | |
| Binder content of RAP/RAS | QC lab | QC: 1 per 4 sublots  
QA: 1 per project | |
| Calculate Voids Filled (VFA): \[VFA=\left(\frac{VMA-Va}{VMA}\right)\times100\] | Roadway | QC: 1 per subplot  
QA: 1 per 4 sublots | |
| Drill unconfined joint cores | Roadway | QC: 1 sample per subplot  
QA: 1 sample per 4 sublots | |
| Drill longitudinal joint and shoulder cores | Roadway | See Module 5, Sampling | |
| Calculate pavement density: \[Density=\left(\frac{G_{mc}+G_{mm}}{2}\right)\times100\] | | See Module 5, Sampling | |

*Compare to Density Pay Adjustment Table if an unconfined joint core*  
*This is a pay adjustment factor*
Module 3

Plant Operations Overview
MODULE 3
PLANT OPERATIONS OVERVIEW

Outline

- Plant equipment
- Plant problems
- Aggregate sampling & testing
- RAP & RAS sampling & testing

Types of Asphalt Plants

- Batch Plants
- Drum Mix Plants
Batch Plant

- Aggregate is heated.
  Reduces moisture related problems.
- Aggregate is rescreened.
- Aggregate is batched by weight.
- Batch plants provide a consistent mixture.
Schematic of a batch plant

Batch Plant

Screen
Hot Storage Bin
Mineral Filler Feeder
Bin Gates
Asphalt Batcher
Aggregate Batcher
Mixer

Screen Deck

• Holes - total gradation too coarse.
• Clogged - total gradation too fine.
• Check screens every other day.
Hot bin %'s not equal to JMF %'s
Will also need RAP gradations.
Then mathematically combine to
hit target JMF gradation.

Batching Aggregates

1. The discharge gate of an aggregate bin is opened
   and the aggregate pours into the weigh bins.
2. When the scale reading reaches a preset weight,
   the discharge gate is closed.
3. The discharge gate of the next aggregate bin is
   opened.
4. When the scale reading reaches a preset weight,
   the discharge gate is closed.
5. These steps are repeated for the remaining
   aggregate bins of the selected type.

Batch Plant

Enlarged
Weighing Aggregates and Mineral Filler in a Batch Plant

1. The discharge gate of an aggregate bin is opened and the aggregate pours into the weigh box.
2. When the scale reading reaches a preset weight, the discharge gate is closed.
3. The discharge gate of the next aggregate bin is opened.
4. When the scale reading reaches a preset weight, the discharge gate is closed.
5. These steps are repeated for the remaining aggregate sizes and the mineral filler.
Drum Mix Plant

- Aggregate is divided into different bins and proportioned by bin percentages.
- More bins allow you to control your mixture better.
- Drum mix plants feed material continually.
- Drum mix plants have a high production rate but may not be able to use potential because of limiting roller rate.

Drum Mix Plant

13

Drum Plant

There is an optimum flight configuration for the % RAP to maintain the veil of aggregate that protects the RAP, binder, and baghouse.

RAP collar ok up to ~20% RAP; problems for greater amounts.

Drum Mix Plant

14

Cold Feed

Depending on the plant, aggregate fraction JMF %'s are probably at cold bins.

Drum Mix Plant

15
There is an optimum flight configuration for the % RAP to maintain the veil of aggregate that protects the RAP, binder, and baghouse.

RAP collar ok up to ~20% RAP; problems for greater amounts
Temperature Profile in Drum Mixer

Superheated aggregate dries the RAP
Can be a problem with high RAP content

Counter Flow Drum

RAP Feeder
Mixer Drum

Weigh bridge: Wind flops belt, "weight" of aggregate changes, so amount of binder changes, thus air voids change; 0.1% binder change results in ~0.3% air voids.
Aggregate Moisture Content

- Daily moisture contents are needed for every aggregate bin for drum mix plants.
- Wet fine aggregate will stick to conveyor belts. This may cause over-asphalting & low voids.
- Moisture may cause tender mix behavior.

Aggregate Moisture cont’d.

- May need to slow down production to get the aggregate completely dried.
- Moisture affects the amount of dust that goes either to baghouse or stays in the dried aggregate. Thus, it affects the required dust return feed rate. The amount of dust affects the mix volumetrics.

Aggregate

- Daily gradation checks at the asphalt plant may help you spot a problem.
- Make sure aggregate stockpiles are properly labeled.
- Make sure the loader operator loads the correct aggregate in the cold feed bins.
- Loader operator should work to minimize degradation, contamination, and segregation.
Daily Plant Procedures

• Make sure all equipment is well maintained. (e.g., look for holes in screens)
• Check the bill of lading on all materials before you unload them:
  • Correct material
  • Check for "testing statement"—some binder suppliers are now sending out non-certified binder
• Check the quantities of AC, mineral filler, hydrated lime, burner fuel, etc.
• Dust control is important with Superpave. Make sure your dust collection system is working properly.

Possible Issues at the Plant (Quarry)

• Quarry delivers material not in conformance with Contractor-Quarry agreement:
  • Production stone now only being checked by MoDOT at the plant
  • MoDOT doesn't see the agreement
  • No longer a Quarry QC plan in some Districts

Possible Issues at the Plant (Quarry) cont'd.

• Quarry has already changed screens and is no longer making the product required so it substitutes something else.
• Quarry delivers the wrong material (e.g., makes several 3/4" products).
• Keep an eye on:
  • Gradation
  • Specific gravity for certain products
  • Flat & elongated (crusher wear)
Possible Issues at the Plant (Receiving)

- Contractor orders the wrong material (MoDOT and quarry may have different definitions of fractions).
- Contractors do not check material daily to ensure correct material is being delivered.

Possible Issues at the Plant (Loader Operator)

- Piles get mixed together.
- Loader operator pushes dirt and bedding material up into stockpile or gets it on tires and tracks it onto pile.
- Loader operator gets both sets of wheels on stockpile and breaks it down.

Possible Issues at the Plant (Loader Operator)

- Loader operator falls behind production, allows bin to empty, fills them with closest available rock.
- Wrong material in bins from spillage from adjacent bin.
- Wrong material in bins from getting piles mixed up.
- Bin runs empty, then gets material dumped in, locks collector belt, no material gets to cold feed belt.
Possible Issues at the Plant
(Plant Operator)

• Doesn't pay attention to computer screens and one bin runs faster or slower than it's supposed to, thus the combined grading changes.

• Somebody changes gate settings on cold feed or puts them in improper position for the mix being made, thus the combined grading is wrong.

Possible Issues at the Plant
(Plant)

• Hole wears in shaker (scalper) screen and allows various oversized materials to get into mix: dirt clods, sticks, oversized aggregate, bottles, cans, etc.

• Motor or belts burn up on a bin and it stops running but plant diagnostics do not catch it.

Possible Issues at the Plant
(Plant)

• Wind blows belts up and down - causes problems in weighing.

• Lose a leg from 3 phase power-scalping screens run slower.

• Times of peak power demand - screens run slower.

• Mix silo-problems of carryover of wrong product when switching mixes.
Possible Issues at the Plant (Plant)

- AC hauler loads wrong grade of binder.
- AC hauler doesn't know which tank to unload into and contaminates burner fuel.
- AC hauler has hauled a different grade the previous night and rather than clean out this tank, he loads a new load on top of what was left in the tank.
- Pugmill paddles wear >3/4"-poor mixing and coating.

Possible Issues at the Plant (Plant)

- Two separate storage tanks for 2 different grades of binder are connected—if valves are not in correct position, one tank can drain or equilibrate with the other tank, mixing the 2 grades.
- If binder sample fails—must mill.
- Burner fuel hauler doesn't know which tank to unload into and uncads into binder tank (possible explosion risk here).
- Valves are cleaned with diesel-can contaminate a sample-need to run some binder (~gal) through before sampling.

Asphalt Production

- Keep good records of plant settings. Note any irregularities or changes.
- Keep a separate copy:
  - Hard drives crash.
  - New computer system installation-lose files.
- Train all personnel to look for problems.
- Use your test strips wisely...look for trouble spots before you go to full production:
  - Get the volumetrics right.
  - Get the nuclear gage settings.
- Rolling patterns are likely to change from job to job or even on same job if material underneath fails.
Coarse RAP (½ to 1 inch)

Fine RAP (minus ½ inch)

Shingles are usually covered. Sometimes RAP would take a huge cover for a 40% RAP mix.
Module 4

Aggregate Testing

Overview
MODULE 4
AGGREGATE TESTING
OVERVIEW

Aggregate Acceptance

- Aggregate acceptance for Asphalt is at the mixing facility.
- MoDOT performs sampling/testing of ledges.
- MoDOT visits quarries to assure that proper ledges are being used.

Production Aggregate Test

Gradation
Deleterious
Consensus tests:
- FAA Fine Aggregate Angularity
- CAA Coarse Aggregate Angularity
- SE Sand Equivalency
- F&E Flat & Elongated
**SAMPLING: Aggregate**

- **Gradation:**
  - Drum - Cold feed belt
  - Batch - Hot bins
  - Can use Asphalt sample - T308 residue
    (Not applicable for dolomite).
  - RAP - T308 residue; combine mathematically with virgin gradation. (Dolomite – will need to extract)

- **Deleterious:**
  - All plants - Cold feed belt

- **Consensus:**
  - All plants - Cold feed belt

- **QC retains half their sample (after final split) for QA.**

---

**COLD BINS**
MoDOT
Monitors geology & Performs benchmark physical testing of crushed product
Preliminary Ledge ID sampling
Annual source sampling during production (ledge specific)

CONTRACTOR
Initiates contact with quarry
Samples product for the purpose of designing a job mix (*1)
Makes production agreements with producer

PRODUCER
Ongoing production
Non job specific

CONTRACTOR
Designs mix
Submits mix design to District

PRODUCER

MoDOT mix review/approval

Production
Aggregate QC & QA is per the agreement between producer and contractor (*2)

CONTRACTOR

MoDOT
QA testing per contract
Contract administration
Material acceptance is made off the belt

NOTES
*1 The producer may use any combination of ledges so long as the crushed product meets the minimum requirements for that material section.

*2 MoDOT will not set requirements for aggregate quality control but the producer will need to be able to designate what is in each fraction.

*3 Material acceptance is based on combined belt sample.

*4 Gradation & del for 401 mixes. Include consensus tests for 403 mixes.

*5 Percent Del.

*6 PI on 401 mixes. If PI > 3 on job mix, TSR will be required during mix production. Contractor may elect to avoid TSR during production by making available test results of PI during aggregate production.
Sampling
Drum Plant Methods

- Off the combined cold feed belt
- Diverter

Sampling Gradation

Sampling Cold Feed Belt

Get equal increments if more than one is not enough.
Drum Mix Plant

Diverter Chute

Diverter chute: Get 3 grabs to combine.

Sampling - Batch Plant

Do 3 slides per 4 bins to get a 12-portion composite sample.
Sampling - Hot Bins

QC Aggregate Sampling/Testing

- Gradation - 1 per 2 sublots
- Consensus tests - 1 per 10,000 tons mix (at least 1 per project per mix type)
- Deleterious - 1 per 2 sublots
- Save a retained sample of each for QA.

QA Aggregate Sampling/Testing

- Independent:
  - Gradation - 1 per 4 sublots minimum
  - Consensus - 1 per project minimum (no matter how many mixes)
  - Deleterious - 1 per 4 sublots
- QC retained split:
  - Gradation - 1 per week minimum
  - Consensus - 1 per project minimum (no matter how many mixes)
  - Deleterious - 1 per week minimum
**Aggregate**

Acceptance:
- Be within tolerance of JMF values
  (Gradation and Consensus tests)
- Be within standard specs
  (Deleterious)
- Compare "favorably" with QA results

**Unfavorable Comparison**

- Has been traced to the splitting operation and equipment that each side was using.
**2: Aggregate Cold feed:**
- Deleterious
- Consensus
- Gradation: if dolomite and maybe if limestone

**5: RAP**
- Binder content (T308/T164)
- Gradation-binder residue
- Mathematically combined with cold feed gradation if not using roadway sample for gradation
- Micro-Deval- maybe

**7: Silo Discharge-Truck or HMA Mini-stockpile:**
- Maybe TSR

**Not Shown-Roadway sample:**
- Binder content/moisture
- Gradation-binder residue
- Gyro pucks
- Rice Gravity
Gradation

- 403 master spec
- Field tolerances
- Comparison tolerances

### SPECIFIED GRADATIONS

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>SP250</th>
<th>SP190</th>
<th>SP125</th>
<th>SP095</th>
<th>SP048</th>
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<tr>
<td>1½&quot;</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>90-100</td>
<td>100</td>
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<tr>
<td>3/4</td>
<td>90 max</td>
<td>90-100</td>
<td>100</td>
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</tr>
<tr>
<td>3/8</td>
<td>90 max</td>
<td>90-100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td>90 max</td>
<td>90-100</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>#8</td>
<td>19-45</td>
<td>23-49</td>
<td>28-58</td>
<td>32-67</td>
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<tr>
<td>#16</td>
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<td></td>
<td></td>
<td>30-60</td>
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</tr>
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</tr>
<tr>
<td>#50</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>#100</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>#200</td>
<td>1-7</td>
<td>2-8</td>
<td>2-10</td>
<td>2-10</td>
<td>7-12</td>
</tr>
</tbody>
</table>

Field Tolerances

Aggregate Gradation (Non-SMA)

(3 sieves):

- 1 size smaller than NMS: not to exceed 92.0%
- #8: not to exceed 2.0% beyond master spec.
- #200: within master spec.
### Example SP 190

<table>
<thead>
<tr>
<th>Sieve</th>
<th>SP190</th>
<th>Tolerance</th>
<th>Test</th>
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</tr>
<tr>
<td>1</td>
<td>100</td>
<td>---</td>
<td>100</td>
</tr>
<tr>
<td>⁴/₉</td>
<td>90-100</td>
<td>---</td>
<td>99</td>
</tr>
<tr>
<td>₃/₈</td>
<td>90 max</td>
<td>92 max</td>
<td>91</td>
</tr>
<tr>
<td>#4</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>#8</td>
<td>23-40</td>
<td>21-51</td>
<td>22</td>
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<tr>
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<td>---</td>
</tr>
<tr>
<td>#30</td>
<td>---</td>
<td>---</td>
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</tr>
<tr>
<td>#50</td>
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</tr>
<tr>
<td>#200</td>
<td>2-6</td>
<td>2-8</td>
<td>5.2</td>
</tr>
</tbody>
</table>

### SMA Tolerances

%'s off JMF Target Gradation

<table>
<thead>
<tr>
<th>Sieve</th>
<th>SP095</th>
<th>SP125</th>
</tr>
</thead>
<tbody>
<tr>
<td>¾&quot;</td>
<td>---</td>
<td>± 4</td>
</tr>
<tr>
<td>½&quot;</td>
<td>---</td>
<td>± 4</td>
</tr>
<tr>
<td>³/₁₆&quot;</td>
<td>± 4</td>
<td>± 4</td>
</tr>
<tr>
<td>#4</td>
<td>± 3</td>
<td>± 3</td>
</tr>
<tr>
<td>#8</td>
<td>± 3</td>
<td>± 3</td>
</tr>
<tr>
<td>#200</td>
<td>± 2</td>
<td>± 2</td>
</tr>
</tbody>
</table>

### Minor Deviations

- Minor deviations outside the tolerances are allowed if Asphalt test results indicate the binder content, volumetrics, and density are satisfactory.
Aggregate

Acceptance:
- Be within tolerance of JMF values (Gradation and Consensus tests)
- Be within standard specs (Deleterious)
- Compare "favorably" with QA results

Comparing QA to QC
(QC Retained Sample)
- Consensus Tests:
  - CAA: QC ± 5%
  - FAA: QC ± 2%
  - SE: QC ± 8%
  - F & E: QC ± 1%
- Gradation: see table
  - If QC meets spec and QA compares favorably (Verifies QC) but QA is out of spec, the sample passes.
#8: 2% outside master spec

1 sieve smaller than NMS: 2% above master spec

Figure 3.10 Superpave Gradation Limits

#200: within master spec
Example Comparison

- FAA: QC= 46, QA= 48
- Is there "favorable comparison"?
- Yes, must be within 2, and they are.

Unfavorable Comparison

- FAA most prone to "unfavorable comparison" because of incorrect specific gravity

(e.g. - Just using Gsb from JMF, which erroneously would include Gsb of coarse aggregate)

Gradation

on QC retained sample so are running same type of sample.
(Use for Gradation comparisons)

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percentage points</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥3/4&quot;</td>
<td>± 5.0%</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>± 5.0%</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>± 4.0%</td>
</tr>
<tr>
<td>#4</td>
<td>± 4.0%</td>
</tr>
<tr>
<td>#8</td>
<td>± 3.0%</td>
</tr>
<tr>
<td>#10</td>
<td>± 3.0%</td>
</tr>
<tr>
<td>#16</td>
<td>± 3.0%</td>
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<tr>
<td>#20</td>
<td>± 3.0%</td>
</tr>
<tr>
<td>#30</td>
<td>± 3.0%</td>
</tr>
<tr>
<td>#40</td>
<td>± 2.0%</td>
</tr>
<tr>
<td>#50</td>
<td>± 2.0%</td>
</tr>
<tr>
<td>#100</td>
<td>± 2.0%</td>
</tr>
<tr>
<td>#200</td>
<td>± 1.0%</td>
</tr>
</tbody>
</table>
Unfavorable Comparison

- If unfavorable comparison, initiate "dispute resolution"
Module 5

Asphalt Sampling
Loose Mix & Cores
MODULE 5 OUTLINE

- Resources
- Sample Types
- Retaining Samples
- Lots and Sublots
- Sample Location (RN)
- Sampling Asphalt - Loose Mix
  - Loose Mix Sampling Steps
- Sampling Asphalt – Cores
  - QLA Core Sampling Steps

RESOURCES

403 specification
General provisions & Supplemental Specifications
AASHTO Test Methods:
  - R 97 Sampling Asphalt Mixtures
  - R 67 Sampling Asphalt Mixtures (Cores)
Engineering Policy Guide (EPG)
FAQ – located in EPG
Superpave Course Notebook
**SAMPLE TYPES**

- **Quality Level Analysis (QLA)**
  - Randomly Chosen
  - QC - For determination of pay factors.
  - QA - For seeing if QC samples define the characteristics of the lot (Favorable Comparison).

- **“Extra” or “Check” or “Self-test” samples.**

**NOTE:** Samples should be clearly marked as to what they are.

---

**Extra or Check Samples**

Extra sampling by QA or QC:

- Check how the mix is doing.
- Investigate problem areas *e.g.*, does a problem exist?
- Determine limits of the problem.
- Can be from truck, plant or roadway
- Not random and can not be used for QLA.
  - Quality Level Analysis (QLA).
- Can be used to define removal limits, but must be “Well - Documented”

---

**“Well - Documented”**

The Following are Available:

- Gyratory (Gyro) pucks
- Gyration/height printouts
- Binder content printouts

---

*Sample Types*
**RETAINING SAMPLES**

EPG Sec: 403, Clearly label the samples that are to be retained. Do not discard retained samples until all QC/QA comparison issues are resolved.

If the lab becomes crowded, the RE should store the samples in the project office.

The retained sample is a contract requirement and belongs to the Commission.

The contractor can keep ADDITIONAL mix for internal use.

The retained samples can be used for dispute resolution.

---

**LOTS AND SUBLOTS**

- Sampling, testing, and payment is done on a lot-by-lot basis.

---

**Lots and Sublots**

- Definition of a “Lot”:
  - Typically, 3000 or 4000 tons
  - Must have a minimum of 4 Sublots
  - Sometimes a lot is much larger, for example: “Superlot”.
    - Superlots can go up to 28 sublots.
    - (28 is the maximum) EPG sec 403.1.19
  - Number of lots: Contractor's choice – must be in the QC plan.
**Lots and Sublots**

**Sublot:**
- Maximum sublot size = 1000 tons.
- More sublots means more lab work but may increase the pay factor somewhat.

NOTE: If a lot = 3000 tons, a sublot = 750 tons.

---

**Lot Routines for 403 mixes**

- Traveled way + Integral Shoulders
- Non-integral Shoulders (If SuperPave)
- If not Superpave, (e.g., BP-1 mix), random numbers are not required, see “non-traveled area” next slide.

NOTES:
- A 403 mix is a mix as described in MODOT’s EPG under Category 403.
- Superpave mixes will begin with SP, for example; SP250, SP190, SP125.
- Non Superpave examples would be BP-1, and BB mixes.

---

**Traveled Way and Shoulder Types**

---

---
Traveled Way and Shoulder Types

Not an unconfined joint

confined joint

unconfined joint

No unconfined joint core

Pass 2

Pass 1

Integral shoulder

Traveled way

Non-Integral shoulder
Random Numbers are used to generate a random location for sampling.

- **Object**: to produce unbiased samples. Sample bias occurs either during construction or during sampling.
  - See ASTM D3665 on Random Samples

- **QC** should provide contingencies in QC Plan to handle random numbers in weird locations (does not apply to early tonnage e.g., first 50 tons).

**Sample Location**

Random Numbers

- Random Numbers are generated by **QA**.
- Methods of generating random numbers:
  - By compute (Routines, websites, MoDOT spreadsheet, etc.).
  - Use of random number tables.

**Sample Location**

Random Number Generation

- MoDOT spreadsheet is the preferred method.
- Use the "Asphalt Random Location spreadsheet"
- MoDOT internal site:
  - [http://eprojects/Template/Forms/AllItems.aspx](http://eprojects/Template/Forms/AllItems.aspx)
## Set-Up Sheet

### TOTAL TON PRODUCED TO DATE
*All days Total Tons for specific mix

### MINUS FOR LOT SHUTDOWN
**FOR PLANT MAN WHEN AC IS CHANGED DURING PRODUCTION**

**ENTER IN DAILY LOT NUMBERS, SUBLOTS, RANDOM TONS AND THE OFFSET FOR THE DAY. THEN CLICK ON THE MACRO BUTTON FOR THE TOTAL LOT TONNAGE.**

### QC

<table>
<thead>
<tr>
<th>SUBLOT</th>
<th>LOT</th>
<th>TONS</th>
<th>OFFSET</th>
</tr>
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<tbody>
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### QA

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<tbody>
<tr>
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</tr>
</tbody>
</table>

FROM QC QA PLAN SUBMITTED

Superlot
Helpful spreadsheet on where to obtain QC/QA Samples in Superpave jobs for each day's production based off the Random Numbers Generated

**EXAMPLE**

**DAILY TONNAGE FOR SUBLOTS PLANT AND ROADWAY**

*Use colored areas for entering data*

**DATE:** 8/1/2019

**MIX:** SP125

*Can be any format

*Use type of mix (SP125C etc.)*

**TOTAL TON PRODUCED TO DATE:** 3500.00

*All days Total Tons for specific mix

**MINUS FOR LOT SHUTDOWN:**

**FOR PLANT MAN WHEN AC IS CHANGED DURING PRODUCTION**

**ENTER IN DAILY LOT NUMBERS, SUBLOTS, RANDOM TONS AND THE OFFSET FOR THE DAY. THEN CLICK ON THE MACRO BUTTON FOR THE TOTAL LOT TONNAGE.**

**QC**

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<th>OFFSET</th>
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<td>8</td>
</tr>
<tr>
<td>5</td>
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<td>5</td>
</tr>
<tr>
<td>6</td>
<td>A</td>
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<tr>
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<td>2575</td>
<td>7</td>
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**QA**

**Entered from the Random Number Spreadsheet**

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<th>OFFSET</th>
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<td>A</td>
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FROM QC QA PLAN SUBMITTED
**Superpave Module 5 Random Number Spreadsheet**

### Daily Tonnage for Superlots

<table>
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<th>QC</th>
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<table>
<thead>
<tr>
<th>Date</th>
<th>Daily Tonnage for Superlots</th>
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<tbody>
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<td>8/1/2019</td>
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<th>Offset</th>
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<td>2</td>
</tr>
<tr>
<td>7</td>
<td>A</td>
<td>2575</td>
<td>7</td>
</tr>
</tbody>
</table>

**QC Test For**

- **A4** -250.0 Offset 8
- **A5** 1000.0 Offset 5
- **A6** 2060.0 Offset 2
- **A7** 3075.0 Offset 7

**Roadway Tons on Ticket to End of Sublot**

- 4 A 500.0
- 5 A 1500.0
- 6 A 2500.0
- 7 A 3500.0

**Passed Random Tons for Sublot, but 500 tons left to end of Sublot**

**Today's Tons to Get Out of Lot**

**How many tons into today's mix to grab sample to satisfy Random tons for this sublot**

---

### QA Sample for the Lot or Lots

<table>
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<tr>
<th>Sublot</th>
<th>Lot</th>
<th>Random Tons</th>
<th>Offset</th>
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<tbody>
<tr>
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<td>A</td>
<td>3107</td>
<td>4</td>
</tr>
</tbody>
</table>

**QA Test For**

- **A4** -393.0 Offset 4
- **A7** 3320.0 Offset 6
The pair of random numbers are different for each sample location (Loose Mix or Core) QC, or QA.

- Location of a loose mix:
  - Longitudinal **tonnage** and a transverse distance generated by random number.
  - **Longitudinal** position in terms of tons of mix from the start of the lot. = A
  - **Transverse** position in terms of distance from edge of mat. = B
**Core Sample Location**

*Position of a core:*

A transverse distance and a longitudinal distance. (stations)

Distances are determined by random numbers one for longitudinal (A), one for transverse (B).
<table>
<thead>
<tr>
<th>Sublot</th>
<th>Tons in Sublot <em>T</em></th>
<th>Beginning Tons <em>BT</em></th>
<th>Ending Tons <em>ET</em></th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>750</td>
<td>750</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>B</td>
<td>750</td>
<td>750</td>
<td>1500</td>
<td>12</td>
</tr>
<tr>
<td>C</td>
<td>750</td>
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<td>12</td>
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<tr>
<td>D</td>
<td>750</td>
<td>2250</td>
<td>3000</td>
<td>12</td>
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<th>B</th>
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<tr>
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<th>Beginning Tons <em>BT</em></th>
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<tr>
<td>B</td>
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<td>12</td>
</tr>
<tr>
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<td>2250</td>
<td>3000</td>
<td>12</td>
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<table>
<thead>
<tr>
<th>Random No.</th>
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<th>B</th>
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<tr>
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<td>0.628</td>
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<table>
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<th>Random No.</th>
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<tbody>
<tr>
<td>A</td>
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<th>Random No.</th>
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<tr>
<td>A</td>
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<tr>
<td>B</td>
<td>0.596</td>
<td>0.0308</td>
</tr>
</tbody>
</table>
Example on the next slide illustrates how the random numbers, 0.892 & 0.696 are used from this chart.

<table>
<thead>
<tr>
<th>Random Numbers for A Longitudinal and B Transverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>0.892</td>
</tr>
<tr>
<td>0.058</td>
</tr>
<tr>
<td>0.195</td>
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<tr>
<td>0.220</td>
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</table>

Uses Random Numbers for A Longitudinal and B Transverse

Sublot 1
Longitudinal = 0.892 x 1000 = 892 FT
Transverse = 0.696 x 12 = 8.4 FT

Stations for Cores

- Longitudinal distance may be in "Stations"= 100 ft.
- 5010 ft = 50 stations + 10 ft or "Station 50+10":

• Longitudinal distance may be in "Stations“= 100 ft.
• 5010 ft= 50 stations + 10 ft or "Station 50+10":
Random Numbers

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th></th>
<th>2</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
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Superpave Module 5 Random Numbers
Stationing Example for Cores

**Longitudinal**

- Beginning station = 1200+00
- Add 5238 ft = 52+38'
- Ending station:

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<tr>
<th>Beginning</th>
<th>Add</th>
<th>Ending</th>
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</thead>
<tbody>
<tr>
<td>1200+00</td>
<td>52+38</td>
<td>1252+38</td>
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Stationing Example for Cores

**Stratified Random Sampling**

- Stratified sampling divides the lot into the desired number of equal sublots and then calls for random samples of each subplot.
- Ensures that samples are obtained throughout the lot.
- Prevents the possibility of acquiring random numbers that result in samples clustered in only one area of the lot.
Stratified Random Sampling Core

<table>
<thead>
<tr>
<th>Sublot A</th>
<th>Sublot B</th>
<th>Sublot C</th>
<th>Sublot D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 100</td>
<td>Station 110</td>
<td>Station 120</td>
<td>Station 130</td>
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SAMPLING ASPHALT - LOOSE MIX

Sample Areas for Loose Mix Asphalt

- Truck
- Roadway
- Asphalt Stream - Plant Discharge
- Mini Stockpile

NOTE: Sampling by AASHTO R97, is covered in Bit. Tech.
**Truck**

**Procedure:**
- Use a platform with safety railing.
- Use a shovel.
- Remove 1 foot from the top surface.
- Visually divide an area into 4 quadrants.
- Obtain an increment from a quadrant and another increment from the opposite quadrant, repeat if needed, combine for a sample.

---

**Volumetric and % Binder Samples**

**Roadway Sampling**
- QA samples in the same place as QC, but at a different time.

*Note:* Use of spray paver or trackless tack may contaminate sample on the roadway - consider an alternate sample type.

---

**QLA Roadway Loose Mix Sampling:**
- Sampled from the Roadway
- Random Locations:
  - QC = Required
  - QA = Required*

* Might become part of the data set from which Pay Factors are computed.
### Volumetric and % Binder Sample

#### QC Roadway Loose Mix Sampling:
- Samples their own + retains a sample for QA.
- **Random**
- Sampled from the Roadway behind the paver.
- **1 per subplot.**
- Size: **About 50 lbs. each** = **Total of 100 lbs.**
  - Mix & quarter
  - Two opposite quarters (50 lbs.) to be retained for QA.
  - The other two quarters (50 lbs.) for QC.

#### QA Roadway Loose Mix Sampling:
- Obtains their own independent sample + their own retained sample.
- Sampled from the Roadway.
- **Random**
- **1 per 4 sublots** - “Independent Sample”
- Size: ~100 lbs.

#### QA Roadway Loose Mix Sampling:
- Once per week test a QC “Retained Sample”
- This weekly test can be omitted on days when independent QA samples are taken,
  1. If confident in QC testing.
  2. “Favorable Comparison” exists between QA’s – QC.
**TSR Samples**

- **QC**: 1 per 10,000 tons or fraction thereof.
- **QA**: 1 per 50,000 tons or minimum 1 per combination of projects
- **Random locations**
  - Required by spec.
  - Not enforced (EPG)

**TSR Box Information**

Write on the side of the box:
- AWP ID number
- Mix number
- \( G_{mm} \) from sublot taken (QC or QA)
- Specimen weight QC is using.
- Sample Date

**Locations:**
- Roadway (Behind the paver)
- Truck (Preferred)
- Plant Discharge
- Stream
- **Random**
  - **Size**: 75-125 lbs.

QA get samples in same place as QC, but at a different time.
**TSR Samples – QC**

- **QC Location:** Truck sample, At the plant, Roadway behind the paver*.
  *Full depth of the course.
- **Random**
- **Size:** 75-125 lbs.
  (Plus, another 125 lb. sample retained for QA)

---

**TSR Samples – QA**

- **QA Location:** Truck sample, At the plant, Roadway behind the paver*.
  *Full depth of the course.
- **Random**
- **Size:** 75-125 lbs.
  (Plus, another 125 lb. sample retained for QA)

---

**TSR Samples – At the Plant**

- Mini Stockpile
- Plant Discharge

**Note:** Normally utilized to avoid sampling from a truck due to safety concerns.
"Mini-Stockpile"

- Used for TSR samples
- Need about 2 tons sampled from silo discharge into a truck.
- Dumped
- Back dragged
- Sampled into, 4 buckets or boxes.
- Back at lab; material is combined, mixed, quartered, and combined into 2 piles.
- Then 4 pucks are sampled from each pile.

---

Plant Discharge
(Chop Gate-Diverter Chute)

- Used for TSR samples
- Divert entire production stream to a loader bucket.
- Sample across the loader bucket, one shovel per box, all boxes.
- Repeat until boxes are full.
- Cool (beware of dust) and close boxes.

---

CAUTION!

- Sampling methods limits the position of sampling.
- Do not leave sample boxes uncovered at this location—may get contaminated with dust and overspray of release agent.
1. QA generates pairs of Random Numbers (RN) for upcoming lot. Numbers are placed in a sealed envelope & kept in a secure location in QC lab. QA keeps a copy. Both QA & QC sign & date the seal.

2. QA uses random numbers to calculate the longitudinal measurement to sample (ton or distance) and the transverse measurement (distance).

3. QA gives info to QC 100-150 tons in advance of the test.
4. QC gives info to plant operator.
5. Plant operator marks ticket of the load that the RN ton fell in.
6. QC follows truck to site.
7. QC notes the location (station) where the load went down. This will be arbitrary.
8. Samples should not be taken in areas of handwork; move 10 ft ahead of affected area.

Loose Mix Sampling Steps

9. QC measures transversely from edge of mat to the sampling location, if possible, away from traffic, once defined keep consistent.

Loose Mix Sampling Steps

10. **Loose mix** is removed from roadway.
* Using a square-nosed shovel and possibly a template, mark the area to be removed.
* Remove all mixture within the area.
* Sample full depth without contaminating the sample with underlying material.
* Avoid segregation of the material.
### 11. QC places sample in insulated containers or boxes, label, and transport containers to mobile lab.

Loose Mix Sampling Steps

---

### CAUTION!

- Filling one box (bucket) at a time may render different characteristics box to box, better to place one shovelful per box at a time.  
- Should recombine and quarter.

Loose Mix Sampling Steps

---

### SAMPLING ASPHALT - CORES

---
Types of Cores

- **Quality Level Analysis Cores**
  - *(QLA) Cores* ---- QLA Pay Factor
- **Non-integral Shoulder Cores**
  - Pay Adjustment Factor.
- **Longitudinal Unconfined Joint Cores**
  - Pay Adjustment Factor.
- **Confined Joint Cores**

Sampling Cores 58

Traveled Way and Shoulder Types

Pass 1
Pass 2

Sampling Cores 59

QC/QA Coring Frequency & Location

**Quality Level Analysis Cores**

- **QC**: 1 sample per sublot.
  - **QC Sample**: 1 Core, Up to 2 more cores (If stated in QC Plan), can be obtained, at the same offset, within one foot of the random location.
- **Density** is average of all 2-3 cores.
- **Location** by Random Numbers
  - Longitudinally by station or tonnage
  - Transversely by feet

Sampling Cores 60
### QC/QA Coring Frequency & Location

#### Quality Level Analysis Cores

- **QA**: 1 sample per 4 sublots.
- **QA’s Core** can be at same location as one of the QC cores: same offset; within 6” longitudinally; or randomly located.
- In traveled way (Not on integral shoulder).
- Applies to unconfined joints as well as traveled way.

#### QA Independent Core

- Independent = Acceptance sample
- Can be randomly located as a location independent from QC’s core, OR
- Typically, same “location” as QC core sample:
  - Same transverse offset from mat edge as QC sample.
  - Within 6 in. longitudinally from QA core.

### Core Positions

#### Quality Level Analysis Cores

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<th>No</th>
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Sampling Cores
### Coring

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**403.22.4.2** — Density core holes should be patched promptly to prevent moisture intrusion and damage to the pavement.

---

### Extra QC Cores

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- Recommended that QA witness extra coring to avoid questions about unidentified holes.

---

### Thick Lifts

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</table>

- If mix is placed in lifts \( \geq 6 \times \text{NMS} \), cores should be cut in half & density determined separately
- **Example:** SP250
  - NMS = 1”, 6” mat
- **PF density** will be based on \( N = 8 \), not \( N = 4 \)
Non-Traffic Areas - (403 mixes)

Non-integral Shoulder Cores

* Non-integral shoulders, medians, etc.

* Required density: specified density of the mixture [94.5 ± 2.5%].

Non-traffic Areas - (403 mixes)

Non-integral Shoulder Cores

* When rolling pattern demonstrates successful achievement of density, RE may allow the pattern in lieu of density tests.

  * Intelligent Compaction

* On re-surfacing projects where shoulders cannot withstand the compactive effort, RE can relax the density requirements.

Sampling Cores

Density Pay Adjustment Factor

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<th>Field Density, % of Gmm</th>
<th>% of Contract Unit Price</th>
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<td>91.0 - 91.4 or 97.1 - 97.5</td>
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<td>90.5 - 90.9 or 97.6 - 98.0</td>
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<td>90.0 - 90.4 or 97.6 - 98.0</td>
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<td>Below 90.0 or above 98.0</td>
<td>Remove &amp; replace</td>
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Longitudinal Joint

Longitudinal Unconfined Joint Cores

There are two common joint conditions when paving HMA, confined and unconfined. A confined joint occurs when a longitudinal joint is constructed abutting up to existing HMA or Concrete pavement or curb and gutter. An unconfined joint occurs when a longitudinal joint is constructed along a free edge.

Sampling Cores

| Sampling Cores | 70 |

70

Longitudinal Joint

Longitudinal Unconfined Joint

The weakest part of a new asphalt pavement is the longitudinal construction joint between paving machine passes.

Sampling Cores

| Sampling Cores | 71 |

71

Coring Frequencies

Longitudinal Unconfined Joint Cores

• QC: 1 sample per sublot
• QA: 1 sample per 4 sublots

Sampling Cores

| Sampling Cores | 72 |

72

SP_Module-5_Sampling Mix & Cores
Longitudinal Unconfined Joint Density

Longitudinal Unconfined Joint Cores

- Area within 6” of joint on traveled way side.
- Average of 4 cores, each randomly located (1 sample per subplot).

Sampling Cores

73

Longitudinal Unconfined Joint Density

Longitudinal Unconfined Joint Cores

- Typically use the same longitudinal location as the mat density cores or can generate new random locations.

Sampling Cores

74

Longitudinal Joint Density

Longitudinal Unconfined Joint Cores

NOTE:
Must alternate sides if have 2 unconfined joints.

Sampling Cores

75
## LONGITUDINAL JOINT DENSITY

### UNCONFINED JOINT CASE

#### LONGITUDINAL JOINT DENSITY

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Measure from unconfined edge.

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Measure from unconfined edge.

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Measure from unconfined edge.

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<th>LOT NO.</th>
<th>RANDOM NO.</th>
<th>EDGE</th>
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### Joint Density

**Confined Joint Cores**

- Density on confined joints is handled with the traveled way coring. Required density is same as for the traveled way.
- 94.5 ± 2.5% for non-SMA.
- 94.0% minimum for SMA.

**SMA:** Stone-Mastic (Matrix)-Asphalt, is a gap-graded HMA that is designed to maximize rutting resistance and durability by using a structural basis of stone-on-stone contact. Stone-on-stone contact greatly reduces rutting and requires more durable aggregates, higher asphalt content and, typically, a modified asphalt binder and fibers.

### QLA Coring

**Sampling Steps**

**Typical Scenario**

1. Roadway inspector marks where each sublot starts.
2. QA generates and records Random Numbers for freshly laid sublot.
3. QA gives random numbers to QC when rolling is complete.
4. Freshly compacted asphalt mixture allowed to cool.
5. Cores are marked on the asphalt mat.

**AASHTO R67**
6. QC cuts the core no later than the day following placement. Use water or air to aid in drilling.

7. Keep bit perpendicular to the surface with constant pressure. **AASHTO R67**

8. Drill slightly below the bottom of the asphalt mix to be sampled.

9. Use a retrieval device to remove the core without damage.

10. Brush or wash off any loose particles from the core.
    - Cores should be free from seal coats, soil, paper, paint, and any other foreign materials.

11. When cool, label the core and place it in a protective container.
    - Write the type of core, job number and Mix ID on the core with a sharpie or paint pen.
    - A concrete cylinder mold with lid will work for a container.
    - May need to place the core in a tamper proof bag.
    - Un-marked cores are not accepted at the lab.

---

**Tamper Proof Bags**

- **QA core chain-of-custody:** cores not in the engineer’s possession shall be sealed in tamper-proof bags
- **Mark:**
  - Project number
  - Lot number
  - Location
  - Inspector’s signature
12. QA takes possession of the cores, if possible.

13. Transport to the lab without jarring, rolling, freezing or excessive heat.
   - If core is damaged, contact MoDOT for further instructions.

14. Cores may be separated from other pavement lifts by sawing or other appropriate methods.

15. Cores should be allowed to air dry overnight to a constant weight next day; check at 2-hour intervals as per AASHTO T166.

### Sampling Core Steps

16. Core density \( \left( G_{mc} \right) \) is determined:

\[
\text{Density} = \left( \frac{G_{mc}}{G_{mm}} \right) \times 100
\]

\( G_{mm} \) is from the loose mix "Rice Test" sampled from the same sublot

### QLA Coring for QC

### Core Sampling Steps

### Coring Examples

- No unconfined joints
- One unconfined joint
- Two unconfined joints
Compacted Mat Density
No Unconfined Joint Case

Sample full width (12 ft)

12’ x 0.9825 = 11.8’

If random number is 0.000 or 1.000, move over ~6 in. to cut core.

• Leave out the 6” strip by the unconfined joint in the calculations (sample 11.5 ft).
COMPACTED MAT DENSITY
No Unconfined Joint Case

Sample full width (12 ft)
COMPACTED MAT DENSITY
One Unconfined Joint Case

1. Leave out the 6” strip by the unconfined joint in the calculations (sample 11.5 ft)
Compacted Mat Density
One Unconfined Joint Case

11.5’ x 0.9825 = 11.3’

Confined joint

Unconfined joint

11.5’

0.5’

11.3’

11.3’

11.8’

Sampling Cores

Compacted Mat Density
Two Unconfined Joint Case

Leave out both 6” strips at mat edges (sample 11.0 ft)

Sampling Cores

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<th>Who</th>
<th>Core Location Determination</th>
<th>Coring Frequency</th>
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Sampling Cores

88

89

90
Leaves out both 6" strips at mat edges (sample 11.0 ft)
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<td>1 Sample/sublot</td>
<td>Density Pay Adjustment Factor</td>
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Conflict Avoidance

• QC and QA should observe each other’s sampling & testing procedures *early on.*

• Resolve sampling & testing method issues *early on.*

Common Errors: Sampling Cores

• Avoid distorting, bending, or cracking during and after removal from the pavement.
• Samples should be free from seal coats, tack coats, soil, paper, paint, etc.
• Make sure puck /core has cooled to proper temperature.
Module 6

Sample Reduction and Aging

MoDOT
Module 6 Out-Line

**AASHTO R 47 Reducing Sample Size**
- Splitting loose mix samples
  - Mechanical Splitter
  - See Bituminous Manual for more information
- Quartering loose mix samples
  - Volumetric Samples
  - Tensile Strength Ratio Samples

**AASHTO R 30 Mixture Conditioning (Aging)**
- Short Term Conditioning
- Long Term Conditioning

---

**AASHTO R47**

Reducing Samples of Asphalt Mixtures to Testing Size

- This practice outlines methods for reducing large samples of asphalt mixture to the appropriate size for testing.
- The individual test methods provide the minimum quantity of material needed.
- For larger samples, the preferred methods for reducing asphalt is by mechanical splitter, or the quartering method.

For more information Refer to your Bituminous Technician Manual.
Preferred methods for reducing sample sizes

Splitting
- Mechanical Splitter Type A

Quarthing
- Quartering Templates

Reducing the loose mix sample taken from the road - four samples.

Equipment

Riffle Splitter

Quartering Templates

Mechanical Splitter Type A

Quartering

Splitting

Mechanical Splitter Type “A”
Quartering for Volumetrics

For more information Refer to your Bituminous Technician Manual.

Quartering for Volumetric Samples

• Get portions for:
  • 2 – Volumetric Pucks
  • 1 - Rice
    Theoretical Maximum Specific Gravity (Gmm)
  • 1 - Asphalt Content
    Ignition Oven or Nuclear Testing (%AC)
  • 1 - Moisture Content

See insert for method
QUARTERING LOOSE MIX

Both QC and QA samples must be taken from the roadway. They are to be taken separately. The sample locations in both cases will be determined with a different set of random numbers.

Both QC and QA samples should be quartered at the site lab.

ORDER OF IMPORTANCE

1. If the mix type to be quartered has changed since the last quartering, clean the 2’X2’ square pan. Otherwise, use a buttered pan. Butter = hot mix.

2. Place the whole 50 lb. loose mix sample into the pan. Mix by turning material over a minimum of 4 times with a flat-bottom scoop, shape into a cone, flatten. Bring up big pieces, distribute evenly on top so that all 4 quarters get the same amount. Shape the pile so that all 4 quarters have the same amount of material.

3. Insert quartering plates.

4. From a given quarter, pull just enough mix to make one gyro specimen (the required weight is on the Job Mix Formula) and place in a clean pan. Clean off scoop into the pan.

Do the same for the opposite quarter. Place an ID tag in each pan.

Put the pans into the oven to get the mix to the compaction temperature (30 minute maximum heating allowed, therefore, may have to set oven higher than molding temperature to keep within the 30 minutes). Do not heat the mix above the molding temperature.

5. From a third quarter, pull the proper amount for a Rice specimen and set aside for cooling:

   SP250 → 2500 grams (minimum)
   All others → 2000 grams (minimum)
Scrape material stuck on the scoop into the appropriate pan. Place an ID tag in each pan.

6. Remove the quartering plates; remix the material, cone, flatten, quarter.

7. Remove sufficient material for the nuclear sample. The required amount is stated on the Job Mix Formula sheet. Scrape the scoop; place an ID tag in the pan.

Compact nuclear sample into the nuclear gage pan while mix is still warm (may have to re-warm).

If running AC content by the ignition oven method, obtain the sample out of this quarter:

- SP250 \(\rightarrow\) 3000 to 3500 grams
- SP190 \(\rightarrow\) 2000 to 2500 grams
- SP125 \(\rightarrow\) 1500 to 2000 grams
- SP095 and SP048 \(\rightarrow\) 1200 to 1700 grams

8. Obtain moisture sample from same sample as the asphalt content sample. Treat the moisture sample the same as the mix sample in terms of the time interval between splitting and testing.

9. Leave the 2’X2’ pan buttered if the type of mix will not change before the next 50 lb. is quartered.
Volumetric Samples

Result = 2 Volumetric pucks, 1 Rice, 1 ignition, and 1 moisture

Quartering for TSR Samples

TSR = Tensile Strength Ratio

Get portions for:

- 6 – TSR Pucks
- 1 - Rice

Theoretical Maximum Specific Gravity (Gmm)

Combine opposite quarters for 2 portions.
Quartering for TSR Samples
Quarter one of those portions to obtain 4 TSR pucks.

Result = 6 TSR pucks and 1 Rice

Quartering for TSR Samples
Quarter the second portion to obtain 2 TSR pucks and 1 Rice.
AASHTO R30

Laboratory Conditioning of Asphalt Mixtures
- Used for lab mixed volumetric specimens.
- Field Extracted Cores.
- Short Term is also used in preparation of lab mixed asphalt for performance testing.
- Example of performance tests below:

Significance and Use

The properties and performance of Asphalt can be more accurately predicted by using conditioned test samples.
- Short term conditioning is used for mechanical property (performance) testing to simulate plant mix and construction effects on the mixture.
- Long term conditioning for mixture mechanical property testing to simulate the aging that occurs in a dense-graded surface layer over the first one to three years of a pavement’s life.
**Equipment**

| **Oven** – A forced-draft oven, thermostatically controlled, capable of maintaining any desired temperature setting from room temperature to 176°C with in ±3 °C. |
| **Thermometers** – having a range from 25 to 185°C and readable to ± 0.75°C. |
| Thermometers to use: |
| - ASTM E1 Mercury thermometers |
| - ASTM E230/E30M thermocouple thermometer, Type T, Special Class; |
| - IEC 60584 thermocouple thermometer, Type T, Class1 |

**Metal pan, metal spatula or spoon, timer, and gloves.**

---

**Mix Conditioning**

- **Hot mix ages at high temperatures**: in asphalt plants, trucking, and material transfer vehicles. This is called *short-term aging.*

- Aging means the binder gets more brittle due to oxidation and volatilization.

- Embrittlement leads to premature cracking and raveling.

---

**Mix Conditioning**

- The binder will also be absorbed by the aggregate.

- **More absorption**, less effective binder left between the particles to function: less compactible, lower durability.

- **Long-term aging**, is the aging that occurs during the *service* life of the pavement.
**Short Term - Mixture Conditioning**

- Applies to laboratory-prepared loose mixtures only.
- Use for volumetric properties as well as mechanical tests.
- Place mixture **25-50 mm thick** in a pan.
- Place in a force draft oven for **2 hr. ± 5 min.** at:
  - **116 ± 3°C** for WMA
  - **135 ± 3°C** for HMA
  - Or at compaction temperature
- Stir after **60 ± 5 min.**
- The Mixture is now ready for compaction.
- Compact Specimens using Gyratory Compactor (T312).
- Cool specimen overnight or cool faster place specimens in front of a fan.

**Long Term - Mixture Conditioning**

- This procedure is for long term aging of compacted specimens.
- Lab prepared specimens that have been through short term conditioning.
- Roadway specimens (cores) that have been cut, trimmed, and dried to a constant mass.
- Use cooled compacted specimens.
- Place specimen in a conditioning oven for **120 ± 0.5 hr.** at a temperature of **85 ± 3°C.**
- Then turn off the oven and open doors to allow specimens to cool to room temperature.
  - Note: Allow at least **16 hrs.** for cooling.
- Specimens are now ready for testing.
Module 7

Gyratory Compactor

AASHTO T312

MoDOT
**SCOPE**

- This AASHTO method covers the compaction of cylindrical specimens of asphalt mixtures using the Superpave Gyratory Compactor.
REFERENCED DOCUMENTS

- R35 Superpave Volumetric Design for Asphalt Mixtures
- M323 Volumetric Design Specs
- R30 Mix Conditioning
- T 312 Gyrotry Compactor operation
- T 166 Bulk Specific Gravity of gyrotry pucks
- T 209 Maximum Specific Gravity of Voidless Mix (Rice)
- T 283 Moisture Sensitivity
- M339M/M339, Thermometers Used in the Testing of Construction Materials

SIGNIFICANCE AND USE

- To prepare specimens for determining mechanical and volumetric properties of asphalt mixtures. Specimens simulate the density, aggregate orientation, and structural characteristics of the actual roadway.
- May be used to monitor the density of test specimens during preparation.
- May be used for field control of mixture during the production process.

Uses of the GYRO

1. During mix design (lab fabricated sample)
2. During construction for field verification (plant-mixed material)

To Evaluate:
- Volumetric properties e.g., air voids and VMA
- Densification properties e.g., tenderness potential
- Moisture sensitivity (TSR)
- Other performance tests – Hamburg
**EQUIPMENT**

- Superpave Gyratory Compactor
- Specimen Height Measurement and Recording Device
- Specimen Molds
- Ram Heads and End Plates
- Lab Equipment such as balance, thermometer, oven, pans etc.

More information on equipment can be found in the appendix, item #7
## Compaction

### Gyratory Compactor:
- Axial and shearing action
- 150 mm diameter molds
- Aggregate size up to 37.5 mm
- Height measurement during compaction
  - Allows densification during compaction to be evaluated.

![Diagram](image)

- Ram pressure
  - 600 kPa
- Internal angle 1.16°
- 1.25°

## Calibration and Verification
- Must check:
  - Rate of gyration (rotational speed)
  - Roller clearance & zero position
  - Height measurement
  - Ram force (load)
  - Angle of gyration:
    - Internal angle (calibration)
    - External angle (verification)
  - Check with owner’s manual and/or contact the manufacturer as needed.

## Actions

### Calibration:
- Annually, if Verification fails, if moved.
  - Measure
  - Adjust
  - Re-measure

### Verification:
- Daily, After maintenance, or questionable results.
  - Measurement
  - Note: Calibration and Verification should only be performed on a clean/cold machine.
Gyro Mold Evaluation

- Frequency: min. 12 months or 80 operating hours
  - External calibration service (usually in conjunction with gyro calibration), or:
  - In-house
- Critical dimensions:
  - Mold inside diameter
  - End plate diameter
  - Mold length

Maintenance

- Maintenance of Gyratory Compactor Operation:
  - Clean rollers with solvent
  - Keep rotation ring cleaned and oiled
  - Periodically, check oil level
  - Make sure anti-rotational cogs are tight. Keep some spares on hand.

Equipment - ID

- Must have a unique ID on each piece of equipment.
- Must keep a list of equipment for IAS inspection.
**PREPARATION OF GYRATORY**

- Prior to the time to compact a sample, turn on the Gyratory Compactor to warm up. (see manufacturers instructions)
- Verify the machine settings are correct for angle, pressure, and number of gyrations.
- Lubricate any bearing surface as needed.
- If applicable, turn on the device for measuring and recording the height of the specimen, and verify the readout is in the proper units, and recording device is ready.

**Verification/Calibration**

Verify the gyratory on a cold (Powered up 10-15 min) and clean machine.

1) Daily during use
2) If gyratory compactor is moved.

Calibrate:
1) Annually
2) If verification fails

**SPECIMEN PREPARATION**

**Volumetrics puck**

Height = 115 ± 5 mm
Mold to # of gyrations JMF

**TSR puck**

Height = 95 ± 5 mm
Mold to Height
Molding 6 TSR Pucks

TSR material sampled from Truck. (Road, Pile, Stream)
For performance test Tensile Strength Ratio (TSR) compacted to a fixed height = 95mm.

---

TSR Sample

- Need 60-75 lb. sample for six TSR pucks.
- Use the JMF to get the grams needed.
- Example on next slide, JMF shows 4,610 grams is needed to produce a 95mm height TSR specimen.

---

Location of Gyro TSR Puck Weight on JMF

---
## Location of Gyro Puck Weight on JMF

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<th>Location of Gyro Puck Weight on JMF</th>
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#### SUPERPAVE MODULE 7

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<tr>
<td>MASTER GAUGE SER. NO.</td>
</tr>
<tr>
<td>MASTER SAMPLE FILTER</td>
</tr>
<tr>
<td>SAMPLE FILTER</td>
</tr>
<tr>
<td>SAMPLE WEIGHT</td>
</tr>
</tbody>
</table>

---

*Aggregate & Mixture Properties Based on Contractor's Mix Design*
Molding Two Volumetric Pucks

Loose mix Sampled from the Roadway.

Volumetric pucks

For Volumetric specimens, compact to a fixed number of gyrations, resulting height must be \(115 \pm 5\) mm.

Number of Gyrations

- \(N_{ini}\): initial number of gyrations: at a low number, the ease of mix densification is analyzed to spot tenderness potential.
- \(N_{des}\): the number of gyrations corresponding to the design traffic; want 4% air voids at this point (96% density).
- \(N_{max}\): maximum number applied to the specimen to assess densification after many years; want > 2% \(V_a\) (<98% density).

Volumetrics/Binder Content Sample

- Get 2 portions for the 2 volumetric pucks.
Location of Gyration Info on JMF

Gyration Levels

<table>
<thead>
<tr>
<th>Design</th>
<th>(N_{\text{ini}})</th>
<th>(N_{\text{des}})</th>
<th>(N_{\text{max}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>--</td>
<td>50</td>
<td>--</td>
</tr>
<tr>
<td>E</td>
<td>7</td>
<td>75</td>
<td>115</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>80 or 100</td>
<td>160</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>125</td>
<td>205</td>
</tr>
</tbody>
</table>

• C Mixes at 80 gyrations:
  • no \(N_{\text{ini}}\) or \(N_{\text{max}}\) requirements.

• SMA Mixes:
  • \(N_{\text{des}} = 100\)
  • No \(N_{\text{max}}\) requirement

Number of Gyrations

• \(N_{\text{sum}}, N_{\text{des}},\) and \(N_{\text{max}}\) are shown on the JMF.

• *Samples for field verification of volumetrics should be compacted to \(N_{\text{des}}\) gyrations.*
**Location of Gyration Info on JMF**

---

### Missouri Department of Transportation - Division of Materials

**Asphaltic Concrete Type SP125HB**

**Date:** 10/29/03

**Contractor:** MY BUSINESS

**Superpave Module 7**

#### Location of Gyration Info on JMF

<table>
<thead>
<tr>
<th>Location</th>
<th>Gyration Info</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nini</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Ndes</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>Nmax</td>
<td>205</td>
<td></td>
</tr>
</tbody>
</table>

---

**MATERIAL**

<table>
<thead>
<tr>
<th>IDENT #</th>
<th>35JSJ001 35JSJ002</th>
<th>35JSJ003 35GAJ016</th>
</tr>
</thead>
<tbody>
<tr>
<td>03016</td>
<td>3/4&quot; 3/8&quot;</td>
<td>6/8 6/16 1/2 2&quot;</td>
</tr>
</tbody>
</table>

**Laboratory**

<table>
<thead>
<tr>
<th>Test</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grad</td>
<td>2.405</td>
</tr>
<tr>
<td>% Voids</td>
<td>4</td>
</tr>
<tr>
<td>TSR</td>
<td>95</td>
</tr>
<tr>
<td>Mix Composition</td>
<td>Nini = 9</td>
</tr>
<tr>
<td>Mix AGG</td>
<td>90.8%</td>
</tr>
<tr>
<td>Asphalt Content</td>
<td>6.2%</td>
</tr>
</tbody>
</table>

**Calibration Number**

99004

**Master Gauge Back Cont.**

2196

**Sample Weight**

7200

---

Aggregate & Mixture Properties Based on Contractor's Mix Design
Sample Preparation

For Field Samples

• Weigh enough mix to achieve the desired height and/or void target. Adjust specimen weight as needed during the design phase of establishing a mix design.
• Condition mixture as required in AASHTO R30 for the type of specimens to be molded.
• Heat mix to molding temperature. (See JMF)
### Location of Gyro Molding Temperature on JMF

#### MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

**ASPHALTIC CONCRETE TYPE SP125HS**

<table>
<thead>
<tr>
<th>IDENT</th>
<th>PRODUCT CODE</th>
<th>PRODUCER, LOCATION</th>
<th>SP OR</th>
<th>SP GR</th>
<th>% ABS</th>
<th>FORMATION</th>
<th>LEDGES</th>
<th>% CHERT</th>
</tr>
</thead>
<tbody>
<tr>
<td>35JSJ001</td>
<td>100207 LD1</td>
<td>Hard Rock Stone, Dig Deep, MO</td>
<td>2.515</td>
<td>2.713</td>
<td>2.9</td>
<td>Jet City Dolso</td>
<td>5-8</td>
<td>25</td>
</tr>
<tr>
<td>35JSJ002</td>
<td>100204 LD1</td>
<td>Hard Rock Stone, Dig Deep, MO</td>
<td>2.476</td>
<td>2.725</td>
<td>3.7</td>
<td>Jet City Dolso</td>
<td>5-8</td>
<td>25</td>
</tr>
<tr>
<td>35JSJ003</td>
<td>1002MRS MSLD</td>
<td>Hard Rock Stone, Dig Deep, MO</td>
<td>2.480</td>
<td>2.761</td>
<td>3.7</td>
<td>Jet City Dolso</td>
<td>5-8</td>
<td>10</td>
</tr>
<tr>
<td>30CAJ815</td>
<td>1002HL HL</td>
<td>Missy Lime Co. #2, Ste. General, MO</td>
<td>2.303</td>
<td>2.303</td>
<td>3.7</td>
<td>Hyd. Lime</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### MATERIAL

<table>
<thead>
<tr>
<th>IDENT #</th>
<th>35JSJ001</th>
<th>35JSJ002</th>
<th>35JSJ003</th>
<th>30CAJ815</th>
<th>COMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>03016</td>
<td>3/4”</td>
<td>3/4” MAN SAND</td>
<td>Hyd. Lime</td>
<td>1.023</td>
<td>PG70-22 Gyro Mold Temp. 300-310°F</td>
</tr>
</tbody>
</table>

#### PG70-22 Gyro Mold Temp. 300-310°F

<table>
<thead>
<tr>
<th>#12</th>
<th>#18</th>
<th>#30</th>
<th>#50</th>
<th>#100</th>
<th>#200</th>
</tr>
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<tbody>
<tr>
<td>58.6</td>
<td>12.0</td>
<td>26.0</td>
<td>2.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>58.6</td>
<td>12.0</td>
<td>26.0</td>
<td>2.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>38.6</td>
<td>12.0</td>
<td>26.0</td>
<td>2.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>58.6</td>
<td>12.0</td>
<td>26.0</td>
<td>2.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

**LABORATORY**

Gmm = 2.405
% voids = 4
TSR = 95
TSR WR = 95
New = 9
Mix Com Position =

**CHARACTERISTICS**

Gmm = 2.308
V.M.A. = 14.4
200AC = 1.1
3865.0
Nides = 125
MIN. AGG = 90.8%

**AASHTO T312**

Gmm = 2.026
% Filled = 72
Gyro TR = 49.1
Nmax = 200
Asphalt content = 6.3%

**CALIBRATION NUMBER**

99004
MASTER GAUGE BACK OBT. = 2796
A1 = 6.234741
MASTER GAUGE SER. No. = 77X
SAMPLE WEIGHT = 7200
A2 = 3.43695

Aggregate & Mixture Properties Based on Contractor's Mix Design
**PROCEDURE - COMPACTION**

- Preheat gyratory mold and plates to molding temperature (see JMF) for ≥ 30 min.
- Reduce loose mix according to AASHTO R47.
- Place the mix in a preheated oven set to JMF molding temperature.
- Place a thermometer in the loose mix to check temperature before molding.
- When loose mix is at molding temperature, move quickly to compaction.

---

**Procedure - Compaction**

- Pull the mold items out of the oven.
  - Assemble if needed.
  - Place a paper disc to the bottom.

---

**Procedure - Compaction**

- Place a funnel on top of the mold.
- At the oven, check if mix is at molding temperature.
- If on temperature, place the mix in the mold in one lift. Scrap the pan and spatula to include all the sample into the mold.
### Procedure - Compaction

- Level the mix and place a paper disc on top the sample.
- Place the lid on top with beveled side facing up.
- Place the mold into the gyratory compactor.
- Verify settings on the gyro are correct.

<table>
<thead>
<tr>
<th>Items to verify:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify 150mm specimen diameter.</td>
</tr>
<tr>
<td>Verify compaction pressure = 600 kPa.</td>
</tr>
<tr>
<td>For Volumetric pucks,</td>
</tr>
<tr>
<td>- Set to # gyrations = Ndes from JMF.</td>
</tr>
<tr>
<td>For TSR pucks,</td>
</tr>
<tr>
<td>- Set specimen height to 95 mm.</td>
</tr>
</tbody>
</table>

- Press the START button.
- Once compaction is finished, extrude the sample from mold.
- Allow to cool for a minute or two for stability before handling.
- Flip the puck over onto a cooling table and remove the other Paper disc.
**Procedure - Compaction**

When cooled enough label the puck on the side.

---

**DENSITY PROCEDURE**

**Specific Gravity G<sub>mb</sub>**

Once cooled, the resulting specimens are ready to be tested for specific gravity (G<sub>mb</sub>) or other testing as required.

*Note:* "AASHTO T166 for Bulk Specific Gravity can be found in your Bituminous Technician Manual"
% Absorption (% Abs)

The percentage of water absorbed by the specimen based on the volume of the specimen.

\[
\% \text{ Abs} = \frac{(B - A)}{(B - C)} \times 100\%
\]

\begin{align*}
A &= \text{Dry Mass, 0.1 g} \\
B &= \text{SSD Mass, 0.1 g} \\
C &= \text{Submerged Mass, 0.1 g}
\end{align*}

Report absorption to nearest 0.01%

---

Reporting

* Keep all gyratory print outs of each compacted specimen for records.
* Keep all additional reports on Density testing of each specimen for records.
* Also keep any additional information that is required for the job.

---

COMMON ERRORS

* Not placing a paper disk on bottom or top of specimen.
* Not removing paper disks while puck is still warm.
* Not using top or bottom plates.
* Not compacting mix at proper temperature.
* Not properly verifying the calibration of the compactor prior to use.
* Not pre-heating the mold and plates.
* Not charging the mold with mix quickly in one lift without spading or rodding.
**Common GYRO Errors**

- Avoid allowing built-up asphalt in gyro mold to smear the sides of the puck as it is extruded, closing off voids. As a minimum, wipe off top and bottom lids after every puck.

- Don’t let paper disks become brittle by keeping them in the bottom of the mold in oven overnight.
### Pre-Verification Checklist: (Note: State operation & frequency).

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>State required frequency of verification &amp; calibration:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verify on a cold (powered up for 10-15 minutes) and clean machine</td>
<td>1) Daily during use, or 2) if gyro is moved</td>
<td></td>
</tr>
<tr>
<td>Calibrate: 1) Annually, or 2) If verification fails</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Pre-Compaction Checklist: (Note: Proctor will tell you the type of specimen to be molded, you will explain the setting for the machine for that operation.)

State & verify required parameters for compaction:

1. Verify 150 mm specimen diameter
2. Verify compaction pressure = 600 kPa
3. For Volumetric pucks, SET GYRATIONS = N_{des} (from JMF)
4. For TSR pucks, set SPEC. HT. (specimen height) = 95.0 mm
5. Preheat gyratory mold and plates to molding temperature. (see JMF for ≥ 30 minutes)
6. Loose Mix sample must be reduced according to AASHTO R47. (see JMF for information)
7. Place the mix in a preheated oven set to molding temp. (See JMF for temp.)
8. Place a thermometer in the loose mix to check temperature.
9. When loose mix is at molding temperature, move quickly to compaction.

### Compaction Procedure: (Mold specimen, proctor can assist with machine operation as needed.) CAUTION!! Use PPE, everything is HOT!

10. Pull the hot mold items out of the oven.
11. Assemble mold & bottom plate (If necessary) & insert a paper disk into the bottom of the mold and place a funnel on the top.
12. Check if mix is at molding temperature, if so, take the loose mix from the oven, place it in the mold in 1 lift.
   a. Scrape pan and spatula clean to include all of the sample to the mold.
13. Level the surface of loose mix in the mold, place 2nd paper disk on top.
14. Place top plate on top beveled side up.
15. Place mold in machine according to manufactures instructions.
16. Verify setting are correct on the Gyro, Press START and let compaction proceed.
17. When the compaction has completed, open door and move mold to puck extrusion station.
   a. Note: Some machines will automatically extrude the sample.
18. Carefully remove the top plate and paper disk.
   a. If the mix is tender, may need to cool a few seconds before handling to avoid collapse.

19. After minimum cooling period to assure puck stability, carefully set puck upside-down on cooling rack, and remove 2\textsuperscript{nd} paper disk ASAP.

20. Mark the puck for identification purposes on the side of the sample.

<table>
<thead>
<tr>
<th>PASS?</th>
<th>FAIL?</th>
</tr>
</thead>
</table>

Proctor__________________________________________ Date__________________
Reviewer________________________________________ Date__________________
Module 8

Maximum Specific Gravity

AASHTO T209

(Gmm), (Rice)

MoDOT
SCOPE

This test method covers the determination of the theoretical maximum specific gravity/gravity mix maximum (Gmm) and density of uncompacted asphalt mixture at 25°C (77°F).
Maximum Specific Gravity of Voidless Mix

- Specific gravity is the ratio of the mass in air of a volume of material to the mass in air of an equal volume of water.
- Maximum Specific Gravity is sometimes called a "Rice" test.
- "G_{mm}":
  - G = specific gravity
  - m = mix
  - m = maximum

SIGNIFICANCE AND USE

- Used to calculate percent air voids.
- Used to calculate core density.
- Provides target values for the compaction of asphalt mixture.
- Is essential when calculating the amount of asphalt binder absorbed by the internal porosity of the individual aggregate particles in asphalt mixture.

Used to determine the relative density and % compaction of compacted asphalt mixtures.

1. Computing %Air Voids:
   (a pay factor)
   - \( V_a = \left[ \left( G_{mm} - G_{mb} \right) \div G_{mm} \right] \times 100 \)

2. Computing pavement Density:
   (a pay factor)
   - Density = \( \left( G_{mc} \div G_{mm} \right) \times 100 \)
   - \( G_{mc} \) = core specific gravity
**EQUIPMENT**

Follow AASHTO R18 and R61 for calibrations, standardizations and checks

See The Appendix Item #7 for more information.

- Vacuum Container
- Pycnometer – Standardized Daily
- Scale – Standardized yearly
- Vacuum Pump – Vacuum to pressure of 25mmHg
- Vacuum Measurement Device – Standardized yearly measure residual pressure to 25mmHg
- Bleeder Valve –
- Thermometer – Standardized yearly
- Drying Oven – maintaining 135 ± 5°C (275 ± 9°F)
- Water Bath – maintained at 25 ± 1°C (77 ± 2°F)

**Pycnometer Daily Standardization**

**Note:** Keep a record of daily weights of the pycnometer daily standardizations.

- Determine weight of empty pycnometer immersed in 25 ± 1.0 °C, for 10 ± 1 min.
- Check wt. against the average of the last 3 daily weights, today’s wt. must be within 0.3g of that average.
- If it is in, weight is good to use.
- If no, redo 2 more times, use average of today’s 3 weights as “Empty wt. of Pycnometer”.
  (Report to 0.1)

**SAMPLING**

- **Volumetric Sample:** Sampled behind the paver
- **TSR Sample From one of the following:**
  - Truck (preferred)
  - Plant discharge
  - Behind paver
### Sample Size For T209 (Rice)

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size, mm</th>
<th>Minimum Sample Size, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5mm or Greater (1.5&quot;)</td>
<td>4000</td>
</tr>
<tr>
<td>19 to 25mm (¾ - 1&quot;)</td>
<td>2500</td>
</tr>
<tr>
<td>12.5 mm (½&quot;) or smaller</td>
<td>2000</td>
</tr>
</tbody>
</table>

**MODOT NOTES:**

SP260 → 2500 grams (minimum)  
All others → 2000 grams (minimum)

---

### SAMPLE PREPARATION

Samples may be short-term conditioned according to R30 (see Module 6).

**Sample Split**

- Dry specimen to constant weight at 221 ± 9°F (105 ± 5 °C) until mass repeats within 0.1%.
- **NOTE:** See appendix for cookbook on “mass repeats”.

Or Use AASHTO T 329 Moisture content of mix to be assured that the specimen is dry (< 0.1%).

---

SP_Module-8, Max Specific Gravity
• While sample is cooling, separate loose mix into small pieces. Avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than ¼ inch in size. Bring specimen to room temperature.

PROCEDURE – Weigh in Water

• Check level of the water bath and the temperature of the bath.
  • Temperature of the bath should be 77°F (25°C).
• Determine and record the empty weight of the Pycnometer (without lid).

Weigh in Water - Procedure

- Place dry loose sample in pycnometer and level the out the top surface.
- Record the weight of oven dried sample plus pynometer. Calculate and record as oven-dry weight of sample (A).

Total - tare = “A” (Report to 0.1)
Add sufficient water to cover the sample completely. (~1 inch) De-air the specimen by agitating under vacuum for 15 ± 1 min.

The vacuum is required to be 30 ± 5 mm Hg, maintain this residual pressure for 15 ± 1 min.

Agitation

* **Mechanical Agitation – Method A**
  * Maintain vacuum at 30 ± 5 mm Hg for 15 ± 1 min.
  * Agitate using the mechanical device during the vacuum period.

* **Manual Agitation – Method B**
  * Maintain vacuum at 30 ± 5 mm Hg for 15 ± 1 min.
  * Agitate the pycnometer & sample during the vacuum period by vigorously shaking at intervals of about 2min.
  * Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat to avoid excessive impact while under vacuum.

• After 15 ± 1 min slowly release the vacuum at a rate of 60 mm Hg/sec.

• Disassemble apparatus.
* Weigh suspended pycnometer with sample below the scale in water 25 ± 1°C (77 ± 2°F) without lid for 10 ± 1 min:
  [pycnometer + specimen] under water = “C”
(Report to 0.1)

Avoid loss of fine particles

---

**Weigh in Water - Pycnometer Standardization**

* Remove specimen from pycnometer. Immediately determine weight under water of empty pycnometer.
  [pycnometer] under water = “B” (Report to 0.1)

---

**Weigh in Air - PROCEDURE**

Fill the pycnometer with water and bring the specimen to test temperature (25 ± 1°C).
After 10 ± 1 min. determine weight of [specimen + pycnometer + water] = “E”
(Report to 0.1)

Determine weight of pycnometer full of water to determine its volume. The water is required to be at 25 ± 1.0 ºC.

Report as “D”
(Report to 0.1)

“D” will be too high with cold temperature & cloudiness.
“D” will be too low with high temperature.

\[ G_{mm} = \frac{A}{(A + D - E)} \]

- A=Dry Sample Mass in Air
- D=Container & Water
- E=Container, Water & Sample

Report \( G_{mm} \) to nearest 0.001
Calculate Gmm for Sample #ZZTOP

• A = Dry Sample Mass in air = 2,510.5 g
• D = Container & Water = 7,442.6 g
• E = Container, Water & Sample = 8,974.1 g

What is the Gmm? ___________

Report Gmm to nearest 0.001

---

Weight in Water - Calculation

\[
Gmm = \frac{A}{(A + B - C)}
\]

• A = Dry Sample Mass in Air.
• B = Container & Water
• C = Container, Water & Sample

Report Gmm to nearest 0.001

---

Calculate Gmm for Sample #ACDC

• A = Dry Sample Mass in air = 2,510.5 g
• B = Container & Water = 7,440.8 g
• C = Container, Water & Sample = 8,966.1 g

What is the Gmm? ___________

Report Gmm to nearest 0.001

Answer is 2.548
**Supplemental Procedure**

**Dry-Back**

- **Purpose** - to see if water has penetrated the binder coating.
- **Dry** the sample back to a surface-dry condition -- don't oven dry all the way to ~ zero moisture.
**SUPERPAVE MIXTURE PROPERTIES**

<table>
<thead>
<tr>
<th>JOB</th>
<th>0</th>
<th>ROUTE</th>
<th>0</th>
<th>MIX NO.</th>
<th>#VALUE!</th>
<th>LOT NO.</th>
<th>0</th>
</tr>
</thead>
</table>

**SUBLOT**

**DATE**

AASHTO T 209

**TECHNICIAN**

* Rice Gmm *

A2 required when T85 absorption >2.0% on any aggregate fraction.

<table>
<thead>
<tr>
<th>A</th>
<th>1594.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>7472.2</td>
</tr>
<tr>
<td>X</td>
<td>9066.6</td>
</tr>
<tr>
<td>Y</td>
<td>645.1</td>
</tr>
<tr>
<td>Gmm</td>
<td>2.472</td>
</tr>
</tbody>
</table>

**AASHTO T 166**

**TECHNICIAN**

MOLDING TEMPERATURE

<table>
<thead>
<tr>
<th>A</th>
<th>4867.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>2801.9</td>
</tr>
<tr>
<td>C</td>
<td>4860.4</td>
</tr>
<tr>
<td>Gmb</td>
<td>2.342</td>
</tr>
<tr>
<td>A</td>
<td>4899.1</td>
</tr>
<tr>
<td>B</td>
<td>2814.5</td>
</tr>
<tr>
<td>C</td>
<td>4911.9</td>
</tr>
<tr>
<td>Gmb</td>
<td>2.336</td>
</tr>
</tbody>
</table>

**Pb**

MoDOT TM54 (NUCLEAR)

SAMPLE WEIGHT

<table>
<thead>
<tr>
<th>GAUGE % AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEC. 1</td>
</tr>
<tr>
<td>AASHTO T 308 (IGNITION)</td>
</tr>
<tr>
<td>SPEC. 2</td>
</tr>
<tr>
<td>NUCLEAR OR IGNITION</td>
</tr>
<tr>
<td>% MOISTURE</td>
</tr>
<tr>
<td>AVG. Gmb</td>
</tr>
</tbody>
</table>

| A = Gmm (FIELD) | 2.472 |
| C = Gsb (Job Mix) | 2.557 |
| D = P5 = Percent Agg. in mix | 94.8 |
| VMA = 100 - (B X D) / C | 13.3 |
| Va = 100 X ((A - B) / A) | 5.4 |
| VFA = \( \frac{(VMA-Va)}{VMA} \) | 59 |

| AASHTO T 166 |
| TECHNICIAN |

| A | 1255 |
| B | 710 |
| C | 1260 |

| Gmm = MAX. SPECIFIC GRAVITY (T209) | 2.472 |

**THICKNESS**

**SUBLOT**

FOR 2ND CORE SUBLOT WHEN DENOTED IN QC PLAN

| A | 0.00 |
| B | 0.00 |
| C | 0.00 |
| Gmc = CORE SPECIFIC GRAVITY = A / (C - B) | 0.00 |
| Gmm = MAX. SPECIFIC GRAVITY (T209) | 2.472 |
| % COMPACTION OF CORE = 100 x (Gmc / Gmm) | 0.0 |

**Mixture Properties wksheet**
### SPREADSHEET CALCULATIONS

#### AASHTO R 35

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
<th>Value 5</th>
<th>Value 6</th>
<th>Value 7</th>
<th>Value 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>A = Gmm (FIELD)</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
</tr>
<tr>
<td>B = Gmb (FIELD) (Avg.)</td>
<td>2.339</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>C = Gsb (Job Mix)</td>
<td>2.557</td>
<td>2.557</td>
<td>2.557</td>
<td>2.557</td>
<td>2.557</td>
<td>2.557</td>
<td>2.557</td>
<td>2.557</td>
</tr>
<tr>
<td>D = Ps = Percent Agg. in mix</td>
<td>94.8</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>VMA = 100 - (B X D / C)</td>
<td>13.3</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Va = 100 X ((A - B) / A)</td>
<td>5.4</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>VFA = (VMA-Va) / VMA</td>
<td>59</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

#### AASHTO T 155

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
<th>Value 5</th>
<th>Value 6</th>
<th>Value 7</th>
<th>Value 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>A = Weight of sample in air:</td>
<td>1255</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B = Weight in water:</td>
<td>710</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C = Weight of surface dry sample:</td>
<td>1260</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gmc = CORE SPECIFIC GRAVITY = A / (C - B)</td>
<td>2.282</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Gmm = MAX. SPECIFIC GRAVITY (T209)</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
<td>2.472</td>
</tr>
<tr>
<td>% COMPACTION OF CORE = 100 x (Gmc / Gmm)</td>
<td>92.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>THICKNESS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUBLOT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dry-Back Step

* If absorption of *any* coarse aggregate (+4) fraction is greater than 2.0%, dry back the specimen to a surface dry condition and weigh. Use this weight "$A_2$" in the denominator in place of "$A$".

* Absorption data is on the JMF.

Spread the sample out in front of a fan

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Dry-Back Step

* Continue drying in front of a fan.
* Determine and record the mass at 15-minute intervals.
* When the loss in mass is less than 0.05% for this interval the sample may be considered surface dry. (SSD state)
* Procedure generally takes approximately 2 hr.

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Dry-Back Calculation "$A_2$"

* Knowing mass of specimen and mass of water displaced (volume of specimen), calculate $G_{mm}$

$$G_{mm} = \frac{A}{(A_2 + B - C)}$$

"$C$" will be incorrect if water temperature is not standard.

Report $G_{mm}$ to nearest 0.001

33
Sample Problem – Dry Back

\[ G_{mm} = \frac{A}{(A_2 + B - C)} \]

Calculate Gmm for Sample #ACDC

- \( A \) = Dry Sample Mass in air = 2,510.5 g
- \( A_2 \) = Dry Sample Mass in air = 2,511.9 g
- \( B \) = Container & Water = 7,440.8 g
- \( C \) = Container, Water & Sample = 8,966.1 g

What is the Gmm? ___________ What is the new \( G_{mm} \)? ___________

Report \( G_{mm} \) to nearest 0.001

When to Implement Dry Back

- If coarse aggregate absorptions are excessive, perform on first lot (all sublots).
- If initial Gmm and the dry-back Gmm are within 0.002 of each other in each of the first 4 sublots, the dry-back procedure may be reduced to once per 4 sublots.

REPORT

- Gmm and density to the nearest 0.001
- All weighs to nearest 0.1
- Temperature of the water
- Type of asphalt mixture
- Type of sample
- Sample ID
- Date
- Type of procedure “Water” or “Air”
- Report if used dry back procedure
- Report \( G_{mm} \) to the nearest 0.001
CHANGES IN "G_{mm}"
In silo, trucks, MTV

- Time interval at high temperature
- Absorptiveness of aggregate

Time at High Temperature

Absorptiveness of Aggregate
### COMMON TESTING ERRORS

- Not allowing specimen to cool to proper temperature.
- Over-manipulating the specimen, producing broken, uncoated particles
- Not having a manometer connected directly to the pycnometer
- Not maintaining the proper level of vacuum.
- Not breaking up sample completely
- Not agitating sample enough
- Agitating sample too much

### Common Testing Errors, cont’d

- If the specimen was too warm when placed in the pycnometer: after the vacuum step, if stirring is done, aggregate may be broken.
- Not placing the lid in the same position each time.
- Not sufficiently drying the outside of the pycnometer before weighing.
- Allowing entrapped air bubbles in pycnometer.
- Not performing the dry-back procedure for highly absorptive aggregates.
- Not calibrating the pycnometer often enough.
- Not maintaining proper water temperatures.
### Pre-Procedure Checklist: (Note: State operation & frequency).

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Pycnometer calibration required daily</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Sample moisture content must be &lt;0.1%: Verify by either</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Oven drying until mass repeats within 0.1%, or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Use results of AASHTO T329</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Perform “dry-back” procedure if ANY coarse aggregate fraction has</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Absorption &gt;2.0% (use surface-dry weight “A2” in place of “A” in the denominator of the non-dry-back Gmm equation.)</td>
<td></td>
</tr>
</tbody>
</table>

### Routine Rice Test Procedure: (Demonstrate procedure, Proctor will shorten time frames)

|4. | Separate particles while cooling sample: |   |
|   | a. Don’t break aggregate |   |
|   | b. Reduce sand-binder clumps to ≤ ¼ inch |   |
|   | c. Cool until mix is at room temperature |   |
|5. | Determine and record empty weight of the pycnometer (without lid). |   |
|   | a. Place and level sample in pycnometer. |   |
|   | b. Record weight of sample + pycnometer. |   |
|   | c. Calculate oven-dry weight of sample [A] |   |
|6. | Cover sample with approximately 1” of bath water |   |
|7. | Subject to specified vacuum of 30 ±5 mm Hg while agitating for 15 ± 1 min. |   |
|   | (Manually agitate at intervals of 2 min for 15 ± 1 min using a rubber/plastic mat.) |   |
|8. | Immediately after the 15± 1 min. time period (i.e., the vacuum application stops), very slowly release vacuum at 60mm Hg/sec. |   |
|9. | Start 10 ± 1 minute time period in which the final weight must be obtained (i.e., finish the test). Disassemble apparatus. |   |
|10. | Being careful not to expose the mix to the air slowly submerge pycnometer in water bath at the specified temperature (is it?) and carefully place capillary lid on pycnometer. |   |
|11. | Just prior to end of 10 ± 1 min. time period, remove pycnometer, dry off the exterior, then determine and record total weight [E]. |   |
|12. | After recording E, completely remove contents, re-submerge empty pycnometer in water bath, place capillary lid on pycnometer, wait 10 ± 1 min. for temperature stabilize, remove pycnometer, dry off the exterior, then determine and record total weight [D]. |   |
|13. | Calculate non-dry-back Gmm = A / (A + D - E) : Nearest 0.001? |   |
|14. | Calculate dry-back Gmm = A / (A2 + D - E) : Nearest 0.001? |   |

### PASS?  
### FAIL?
# AASHTO T 209: Theoretical Maximum Specific Gravity (Rice Test): “Weigh In Water” Method

**Pre-Procedure Checklist: (State for proctor operation and frequency)**

State the following requirements for routine testing of a particular mix:

1. Pycnometer calibration required daily

2. Sample moisture content must be <0.1%: Verify by a) oven drying until mass repeats within 0.1% OR b) use results of AASHTO T 329

3. Perform “dry-back” procedure if **ANY coarse aggregate fraction** has absorption > 2.0% (use surface-dry weight “A2” in place of “A” in the denominator of the non-dry-back Gmm equation)

## Routine Rice Test Procedure: (Demonstrate procedure, proctor will shorten time frames where needed.)

4. Separate particles while cooling sample: 1) Don’t break aggregate; 2) Reduce sand-binder clumps to ≤ ¼”; 3) Cool until mix is at room temperature

5. Determine and record empty weight of the pycnometer (without lid). Place and level sample in pycnometer. Record weight of sample + pycnometer. Calculate and record oven-dry weight of sample [A]

6. Cover sample with approximately 1” of bath water

7. Subject to specified vacuum of **30 ± 5 mm Hg** while agitating for **15 ± 1 minutes**

8. Very slowly release vacuum at a rate not to exceed 60 mm Hg, then disassemble apparatus

9. Confirm that water bath temperature is in spec. and water is at default level (are they?), then zero out the weigh-in-water system.

10. Being careful not to expose the mix to the air, suspend pycnometer (without lid) and contents in water bath

11. Determine and record combined mass of pycnometer and contents [C] after 10 ± 1 minutes of immersion

12. After recording C, remove pycnometer from water bath, completely remove the contents, reset the weigh-in-water system to its default condition, re-suspend empty pycnometer (without lid) in water bath, then determine and record mass [B] after steady-state has been achieved (tank stops overflowing).

13. Calculate non-dry-back Gmm = A / (A + B – C): Nearest 0.001?

14. Calculate dry-back Gmm = A / (A2 + B – C): Nearest 0.001?

<table>
<thead>
<tr>
<th>Trial#</th>
<th>1</th>
<th>2</th>
<th>R</th>
</tr>
</thead>
</table>

**PASS?**

**FAIL?**

**Proctor** ____________________________ **Date** __________________

**Reviewer** ____________________________ **Date** __________________
Module 9

Binder Ignition
AC Content
AASHTO T308
This test method AASHTO T308:

- Covers the determination of asphalt binder content of asphalt mixtures by ignition at temperatures that reach the flashpoint of the binder in a furnace.
- Heating may be convection method or direct infrared (IR) irradiation method.
- Two Methods,
  - **Method A** requires an ignition furnace with an internal balance.
  - **Method B** requires an ignition furnace with an external balance.

This method can be used for:

- Quantitative determinations of asphalt binder content.
- Gradation in asphalt mixture and pavement specimens for quality control.
- Specification acceptance.
- Mixture evaluation studies.
- For gradation analysis according to AASHTO T30.
**EQUIPMENT**

- **Ignition Furnace** – A forced air oven that heats by convection or direct IR irradiation. The convection type must be capable of maintaining 538 ± 5°C (1000 ± 9°F).
  - For Method A the oven shall have an internal balance.
- Specimen basket assembly consisting of
  - Specimen Baskets
  - Catch Pan
  - Assembly guard
- See appendix, Item #7 for more information on equipment.

---

**Oven Verification:**

- The oven must be “verified” every 12 months and after each move.
  - Temperature
  - Balance

**Methods:**

- Yearly outside service (usually along with gyro and mold calibrations, etc.)
- In-house

---

**Ignition Oven Basics:**

- **% Binder**: Loss in mass of specimen
- **Problem**: Other materials also burn off
  - Moisture
  - Aggregate
  - Miscellaneous
CORRECTIONS

1. Moisture
   • Moisture Content “MC”

2. Aggregate Burn Loss
   • Aggregate Correction Factor “Cf”

3. Temperature effects on weighing
   • Temperature Correction Factor “TCF”

1. Moisture
   • Moisture in mix will evaporate.
   • This will count as binder unless corrected.
   • There are two methods to correct for moisture:
     - Dry mix to a constant mass at 110 ± 5°C (230 ±9°F) prior to testing.
     - “Aging”—must still verify that constant mass has been achieved.

     OR

   Method 2
   - Determine moisture content of mix (AASHTO T 329), subtract it from the apparent binder content.

Moisture Content (AASHTO T 329): Method 2

- Temperature: (See BT Manual for T329)
  - Within the JMF mixing temperature range.
  - If unavailable, use 163 ±14°C (325 ±25°F)
  - ≥1,000g sample, Initial drying time is 90 ± 5 min.
  - Continue drying checking at 30 ± 5 min intervals until the mass changes less than 0.05% (±1g per sample) from the previous mass = Constant Mass.
  - Report to nearest 0.01%
  - Moisture is calculated based on dry weight of HMA.
Calculate the **PERCENT CHANGE** as follows:

\[
\% \text{ Change} = \left( \frac{A - B}{A} \right) \times 100
\]

- **A** = Previous mass determination
- **B** = Newest mass determination
- REPORT = To the nearest 0.01%

**Reminder from BT certification:**
First subtract the container weight from the total weight for A and B then record the weights to the nearest 0.01 g before calculating % change.

---

**Moisture Content (AASHTO T 329):**

\[
\text{Moisture Content} = \left( \frac{M_i - M_f}{M_f} \right) \times 100
\]

Where:
- \(M_i\) = Mass of initial, moist test sample
- \(M_f\) = Mass of the final, dry test sample
- Report = % Moisture to the nearest 0.01%

---

**Classroom Practice**

\[M_i = 1134.9\]
\[M_f = 1127.3\]

% Moisture = _____________ %

Report to the nearest 0.01%
### Rounding:

- When calculating, moisture content, binder content, and Cf, round to nearest 0.01%.

### Side note:

**Binder Content:** When comparing to specification, round binder content to nearest 0.1%.

---

### Moisture Testing Frequency:

- "Common Wisdom" as needed...
- High RAP/RAS mixtures especially prone to moisture.
- Rainy weather
- "Warm mix"
- New aggregate
- If plant operator reports burning more fuel to maintain temperature.
- Fluctuating volumetrics or binder contents
- Watering piles per DNR.
- Same stockpiles
- Dry weather
- No moisture when tested

---

### 2. Aggregate Burn Loss

**Aggregate Correction Factor:**

- To correct for loss of mass during the mix ignition due to aggregate burn-off.
- Determined during mix design by mix designer (usually QC).
- Re-determined if mix design changes (e.g. >5% change in stockpiled aggregate proportions).
- Re-determined if a different oven is used (QA or QC).
**CF Procedure:**

- Mix specimen in lab with dry aggregate at a known (actual) \% binder.
- Input “zero” for the $C_F$.
- Burn, obtain measured (apparent) \% binder.
- The difference between the measured and the actual \% binder is the Asphalt Binder Correction Factor ($C_F$).
- If the $C_F$ is > 1.0\%, re-determine at a lower temperature.

**Definitions:**

- $M$ = mass (g)
- $M_{i(dry)}$ = Mass of mix before burning, dry already.
- $M_f$ = Final mass of mix after burning (binder and some aggregate burned off).
- $(M_{i(dry)} - M_f) = $ Binder & aggregate burned off.
- $M_{agg} = $ Initial unburned mass of just the aggregate, dry.
- $(M_{i(dry)} - M_{i(agg)}) = $ Mix mass minus aggregate mass is the mass of binder, initially.

**$C_F$ Calculations:**

\[
C_F = \frac{M_{i(dry)} - M_f}{M_{i(dry)}} - \frac{M_{i(dry)} - M_{i(agg)}}{M_{i(dry)}}
\]

- The difference is the aggregate mass loss
- The Measured binder content can be from the oven ticket
- The Actual binder content can be from a bench scale
- If the $C_F$ is > 1.0\%, re-determine at a lower temp.
- Report to the nearest 0.1\%
Two types of Ovens

Infrared Oven

Convention Oven

Convection Oven Temperatures:

* **AASHTO:**
  - Normal: 538 °C (1000.4 °F)
  - High C_F’s (>1.0%): 482 °C (899.6 °F)

* **MoDOT:**
  - Normal: 538 °C (1000.4 °F)
  - High C_F’s: if >1.0% try 482 °C (899.6 °F)
  - Very high C_F’s: if >1.0% at 482 °C, use 427 °C
    Very high C_F’s: if >1.0% at (899.6 °F), use (800.6°F)

Cf Determination:

Number of Replicate Specimens

* Use two
  - If the difference in measured asphalt contents is > 0.15%, test two more replicates.
  - For the four replicates, discard the high and low results.
## Asphalt Binder Correction Factor

(Aggregate Correction Factor)

Data Sheet

<table>
<thead>
<tr>
<th>Sample</th>
<th>Lab No.</th>
<th>Date</th>
<th>Initials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Replicate</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Temperature</td>
<td>538</td>
<td>538</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tare (basket, etc.) Mass (g)</td>
<td>3000.0</td>
<td>3000.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Dry Mass (g)</td>
<td>5000.1</td>
<td>5005.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Initial Dry Specimen Mass (g)**

<table>
<thead>
<tr>
<th></th>
<th>2000.1</th>
<th>2005.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss in Weight (g)</td>
<td>125.2</td>
<td>126.1</td>
</tr>
<tr>
<td>%AC, measured = M</td>
<td>6.26</td>
<td>6.29</td>
</tr>
<tr>
<td>%AC, actual = A</td>
<td>6.00</td>
<td>6.01</td>
</tr>
<tr>
<td>%AC\text{diff} (M_1 - M_2)</td>
<td>0.03</td>
<td>&gt; 0.15%? If so, 2 more replicates</td>
</tr>
<tr>
<td>C_F = M - A</td>
<td>0.26</td>
<td>0.28</td>
</tr>
<tr>
<td>C_F Average</td>
<td></td>
<td>0.27</td>
</tr>
</tbody>
</table>

\[
\%AC, \text{measured} = \frac{\text{Loss in weight}}{\text{Initial Dry Mass}} \times 100
\]

Total Dry Mass – Tare Basket Mass = Initial Dry Specimen Mass
<table>
<thead>
<tr>
<th>Sample</th>
<th>Lab No.</th>
<th>Date</th>
<th>Initial Dry Specimen Mass (g)</th>
<th>Loss in Weight (g)</th>
<th>%AC, measured = M</th>
<th>%AC, actual = A</th>
<th>%AC_{diff} (M_1 - M_2)</th>
<th>C_F = M - A</th>
<th>C_F, average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicate</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>65.7</td>
<td>62.9</td>
<td>5.25</td>
<td>5.23</td>
<td>&gt; 0.15%? If so, 2 more replicates</td>
</tr>
</tbody>
</table>
Use of Cf:

• Before production, when Cf is the unknown:
  \[ \text{Cf} = \text{Measured Content} - \text{Actual Content} \]

• During production, when Actual Content is unknown:
  \[ \text{Actual} = \text{Measured Content} - \text{Cf} \]

Infrared Burn Profiles:

• “Default”
  Most mixes

• “Option 1”
  (Less) - For Cf > 1.0% e.g., RAP containing dolomite.

• “Option 2”
  (More) – Hard to burn mixes

RAP Aggregate Correction Factor:

(Asphalt Binder Correction Factor)

• Follow TM-77:
  • Assumes aggregate C_f for RAP aggregate is same as C_f for virgin aggregate.
  • Follow the standard procedure as if there was no RAP, i.e., use only the virgin aggregate, and only the binder content associated with the virgin aggregate portion when fabricating the specimen.
  • So, the Cf from the virgin materials test is used as the Cf for the whole mix.
### 3. Temperature Effects on Weighing Temperature Compensation Factor (TCF)

**Convection Oven:**
- Material “weighs” differently at elevated temperatures.
- Mass loss shown on the oven printout must be corrected.
- Oven calculates and prints the “Temperature Correction Factor (TCF)” for the particular test run.
- \( TCF = \text{Apparent loss in mass due to heating} \)

### Use of Temperature Correction Factor:

- When determining the Aggregate Correction Factor, if the oven printout is used for determination of the Measured Asphalt Content, include the Temperature Correction Factor (TCF).
- If all weighing is performed outside of the oven and specimen is cooled to room temperature, do not use the TCF.

### Second Generation Infrared oven:

- No Temperature Correction Factor
- **Anecdotal:** Scale is better insulated from the chamber.
**PROCEDURE FOR T308**

Determining the Asphalt Binder Content of Asphalt Mixtures by the Ignition Method

**Test Methods**

- Method A – Furnace with internal scale
- Method B – Furnace without internal scale

**SAMPLING/REHEATING**

EPG 403.1.5 Link: Engineering_Policy_Guide (modot.org)

**Sampling:**
- Obtain samples of Loose Mix according to AASHTO R97. (See Module 5 on Sampling)

**Reheating:**
- Place the box or bucket of sample in an oven 110 ± 5°C (230 ± 9°F) gently warm the sample until workable.
- Remove the sample from box or bucket.
Reducing:
- Reduce the sample per AASHTO R47 (see module 6) to amount listed on Table 1.
- Spread sample in a large pan or two.
  If needed, reheat the pan just until sample is workable. 110 ± 5°C (230 ± 9°F)

NOTE: Monitor the heating, do not leave sample in the oven too long.

<table>
<thead>
<tr>
<th>Mix</th>
<th>NMS, in.</th>
<th>Specimen Size, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP048 &amp; BP-3</td>
<td>#4</td>
<td>1200-1700</td>
</tr>
<tr>
<td>SP095</td>
<td>3/8</td>
<td>1200-1700</td>
</tr>
<tr>
<td>SP125, BP-1 &amp; BP-2</td>
<td>1/2</td>
<td>1500-2000</td>
</tr>
<tr>
<td>SP190 &amp; Bit Base</td>
<td>3/4</td>
<td>2000-2500</td>
</tr>
<tr>
<td>SP250</td>
<td>1</td>
<td>3000-3500</td>
</tr>
</tbody>
</table>

PROCEDURE
Method A
Using the Convection Oven
- Preheat the furnace to 538±5°C (1000±9°F), or use temperature determined by the correction factor.
- Enter the chamber set point.
At the bench...

- Record weight of empty basket assembly. (0.1g)
- Place ~ half of the mix in each basket.
- Use a spatula or trowel to level and move the mix about **one inch** away from the edges of the basket.

**Method A**

- Cool to room temp.
- Weigh the test specimen and basket on external bench scale. (0.1g)
- Calculate and record the initial weight of the sample.
- Record to nearest 0.1g

**Total weight_{total} = Empty Basket weight - Sample Weight_{initial}**

**Method A**

- Input the initial sample weight in whole grams into the ignition furnace controller.
- Enter the **asphalt correction factor (C_p)**.
- Reset the internal scale to zero.
• Put on safety gear.
• Open the chamber door and place the specimen basket with sample in the furnace.
  • Make sure basket is not touching the walls.
• Close the door.

Method A

• Verify that the specimen weight is displayed on the furnace scale equals the total mass$_{\text{initial}}$ weighed on bench scale ± 5 grams.
• Start the oven. "Burn"

Method A

• Oven will stop when burn is complete.
• Tare off ticket of burn results.
• Put on safety gear, open the door, carefully pull out the basket and place it on a cooling plate.
• Place a protective cage on top of the basket assembly.
• Allow to cool to room temperature. ~ 60min.
• Move the basket assembly with sample to a scale and record the total weight after ignition. (0.1g)

• Calculate and record the final weight of the specimen to nearest 0.1g

CALCULATION/REPORTING

• The furnace will calculate % binder based on the:
  • Original specimen weight entered
  • Total loss
  • Asphalt correction factor ($C_F$) that you entered.
  • “Temperature Compensation Factor” that the oven calculates = apparent loss in weight due to heating.
  • You must then correct (subtract) for moisture if started with a wet sample.
<table>
<thead>
<tr>
<th>Elapsed Time: 39:00</th>
<th>Temp Comp: 0.17%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Weight: 1270g</td>
<td>Calib. Factor: 0.26%</td>
</tr>
<tr>
<td>Weight Loss: 79.8g</td>
<td>Bitumen Ratio: 6.27%</td>
</tr>
<tr>
<td>Percent Loss: 6.28%</td>
<td></td>
</tr>
</tbody>
</table>

Calibrated Asphalt Ctn: 5.85%

| 38 | 494 | 79.6 | 6.29 |
| 37 | 495 | 79.7 | 6.27 |
| 36 | 495 | 79.5 | 6.27 |
| 35 | 497 | 79.3 | 6.24 |
| 34 | 499 | 79.1 | 6.22 |
| 33 | 503 | 78.7 | 6.19 |
| 32 | 506 | 78.2 | 6.17 |
| 31 | 509 | 77.7 | 6.11 |
| 30 | 513 | 77.1 | 6.07 |
| 29 | 516 | 76.2 | 6.00 |
| 28 | 519 | 75.4 | 5.93 |
| 27 | 521 | 74.5 | 5.86 |
| 26 | 524 | 73.5 | 5.78 |
| 25 | 526 | 72.2 | 5.68 |
| 24 | 528 | 70.8 | 5.57 |
| 23 | 529 | 69.5 | 5.47 |
| 22 | 530 | 68.0 | 5.35 |
| 21 | 531 | 66.4 | 5.22 |
| 20 | 531 | 64.8 | 5.19 |
| 19 | 532 | 63.2 | 4.97 |
| 18 | 536 | 59.6 | 4.69 |
| 17 | 556 | 59.3 | 4.66 |
| 16 | 556 | 59.0 | 4.64 |
| 15 | 537 | 58.2 | 4.58 |
| 14 | 539 | 56.9 | 4.48 |
| 13 | 546 | 54.8 | 4.31 |
| 12 | 563 | 50.9 | 4.00 |
| 11 | 612 | 45.9 | 3.45 |
| 10 | 640 | 34.1 | 2.68 |
| 9  | 556 | 22.1 | 1.74 |
| 8  | 459 | 11.7 | 0.92 |
| 7  | 439 | 5.3 | 0.41 |
| 6  | 433 | 4.0 | 0.31 |
| 5  | 427 | 2.9 | 0.22 |
| 4  | 420 | 2.0 | 0.15 |
| 3  | 414 | 1.4 | 0.11 |
| 2  | 409 | 0.9 | 0.07 |
| 1  | 411 | 0.5 | 0.03 |

Probable Ignition starts here.

You set, (Factory Default):
- Filter Set Pt: 750°C
- Chamber Set Pt: 538°C
- Temp Comp: 0.17%
- Calib. Factor: 0.26%
- Bitumen Ratio: 6.27%

You set, (Typically 538 C):
- Filter Set Pt
- Chamber Set Pt

Apparent loss of wt. due to heat: 0.17%

Aggregate Loss: you entered 0.26%

% AC by wt. of Aggregate: 6.27%

% AC by wt. of Mix:
- 5.85%
- 6.28%
- -0.17
- -0.26

3 consecutive readings w/in 0.01% loss.
**ASPHALT CONTENT IGNITION METHOD (AASHTO T 308-10) METHOD A**

Reproducing Oven Ticket Values

Revised 12-9-15

*If \( w_i \) = wet

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Job No.</th>
<th>Route</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technician</th>
<th>Date</th>
<th>Sublot No.</th>
<th>Mix No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Empty Basket Assembly Weight (g), \([T_e]\)
  - 3000.2

- Basket Assembly + Wet (or dry) Sample Weight (g), \([T_i]\)
  - 4270.2

- Wet (or dry) Sample Weight (g), \([W_i = (T_i - T_e)]\)

- Loss in Weight (g), \([L]\) (from tape)

- Total % Loss, \([P_L = (L / W_i) \times 100]\)

- Temperature Compensation (%), \([C_{tc}]\) (from tape)

- % AC, uncorrected, \([P_{bu} = P_L - C_{tc}]\)

- Aggregate Correction (Calibration) Factor (%), \([C_r]\) (from tape)

- Calibrated %AC (from ignition oven tape), \([P_{bcal} = P_{bu} - C_r]\)

- % Moisture Content, \([MC]\) (previous test)*
  - 0.13

- % AC, corrected (by weight of mix), \([P_b = P_{bcal} - MC]*\)
### Asphalt Content Ignition Method

**Method A**

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty Basket Assembly Weight (g)</td>
<td>3000.2</td>
</tr>
<tr>
<td>Basket Assembly + Wet (or dry) Sample Weight (g)</td>
<td>4270.2</td>
</tr>
<tr>
<td>Wet (or dry) Sample Weight (g)</td>
<td>1270.0</td>
</tr>
<tr>
<td>Loss in Weight (g) (from tape)</td>
<td>79.8</td>
</tr>
<tr>
<td>Total % Loss, ( P_L = \frac{L}{W_i} \times 100 )</td>
<td>6.28</td>
</tr>
<tr>
<td>Temperature Compensation (%), ( C_{tc} ) (from tape)</td>
<td>0.17</td>
</tr>
<tr>
<td>% AC, uncorrected, ( P_{bu} = P_L - C_{tc} )</td>
<td>6.11</td>
</tr>
<tr>
<td>Aggregate Correction (Calibration) Factor, ( C_f ) (from tape)</td>
<td>0.26</td>
</tr>
<tr>
<td>Calibrated % AC (from ignition oven tape), ( P_{bc} = P_{bu} - C_f )</td>
<td>5.85</td>
</tr>
<tr>
<td>% Moisture Content, ( MC ) (previous test)*</td>
<td>0.13</td>
</tr>
<tr>
<td>% AC corrected by weight of mix, ( P_{bc} = P_{bc} - MC )</td>
<td>5.72</td>
</tr>
</tbody>
</table>

### Asphalt Binder Correction Factor

(Formerly Aggregate Correction Factor) Calculation

If final weighing is performed on bench top scale, calculation:

\[
P_b = \left( \frac{M_i - M_f}{M_i} \times 100 \right) - C_f - MC
\]

Where:
- \( M_i \) = initial weight of mix, wet or dry
- \( M_f \) = final mass of mix
- \( MC \) = % moisture
- \( C_f \) = Asphalt Binder Correction Factor
  (old Aggregate Correction Factor)

Method A

---

**Enlarged**
**PROCEDURE Method B**

- Note the special heat resistant shirt.

*Use SAFETY gear!*

Dr. Richardson

---

**Method B - No internal scale – Manual Weigh**

- Weigh out specimen.
- Burn for about 45 minutes.
- Remove, cool, weigh.
- Burn for another 15 minutes.
- Remove, cool, weigh.
- Keep repeating the 15-minute burn intervals until 2 consecutive mass weighings do not change by > 0.05%.
- Subtract moisture % if necessary.

---

**Information needed for the report:**

- Moisture = 0.05%
- \( C_f = 0.22\% \)
- Initial wet mass = 5400.2 g
- Final burned mass (after cooling to room temperature) = 5256.2 g
### SUPERPAVE MIXTURE PROPERTIES

<table>
<thead>
<tr>
<th>SUBLOT</th>
<th>ROUTE</th>
<th>MIX NO.</th>
<th>#VALUE!</th>
<th>LOT NO.</th>
<th></th>
</tr>
</thead>
</table>

#### TECHNICIAN

**Nuclear gage**

<table>
<thead>
<tr>
<th>SUBLOT</th>
<th>ROUTE</th>
<th>MIX NO.</th>
<th>#VALUE!</th>
<th>LOT NO.</th>
<th></th>
</tr>
</thead>
</table>

#### TECHNICIAN

**Ignition oven**

<table>
<thead>
<tr>
<th>SUBLOT</th>
<th>ROUTE</th>
<th>MIX NO.</th>
<th>#VALUE!</th>
<th>LOT NO.</th>
<th></th>
</tr>
</thead>
</table>

---

**AASHTO T 209**

A = Wt. of sample:

| A | 1594.4 |

A2 = Wt. of sample (dry-back):

| A2 | 7472.2 |

D = Wt. of flask filled with water:

| D | 9066.6 |

X = A + D (A2 used in lieu of A for dry-back)

| X | 8421.5 |

E = Wt. of flask filled with water and sample:

| E | 645.1 |

Y = X - E

| Y | 2.472 |

Gmm = MAX. SPECIFIC GRAVITY = A / Y

| Gmm | 2.472 |

---

**AASHTO T 166**

TECHNICIAN

MOLDING TEMPERATURE

A = Weight of sample in air:

| A | 4867.8 |

B = Weight of sample in water:

| B | 2801.9 |

C = Weight of surface dry sample:

| C | 4880.4 |

Gmb = BULK SP. G. = A / (C-B)

| Gmb | 2.342 |

A = Weight of sample in air:

| A | 4899.1 |

B = Weight of sample in water:

| B | 2814.5 |

C = Weight of surface dry sample:

| C | 4911.9 |

Gmb = BULK SP. G. = A / (C-B)

| Gmb | 2.336 |

AVG. Gmb

| AVG. Gmb | 2.339 |

---

**MoDOT TM54 (NUCLEAR)**

SAMPLE WEIGHT

BACKGROUND

COUNTS

GAUGE % AC

| GAUGE % AC | 5.35 |

NUCLEAR OR IGNITION

% MOISTURE

| % MOISTURE | 0.12 |

% AC BY IGNITION OR NUCLEAR

| % AC BY IGNITION OR NUCLEAR | 5.2 |

---

**AASHTO T 308 (IGNITION)**

| A = Gmm (FIELD) | 2.472 |

B = Gmb (FIELD) (Avg.)

| B | 2.339 |

C = Gspb (Job Mix)

| C | 2.557 |

D = Ps = Percent Agg. in mix

| D | 94.8 |

VMA = 100 - (B X D / C)

| VMA | 13.3 |

Va = 100 X ((A - B) / A)

| Va | 5.4 |

VFA = (VMA-Va) / VMA

| VFA | 59 |

---

**AASHTO T 166**

TECHNICIAN

| A = Weight of sample in air: | 1255 |

B = Weight in water:

| B | 710 |

C = Weight of surface dry sample:

| C | 1260 |

Gmc = CORE SPECIFIC GRAVITY = A / (C - B)

| Gmc | 2.282 |

Gmm = MAX. SPECIFIC GRAVITY (T209)

| Gmm | 2.472 |

% COMPACTION OF CORE = 100 x (Gmc / Gmm)

| THICKNESS | 92.3 |

---

**FOR 2ND CORE SUBLOT WHEN DENOTED IN QC PLAN**

TECHNICIAN

| A = Weight of sample in air: | |

B = Weight in water:

| B | |

C = Weight of surface dry sample:

| C | |

Gmc = CORE SPECIFIC GRAVITY = A / (C - B)

| Gmc | |

Gmm = MAX. SPECIFIC GRAVITY (T209)

| Gmm | |

% COMPACTION OF CORE = 100 x (Gmc / Gmm)

| THICKNESS | |

---
**Reporting binder content of mix**

**Binder Portion**

<table>
<thead>
<tr>
<th>TECHNICIAN</th>
<th>MOIST THERM NUCLEAR</th>
<th>SAMPLE WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>Counts</td>
<td></td>
</tr>
<tr>
<td>GAUGE % AC</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>GAUGE % WC</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>NUCLEAR OR IGNITION</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>% AC BY IGNITION OR NUCLEAR</td>
<td>5.2</td>
<td></td>
</tr>
</tbody>
</table>

**Binder content of RAP**

**RAP Binder Content**

- *Per Spec 403.19.3*: RAP binder content must be determined.
- *QC*: 1 per 4 sublots
- *QA*: 1 per project
- *T164* (solvent extraction)
- Can use *T308* (ignition) if a correction factor is determined which is the difference between T164 & T308 (best to use your own oven when T164 is determined by another lab).
## Binder Portion

<table>
<thead>
<tr>
<th>TECHNICIAN</th>
<th>MoDOT TM54 (NUCLEAR)</th>
<th>SAMPLE WEIGHT</th>
<th>BACKGROUND</th>
<th>COUNTS</th>
<th>GAUGE % AC</th>
<th>AASHTO T 308 (IGNITION)</th>
<th>GAUGE % AC</th>
<th>NUCLEAR OR IGNITION</th>
<th>% MOISTURE</th>
<th>% AC BY IGNITION OR NUCLEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.35</td>
<td></td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.2</td>
<td></td>
</tr>
</tbody>
</table>
Some contractors stockpile RAP & RAS, prepare (grind) it, and sample it. Send sample to a commercial lab to have extractions run (T164), obtain binder content & gradation. This is what is submitted to MoDOT during mix design. During production, RAP is sampled, and ignition oven used to get binder content & gradation.

MoDOT allows gradation sample testing to be satisfied by using the residue from the HMA ignition oven sample. An aggregate (gradation) correction factor (AGCF) may be necessary to account for the breakdown in rock. RAP gradation in the field is determined with ignition oven.

Not recommended to use T308 on RAS (too dangerous). Fan will suck fines out. Use extraction to get gradation or use the standard gradation.
**Aggregate Gradation**

**RAS Gradation**

- Ground to minus 3/8 inch.
- Gradation from solvent extraction, or assumed from table:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>100</td>
</tr>
<tr>
<td>#4</td>
<td>95</td>
</tr>
<tr>
<td>#8</td>
<td>85</td>
</tr>
<tr>
<td>#16</td>
<td>70</td>
</tr>
<tr>
<td>#30</td>
<td>50</td>
</tr>
<tr>
<td>#50</td>
<td>45</td>
</tr>
<tr>
<td>#100</td>
<td>35</td>
</tr>
<tr>
<td>#200</td>
<td>25</td>
</tr>
</tbody>
</table>

---

**Aggregate Gradation**

**Mix Gradation Samples**

- When determining the aggregate (gradation) correction factor (AGCF), prepare an aggregate blank (no binder) specimen.
- Do a washed gradation analysis (AASHTO - T 30 Test for Mechanical Analysis of Extracted Aggregate) of the blank.
- Do a washed gradation analysis of the burned HMA specimen (T 30): Two replicates.
**Gradation Samples**
Burned and Unburned
Plus #200 Portion

- Determine a difference for each sieve, each replicate, say, for the #4 sieve:
  
  
  \[
  (\% - \#4)_{\text{blank}} - (\% - \#4)_{\text{burned, replicate #1}}
  \]

  
  \[
  (\% - \#4)_{\text{blank}} - (\% - \#4)_{\text{burned, replicate #2}}
  \]

- Calculate the average difference for that sieve (#4).
- The difference is called the AGCF for #4 sieve material.

---

**Gradation Samples**
Burned and Unburned
Plus #200 Portion

- If the difference on any sieve exceeds the allowable (see below), then each sieve must have its own AGCF applied to the result.

**Allowable differences:**

- \( \geq \#8 \): \( \pm 5.0\% \)
- \( \geq \#200 \) to \(< \#8 \): \( \pm 3.0\% \)
- \( \leq \#200 \): \( \pm 0.5\% \)

---

**Gradation Samples**
Passing the #200 Portion

- If only the #200 sieve exceeds the limit, apply the AGCF only to the #200 sieve.

---
Example
Adapted From FHWA “Addendum T308”

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Burned Rep#1</th>
<th>Burned Rep#2</th>
<th>Unburned Blank</th>
<th>Rep#1 Diff</th>
<th>Rep#2 Diff</th>
<th>Avg Diff</th>
<th>Avg Diff=AGCF</th>
<th>Allowable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>±5.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>¾ &quot;</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>±5.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>86.5</td>
<td>89.5</td>
<td>89.7</td>
<td>3.2</td>
<td>0.2</td>
<td>1.7</td>
<td>±5.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>69.3</td>
<td>72.1</td>
<td>70.4</td>
<td>1.1</td>
<td>-1.7</td>
<td>-0.3</td>
<td>±5.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>#4</td>
<td>52.1</td>
<td>55.6</td>
<td>53.9</td>
<td>1.8</td>
<td>-1.7</td>
<td>0.1</td>
<td>±5.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>#8</td>
<td>38.5</td>
<td>42.3</td>
<td>41.0</td>
<td>2.5</td>
<td>-1.3</td>
<td>0.6</td>
<td>±3.0</td>
<td>±3.0</td>
</tr>
<tr>
<td>#30</td>
<td>32.7</td>
<td>37.0</td>
<td>34.4</td>
<td>1.7</td>
<td>-2.6</td>
<td>-0.5</td>
<td>±3.0</td>
<td>±3.0</td>
</tr>
<tr>
<td>#60</td>
<td>16.1</td>
<td>17.9</td>
<td>18.3</td>
<td>2.2</td>
<td>0.4</td>
<td>1.3</td>
<td>±3.0</td>
<td>±3.0</td>
</tr>
<tr>
<td>#200</td>
<td>6.8</td>
<td>7.4</td>
<td>7.1</td>
<td>0.3</td>
<td>-0.3</td>
<td>0.0</td>
<td>±0.5</td>
<td>±0.5</td>
</tr>
</tbody>
</table>

For #4 sieve:
Rep#1: 53.9-52.1 = 1.8
Rep#2: 53.9-55.6 = -1.7
Avg diff = [(1.8 + (-1.7))/2] = 0.05 = 0.1 (rounded)
Compare to ±5.0: 0.1 < 5.0 OK

Common Testing Errors of Non-Comparison/Early Shut-off

• Starting test when oven is cold: incomplete burn; can affect TCF.
• Neglecting to push “Start” (binder burns but is not recorded).
• Not cleaning oven & vents often enough.
  • Tip: Perform “Lift” test regularly to verify clean oven.
• Using vent pipe less than 4 in, diameter.
• Asphalt correction factor ($C_F$) not used.
• Not cleaning baskets.
• Allowing scale plate or support tubes to rub.
• Not spreading specimen out.
• Not tearing off ticket before opening oven door.
• Allowing door to not latch correctly.
• Not correcting for moisture (e.g., when plant speed increases, etc.).
Example
Adapted from FHWA “Addendum T308”

For #4 sieve:

Rep#1: 53.9 - 52.1 = 1.8

Rep#2: 53.9 - 55.6 = -1.7

Avg diff = [1.8 + (-1.7)] / 2 = 0.05 = 0.1 (rounded)

Compare to ±5.0: 0.1 < 5.0 OK
Common Testing Errors

- Using an oversize specimen.
- Not using the same size specimen for asphalt correction factor ($C_F$) determination and all production tests.
- Using a plant-made specimen instead of a lab-made specimen for ($C_F$) determination.
- Not double-checking specimen weight on oven scale against exterior scale weight.

Common Testing Errors

- Materials used for ($C_F$) determination not the same as project materials.
- Inaccurate asphalt contents used for ($C_F$) determination.
- QA & QC starting with different temperature specimens.
- Door left open too long between loadings.
- Wrong chamber set point.
- Wrong burn profile.
- Weighing on bench balance when specimen is hot.

Operation Problems

- **Oven won't shut itself off**—it's OK to manually shut off as long as 3 consecutive readings show less than 0.01% loss, and the sample appears to be completely burned (EPG 403.1.5).
**Premature Burn Stop**

- Vibrations
- Basket or strap up against wall or top of chamber.
- Clogged port

More information on Binder Ignition in the Appendix item #5.

---

**Incomplete Burn Pattern: Shingle Mix**

---

**Soot**

---
Coke
**AASHTO T 308: Asphalt Content by Ignition; Method A**

<table>
<thead>
<tr>
<th>Trial#</th>
<th>1</th>
<th>2</th>
<th>R</th>
</tr>
</thead>
</table>

### Pre-Production Oven Parameters Checklist: *(Demonstrate oven setup)*

Input required parameters for routine production of a particular mix:

1. Enter TEMP setpoint [chamber temperature]
2. Enter CALIB. FACTOR [binder (aggregate) correction factor]

### Routine Production Ignition Oven Procedure: *(Demonstrate test procedure with proctor instruction)*

3. Obtain weight of empty basket assembly
4. Place \( \frac{1}{2} \) of hotmix sample in each basket; move mix \( \frac{3}{4} '' \) away from sides; re-assemble basket. Cool to room temperature.
5. Obtain total weight of sample plus basket then calculate initial weight of hotmix sample
6. Enter initial sample WEIGHT
7. Zero oven scale (push the number 0)
8. After putting on safety gloves, face shield, etc., carefully load sample into oven, making sure basket is not touching walls; close door
9. Check total weight: oven vs. exterior scale: No good if > 5 grams difference: Is it?
10. Initiates burn-off program by pressing START/STOP
11. After burn-off stops, remove and examine paper readout
12. Again, with safety gear on, open oven door, remove basket & place on cooling rack. Cool to room temperature.
13. Determine and record basket + specimen weight, then calculate and record final specimen weight (for manual calculations and/or verification of %AC).
14. Obtain Calibrated %AC through calculations *(NOTE: in the field, this value will automatically be on the printout tape)*
15. Correct the Calibrated %AC for moisture

<table>
<thead>
<tr>
<th>PASS?</th>
<th>FAIL?</th>
</tr>
</thead>
</table>

Proctor ___________________________ Date ___________________
Reviewer _________________________ Date ___________________
Module 10

Job Mix Formula
(J MF)
MODULE 10

JOB MIX FORMULA SHEET (JMF)
JMF Virgin Aggregate Information

- Product Ident. Number
- Product Code
- Producer Location
- Bulk SP. (Specific) GR. (Gravity)
- Apparent SP. GR.
- %ABS (Absorption)
- Formation
- Ledges
- %Chert

JMF Virgin Aggregate Information

- Each mix design is acceptable for use for a three year period.
- Ledge information is generally updated annually by the aggregate producer and MoDOT.
- If the product remains close (ledge is same, gravity, absorption, etc.), acceptable to use JMF information.
### Binder and Additive Information

- Product Ident. Number
- Product code
- Producer Location
- Bulk SpGr
- PG Grade
- Molding Temperature

### Binder and Additive Information

- Additives such as Warm Mix additives, Rejuvenators, Fibers are shown in this area.
- Name of product
- Supplier
- Rate of incorporation
JMF
Weighted and Combined Gradations

This area contains the weighted gradation of each fraction based on its bin percentage. The combination of these yields the combined mix gradation.

JMF
Target Mix Characteristics

- $G_{mm}$ from mix design phase (Rico).
- $G_{mb}$ from mix design phase (Puck).
- $G_{sb}$ Calculated from the combined weighted aggregate bulk gravities.
JMF
Target Voids, VMA and VFA

- Voids Specified.
- VMA and VFA generated during the mix design phase adhering to specifications.
JMF
TSR, Dust/Binder, Specimen Weights

- TSR results from the design phase.
- Dust to Binder ratio (limited by specification).
- Specimen weights for pucks:
  - ND (approx. 115mm)
  - TSR (95mm)

JMF
Gyration Levels

- Number of Gyration levels for:
  - Ni
  - Nd
  - Nmax

Volumetric pucks are made to Nd during production.

LG mixes only specify Nd gyrations.
Mix Composition

* Percentages of Aggregate and AC are in this area. If RAP and/or FAS are being used, then the percentage of virgin AC along with the Total AC are provided.
## Aggregate & Mixture Properties Based on Contractor's Mix Design

### AASHTO T312

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>IDENT #</th>
<th>21CDMAC001</th>
<th>21CDMAC002</th>
<th>21CDMAC003</th>
<th>21CDMAC004</th>
<th>21CDMAC005</th>
<th>21CDMAC006</th>
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<td>/ Hard Rock Co., Little Town, MO</td>
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<td>2.693</td>
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<td>100204..LD1</td>
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<td>RAP</td>
<td>4.9% AC</td>
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<tr>
<td>21CDMAC006</td>
<td>1002..SHGL</td>
<td>/ My Asphalt Paving Co., Our Town, MO</td>
<td>2.600</td>
<td>2.600</td>
<td>1.9</td>
<td>SHINGLES</td>
<td>26.3% AC</td>
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</tbody>
</table>

### Mix Composition

<table>
<thead>
<tr>
<th>LABORATORY</th>
<th>Gmm</th>
<th>TSR Wt.</th>
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</thead>
<tbody>
<tr>
<td>Stick to It</td>
<td>0.75% BY WT OF AC</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>CHARACTER/STCS</th>
<th>Gmb</th>
<th>V. M. A.</th>
<th>-200/AC</th>
<th>Ndes</th>
<th>MIN. AGG.</th>
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<td>PG46-34</td>
<td>1.035</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gyrö Mold Temp. 270-280°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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</table>

<table>
<thead>
<tr>
<th>AASHTO T312</th>
<th>Gm</th>
<th>TSR Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.599</td>
<td>47.10</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>VIRGIN ASPHALT CONTENT</th>
<th>2.7%</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>CALIBRATION NUMBER</th>
<th>MASTER GAUGE BACK CNT.</th>
<th>X.XXXXXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST</td>
<td>A1 = -X.XXXXXX</td>
<td>ASPHALT CONTENT W/ RAP AND SHINGLES</td>
</tr>
<tr>
<td>SECOND</td>
<td>A2 = X.XXXXXX</td>
<td></td>
</tr>
</tbody>
</table>

- **New Product, This Town, USA**
- **Hot Oil Co., Seaport, LA**
- **My Asphalt Paving Co., Our Town, MO**
- **Hard Rock Co., Little Town, MO**
- **Stick to It**
Module 11

Pay Factors
## Pay Factors

- What % of the lot is within spec limits?
- Pay Factors are based on this

### Spec Limits

<table>
<thead>
<tr>
<th>Factor</th>
<th>Spec Limit</th>
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<tbody>
<tr>
<td>Air voids</td>
<td>4.0 ± 1.0 %</td>
</tr>
<tr>
<td>VMA</td>
<td>-0.5 to +2.0%</td>
</tr>
<tr>
<td></td>
<td>Applied to min. design</td>
</tr>
<tr>
<td></td>
<td>VMA: 12.0, 13.0, 14.0</td>
</tr>
<tr>
<td>Binder content</td>
<td>Design ± 0.3 %</td>
</tr>
<tr>
<td>Density</td>
<td>94.5 ± 2.5 %</td>
</tr>
<tr>
<td>Density (SMA)</td>
<td>≥ 94.0 %</td>
</tr>
</tbody>
</table>
Pay Factors

- Pay Factors (PFs) are numbers that you multiply times the contract unit price to adjust for quality.
- PFs are either incentives or disincentives.

Pay Factors

- Incentive:
  PF is over 100%: Say unit price is $43.50 per ton and PF is 105% on a 4000-ton lot: adjusted price is:

  \[(1.05-1.00)(\$43.50)(4000) = 8700\]

Pay Factors

- Disincentive:
  PF is less than 100%:
    Say PF = 80%

  Adjusted price =
  \[(0.80-1.00)(\$43.50)(4000) = -34,800\]
QLA Pay Factors

- **QLA** = Quality Level Analysis
- **PFs** = Pay Factors

- QLA PFs are calculated for each lot, say 3000 tons of mix.
- Next lot, new PFs.

Pay Factors (PFs)

Pay Factors

Lot:

- $G_{db}$
- $G_{mm}$
- $P_t$
- $G_{nc}$
- $V_{air}$
- VMA
- $P_v$
- $P_d$
- $G_{nc}$
- $V_{air}$
- VMA
- $P_v$
- $P_d$
- $G_{nc}$
- $V_{air}$
- VMA
- $P_v$
- $P_d$
- $G_{nc}$
- $V_{air}$
- VMA
- $P_v$
- $P_d$

Pay Factors

QLA Pay Factors

- The overall $PF_t$ for the lot is the average of (usually) 4 PFs:
  1. $PF_{air}$ voids (Va)
  2. $PF_{VMA}$
  3. $PF_{binder content}$ (Pt)
  4. $PF_{mat density}$

\[
PF_t = \frac{PF_{AC} + PF_{Va} + PF_{VMA} + PF_{Dens}}{4}
\]
QLA Pay Factors

- Each subplot is sampled, (50 lbs. of loose mix behind the paver and 1 core sample from the compacted mat).
- Each loose mix sample is tested for air voids, VMA, and binder content.
- Each core is tested for density.
- There must be at least 4 sublots per lot.

QLA Pay Factors

- So now, for a given lot, you have 4 air void values, 4 VMA's and so forth.
- Average the 4 values of each test parameter.
- Average = "mean" = \( \bar{x} \)

QLA Pay Factors

- Calculate the variability of the 4 values of each parameter, say air voids.
- The measure of variability is called the "Standard deviation" (S).
Standard Deviation

- Standard deviation:
  \[ S = \sqrt{\frac{\sum((x_i - \bar{x})^2)}{n-1}} \]
  
  \( x_i \) = Each test value  
  \( \bar{x} \) = Mean  
  \( n \) = Number of test values  
  (usually = number of sublots)

QLA Pay Factors

- So now you have the average (mean) and standard deviation for voids, for VMA, for binder content, and for density for a certain lot:
  \( \bar{x}_{\text{air}}, S_{\text{air}} \)  
  \( \bar{x}_{\text{VMA}}, S_{\text{VMA}} \)  
  \( \bar{x}_{\text{AC}}, S_{\text{AC}} \)  
  \( \bar{x}_{\text{dens}}, S_{\text{dens}} \)

QLA Pay Factors

- PFs are based on the quality of the mix:  
  - How close to the target is the average value of the lot.  
  - How much variability is there between the 4 subplot values. (How large is the S)
  - So, to get a high pay factor, you want low variability—you want **CONSISTENCY**!
Consistency of Mix

- Consistent gradation
- Consistent baghouse fines feed
- Consistent binder content
- Consistent temperature
- Consistent cleanliness:
  - Low deleterious materials
  - High sand equivalent
- Consistent construction operations

QLA Pay Factors

- QLA PFs are part of the overall statistically-based Quality Level Analysis (QLA) program as specified in Section 403, Standard Specs.
- Samples must be obtained in a random (unbiased) manner.

QLA Pay Factors

- PFs are based on how much of the lot is within the spec limits: "Percent Within Limits (PWL)".
**Quality Index (Q)**

\[
Q_U = \frac{USL - \bar{X}}{S} \\
OR \\
Q_L = \frac{\bar{X} - LSL}{S}
\]

**X = Mean**

**Note:**
You want a High "Q" 
And a Lower "S"

---

**Basis for PWL'S**

- No matter what you are testing, if you keep sampling and testing batch after batch of the "same stuff" you will not get the same answer each time. There will be some variability due to variability in the material, sampling methods, and testing procedures.

---

**The Normal Distribution is the most important for highway materials**
USL and LSL

- When producing materials, we would like 100% of all the material to be within the specifications. Usually, we have a target value, and we place a tolerance around it, e.g., target asphalt content ± 0.3%.
- **Lower Spec Limit (LSL) =** Target value - 0.3%
- **Upper Spec Limit (USL) =** Target value + 0.3%

Acceptable Product

Percent Within Limits

- When the average ("mean") of the test data for the lot is close to the LSL or USL, and if there is a large variability in the data, it is likely that some of the material is out-of-spec.
- We would like to estimate the percent of the total material that is out (or how much is in-spec) and let the payment for material reflect this fact.
Unacceptable Product

Percent Within Limits

- So, we need to calculate the area (probability) under the curve that is between the USL and the LSL.
- This is called the "Percent Within Limits (PWL)"

Percent Within Limits

- Every set of test results (every lot) will result in a different probability distribution, therefore a different curve.
- It is difficult to calculate the area (probability) under each curve.
- There is a method to convert any curve to a standard curve, with various areas under the curve already worked out.
Percent Within Limits

* The areas under the standard curve (probabilities) are published in a table called the "Quality Index" table. (502.15.8)
* To obtain the probability value from the Q-table, you must use your curve's statistical characteristics: mean (x) and standard deviation (S) to calculate Q.

Quality Index (Q)

\[ Q_L = \frac{X - LSL}{S} \]

or

\[ Q_U = \frac{USL - X}{S} \]
<table>
<thead>
<tr>
<th>QUALITY INDEX</th>
<th>PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Q₁₀ or Q₁₁)</td>
<td>n=3</td>
</tr>
<tr>
<td>0.41</td>
<td>61.56</td>
</tr>
<tr>
<td>0.42</td>
<td>61.85</td>
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<tr>
<td>0.43</td>
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<td>62.44</td>
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<td>0.47</td>
<td>63.34</td>
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<td>75.15</td>
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<tr>
<td>0.83</td>
<td>75.54</td>
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</tbody>
</table>
Percent Within Limits

* First you get the area (probability) under the curve above the LSL, then the area (probability) below the USL, then combine them for the total area under the curve between the USL and the LSL. This is the Total Percent Within Limits.

Percent Within Limits

* Knowing the $Q_L$, enter the Q-table and obtain the corresponding $PWL_L$ (percent of the area above the LSL)
* Likewise, knowing the $Q_U$, enter the Q-table and obtain the corresponding $PWL_U$
* Combine the 2 PWL's:
  $$PWL_T = (PWL_U + PWL_L) - 100$$
Percent Within Limits

- Let's examine 2 different operations.
- Lot 2's mean is crowding the Lower Spec Limit much closer than the data in lot 1, but there is much less variability in the data of lot 2. The area (probability) in the left-hand tail is equal under both curves.

Percent Within Limits

- So, even though lot 2's mean was lower than that of lot 1, lot 2 had the same PWL because it had less variability (taller, slenderer curve).
- The smaller the standard deviation, the slenderer the curve.
- This illustrates that consistency of results is very important.
QLA Pay Factors

- For each lot, each test parameter (air voids, VMA, binder content, density) will have its own curve (based on 4 or more sublot test values).
- A separate PF for each test parameter will be calculated, as follows.

QLA Pay Factors

- If PWL_L < 70%:
  \[ PF = 2(PWL_L) - 50 \]
- If PWL_L \( \geq 70\%\):
  \[ PF = 0.50(PWL_L) + 55 \]

QLA Pay Factors

- The PFs for each test parameter are then averaged to obtain the total PF_T:

  **For the traveled way:**
  \[ [PF_{AC} + PF_{Ya} + PF_{VMA} + PF_{Dens}] \div 4 \]

  **For non-integral shoulders:**
  \[ [PF_{AC} + PF_{Ya} + PF_{VMA}] \div 3 \]
QLA Pay Factors

- So, back to our original example, if the average of the 4-test parameter PFs is 105%, then the contract price of $43.50 per ton per 4000-ton lot is adjusted by:

\[(1.05-1.00)(4000)(\$43.50) = \$8700\]

The maximum PF is **105%**.

Example

- See handout of MoDOT spreadsheet.
- The Q table is in Section 403, Standard Specifications (Link to 502.15.8).
- Note: density is now 94.5 ± 2.5%.
EQUATIONS:

\[ V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100 \quad P_s = 100 - P_b \quad VMA = 100 - \left( \frac{G_{mb} \times P_s}{G_{slb}} \right) \]

\[ VFA = \frac{VMA - V_a}{VMA} \times 100 \quad \text{Density} = \frac{G_{mc}}{G_{mm}} \times 100 \]

MEAN:

\[ \bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \]

Example: \( n = \) number of samples = 3 \quad \text{Therefore:} \quad \bar{x} = \frac{x_1 + x_2 + x_3}{3} \]

STANDARD DEVIATION:

\[ s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1}} \]

Therefore: \[ s = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + (x_3 - \bar{x})^2}{2}} \]

USL = Target + Tolerance \quad LSL = Target - Tolerance

\[ Q_U = \frac{USL - \bar{x}}{s} \quad Q_L = \frac{\bar{x} - LSL}{s} \]

PWLT = (PWLU + PWLL) - 100

Pay Factor (PF):

IF: PWLT < 70% \quad \text{THEN:} \quad PF = 2(PWLT) - 50

IF: PWLT ≥ 70% \quad \text{THEN:} \quad PF = 0.50(PWLT) + 55

QA to QC Comparison:

\[ [Q_{Cavg} - 2(s)] \leq QA_{avg} \leq [Q_{Cavg} + 2(s)] \]

OUTLIERS:

Highside: \[ t = \frac{x_{max} - \bar{x}}{s} \]

Lowside: \[ t = \frac{\bar{x} - x_{min}}{s} \]
# MoDOT Pay Factor Spreadsheet

## Pay Factor 5.01 7/6/20

**MoDOT Pay Factor Spreadsheet**

### Contract: 0  Route: 0  County: 0  Mix #: SP190

<table>
<thead>
<tr>
<th>JOB MIX</th>
<th>DENSITY</th>
<th>ASPHALT CONTENT</th>
<th>VMA</th>
<th>AIR VOIDS</th>
<th>Gm</th>
<th>% AC</th>
<th>% MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>94.0</td>
<td>5.2</td>
<td>13.0</td>
<td>4.0</td>
<td></td>
<td>5.2</td>
<td>94.8</td>
</tr>
<tr>
<td>B</td>
<td>92.0</td>
<td>5.2</td>
<td>12.8</td>
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**QA1:** 92.5  5.2  13.0  3.8  
**QA2:** 95.5  5.5  13.8  3.4  
**QA3:** 96.8  5.6  13.0  3.6  
**QA4:**  
**QA5:**  
**QA6:**

### QC TSR DATA*

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* TSR results and pay adjustment for tonnage represented based on requirement of one test per 10,000 tons or fraction thereof. This is applied separately from the PWL pay adjustment.

### TOTAL PAY FACTOR: 84.2

**UNCONF. JOINT FACTOR= 90  TONS / SQ YD OF SUBLOTS WITH UNCONF. JOINT**

| PWLU | 100.00 |
| PWLl | 100.00 |
| PWLT | 100.00 |
| PAY FACT. | 105.00 |

### TOTAL $ VALUE OF ADJUSTMENT: $21,330.00
Traveled Way Lot Testing Results

QC/QA TEST RESULTS BY SUBLOTS

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| QA1     | 92.5    | 5.2             | 13.0 | 3.8       |
| QA2     | 92.5    | 5.5             | 13.8 | 3.4       |
| QA3     | 94.0    | 5.6             | 13.0 | 3.8       |
| QA4     |         |                 |      |           |
| QA5     |         |                 |      |           |
| QA6     |         |                 |      |           |

| AVE. X  | 92.87   | 5.22            | 13.22 | 3.42      |
| STD. DEV.| 0.57    | 0.46            | 0.64  | 0.44      |

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<th>14.5 - 11.9</th>
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| 1       | 4        | 4          | 4           | 4         |
| Qu      | 5.49     | 0.61      | 2.78        | 3.59      |
| Qi      | 1.53     | 0.70      | 1.13        | 0.95      |

| PWLu    | 100.00   | 70.33     | 100.00      | 100.00    |
| PWLI    | 100.00   | 73.33     | 87.67       | 81.67     |
| PWlt    | 100.00   | 43.66     | 87.67       | 81.67     |

| PAY FACT. | 105.0 | 37.3 | 98.8 | 95.8 |

TOTAL PAY FACTOR= 84.2

UNCONF. JOINT FACTOR= 90 TONS / SQ YD OF SUBLOTS WITH UNCONF. JOINT = 3000

Superpave Module 11 Traveled Way Lot Testing Results
### Sublot Calculations

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**Ave = 92.87%**  
**Std. Dev. = 0.57**

**USL = 94.0 + 2.0% = 96.0%**  
**LSL = 94.0 - 2.0 = 92.0%**

\[
\begin{align*}
Qu &= \frac{USL - \bar{X}}{S} \\
&= \frac{96.0 - 92.87}{0.57} = 5.49 \\
Ql &= \frac{\bar{X} - LSL}{S} \\
&= \frac{92.87 - 92.0}{0.57} = 1.53
\end{align*}
\]

**PWLₜ = (PWLᵤ + PWLᵢ) - 100**

\[
PF = 0.50(PWLₜ) + 55 = 0.50(100)+55
\]

→ Obsolete: is currently 94.5 ± 2.5
## QL & PWL

### Variability Unknown Procedure

#### Standard-Deviation Method

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## Qu & PWLu

### VARIABILITY-UNKNOWN PROCEDURE

#### STANDARD-DEVIATION METHOD

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# Traveled Way Lot Testing Results

## Pay Factor 5.01 7/8/200

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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>93.3</td>
<td>5.7</td>
<td>15.3</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>92.6</td>
<td>5.2</td>
<td>15.8</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>93.4</td>
<td>5.4</td>
<td>15.5</td>
<td>3.5</td>
<td></td>
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<tr>
<td>D</td>
<td>92.2</td>
<td>4.6</td>
<td>12.3</td>
<td>3.1</td>
<td></td>
</tr>
</tbody>
</table>

| QA1     | 92.5    | 5.2             | 13.0| 3.6       |         |
| QA2     | 92.5    | 5.5             | 13.6| 3.4       |         |
| QA3     | 92.6    | 5.6             | 13.8| 3.8       |         |
| QA4     |         |                 |     |           |         |

**AVE X:** 92.87, **STD. DEV.:** 0.57, **RAE:** 94.9 - 91.7, **TARGET:** 14.5 - 11.9, **4.3 - 2.5**

| USL     | 96.0    | 5.5             | 15.0| 3.0       |         |
| TARGET  | 94.0    | 5.2             | 13.0| 4.0       |         |
| LSL     | 92.0    | 4.9             | 12.5| 3.0       |         |
| 4       | 4       | 4               | 4   | 4         |         |
| Qa      | 5.49    | 0.61            | 2.78| 3.59      |         |
| Ql      | 1.53    | 0.70            | 1.13| 0.95      |         |
| pvLU    | 100.00  | 70.33           | 100.00| 81.67  |         |
| pvLL    | 100.00  | 73.33           | 87.67| 81.67  |         |
| pvLT    | 100.00  | 43.66           | 87.67| 81.67  |         |

**PAY FACTOR:** 105.0, **TOTAL PAY FACTOR:** 84.2, **TOTAL $ VALUE OF ADJUSTMENT:** $-21,330.00

**UNCONF. JOINT FACTOR:** 90 TONS/ SQ YD OF SUBLOTS WITH UNCONF. JOINT 0 $200

**TOTAL $ VALUE OF ADJUSTMENT:** $-21,330.00
Unconfined Joint Deductions

Pay reduction applied to full width of lane for a given lot.

The lowest adjustment factor (PF_total or the PAF for average unconfined joint density) will apply to the lot.

Exception: If the PAF = 100% and the PF_total is over 100 (use the PF_total)

PF_total includes PFs for binder content, air voids, VMA, and density

---

Example: For a given lot, if

\[ PF_{\text{total}} = 95\% \text{ and } PAF = 90\% \]

The 90% controls the whole lot.

Example: For a given lot, if

\[ PF_{\text{total}} = 105\% \text{ and } PAF = 100\% \]

The 105% controls the whole lot.

403.23.6 and EPG 403.1.21

---

SP_Module-11, Pay Factors
Unconfined Joint Factor

Use smaller of 90% or 84.2%

(3000 tons)($45.00/ton)(0.842-1.000) = -$21,330.00

Superpave Module 11 Unconfined Joint Factor
**TSR Results**

```
(0.98-1.00)(10,000 tons)($45/ ton) = -$9000
```
### “Asphalt QA” / Analysis / QC

#### QC Import Log

- **Imported**: 2/4/2016 6:28
- **By**: Glen Cary

<table>
<thead>
<tr>
<th>QC Lot #</th>
<th>Sublot</th>
<th>%AC</th>
<th>VMA</th>
<th>Va</th>
<th>Mat.</th>
<th>Joint</th>
<th>QC Info Only</th>
<th>Use in Payfactor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>QCA</td>
<td>5.1</td>
<td>14.2</td>
<td>3.2</td>
<td>92.2</td>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>QCB</td>
<td>5.1</td>
<td>14.8</td>
<td>3.9</td>
<td>94.5</td>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>QCC</td>
<td>4.8</td>
<td>13.6</td>
<td>3.1</td>
<td>92.2</td>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>QCD</td>
<td>5</td>
<td>14.1</td>
<td>3.2</td>
<td>94.6</td>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>QCE</td>
<td>5</td>
<td>13.8</td>
<td>3.2</td>
<td>93.5</td>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- **Sample Records Imported**:
  - 15QMAPA6519

- **Average**
  - Volumetrics: 5.0, 14.1, 3.3, 93.4
  - Density: 0.12, 0.45, 0.32, 1.17

- **N = 5 (all QC)**
### VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD

<table>
<thead>
<tr>
<th>QUALITY INDEX (Q_U or Q_L)</th>
<th>PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=3</td>
</tr>
<tr>
<td>2.56</td>
<td>100.00</td>
</tr>
<tr>
<td>2.57</td>
<td>100.00</td>
</tr>
<tr>
<td>2.58</td>
<td>100.00</td>
</tr>
<tr>
<td>2.59</td>
<td>100.00</td>
</tr>
<tr>
<td>2.60</td>
<td>100.00</td>
</tr>
<tr>
<td>2.61</td>
<td>100.00</td>
</tr>
<tr>
<td>2.62</td>
<td>100.00</td>
</tr>
<tr>
<td>2.63</td>
<td>100.00</td>
</tr>
<tr>
<td>2.64</td>
<td>100.00</td>
</tr>
<tr>
<td>2.65</td>
<td>100.00</td>
</tr>
</tbody>
</table>

**3.3 → 100.00**
**Pay Factors (%AC)**

**USL = Target + Tolerance = 5.1 + 0.3 = 5.4**

**LSL = Target - Tolerance = 5.1 - 0.3 = 4.8**

\[
Q_U = \frac{USL - \bar{X}}{S} = \frac{(5.4 - 5.0)}{0.12} = 3.33 = 3.3 
\rightarrow PWL_U = 100.00
\]

\[
Q_L = \frac{\bar{X} - LSL}{S} = \frac{(5.0 - 4.8)}{0.12} = 1.67 = 1.7 
\rightarrow PWL_L = 98.97
\]

**PWL_T = (PWL_U + PWL_L) - 100 = 98.97 = 99.0**

**PF_{AC} = 0.50(PWL_T) + 55 = 0.50(99.0) + 55 = 104.4**

**PF_T = (104.4 + 101.2 + 96.8 + 99.6)/4 = 100.8**
Shoulders

- In the case of a non-integral shoulder, there is no OLA pay factor for density.
- Thus, the total PF is the average of the PFs for binder content, air voids, and VMA.
VARIABILITY-UNKNOWN PROCEDURE
STANDARD-DEVIATION METHOD

QUALITY INDEX PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES

\((Q_{10} \text{ or } Q_{Q})\) | n=3 | n=4 | n=5 | n=6 | n=7 | n=8 | n=9 | n=10
---|---|---|---|---|---|---|---|---
1.27 | 100.00 | 92.33 | 91.04 | 90.64 | 90.44 | 90.32 | 90.25 | 90.19
1.28 | 100.00 | 92.67 | 91.29 | 90.86 | 90.65 | 90.53 | 90.44 | 90.38
1.29 | 100.00 | 93.00 | 91.54 | 91.09 | 90.86 | 90.73 | 90.64 | 90.58
1.30 | 100.00 | 93.33 | 91.79 | 91.31 | 91.07 | 90.94 | 90.84 | 90.78
1.31 | 100.00 | 93.66 | 92.03 | 91.52 | 91.27 | 91.13 | 91.03 | 90.96
1.32 | 100.00 | 94.00 | 92.27 | 91.73 | 91.47 | 91.32 | 91.22 | 91.15
1.33 | 100.00 | 94.33 | 92.50 | 91.95 | 91.68 | 91.52 | 91.40 | 91.33
1.34 | 100.00 | 94.67 | 92.74 | 92.16 | 91.88 | 91.71 | 91.59 | 91.52
1.35 | 100.00 | 95.00 | 92.98 | 92.37 | 92.08 | 91.90 | 91.78 | 91.70
1.36 | 100.00 | 95.33 | 93.21 | 92.57 | 92.27 | 92.08 | 91.96 | 91.87
1.37 | 100.00 | 95.67 | 93.44 | 92.77 | 92.46 | 92.26 | 92.14 | 92.04
1.38 | 100.00 | 96.00 | 93.66 | 92.97 | 92.64 | 92.45 | 92.31 | 92.22
1.39 | 100.00 | 96.34 | 93.89 | 93.17 | 92.83 | 92.63 | 92.49 | 92.39
1.40 | 100.00 | 96.67 | 94.12 | 93.37 | 93.02 | 92.81 | 92.67 | 92.56
1.41 | 100.00 | 97.00 | 94.33 | 93.56 | 93.20 | 92.98 | 92.83 | 92.72
1.42 | 100.00 | 97.33 | 94.55 | 93.75 | 93.37 | 93.15 | 93.00 | 92.88
1.43 | 100.00 | 97.67 | 94.76 | 93.94 | 93.55 | 93.31 | 93.16 | 93.05
1.44 | 100.00 | 98.00 | 94.98 | 94.13 | 93.72 | 93.48 | 93.33 | 93.21
1.45 | 100.00 | 98.33 | 95.19 | 94.32 | 93.90 | 93.65 | 93.49 | 93.37
1.46 | 100.00 | 98.66 | 95.39 | 94.49 | 94.06 | 93.81 | 93.64 | 93.52
1.47 | 100.00 | 99.00 | 95.59 | 94.67 | 94.23 | 93.97 | 93.80 | 93.67
1.48 | 100.00 | 99.33 | 95.80 | 94.84 | 94.39 | 94.12 | 93.95 | 93.83
1.49 | 100.00 | 99.67 | 96.00 | 95.02 | 94.56 | 94.28 | 94.11 | 93.98
1.50 | 100.00 | 100.00 | 96.20 | 95.19 | 94.72 | 94.44 | 94.26 | 94.13
1.51 | 100.00 | 100.00 | 96.39 | 95.35 | 94.87 | 94.59 | 94.40 | 94.27
1.52 | 100.00 | 100.00 | 96.57 | 95.51 | 95.02 | 94.73 | 94.54 | 94.41
1.53 | 100.00 | 100.00 | 96.76 | 95.68 | 95.18 | 94.88 | 94.69 | 94.54
1.54 | 100.00 | 100.00 | 96.94 | 95.84 | 95.33 | 95.02 | 94.83 | 94.68
1.55 | 100.00 | 100.00 | 97.13 | 96.00 | 95.48 | 95.17 | 94.97 | 94.82
1.56 | 100.00 | 100.00 | 97.30 | 96.15 | 95.62 | 95.30 | 95.10 | 94.95
1.57 | 100.00 | 100.00 | 97.47 | 96.30 | 95.76 | 95.44 | 95.23 | 95.08
1.58 | 100.00 | 100.00 | 97.63 | 96.45 | 95.89 | 95.57 | 95.36 | 95.20
1.59 | 100.00 | 100.00 | 97.80 | 96.60 | 96.03 | 95.71 | 95.49 | 95.33
1.60 | 100.00 | 100.00 | 97.97 | 96.75 | 96.17 | 95.84 | 95.62 | 95.46
1.61 | 100.00 | 100.00 | 98.12 | 96.88 | 96.30 | 95.96 | 95.74 | 95.58
1.62 | 100.00 | 100.00 | 98.27 | 97.02 | 96.43 | 96.08 | 95.86 | 95.70
1.63 | 100.00 | 100.00 | 98.42 | 97.15 | 96.55 | 96.21 | 95.98 | 95.81
1.64 | 100.00 | 100.00 | 98.57 | 97.29 | 96.68 | 96.33 | 96.10 | 95.93
1.65 | 100.00 | 100.00 | 98.74 | 97.42 | 96.81 | 96.45 | 96.22 | 96.05
1.66 | 100.00 | 100.00 | 98.84 | 97.54 | 96.92 | 96.56 | 96.33 | 96.16
1.67 | 100.00 | 100.00 | 98.97 | 97.66 | 97.04 | 96.67 | 96.44 | 96.27
1.68 | 100.00 | 100.00 | 99.09 | 97.78 | 97.15 | 96.79 | 96.54 | 96.37
1.69 | 100.00 | 100.00 | 99.27 | 97.90 | 97.27 | 96.90 | 96.65 | 96.48
Module 12

Quality Level Analysis (QLA)

MoDOT
Quality Level Analysis

- Pay Factor computation
- **Favorable comparison between QC and QA results:**
  - Do QC's results represent the entire population of data from the lot? (does QA's result fit within QC's).
  - If not, add QA's result to QCs to include it in the population.

Quality Level Analysis

Comparison of QA to QC

- **Comparison of hotmix QA results to QC results:**
  To consider the QC data to be valid (worthwhile), the QA result must be within 2 standard deviations of the QC mean (QC) for a lot:

  \[
  [QC-2\sigma] \leq QA \leq [QC+2\sigma]
  \]

  **Or**
  
  Within ½ of the specification tolerance, whichever is greater.

This applies to air voids (Va), VMA, %AC, and mat density.
Does QA's result fall somewhere between (QC avg + 2 S) and (QC avg - 2 S)?

Does QA's result fall somewhere between (QCavg + ½ spec limit) and (QCavg - ½ spec limit)?

Example 1
Comparison QA to QC

• For a certain lot, QC results:
  • Mean air voids = 3.43%
  • Standard deviation = 0.44%

• QA result is 3.8%

• Can the contractor's results be used for calculating the pay factor?
Comparison QA to QC, cont'd.

First, should you use 2(S) or ½ the spec. tolerance to establish the acceptable range??

- Allowable range is -1.0% to +1.0%, so the spec tolerance is 1.0%.
- Half of this is 0.5%.

On the other hand:

- 2(S) = 2(0.44) = 0.88

So, use the 2(S) criteria for establishing the allowable range.
Comparison QA to QC cont'd.

* Compared to $2(S) = 2(0.44) = 0.88$, the 0.88% is greater than the 0.5%, so the 0.88% should be used for evaluation.

* If $2(S)$ had turned out to be less than 0.5%, the half-spec rule would apply, and the 0.5% would be used.

Comparison QA to QC cont'd.

* QC - $2(S) = 3.43 - 2(0.44) = 2.6\%$

* QC + $2(S) = 3.43 + 2(0.44) = 4.3\%$

* QA (3.8) lies within 2.6 to 4.3

* Yes, use QC's results

Example 2
Half Tolerance

* **VMA**: Allowable range is -0.5% to +2.0%, so the spec tolerance is 1.25%.

* Half of this is 0.6%.

* So, to be valid, QA must be between $\pm 0.6\%$ of the mean of the QC results for a given lot.
Half Spec Range:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Spec Tolerance (%)</th>
<th>½ Spec Tolerance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Voids (Va)</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Binder Content (Pb)</td>
<td>0.3</td>
<td>0.15</td>
</tr>
<tr>
<td>Mat Density</td>
<td>2.5</td>
<td>1.25</td>
</tr>
<tr>
<td>VMA</td>
<td>-0.5 x 2.0 = 2.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>

QC: QA Comparison

<table>
<thead>
<tr>
<th>JOB MIX</th>
<th>DENSITY %</th>
<th>SUBLOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>93.3</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>92.6</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>93.4</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>92.2</td>
<td></td>
</tr>
</tbody>
</table>

QA1: 92.5
QA2: 92.6
QA3: 92.4
QA4: 92.2
QA5: 91.7 < 92.87 < 94.0

AVE X: 92.87
STD. DEV.: 0.57

QA COMP: 94 - 91.7

QC vs QA Comparison: %AC

- 2 Std Deviations = (2)(0.12) = 0.24
- ½ Spec Tolerance = (½)(0.33) = 0.15
- Difference (QA - QC) = 5.10 - 5.00 = 0.10
- Within ½ Spec Tolerance = 0.15? Yes
- Within 2 Std Dev = 0.24? Yes
Quality Level Analysis - TSR

TSR - favorable comparison is when QA and QC are within 10% of each other.
If the difference is 5 to 10%, TSR's are evaluated by MoDOT field office.
If difference is >10%, initiate dispute resolution.
QC and QA retained samples should be kept for extended periods.

QLA

QLA = Quality Level Analysis

• What if QA falls outside of the QC range?
• "UNFAVORABLE COMPARISON"
• See FAQ (also in EPG)

Example: QA Pb is Suspect, First Comparison

<table>
<thead>
<tr>
<th>Example 1- QA Pb.xls</th>
<th>Initial QA results:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Comparison:</td>
<td>Pb</td>
</tr>
<tr>
<td>Target Pb=</td>
<td>5.2</td>
</tr>
<tr>
<td>QC</td>
<td>5.7</td>
</tr>
<tr>
<td>5</td>
<td>5.2</td>
</tr>
<tr>
<td>VMA</td>
<td>5.4</td>
</tr>
<tr>
<td>QC Avg</td>
<td>5.2</td>
</tr>
<tr>
<td>QC 5</td>
<td>5.38</td>
</tr>
<tr>
<td>Range,lower</td>
<td>4.89</td>
</tr>
<tr>
<td>Range,upper</td>
<td>5.89</td>
</tr>
<tr>
<td>OA</td>
<td>4.1</td>
</tr>
<tr>
<td>Fit?</td>
<td>no</td>
</tr>
</tbody>
</table>
Unfavorable Comparison:  
**Case:** QA Binder Content (Pb)

**Step 1.** Check both QC & QA data & calculations, re-weigh pucks, Rice specimens, check spreadsheet cell formulas.

---

Unfavorable Comparison  
**Loose Mix cont'd.**

**Step 2.** If both QA & QC's appear ok, for all 3 parameters (Air Voids, VMA, Binder Content), one solution is to add all of QA's independent results to the data sets, now:

\[ n = (4 + 1) = 5 \]

Re-run all 3 PWL analyses [Pb, VMA, Va]

\[ Q = \frac{\bar{X} - LSL}{S} \]  
(Mean & S are now different)

New PWL

New PF

---

**Add QA Pb, VMA, Air Voids to QC Sets**  
**Re-run PWL's with QA included**

<table>
<thead>
<tr>
<th>n</th>
<th>PbS</th>
<th>VMA5</th>
<th>VaS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5.7</td>
<td>13.3</td>
<td>3.9</td>
</tr>
<tr>
<td>QC</td>
<td>5.2</td>
<td>13.8</td>
<td>3.7</td>
</tr>
<tr>
<td>QC</td>
<td>5.4</td>
<td>13.5</td>
<td>3.0</td>
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<tr>
<td>QC</td>
<td>5.2</td>
<td>12.3</td>
<td>3.1</td>
</tr>
<tr>
<td>QA</td>
<td>4.1</td>
<td>13.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Avg n=5</td>
<td>5.17</td>
<td>13.24</td>
<td>3.48</td>
</tr>
<tr>
<td>S</td>
<td>0.61</td>
<td>0.55</td>
<td>0.40</td>
</tr>
<tr>
<td>LSL</td>
<td>4.9</td>
<td>12.5</td>
<td>3.78</td>
</tr>
<tr>
<td>Qu</td>
<td>0.03</td>
<td>3.12</td>
<td>1.31</td>
</tr>
<tr>
<td>PWL</td>
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<td>100</td>
<td>100</td>
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<tr>
<td>PWL</td>
<td>62.73</td>
<td>92.03</td>
<td>88.97</td>
</tr>
<tr>
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<td>34.68</td>
<td>92.03</td>
<td>88.97</td>
</tr>
<tr>
<td>PF</td>
<td>19</td>
<td>101</td>
<td>99</td>
</tr>
</tbody>
</table>

So, choose to re-run QA retained split.
Unfavorable Comparison
Loose Mix cont'd.

Step 3a. Or could jointly test a retained loose mix sample (QA or QC on suspect subplot):
- Run whole suite of tests (G_mm, G_mb, P_b)

Unfavorable Comparison Loose Mix cont'd.

- Favorable comparisons between loose mix splits (original vs. retained) is defined as:
  - G_mm: within 0.005
  - G_mb: within 0.010
  - P_b: within 0.1%
- If this step verifies that all 3 original test results are valid, keep using the original results.

| Step 3a | QA  | Retained | Original | Close?
|---------|-----|----------|----------|------
| Pb      |     | 4.1      | 4.1      | yes  
| Gmm     |     | 2.475    | 2.472    | yes  
| Gmb     |     | 2.388    | 2.381    | yes  

Unfavorable Comparison Loose Mix cont'd.

- Add QA's independent results to the 3 data sets (Pb, VMA, Vp), now n = (4 + 1) = 5
- Re-run all 3 PWL analyses.
  (This is shown in Step 2, previous slide 22)

\[ Q_L = \frac{\bar{X} - LS}{S} \]
Unfavorable Comparison Loose Mix cont’d.

Step 3b. Alternate outcome of Step 3a. If running the retained loose mix split shows the original to be invalid, substitute all results (Pb, Gmm, Gmb) from the retained split. Recalculate Va and VMA.

Now you have new QA test values for each parameter (air voids, VMA, binder content).

Step 3b: QA’s Retained Pb Very Different

<table>
<thead>
<tr>
<th>Step 3b</th>
<th>QA</th>
<th>Retained</th>
<th>Original</th>
<th>Close?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>5.3</td>
<td>4.1</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Gmm</td>
<td>2.475</td>
<td>2.472</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Gmb</td>
<td>2.388</td>
<td>2.381</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Va</td>
<td>3.5</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMA</td>
<td>14.1</td>
<td>13.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Unfavorable Comparison, Loose Mix cont’d.

For each parameter (Pb, VMA, Va), re-run the lot comparison of QA vs QC:

QA???

- 2 (S) QC_{avj} + 2 S

* If all 3 are favorable, use these results to re-run PWL (n = 4).
### Comparison Using QA Retained Sample Values

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>VMA</th>
<th>Va</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC</td>
<td>5.7</td>
<td>13.3</td>
<td>3.9</td>
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<tr>
<td>QC</td>
<td>5.2</td>
<td>13.8</td>
<td>3.7</td>
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<tr>
<td>QC</td>
<td>5.4</td>
<td>13.5</td>
<td>3.0</td>
</tr>
<tr>
<td>QC</td>
<td>5.2</td>
<td>12.3</td>
<td>3.1</td>
</tr>
<tr>
<td>QC avg</td>
<td>5.3</td>
<td>13.2</td>
<td>3.4</td>
</tr>
<tr>
<td>S</td>
<td>0.24</td>
<td>0.65</td>
<td>0.44</td>
</tr>
<tr>
<td>Range, lower</td>
<td>4.90</td>
<td>11.93</td>
<td>2.54</td>
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<tr>
<td>Range, upper</td>
<td>5.85</td>
<td>14.53</td>
<td>4.31</td>
</tr>
<tr>
<td>Retained QA</td>
<td>5.3</td>
<td>14.1</td>
<td>3.5</td>
</tr>
<tr>
<td>Fit?</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

Favorable Favorable Favorable

---

### If All 3 Are Favorable, Use These Results to Re-run PWL

**(n = 4)**

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>VMA</th>
<th>Va</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>QC</td>
<td>5.7</td>
<td>13.3</td>
<td>3.9</td>
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<td>QC</td>
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<td>QC</td>
<td>4.4</td>
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<tr>
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<td>5.2</td>
<td>12.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Avg, n=4</td>
<td>5.3</td>
<td>13.2</td>
<td>3.4</td>
</tr>
<tr>
<td>S</td>
<td>0.24</td>
<td>0.65</td>
<td>0.44</td>
</tr>
<tr>
<td>LSL</td>
<td>5.5</td>
<td>15.0</td>
<td>5.0</td>
</tr>
<tr>
<td>LSL</td>
<td>4.9</td>
<td>12.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Cu</td>
<td>0.50</td>
<td>2.78</td>
<td>3.56</td>
</tr>
<tr>
<td>GL</td>
<td>2.70</td>
<td>1.12</td>
<td>0.94</td>
</tr>
<tr>
<td>PWLl</td>
<td>67.87</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>PWLL</td>
<td>70.8</td>
<td>87.83</td>
<td>62</td>
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<td>PWLL</td>
<td>67.87</td>
<td>87.33</td>
<td>82</td>
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<tr>
<td>PF</td>
<td>85</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

---

### Unfavorable Comparison, Loose Mix cont’d.

* Step 4.

If QA vs QC comparison is still unfavorable, add QA's independent results (Pb, VMA, Va) to the 3 data sets. Now n = (4 + 1) = 5

* Re-run all 3 parameters' PWL analyses.

\[
QL = \frac{\overline{X} - LSL}{S}
\]
Unfavorable Core Comparison

Example: QA Core is Suspect From First Comparison

<table>
<thead>
<tr>
<th>QC</th>
<th>93.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC</td>
<td>92.6</td>
</tr>
<tr>
<td>QC</td>
<td>93.4</td>
</tr>
<tr>
<td>QC</td>
<td>92.2</td>
</tr>
<tr>
<td>QC avg</td>
<td>92.9</td>
</tr>
<tr>
<td>QC S</td>
<td>0.57</td>
</tr>
<tr>
<td>Range,lower</td>
<td>91.7</td>
</tr>
<tr>
<td>Range,upper</td>
<td>94.0</td>
</tr>
<tr>
<td>QA</td>
<td>91.2</td>
</tr>
<tr>
<td>Fit?</td>
<td>no</td>
</tr>
</tbody>
</table>

Unfavorable

CORES

- **Case:** QA core is taken at the same location as one of the QC core sample locations.
- **Step 1** - check core and $G_{mean}$ data, etc.
- **Step 2** - There is no "retained QC" sample, so the QC core at the same location can function as a retained sample: QA & QC jointly should re-weigh QA and QC cores; If QC sample is comprised of more than 1 core, use the average of the QC cores.
**CORES, cont'd.**

- **Step 3** - Compare $G_{mc}$'s: QA to QC.
- If $G_{mc}$'s are within 0.010, the QA core is verified, as is the QA % Density.
- Add QA's % Density result to the QC % Density data set, now $n = (4 + 1) = 5$
- Re-run density PWL analysis.

---

**CORES, cont'd.**

- **Step 4** - If the QA and QC $G_{mc}$'s do not compare, then average the QA and QC $G_{mc}$'s-call this the new QA $G_{mc}$. Re-compute the QA % Density.
- Also call this the new QC $G_{mc}$ for the subplot. Re-compute the subplot's QC % Density
- Re-compute the lot's QC % Density average and standard deviation

---

**Step 4: Gmc Comparison**

New QC %Density Average and Standard Deviation.

| QC Gmc  | 2.304 |
| QA Gmc  | 2.254 |
| Avg     | 2.279 |

This is new QA Gmc, so %Density = 92.4 \(\text{using QC Gmm, no QA Gmm from Lot C)}\)

Qc

| QC     | 92.3 |
| QC     | 92.6 |
| new QC | 92.4 |
| QC     | 92.2 |

new avg 92.63
new s 0.48
**Step 5** - Re-run the QA vs QC comparison

<table>
<thead>
<tr>
<th>QC</th>
<th>93.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC</td>
<td>92.6</td>
</tr>
<tr>
<td>new QC</td>
<td>92.4</td>
</tr>
<tr>
<td>QC</td>
<td>92.2</td>
</tr>
<tr>
<td>QC avg</td>
<td>92.63</td>
</tr>
<tr>
<td>QC S</td>
<td>0.48</td>
</tr>
<tr>
<td>Range, lower</td>
<td>91.67</td>
</tr>
<tr>
<td>Range, upper</td>
<td>93.58</td>
</tr>
<tr>
<td>QA</td>
<td>92.4</td>
</tr>
<tr>
<td>Fit?</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>favorable</td>
</tr>
</tbody>
</table>

**Step 6** - If favorable, run the PWL analysis with new QC data

<table>
<thead>
<tr>
<th>QC</th>
<th>%Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>4</td>
</tr>
<tr>
<td>QC</td>
<td>93.3</td>
</tr>
<tr>
<td>QC</td>
<td>92.6</td>
</tr>
<tr>
<td>new QC</td>
<td>92.4</td>
</tr>
<tr>
<td>QC</td>
<td>92.2</td>
</tr>
<tr>
<td>Avg. n=4</td>
<td>92.63</td>
</tr>
<tr>
<td>S</td>
<td>0.48</td>
</tr>
<tr>
<td>USL</td>
<td>97</td>
</tr>
<tr>
<td>LSL</td>
<td>92</td>
</tr>
<tr>
<td>QL</td>
<td>1.31</td>
</tr>
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<td>PWLu</td>
<td>100</td>
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<td>PWLt</td>
<td>93.66</td>
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<tr>
<td>PWLt</td>
<td>93.66</td>
</tr>
<tr>
<td>PF</td>
<td>102</td>
</tr>
</tbody>
</table>
Step 7: Still Non-Favorable Comparison

- **Step 7** - If QA vs QC comparison is not favorable, add QA's % Density into QC's % Density data set for the lot, re-compute the lot's average and standard deviation.
- Re-run the PWI \((n = 5)\).

Retained Samples

- If a retained sample is to be tested:
  - Reheat just enough to become workable-
    remove it from the container.
  - Spread in a pan(s) to heat quicker.
  - Quarter.
  - Run entire suite of tests.

Outliers

- Lot data may be examined for outliers via ASTM E 178.
- Eligible tests:
  - \(G_{\text{min}}\) \(G_{\text{max}}\) \(G_{\text{min}}/G_{\text{max}}\) \(P_{\text{\theta}}\)
- Process is somewhat moot with the advent of the retained split testing procedure now in place.
- See Appendix.
Dispute Escalation

- Look at the QC/QA Checklist—is a hierarchy of resolution levels and associated time frames.
- Make decisions at lowest possible level.

Conflict Resolution

Example

3rd Party

QC Manager ↔ District Construction Materials Engineer

QC Supervisor ↔ Resident Engineer

QC Technician ↔ QA Technician

Pay Adjustment Factors

- QLA Pay Factors
- TSR Pay Adjustment Factor (403.23.5)
- Density Pay Adjustment Factor [403.23.7.4.1(b)]
- Longitudinal Joint Pay Adjustment Factor [EPG]
- Smoothness Pay Adjustment Factor
- From JSP’s:
  - Intelligent Compaction: Passing/Deficient Segments
  - Infrared Thermal Profiles: Thermal Segregation Categories
  - Performance Testing (Cracking)
  - Elevated Density
Coring Summary

<table>
<thead>
<tr>
<th>Location Determination</th>
<th>Coating Frequency</th>
<th>Pay Factor Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Number</td>
<td>1 sample/4 sections</td>
<td>QLA Pay Factor</td>
</tr>
<tr>
<td>Core Number</td>
<td>1 sample/4 sections</td>
<td>QLA Pay Factor</td>
</tr>
<tr>
<td>Random Number</td>
<td>Random Number</td>
<td>Density Pay Adjustment Factor</td>
</tr>
<tr>
<td>Random Number</td>
<td>Random Number</td>
<td>Density Pay Adjustment Factor</td>
</tr>
<tr>
<td>None</td>
<td>Considered part of the traveled way</td>
<td>Density Pay Adjustment Factor</td>
</tr>
<tr>
<td>Not QLA</td>
<td>Considered part of the traveled way</td>
<td>Density Pay Adjustment Factor</td>
</tr>
<tr>
<td>Random Number</td>
<td>Random Number</td>
<td>Density Pay Adjustment Factor</td>
</tr>
<tr>
<td>Random Number</td>
<td>Random Number</td>
<td>Density Pay Adjustment Factor</td>
</tr>
<tr>
<td>Single lift (travelled way)</td>
<td>Random Number</td>
<td>Density Pay Adjustment Factor</td>
</tr>
</tbody>
</table>

TSR Pay Adjustment

<table>
<thead>
<tr>
<th>TSR</th>
<th>% of Contract price</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥90</td>
<td>103</td>
</tr>
<tr>
<td>75-89</td>
<td>100</td>
</tr>
<tr>
<td>70-74</td>
<td>98</td>
</tr>
<tr>
<td>65-69</td>
<td>97</td>
</tr>
<tr>
<td>&lt;65</td>
<td>Remove</td>
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</tbody>
</table>

Density Pay Adjustment Factor

<table>
<thead>
<tr>
<th>Field Density, % of Gnm</th>
<th>% of Contract price</th>
</tr>
</thead>
<tbody>
<tr>
<td>92.0-97.0</td>
<td>100</td>
</tr>
<tr>
<td>91.5-91.9 or 97.1-97.5</td>
<td>90</td>
</tr>
<tr>
<td>91.0-91.4 or 97.1-97.5</td>
<td>85</td>
</tr>
<tr>
<td>90.5-90.9 or 97.6-98.0</td>
<td>80</td>
</tr>
<tr>
<td>90.0-90.4 or 97.6-98.0</td>
<td>75</td>
</tr>
<tr>
<td>Below 90.0 or above 98.0</td>
<td>Remove &amp; replace</td>
</tr>
<tr>
<td>Longitudinal Joint Density</td>
<td>Pay Adjustment Factor (PAF)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Field Density, % of Gmm</td>
<td>% of Contract Unit Price</td>
</tr>
<tr>
<td>90.0 - 96.0</td>
<td>100</td>
</tr>
<tr>
<td>89.5 - 89.9 or 96.1 - 96.5</td>
<td>90</td>
</tr>
<tr>
<td>89.0 - 89.4 or 96.6 - 97.0</td>
<td>85</td>
</tr>
<tr>
<td>88.5 - 88.9 or 97.1 - 97.5</td>
<td>80</td>
</tr>
<tr>
<td>88.0 - 88.4 or 97.6 - 98.0</td>
<td>75</td>
</tr>
<tr>
<td>Below 88.0 or above 98.0</td>
<td>Remove &amp; replace 49</td>
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</tbody>
</table>
### Smoothness Pay Adjustment (IRI)

<table>
<thead>
<tr>
<th>IRI (in/mile)</th>
<th>% Contract Price</th>
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</thead>
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<tr>
<td>40.0 or less</td>
<td>105</td>
</tr>
<tr>
<td>40.1-54.0</td>
<td>103</td>
</tr>
<tr>
<td>54.1-80.0</td>
<td>100</td>
</tr>
<tr>
<td>80.1 or greater</td>
<td>100 after correction to 80.0</td>
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</tbody>
</table>

Correction = diamond grinding

<table>
<thead>
<tr>
<th>IRI (in/mile)</th>
<th>% Contract Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>70.0 or less</td>
<td>103</td>
</tr>
<tr>
<td>70.1-125.0</td>
<td>100</td>
</tr>
<tr>
<td>125.1 or greater</td>
<td>100 after correction to 125.0</td>
</tr>
</tbody>
</table>

---

### Gradation Samples

- MoDOT allows gradation sample testing to be satisfied by using the residue from the HMA ignition oven sample.
- An aggregate (gradation) correction factor (AGCF) may be necessary to account for the breakdown in rock.
- RAP gradation in the field can be determined with ignition oven.

---

### Remove & Replace

- All lots with PF < 50.0
- Any subplot with < 90.0 or > 98.0% density
- Any subplot with < 2.5% air voids
- If TSR < 65%
- If unconfined joint density is < 88.0% or > 98.0%
- Actual limits of removal up to the specified amount is at the RE's discretion.
Remove & Replace

- If QA results fall below removal limits (density and/or air voids) but QC's results do not, and there is favorable comparison, the mix stays.
- If QA results fall below removal limits (density and/or air voids) and favorable comparison is not achieved, initiate dispute resolution.

Remove & Replace

- Replacement mix will be sampled & tested to calculate PWL

Summary

1. Pay Factors (PF's) are multipliers of the contract price to adjust for quality.
2. New QLA PF's are calculated for each lot (say, 3000 tons).
3. PF's are based on the mean and standard deviation of the test results from a lot.
Performance Testing

- Moving from materials & methods specifications to performance specifications.
- What properties of the final product are we interested in, rather than some component of the final product.
- Via JSP's at this point.
- Started in 2018.

Record Keeping and Exchange of Data

* PROCESS REVIEW TEAM NOTED
  2008
Record Keeping Samples
- Contractor samples retained for the engineer:
  - clean covered containers
  - readily accessible
  - *ID'd: Job mix no., sampler, sample location, time & date sampled
  - stored until test results accepted
- QC gradation samples: retain the portion of the QC sample not tested after reducing the sample to testing size.
- *All samples labeled

QC Record Keeping
- *Record and maintain all test results
- *Up-to-date test results
- *Paper backup of results
- *Maintain printouts from gyro and binder content devices
- *Pay Factor records
- Maintain an inventory of major sampling, testing, & calibration equipment.

Documents On Hand
- *Job mix
- *QC plan
- *Current copies of all test method procedures
### Test Equipment & Plant

**Calibration/Verification Records**

- Results of calibration
- Description of equipment calibrated
- Date of calibration
- Person calibrating
- Calibration procedure ID
- Next calibration due date
- ID of calibration device & trace ability of calibration

---

**Calibration**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Requirement</th>
<th>Interval (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyro</td>
<td>Calibrate</td>
<td>12</td>
</tr>
<tr>
<td>Gyro</td>
<td>Verify</td>
<td>Daily; when moved</td>
</tr>
<tr>
<td>Gyro molds</td>
<td>Dimensions</td>
<td>12</td>
</tr>
<tr>
<td>Thermometer</td>
<td>Calibrate</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum</td>
<td>Pressure</td>
<td>12</td>
</tr>
<tr>
<td>Pycnometer</td>
<td>Calibrate</td>
<td>Daily</td>
</tr>
<tr>
<td>Ignition oven</td>
<td>Verify</td>
<td>12 or when moved</td>
</tr>
</tbody>
</table>

---

**Calibration, Cont’d**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Requirement</th>
<th>Interval (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear gage</td>
<td>Drift &amp; stability</td>
<td>1</td>
</tr>
<tr>
<td>Shakers</td>
<td>Sieving thoroughness</td>
<td>12</td>
</tr>
<tr>
<td>Sieves</td>
<td>Physical condition</td>
<td>12</td>
</tr>
<tr>
<td>Ovens</td>
<td>Verify settings</td>
<td>12</td>
</tr>
<tr>
<td>Balances</td>
<td>Verify</td>
<td>12 or when moved</td>
</tr>
<tr>
<td>Timers</td>
<td>Accuracy</td>
<td>12</td>
</tr>
</tbody>
</table>
QC Records

- Maintain 3 years from completion of project.
- What:
  - test reports, including raw data
  - calibrations
  - technician training
  - personnel

Exchange of Data

- QC furnishes raw data (including gyro, and binder printouts) and test results to QA not later than the beginning of the next day following the test.
- QC data, control charts, etc., readily available to QA at all times.
- QA raw data & results made available to QC no later than the next working day.
- QA will make the QLA within 24 hours of receipt of the QC test results.
Balanced Mix Design Performance Testing and Increased Density

- Moving from materials & methods specifications to performance specifications. (Balanced Mix Design = BMD).
- What properties of the final product are we interested in, rather than some component of the final product.
- Via Job Special Provisions (JSP’s) at this point.

Properties of Interest

- **Fatigue cracking** - Ideal CT or “CT Index”
- **Rutting** (and stripping) - “Hamburg Wheel Tracker”
Performance Testing

- **Fatigue Cracking**
- Rutting

**Fatigue Cracking**
Function of repeated traffic loads over time (in wheel paths)

CT\text{Index} = \text{Cracking Test}

- Simple specimen preparation
- ASTM D8225

Test temperature: 25 °C
Loading rate: 50mm/min
Specimen: cylindrical specimen without cutting, gluing, instrumentation, drilling, and notching.

IDEAL-CT

\[ \text{Gf} = \frac{\text{Area under curve}}{\text{TxD}} \]

For non-41 mm thick specimens: \[ \text{CT}_{\text{Index}} = \frac{1}{6} \times \frac{\text{Gf}}{\text{TxD}} \times \frac{(\text{b})^2}{4} \]
Performance Testing

- Fatigue Cracking
- Rutting

Function of warm weather and traffic

Hamburg Wheel Tracker

AASHTO T 324

- Capacity to resist rutting (and stripping)
- Warm temperatures
- Under water

Hamburg Plot

- Number of Passes to Stripping Inflection Point (SIP)
- Number of Passes to Failure, N
- Rut Depth, mm

Number of Passes x 1000
Good  Marginal (Barely In-Spec)
Poor (In-Tolerance/Out-of-Spec)

QC/QA  
_BMD Projects_

- QC: 1 per 10,000 tons
- QA: 1 per 20,000 tons
  - *Up to 3% incentive for CT<sub>Index</sub> in range and*
  - _Hamburg is &lt;12.5 mm_
  - *1% incentive for greater field density (>94 for non SMA and with unconfined joint density &gt;90.0%).*
  - Favorable comparison: QA and QC are within 20%.

---

**Number and Size of Specimens**

<table>
<thead>
<tr>
<th>Performance Test</th>
<th>Min # of Pucks/Set</th>
<th>Molded Ht. mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT&lt;sub&gt;Index&lt;/sub&gt;</td>
<td>3</td>
<td>62</td>
</tr>
<tr>
<td>HWT</td>
<td>4</td>
<td>62</td>
</tr>
<tr>
<td>AMPT</td>
<td>5</td>
<td>180</td>
</tr>
</tbody>
</table>

Cracking Tolerance Index – CT<sub>Index</sub>
Hamburg Wheel Track – HWT
AMPT – Samples for Research Purposes
**CT Index**
Tested according to ASTM D8225 @ 25±1°C

<table>
<thead>
<tr>
<th>Non SMA Mixtures</th>
<th>CT Index</th>
<th>% of Contract Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 45</td>
<td>97%</td>
</tr>
<tr>
<td></td>
<td>45-97</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>&gt;97</td>
<td>103%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SMA Mixtures</th>
<th>CT Index</th>
<th>% of Contract Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 135</td>
<td>97%</td>
</tr>
<tr>
<td></td>
<td>135 – 240</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>&gt;240</td>
<td>103%</td>
</tr>
</tbody>
</table>

**Hamburg Wheel Track**

5.0 Hamburg Wheel Track (HWT). HWT testing will be completed in accordance with AASHTO T324 at test temperature of 50°C and 62 mm specimen height.

<table>
<thead>
<tr>
<th>PG Grade High Temperature</th>
<th>Minimum Wheel Passes</th>
<th>Maximum Rut Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>58S-XX</td>
<td>5,000</td>
<td>12.5</td>
</tr>
<tr>
<td>64S-22</td>
<td>7,500</td>
<td>12.5</td>
</tr>
<tr>
<td>64H-22</td>
<td>15,000</td>
<td>12.5</td>
</tr>
<tr>
<td>64V-22</td>
<td>20,000</td>
<td>12.5</td>
</tr>
</tbody>
</table>

* Determined by the binder grade specified in the contract.

**Design Gyrations**

6.0 Design Gyrations. The number (N) of gyrations required for gyratory compaction shall be in accordance with Sec. 400.4.5. For Non-SMA mixtures, at the option of the contractor the number of gyrations and air voids may be lowered. Mixtures having lowered gyrations shall have a minimum volume of effective asphalt, equal to the VMA minus the air voids, as shown in the chart below, with design air voids between 3.0% to 4.0%. The minimum VMA shall be the design air voids plus the volume of effective asphalt.

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Volume of Effective Asphalt (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP125</td>
<td>11.0</td>
</tr>
<tr>
<td>SP208</td>
<td>12.0</td>
</tr>
<tr>
<td>SP048</td>
<td>13.0</td>
</tr>
</tbody>
</table>

The minimum gyrations level shall be in accordance with the following:

<table>
<thead>
<tr>
<th>Design</th>
<th>N recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>35</td>
</tr>
<tr>
<td>E</td>
<td>50</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
</tr>
<tr>
<td>B</td>
<td>85</td>
</tr>
</tbody>
</table>
More Information

• You can find more and current information on the MoDot Web Site under *Missouri Standard Specifications for Highway Construction*.
• Job Special Provisions
• NJSP2001 or newer

Alternate to Rutting Test: IDT
Indirect Tensile Test (ASTM D6931)

• Test is run on Volumetric Specimen (150x115mm)
• Placed in bags in 52° water bath for 30-60 minutes.
• Broke with TSR Apparatus, Speed
• Results correlate closely with Hamburg
1.0 Description. This work shall consist of providing asphalt mixture in accordance with Sec 403 and meet the Balanced Mix Design (BMD) performance requirements of cracking and rutting resistant properties at an increased density level. The BMD performance requirements will be applied to SuperPave mainline wearing surface mixtures. Bituminous binder and base, level course, shoulder, and pavement repair mixtures are excluded from the BMD requirements.

2.0 Performance Testing. Acceptable test results meeting the 100% pay criteria for both Cracking Tolerance Index (CT\textsubscript{Index}) and Hamburg Wheel Track (HWT) tests shall be submitted with the mix design for approval. The contractor shall conduct Quality Control (QC) testing for CT\textsubscript{Index} and HWT tests at a frequency of 1/10,000 tons for the mainline pavement. The random testing location will be determined by the engineer.

Incentive/disincentive payment will be calculated based upon the mixture cost for the tonnage represented by each sample, generally 10,000 tons. An incentive of 3% of the asphalt mixture item cost will be paid if the CT\textsubscript{Index} results are within the incentive range and HWT results are below 12.5 mm. The engineer will conduct performance testing at a frequency of 1/20,000 tons for Quality Assurance (QA). A favorable comparison will be achieved if the results for QA and QC are within 20%.

In addition, a 1% incentive is being offered for sublots with qualifying density results above 94% for non-SMA mixtures and with unconfined joint density of 90.0% or above.

Gyratory compacted samples for the Asphalt Material Performance Tester (AMPT) shall be fabricated at a minimum of once per project or as directed by the engineer and submitted to the MoDOT Central Laboratory for informational purposes only.

3.0 Mix Sampling and Preparation. Laboratory mixed samples for mix design submittal shall be short term conditioned in accordance with AASHTO R30 prior to conducting performance testing. Loose mix samples from the plant shall be taken during production in accordance with AASHTO R 97 and split to the appropriate size in accordance with AASHTO R 47. No conditioning is required on plant mixed samples. Samples shall then be heated to the compaction temperature +/- 3°C prior to compacting necessary samples for QA/QC testing. QA personnel shall be present during the sampling, splitting, and molding process. QC shall fabricate all test specimens. QA will randomly select the specimens to submit to the MoDOT Central Laboratory for performance testing. The following table details the minimum number of specimens required:

<table>
<thead>
<tr>
<th>Performance Test</th>
<th>Minimum Number of Specimens per Set</th>
<th>Molded Specimen Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cracking Tolerance Index (CT\textsubscript{Index})</td>
<td>3</td>
<td>62</td>
</tr>
<tr>
<td>Hamburg Wheel Track (HWT)</td>
<td>4</td>
<td>62</td>
</tr>
<tr>
<td>AMPT Samples for Research Purposes</td>
<td>5</td>
<td>180</td>
</tr>
</tbody>
</table>
When QA testing is to be performed, three sets shall be fabricated for $CT_{\text{index}}$ and HWT performance testing: QC, QA, and an additional set for QA retention.

AMPT samples for BMD research shall be fabricated in accordance with AASHTO PP 99-19, carefully following the exceptions noted herein:

1) Pour the mixture into the center of the mold to minimize air void variation between samples. Pouring material down the sides of the mold will result in lower air voids on that side of the mold.
2) Charge the mold in two equal lifts. After each lift, use the spatula to scrape the walls of the mold, inserting the spatula 8-10 times around the circumference of the mold. Insert the spatula into the center of the mixture 10-12 times in an evenly distributed pattern. Insert the spatula as far as possible into the mixture without damaging aggregates.

3.1 Molding Samples. The specimens shall be compacted to an air void content of 7.0 +/- 0.5% or 6.0 ± 0.5% for SMA mixtures. The gyratory specimen weight for each performance test shall be submitted with the mix design. The compacted test specimens shall be allowed to cool to 25 +/- 3°C prior to determining the air void content.

3.2 Determining Air Voids. The bulk specific gravity of the test specimen will be determined in accordance with AASHTO T166. Specimens shall be air dried for 24 +/- 3 hours before preconditioning the test specimens for $CT_{\text{index}}$ testing. Test specimens shall be preconditioned as specified in the test methods. If a water bath is utilized, it is critical that samples are kept dry.

3.3 Records. Compaction temperature, times in and out of the oven, gyratory specimen weight, and sample identification shall be recorded.

4.0 Cracking Tolerance Index ($CT_{\text{index}}$) Testing. The $CT_{\text{index}}$ testing shall be completed in accordance with ASTM D8225 and at a test temperature of 25°C +/- 1°C. Incentive/disincentive payment will be calculated based upon the mixture cost for the tonnage represented by each sample, generally 10,000 tons. An incentive of 3% of the asphalt mixture item cost will be paid if the $CT_{\text{index}}$ results are within the incentive range and HWT results are below 12.5 mm.

<table>
<thead>
<tr>
<th>Non SMA Mixtures</th>
<th>Percent of Contract Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cracking Tolerance Index ($CT_{\text{index}}$)</td>
<td></td>
</tr>
<tr>
<td>&lt; 45</td>
<td>97%</td>
</tr>
<tr>
<td>45 - 97</td>
<td>100%</td>
</tr>
<tr>
<td>&gt; 97</td>
<td>103%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SMA Mixtures</th>
<th>Percent of Contract Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cracking Tolerance Index ($CT_{\text{index}}$)</td>
<td></td>
</tr>
<tr>
<td>&lt; 135</td>
<td>97%</td>
</tr>
<tr>
<td>135 - 240</td>
<td>100%</td>
</tr>
<tr>
<td>&gt; 240</td>
<td>103%</td>
</tr>
</tbody>
</table>
5.0 Hamburg Wheel Track (HWT). HWT testing will be completed in accordance with AASHTO T324 at test temperature of 50 C and 62 mm specimen height.

<table>
<thead>
<tr>
<th>PG Grade High Temperature *</th>
<th>Minimum Wheel Passes</th>
<th>Maximum Rut Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>58S-xx</td>
<td>5,000</td>
<td>12.5</td>
</tr>
<tr>
<td>64S-22</td>
<td>7,500</td>
<td>12.5</td>
</tr>
<tr>
<td>64H-22</td>
<td>15,000</td>
<td>12.5</td>
</tr>
<tr>
<td>64V-22</td>
<td>20,000</td>
<td>12.5</td>
</tr>
</tbody>
</table>

* Determined by the binder grade specified in the contract.

6.0 Design Gyrations. The number (N) of gyrations required for gyratory compaction shall be in accordance with Sec 403.4.5. For Non-SMA mixtures, at the option of the contractor the number of gyrations and air voids may be lowered. Mixtures having lowered gyrations shall have a minimum volume of effective asphalt, equal to the VMA minus the air voids, as shown in the chart below, with design air voids between 3.0% to 4.0%. The minimum VMA shall be the design air voids plus the volume of effective asphalt.

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Volume of Effective Asphalt (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP125</td>
<td>11.0</td>
</tr>
<tr>
<td>SP095</td>
<td>12.0</td>
</tr>
<tr>
<td>SP048</td>
<td>13.0</td>
</tr>
</tbody>
</table>

The minimum gyration level shall be in accordance with the following:

<table>
<thead>
<tr>
<th>Design</th>
<th>N_{design}</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>35</td>
</tr>
<tr>
<td>E</td>
<td>50</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
</tr>
<tr>
<td>B</td>
<td>65</td>
</tr>
</tbody>
</table>

7.0 VFA Requirements. Section 403.4.6.3 Voids Filled with Asphalt shall be omitted provided that the HWT requirements described above are satisfied and the CT_{index} is 45 or greater.

8.0 Sec 403 Revisions.

Delete Section 403.5.2 and replace with the following...

403.5.2 Density. The final, in-place density of the mixture shall be between 92.0 and 97.5 percent of the theoretical maximum specific gravity for all mixtures except SMA. SMA mixtures shall have a minimum density of 94.0 percent of the theoretical maximum specific gravity. The theoretical maximum specific gravity shall be determined from a sample representing the material being tested. Tests shall be taken not later than the
day following placement of the mixture. The engineer will randomly determine test locations.

Delete Section 403.23.7.3 and replace with the following...

403.23.7.3 Removal of Material. All lots of material with a PFT less than 50.0 shall be removed and replaced with acceptable material by the contractor. Any sublot of material with a percent of theoretical maximum density of less than 90.0 percent or greater than 98.0 percent shall be removed and replaced with acceptable material by the contractor. For SMA mixtures, any sublot of material with a percent of theoretical maximum density of less than 92.0 percent shall be removed and replaced with acceptable material by the contractor. Any sublot of material with air voids in the compacted specimens less than 2.0 percent shall be evaluated with Hamburg testing and removed and replaced with acceptable material by the contractor if the rut depth is greater than 14.0 mm at the designated number of wheel passes above. No additional payment will be made for such removal and replacement. The replaced material will be tested at the frequencies listed in Sec 403.19. Pay for the material will be determined in accordance with the applicable portions of Sec 403.23 based on the replacement material.

Delete Section 403.23.7.4.1 and replace with the following...

403.23.7.4.1 Small Quantities. Small quantities are defined in Sec 403.19.3.2.1. Unless the contractor has elected to use the normal evaluation in the Bituminous QC Plan for small quantities, the following shall apply for each separate mixture qualifying as a small quantity

(a) QLA and PWL will not be required.

(b) Mixtures shall be within the specified limits for VMA, V_a, AC and density. In addition to any adjustments in pay due to profile, the contract unit price for the mixture represented by each set of cores will be adjusted based on actual field density above or below the specified density using the following schedule:

<table>
<thead>
<tr>
<th>Field Density (Percent of Laboratory Max. Theoretical Density)</th>
<th>Pay Factor (Percent of Contract Unit Price)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For all SP mixtures other than SMA:</td>
<td></td>
</tr>
<tr>
<td>92.0 to 97.5 inclusive</td>
<td>100</td>
</tr>
<tr>
<td>97.6 to 98.0 or 91.5 to 91.9 inclusive</td>
<td>90</td>
</tr>
<tr>
<td>91.0 to 91.4 inclusive</td>
<td>85</td>
</tr>
<tr>
<td>90.5 to 90.9 inclusive</td>
<td>80</td>
</tr>
<tr>
<td>90.0 to 90.4 inclusive</td>
<td>75</td>
</tr>
<tr>
<td>Above 98.0 or Below 90.0</td>
<td>Remove and Replace</td>
</tr>
<tr>
<td>For SMA mixtures:</td>
<td></td>
</tr>
<tr>
<td>&gt;94.0</td>
<td>100</td>
</tr>
<tr>
<td>Density Range</td>
<td>Incentive</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>93.5 to 93.9 inclusive</td>
<td>90</td>
</tr>
<tr>
<td>93.0 to 93.4 inclusive</td>
<td>85</td>
</tr>
<tr>
<td>92.5 to 92.9 inclusive</td>
<td>80</td>
</tr>
<tr>
<td>92.0 to 92.4 inclusive</td>
<td>75</td>
</tr>
<tr>
<td>Below 92.0</td>
<td>Remove and Replace</td>
</tr>
</tbody>
</table>

**9.0 Elevated Density.** Sublots with a QC density test result which compares favorably with QA, has a density result of 97% – 94% and have unconfined joint densities of 90% or greater shall receive a 1% incentive based on the bituminous mixture unit price for non-SMA mixtures.

**10.0 Basis of Pavement.** Payment for compliance with this provision will be made at the contract unit price for Item No. 403-10.56, Asphalt Performance Testing, lump sum.
Module 14

Contract Administration

MoDOT
Superpave QC/QA

Who's Doin' What

What is QC/QA?

Quit
Checking
Quit
Asking

What is QC/QA?

- Actually performing Quality Assurance.
- AASHTO R 10 definition of Quality Assurance:
  “All those planned and systematic actions necessary to provide adequate confidence that a product or facility will perform satisfactorily in service. Making sure the quality of a product is what it should be.”
- QC and QA are activities of performing Quality Assurance.
Benefits of Meeting Quality Requirements

- If meet or exceed quality requirements:
  - Pavement/Material will perform satisfactorily during its design life.
  - Require less maintenance to maintain.
  - Better use of highway funds.
  - Driver satisfaction.

Quality Requirements

- Contract Documents contain the specification.
- Asphalt Mixture Tests
  - Air voids, VMA, % asphalt, density, and TSR.
- Mostly using performance related.
- Moving towards performance tests
  - Balance mix design using Ideal CT and Hamburg.

Parts of Quality Assurance

Quality Assurance

- Quality Control (QC)
- Independent Assurance Samples (IAS)
- Quality Acceptance (QA)
Independent Assurance Samples (IAS)

- Being performed by MoDOT on behalf of the federal government.
- MoDOT personnel not directly involved with acceptance testing.
- Performed on all project with federal funds.
- Ensures that those performing acceptance testing, on the project, are sampling and testing properly. Also ensure testing equipment functioning correctly.
- EPG, Section 123 Federal-Aid Highway Program.

Quality Control (QC)

- Being performed by the contractor.
- Sum-total of the activities performed by the contractor to make sure that a product meets contract quality requirements.
- The party producing the product is in the best position to exercise process Quality Control. [i.e., Contractor].

Quality Control (QC)

- Activities performed:
  1) Testing Material
  2) Inspecting Operation
Quality Control (QC)

- Testing Material
  1) Required Testing
     - Minimum number required.
     - Samples random & designated by engineer.
     - Do not provide too much advance notice about random sample locations.
     - Test results shall comply with the specifications.

Quality Control (QC)

- Testing Material (continued)
  2) Self Testing (extra testing)
     - Contractor's decision.
     - Sample location not required to be random.
     - Not used in pay factor determination.
     - Test results used to control the process.

Quality Control (QC)

- Testing Material (continued)
  3) Optional Testing
     - Contractor's decision.
     - Doing non-required test to check quality.
     - Most likely will encounter with concrete (i.e., unit weight).
Quality Control (QC)

- All 'Required Test' results need to be furnished to the engineer.
- 'Self Test' and 'Optional Test' results do not have to be furnished to the engineer.

Quality Control (QC)

- Inspecting Operation
  1) Monitoring Materials
     - Testing delivered aggregates.
     - Reviewing bill of lading or certifications.
       (i.e., asphalt binder, antistrip, rejuvenator, etc.)
     - Review condition of material.
       (i.e., contamination, segregation, etc.)

Quality Control (QC)

- Inspecting Operation (continued)
  2) Plant Setting
     - Producing Job Mix Formula.
     - Responsible for plant adjustments.
  3) Monitoring Production Facility.
     - Stockpiles
     - Loading of material
     - Equipment
Quality Control (QC)

- Inspecting Operation (continued)
  4) Monitoring Placement
     - Aggregate base compaction.
     - Tack/Prime coat application.
     - Check mat appearance (i.e., Segregation).
     - Work zone and PPE usage.
     - Mat temperature
     - Cross slope.

Quality Control (QC)

- Communication is critical
- Advising QA Inspector about:
  - All test results.
  - Mix design adjustments.
  - Production schedules.
  - Changes in production.

Quality Acceptance (QA)

- Being performed by the MoDOT
- The sum total of the activities performed by MoDOT to accept the Quality Control (QC) data and to confirm that the product provided meets the specification requirements.
Quality Acceptance (QA)

Activities Performed:
1) Acceptance Testing
2) Assurance Testing
3) Inspection

Quality Acceptance (QA)

Acceptance Testing
- Performing to accept QC test results.
- Test performed on independent samples.
- Minimum number of tests required; perform as many tests needed to ensure the quality.
- Random sample location.
- Favorable comparison required for each tested sample.

Favorable Comparison Lot by Lot Basis

QA results must fall within this range
Individual QA Test
Population Produced (Based on QC test results)
2 Std Dev. QC Average 2 Std Dev.
1 Std Dev. 1 Std Dev.
Quality Acceptance (QA)

- Acceptance Testing (continued)
  - If sample(s) do not compare, QC test results may not be used to determine pay factors; need to resolve discrepancies.
  - If unable to resolve disputes in the field:
    1) Resolve by an independent third party.
    2) Use QC and QA test results to determine the pay factor (n = 5).

Why is Acceptance Testing Important?

- Critical because of the incentive and disincentive aspect of the QC/QA program.
- Pay Factors based on percent within limits total (PWL_t):
  - If PWL_t ≥ 70%; PF = (0.5 * PWL_t) + 55
  - If PWL_t < 70%; PF = (2 * PWL_t) - 50

Did you know?

- Can sample material at anytime anywhere.
- "Material will be subject to inspection or test at any time during production or manufacture or at any subsequent time prior to or after incorporation into the work. Material for sampling will be selected by the engineer."
  (Standard Specification 106.1.4)
Quality Acceptance (QA)

- Assurance Testing
  - Performing to confirm (1) QC sampling and testing correctly and (2) using proper operating equipment.
  - Test performed on split samples.
  - Test performed on retained samples.
  - Minimum number of test required.
  - Should perform early in the project to ensure QC is performing test properly.
  - Favorable comparison required.
  - If not comparing need to resolve difference.
Quality Acceptance (QA)

- Inspection
  1) Witness QC Sampling & Testing
     - Ensure proper procedures being used
     - Review testing equipment to ensure
       (1) testing equipment in good working
       order and (2) confirm testing equipment
       has been calibrated.
     - Review Control Charts.

Quality Acceptance (QA)

- Inspection (continued)
  2) Inspecting Plant Operation
     - Review stockpiles.
     - Material Condition.
     - Material Handling (e.g.,
       loading at plant, hauling
       trucks, etc.).
     - Review plant calibration
       records.
     - Facility functioning properly.

Quality Acceptance (QA)

- Inspection (continued)
  3) Inspecting Plant Settings
     - Ensure plant is set on Job Mix Formula.
     - Other settings (e.g., bag house return,
       mineral filler, etc.).
Quality Acceptance (QA)

- Inspection (continued)
- 4) Inspecting Placement Operation
  - Check aggregate base compaction.
  - Check tack/prime application.
  - Check mat temperature.
  - Check mat appearance.
  - Check work zone & PPE usage.

Quality Acceptance (QA)

- Communication is critical.
- Advising QC Inspector about:
  - All test results.
  - Any items of concern.
- QA inspector needs to keep Resident Engineer and District Construction & Materials Engineer advised of any problems.

QUESTIONS
Appendix

Items:

1. Outlier Evaluation ASTM E178
2. ASTM E178 Dealing with Outlying Observations
3. Mix Design Overview Binder, Rap, Shingles Module 2C(1)
4. Mix Design Overview Testing and Evaluation Module 2C(2)
5. Ignition Oven Test Cookbook
6. Rice Test (Maximum Specific Gravity) Cookbook
7. Equipment Information for:
   - AASHTO T312 Gyratory
   - AASHTO T209 Maximum Specific Gravity
   - AASHTO T308 Binder Ignition
Appendix Item #1.

OUTLIER EVALUATION
ASTM E 178
Applies to test values: G_{mn}, G_{mb}, % binder, core sp. gravity

1. If the largest test value ($x_{\text{max}}$) in the set is suspected to be an outlier, calculate the t-statistic:

$$t = \frac{(x_{\text{max}} - x_{\text{avg}})}{S}$$

Where $x_{\text{avg}}$ = average
$S$ = standard deviation

2. If the smallest test value ($x_{\text{min}}$) in the set is suspected to be an outlier, calculate the t-statistic:

$$t = \frac{(x_{\text{avg}} - x_{\text{min}})}{S}$$

3. Compare the largest calculated t-statistic to the critical t-statistic. The critical t-statistic depends on the desired significance level and the number of test results in the set. MoDOT has set the significance level at 5%. If the evaluation is of an outlier either being too high, or too low, the following is a table of t-critical values. Typically, there are 4 sublots per lot, with one test per subplot:

<table>
<thead>
<tr>
<th>No. of tests</th>
<th>t @ 5% in tail</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.153</td>
</tr>
<tr>
<td>4</td>
<td>1.463</td>
</tr>
<tr>
<td>5</td>
<td>1.672</td>
</tr>
<tr>
<td>6</td>
<td>1.822</td>
</tr>
<tr>
<td>7</td>
<td>1.938</td>
</tr>
<tr>
<td>8</td>
<td>2.032</td>
</tr>
<tr>
<td>9</td>
<td>2.110</td>
</tr>
<tr>
<td>10</td>
<td>2.176</td>
</tr>
</tbody>
</table>

If the calculated t-statistic is greater than $t_{\text{critical}} (\alpha=5\%)$, consider the test result to be an outlier. Material from the retained QA or QC sample may be tested to determine a replacement value.
ASTM E-178  Dealing with Outlying Observations

Example

\[ G_{mm} = 2.474, 2.478, 2.484, 2.522 \]

\[ \bar{x} = 2.490 \]

\[ s = 0.022 \]

\[ T_n = \frac{(x_n - \bar{x})}{s} = \frac{\max (2.522 - 2.490)}{0.022} = 1.455 < 1.463 \]

\[ T_1 = \frac{(\bar{x} - x_i)}{s} = \frac{\min (2.490 - 2.474)}{0.022} = 0.727 < 1.463 \]

From Table 1, 5% Significance at 4 observations the limit is 1.463. Therefore, there are no outlying data.

For specific gravity determinations, standard deviation (s) should be to the thousandth place, 0.xxx.

For asphalt content determinations, standard deviation (s) should be to the hundredth place, 0.xx.
MODULE 2C(1)

MIX DESIGN
OVERVIEW:
Binder
RAP & Shingles

OUTLINE

Module 2c(1):
- Binder grading & selection
- M 332 grades

Module 2c(2):
- Testing & evaluation
- RAP & shingles
- Mixing & compaction temperatures

ASPHALT (BINDER) GRADING

- Binder produced in grades
- Grades based on viscosity-temperature behavior
- Choice of grade depends primarily on climate

ASPHALT (BINDER) BEHAVIOR

- Based on rheology
  - Rheology: study of flow and deformation
- Asphalt cement is a viscoelastic material:
  - Elastic: spring
  - Visous: dashpot (piston)
Binder Behavior
- Asphalt is a *thermoplastic*
- Behavior depends on:
  - Temperature
  - *Duration of loading*
  - *Aging* (properties change with time)

**SELECTION OF PG BINDER GRADE**
- Based on:
  - *Climate*
  - Depth in pavement
  - Volume of traffic
  - Vehicle speed
  - Desired level of reliability
  - RAS (shingle) content
  - RAP content

**SELECTION OF PG BINDER GRADE**
*Climate*
- Grade chosen primarily on temperature expected:
  - to prevent rutting, based on cumulative hours at elevated temperatures
  - to prevent cold temperature cracking, based on average single-day low temperature

**CONDITIONING/TESTING**
- Rutting: High temperature (DSR)
- Fatigue Cracking: Intermediate temperature (DSR)
- Cold-temperature cracking: cold temperature (BBR)
Superpave Asphalt Binder Specification
AASHTO M 320
The grading system is based on Climate

**PG 64 - 22**

- Performance Grade
- Cold-temperature crack resistant down to -22 °C (-7.6°F)
- Rut-resistant up to 64 °C (147°F)

---

### AASHTO M320 PG Grading System

- 6 degree increments

<table>
<thead>
<tr>
<th>High Temperature Grades</th>
<th>Low Temperature Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Degrees C)</td>
<td>(Degrees C)</td>
</tr>
<tr>
<td>PG 46</td>
<td>-34, -40, -46</td>
</tr>
<tr>
<td>PG 52</td>
<td>-10, -16, -22, -28, -34, -40, -46</td>
</tr>
<tr>
<td>PG 58</td>
<td>-16, -22, -28, -34, -40</td>
</tr>
<tr>
<td>PG 64</td>
<td>-10, -16, -22, -28, -34, -40</td>
</tr>
<tr>
<td>PG 70</td>
<td>-10, -16, -22, -28, -34, -40</td>
</tr>
<tr>
<td>PG 76</td>
<td>-10, -16, -22, -28, -34</td>
</tr>
<tr>
<td>PG 82</td>
<td>-10, -16, -22, -28, -34</td>
</tr>
</tbody>
</table>

---

### Choosing a PG Grade for a Climate

- Cleveland: say, get 30 years of weather data
- Convert air temperatures to pavement temperatures
- Average high pavement temperature is 52 °C
- Average low pavement temperature is -16 °C
- A PG 52-16 will cover 50% of the data, thus will have a 50% Reliability
- A PG 58-22 will cover ~98% of the data, thus will have a ~98% Reliability
Rule-of-90 (or 92)

- If temperature range (absolute value high to low is less than 90° (or 92°), the binder is probably non-modified ("neat" asphalt)
- If range is ≥ 90°, probably is modified
- Examples:
  - PG 64-22, range = 86° non-modified
  - PG 70-22, range = 92°, modified
  - PG 76-22, range = 98°, modified

TO MODIFY
Optional Materials

- Polymer (eg. elastomeric polymer)
- Polyphosphoric acid (PPA)
- REOB = Re-refined engine oil bottoms
- Air-blown asphalt
- Others

DO I REALLY HAVE POLYMER IN MY BINDER?

- M320 has the Elastic Recovery test - MoDOT has this in the 1015 spec

Elastic Recovery (%)

Elastic Recovery Measurements:

<table>
<thead>
<tr>
<th>Primary shape of briquette</th>
<th>After pulling apart</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 cm</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Seated at the middle</th>
<th>After 3 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(20-3) cm</td>
<td>20 cm</td>
</tr>
</tbody>
</table>

Elastic Recovery % = \frac{(L_0 - L_1)}{L_0} \times 100

- Greater %ER is better
Section 1015.10.3

<table>
<thead>
<tr>
<th>Grade</th>
<th>ER, min. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64-22, 58-22, 58-28</td>
<td>----------</td>
</tr>
<tr>
<td>PG 70-22</td>
<td>55</td>
</tr>
<tr>
<td>PG 76-22</td>
<td>65</td>
</tr>
</tbody>
</table>

State DOTs with Binder “Exclusions” (don’t allow): (PPA), REOB, Air Blown Asphalt, Other

Other DOTs handle the problem in different ways

POLYPHOSPHORIC ACID (PPA)

- Can increase binder high-temp PG & performance without degrading low temp grade & performance
- Typically dosed at 0.25% to 1.5% by weight of asphalt

PPA Possible Issues

- May make mix more prone to moisture sensitivity
- PPA may react with amine-based Liquid Anti Strips (LAS) & Warm Mix Additives (WMA) which will lead to a partial decrease in high-temp PG improvement
- Chemically compatible LAS and WMA function should not be inhibited. Performance testing such as AASHTO T283 (TSR) or T324 (HWT) are highly recommended
- LAS and WMA suppliers make PPA-compatible materials
PPA
Possible Issues, cont'd.

- Good communication with contractor regarding potential use of amine-based LAS
- Ensure compatibility with WMA & LAS

Simple Test to Detect PPA in Asphalt

Other Analysis Methods

- To detect PPA in Asphalt
  - XRF - detect presence of phosphorus
  - DSR - detect drop in binder high PG stiffness
- Note - Just because binder contains phosphorous does not mean it has been modified with phosphoric acid
- It could be Engine Oil Additives - REO9s can contain a heat stabilizing additives that can contain up 8% phosphorous, 8.5% Zinc

SELECTION OF PG BINDER GRADE

- Climate

  - Specify a higher upper number-grade to prevent rutting eg. 58 → 64
  - Specify a lower number-grade to prevent cold temperature cracking, eg. -28 → -34
MATCH GRADE TO CLIMATE - Example

PG Binder Selection

> Many agencies have established zones

LTPPBind Program
Lower PG Number
(Low Temperature Values)

SELECTION OF PG BINDER GRADE

- Based on:
  - Climate
  - Depth in pavement
  - Volume of traffic
  - Vehicle speed
  - Desired level of reliability
  - RAS (shingle) content
  - RAP content

Appendix Item #3
SELECTION OF PG BINDER GRADE

Depth in Pavement

- Place better binder ("modified" binder) in surface mix and first underlying layer (top 4"")

Binder Grading Specs

- The following slides refer to traditional M 320 binder grades (not M 332 "MSCR") unless noted

SELECTION OF A BINDER GRADE

- Can "bump" up a grade (increase the high temperature number) for high traffic levels (greater than 30 million ESAL’s)
- Ex.: PG 64-22 → PG 70-22
Effect of Traffic Amount on Binder Selection

- 10 to $30 \times 10^6$ ESAL
  - Consider increasing -- one high temp grade
- $\geq 30 \times 10^6$ + ESAL
  - Recommend increasing -- one high temp grade

> Equivalent Single Axle Loads

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Selection of PG Binder Grade

- Based on:
  - Climate
  - Depth in pavement
  - Volume of traffic
  - Vehicle speed
  - Desired level of reliability
  - RAS (shingle) content
  - RAP content

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Vehicle Speed

- Slower $\Rightarrow$ increased rutting
- Stopped $\Rightarrow$ worst case for rutting

Why?
- Longer duration of load

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Effect of Loading Rate (Vehicle Speed) on Binder Selection

- Can bump up a grade (increase high temperature number) for slow moving (less than 35 mph) traffic [MoDOT uses 12-45 mph]
- MoDOT bumps 2 grades for <12 mph
- Grade bumps apply to the surface mix and the top lift of the underlying mixture
- Grade bumping: no effect on low temp grade

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**Effect of Loading Rate on Binder Selection**

- Example
  - for toll road
    - PG 64-22
  - for toll booth
    - PG 70-22
  - for weigh stations
    - PG 76-22

**SELECTION OF PG BINDER GRADE**

- Based on:
  - Climate
  - Depth in pavement
  - Volume of traffic
  - Vehicle speed
  - Desired level of reliability
  - RAS (shingle) content
  - RAP content

**SELECTION OF PG BINDER GRADE**

- Can increase reliability for a given climate & depth by increasing the high and/or low temperature values (this may lead to a modified binder)
- PG grades chosen to match average high & low temperatures will give ~ 50% reliability
- 98% reliability’s typically chosen for more critical situations
- Some DOT’s choose 98% reliability for all binder grades

**SELECTION OF PG BINDER GRADE**

- Based on:
  - Climate
  - Depth in pavement
  - Volume of traffic
  - Vehicle speed
  - Desired level of reliability
  - RAS (shingle) content
  - RAP content
RAP/RAS Binders

- **RAP** has aged - stiffer than virgin binder
- **RAS** - roofing binder is much stiffer
- **Combined** virgin & recycled binder → stiffer
- May be too hard

Solutions

- Limit the % of recycled effective binder (eg. 30% max)
- Use a softer virgin grade binder (eg. PG 58-28)
- Add a rejuvenator/viscosity modifier (eg. 3% Hydrogreen)
- Combinations of the above

"Effective Binder"

- When dealing with recycled materials, interested in "effective binder", not total binder

ABSORPTIVENESS OF AGGREGATE

- Absorbed asphalt
- Effective asphalt
**BINDER CONTENT**

Conceptually:
- $P_b = P_{ba} + P_{be}$
- $P_b =$ total binder content
- $P_{ba} =$ abso-bed binder
- $P_{be} =$ effective binder

**RAP & SHINGLES (RAS)**

- If effective virgin binder is less than 70% (more than 30% replacement by RAP+RAS), more binder testing (use of "blending charts") is required to assure that the combined binder meets the JMF specified binder grade
- So, typically contractors are limiting the effective recycle binder content of their mixes to ≤30%

**SHINGLES (RAS)**

- Shingles only allowed for contract specified grade of PG64-22 (if PG 70 and greater, shingles not allowed)
- If effective virgin binder is 60-70% (RAP+RAS =30 to 40%), must use PG 52-28 or 58-28 (no binder testing required)

**MoDOT Binder Grade PG 64-22**

- Climate= whole state
- Position in pavement=
  - surface layer and first underlying layer (lower traffic)
  - Lower lifts (∼all traffic)
- Traffic speed > 45 mph
- Traffic volume < 30 million ESALS
- Reliability= ∼98%
- Upper number (64) is bumped up for increased traffic and/or slower speeds in top layer/top underlying lift
M 320 PG GRADES

MoDOT typically specifies:

- **PG 64-22** in the base course and for lower traffic levels mph in the surface course
- **PG 70-22** for traffic levels >3500 AADT and/or traffic 12-45 mph in the surface course
- **PG 76-22** for some metropolitan areas (<12 mph) or steep grades with slow speeds

---

MoDOT Binder Selection—Depth, Traffic Volume, Vehicle Speed

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Layer</th>
<th>Binder Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstates</td>
<td>Surface = SP125 or SMA &amp; 1st underlying lift Remaining lifts</td>
<td>PG76-22</td>
</tr>
<tr>
<td>Major Routes Heavy Volume</td>
<td>Surface = SP125 &amp; 1st underlying lift Remaining lifts</td>
<td>PG64-22</td>
</tr>
<tr>
<td>Major Routes Medium or Low Volume</td>
<td>Surface = SP125 or BP-1 Underlying lifts</td>
<td>PG64-22</td>
</tr>
<tr>
<td>Minor Routes</td>
<td>All (generally BP-1 surface)</td>
<td>PG64-22</td>
</tr>
</tbody>
</table>

---

MODIFIED PG BINDERS

- How a material handles, compacts, etc., may be greatly affected if the binder is **modified**, eg. with a polymer.
- The supplier of the binder should be contacted to determine if the binder has been modified and what effects this modification might have on the mixture (eg. special handling requirements)

---

BINDER TESTING

**PG 64-22**

- Upper PG number (eg, 64): DSR
- Lower PG number (eg, -22): BBR
OUTLINE

- **Module 2c(1):**
  - Binder grading & selection
  - M 332 grades
- **Module 2c(2):**
  - Testing & evaluation
  - RAP & shingles
  - Mixing & compaction temperatures

ALTERNATE GRADING SYSTEMS

- Original: M 320
- ~New (MSCR): M 332

AASHTO M 320 Issues and the M 332 Solution

- M 320 was developed based on neat asphalts and does not do PMAs justice
  - Therefore some Agencies have added "Plus Tests", such as % Elastic Recovery (% ER).
  - However empirical tests such as % ER only show the presence of, but not the effectiveness of polymer-modification.

Polymer Modification

- Same polymer, same amount of polymer, but different behavior
- Not well characterized with M320 and PG+ tests
AASHTO M 320 Issues and the M 332 Solution

- The MSCR specification M332 corrects the M320 deficiencies by testing at the project climate temperatures and at the stress level commensurate with the expected traffic.
  - M332 uses the non-recoverable compliance % (Jnr) and % Recovery to better qualify the type of modification.

Type of Modification

- M332 (MSCR) is blind to the type of modifier (because the test is physical, not chemical)

M 332 (MP 19) Binder Test/Specification

- MSCR = Multiple Stress Creep Recovery test
- Extra DSR test
- Alternate AASHTO binder specification (M 332) to supplement M 320

M 332 Binder Grades

Section 1015.10.3.1

- Introduces "traffic grades" increasing S → H → V → E
- Before M332, to bump a grade for more traffic, raise upper PG number (e.g., PG 64 → PG 70)
- New: Stay in climate grade (PG 64-22 for Missouri), but bump up by traffic

<table>
<thead>
<tr>
<th>M 320</th>
<th>M 332</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-22</td>
<td>64-22 Grade S</td>
</tr>
<tr>
<td>70-22</td>
<td>64-22 Grade H</td>
</tr>
<tr>
<td>76-22</td>
<td>64-22 Grade V</td>
</tr>
</tbody>
</table>

Appendix Item #3
"Workhorse" Binder Grades

M 332 (MSCR) System
- Test for $J_{nr}$ = non-recoverable creep compliance
- Creep is the plastic deformation from the wheel load (bad → rutting)
- We want the asphalt to recover from creep
- Non-recoverable portion of creep is bad
- So, we want a low $J_{nr}$
- To grade bump for higher traffic ($S \rightarrow H \rightarrow V$), lower the maximum allowable $J_{nr}$
- To do that, must add more modifier

M 332 Grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Traffic/Speed</th>
<th>MoDOT Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>S (Standard)</td>
<td>&lt;10 million ESALS AND &gt; 44 mph</td>
<td>F, E, some C</td>
</tr>
<tr>
<td>H (Heavy)</td>
<td>10-30 million ESALS OR 12 - 44 mph</td>
<td>Some C</td>
</tr>
<tr>
<td>V (Very Heavy)</td>
<td>&gt;30 million ESALS OR &lt; 12 mph (&quot;standing&quot;)</td>
<td>B</td>
</tr>
<tr>
<td>E (Extra Heavy)</td>
<td>&gt;30 million ESALS AND &quot;standing&quot;</td>
<td>B</td>
</tr>
</tbody>
</table>

Appendix Item #3
MOOD SUPRAPHAVE QC/QA TRAINING/CERTIFICATION COURSE

MODULE 2C(2)

MIX DESIGN OVERVIEW:
Testing & Evaluation
RAP & Shingles
Mixing & Compaction
Temperatures

OUTLINE

- Module 2c(1):
  - Binder grading & selection
  - M 332 grades

- Module 2c(2):
  - Testing & evaluation
  - RAP & shingles
  - Mixing & compaction temperatures

M 332 Spec
DSR Tested at 64° C

<table>
<thead>
<tr>
<th>Traffic Level</th>
<th>Max. Allowable Jnr, kPa-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>4.5</td>
</tr>
<tr>
<td>H</td>
<td>2.0</td>
</tr>
<tr>
<td>V</td>
<td>1.0</td>
</tr>
<tr>
<td>E</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Note: decreasing max. allowable Jnr for more severe traffic conditions

Binder Grade System
Transition:
M 320 → M 332

- Contracts & EPG: still M 320 grades
- Many suppliers now supply M 332
- M 332 grades are cheaper than corresponding M 320 grades (less polymer), so contractors prefer
- [MoDOT did not adopt the Appendix in M 332]
**M 332 APPENDIX**

**MSCR % Recovery**

- 2 bits of data from your MSCR test: MSCR % Recovery (R1,2) & Jnr
- Plot: see where your point falls

![MSCR Elastic Response Graph](image)

---

**Example JMF Showing Substitution of purchased grade M 332 (PG 64-22V) for contract grade M 320 (PG 76-22)**

- SMA: No RAP/RAS allowed
- No additives, so in-line grade = PG 64-22V

---

**What's My Grade?**

**Different Example**

- *"Contract Grade"* = the PG grade in the contract, eg. PG 70-22
- *"Purchased Grade"* = what contractor buys from supplier (terminal), eg. PG 58-28 (if RAP/RAS will be used)
- *"In-line Grade"* = Purchased grade + additive (warm mix, anti-stripe, etc.)
  - eg. PG 58-28
- *"In-line Grade"* = Purchased grade + modifier (rejuvenator)
  - eg. PG 52-28

---

**What's My Grade, cont'd.**

- *"True Grade"* = shows at what temperatures the binder actually met the required specs, eg., PG 59.2-29.7
- *"Mixture Grade"* = what the grade is after mixed with recycled binder in RAP/RAS
How Recycle Affects Binder Grade Strategy

- **Contract Grade** is what MoDOT wants for performance (eg. PG 64-22)
- RAP/RAS binder is stiff
- To meet **Contract Grade**, contractor may need to start with a softer **Purchased Grade** (eg. PG 58-28)
- RAP/RAS will provide additional stiffness
- **Mixture grade**, hopefully, will be close to the **Contract Grade**

ADDITIVES vs MODIFIERS

- **Additives:**
  - Compactibility
  - Warm mix
  - Anti-strip
  - Usually a low amount (0.25-1.75% of binder)
  - Doesn't affect PG grade
    (Purchased grade and In-line grade ~ same)

- **Modifiers:**
  - Rejuvenators, viscosity modifiers, etc.
  - Changes the PG base asphalt
  - Usually a greater amount: 2-5% of binder

Example of Contract Grade, Purchased Grade, In-Line Grade (after additives/modifiers)

- Has RAP/RAS
- Has modifier
- **Contract > Purchased > In-Line**
- PG 64-22 > PG 58-28 > PG 52-28

What is Sampled & Tested for Acceptance?

- **Purchased (Terminal) Grade** or
- **In-line Grade (HMA plant)**
- The results of the testing determine whether the sample passes: if rejected, penalties are assessed per Section 460.3.13 EPG:
  - If M 320 binder, the high temperature True Grade will be determined
  - If M 322 binder, penalties will be assessed based on the Jrn (except Grade S-test as if M320)
### M 320 Binder
*Tested On Non-Aged ("Original")
Condition
Example: PG 64*

<table>
<thead>
<tr>
<th>Spec</th>
<th>DSR Testing</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSR ≥ 1.00 kPa</td>
<td>DSR &gt; 0.90 kPa</td>
<td>No penalty</td>
</tr>
</tbody>
</table>

If sample fails:

<table>
<thead>
<tr>
<th>Spec temp</th>
<th>Hi-Temp True Grade Temp</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>64°</td>
<td>&lt; 2° low</td>
<td>No penalty</td>
</tr>
<tr>
<td>64°</td>
<td>&gt; 2° &amp; &lt; 4° low</td>
<td>3% of mix unit price</td>
</tr>
<tr>
<td>64°</td>
<td>&gt; 4° &amp; &lt; 6° low</td>
<td>10% of mix unit price</td>
</tr>
<tr>
<td>64°</td>
<td>&gt; 6° low</td>
<td>16% of mix unit price</td>
</tr>
</tbody>
</table>

### M332 Binder
*Tested On RTFO-Aged Condition For Grade H*

<table>
<thead>
<tr>
<th>Spec</th>
<th>Jnr Tested</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jnr ≤ 2.0 kPa-1</td>
<td>≤ 2.2 kPa-1</td>
<td>No penalty</td>
</tr>
<tr>
<td>Jnr ≤ 2.0 kPa-1</td>
<td>&gt; 2.1 &amp; &lt; 2.7</td>
<td>3% of mix unit price</td>
</tr>
<tr>
<td>Jnr ≤ 2.0 kPa-1</td>
<td>&gt; 2.7 &amp; &lt; 4.0</td>
<td>10% of mix unit price</td>
</tr>
<tr>
<td>Jnr ≤ 2.0 kPa-1</td>
<td>&gt; 4.0</td>
<td>16% of mix unit price</td>
</tr>
</tbody>
</table>

### M332 Binder
*Tested On RTFO-aged Condition For Grade V*

<table>
<thead>
<tr>
<th>Spec</th>
<th>Jnr Tested</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jnr ≤ 1.0 kPa-1</td>
<td>≤ 1.1 kPa-1</td>
<td>No penalty</td>
</tr>
<tr>
<td>Jnr ≤ 1.0 kPa-1</td>
<td>&gt; 1.1 &amp; &lt; 1.3</td>
<td>3% of mix unit price</td>
</tr>
<tr>
<td>Jnr ≤ 1.0 kPa-1</td>
<td>&gt; 1.3 &amp; &lt; 2.0</td>
<td>10% of mix unit price</td>
</tr>
<tr>
<td>Jnr ≤ 1.0 kPa-1</td>
<td>&gt; 2.0</td>
<td>16% of mix unit price</td>
</tr>
</tbody>
</table>

### What is Sampled & Tested for Acceptance, cont’d.

- **Mixture Grade** - not normally tested for acceptance (technically, it has been aged in the drum, so would be difficult to compare to the specification [some criteria require that the binder not be aged at all])
- Hopefully, the **Mixture Grade** is close to the **Contract Grade**
- More likely to be true if the % recycle is kept below 30%
TYPICAL TRENDS

- Most mixes are designed at less than 30% effective binder replacement
- Most products added are additives, not modifiers
- Small majority substitute M 332 for M 320
- Mixes with more than ~20% binder replacement use a softer Purchased Grade than Contract Grade; mixes with less than 20% replacement stay with Contract Grade
- Most softer Purchased Grades drop both upper & lower numbers

RECYCLED ASPHALT PAVEMENT (RAP): Considerations

- OK in all mixes except SMA
- Can use a maximum of 30% virgin effective binder replacement without changing the binder grade
- >30% effective binder replacement can be from RAP+RAS if binder testing (use of blending charts) shows that the combined binder meets the contract specified grade
- Aggregate must meet deleterious spec 1002 (10C4 if a 401 mix)
- Aggregate must pass Micro-Deval test spec (waived if RAP is from a MoDOT project)

OUTLINE

- Module 2c(1):
  - Binder grading & selection
  - M 332 grades
- Module 2c(2):
  - Testing & evaluation
  - RAP & shingles
  - Mixing & compaction temperatures

RAP

Micro Deval
AASHTO T 327

- Remove binder coating by extraction or ignition
- Test aggregate
- % loss should be within 5% of the virgin aggregate utilized in the new mix design
- Ex.: New mix virgin MD = 21
  RAP MD should be 16-26
- 1 test per 1500 tons
- Waived if from MoDOT roadway

Appendix Item# 4
RECYCLED ASPHALT SHINGLES (RAS)

- May be used in any mix that has a specified contract grade of PG 64-22
- If virgin effective binder < 70% of blended total binder: drop virgin grade to PG 58-28 or PG 52-28
- Other restrictions

Re-Calculation of RAP/RAS Binder

- The % effective virgin binder replacement content Pcv must be re-calculated when:
  - Change in % RAP or RAS from a field mix adjustment
  - Change in % binder content in the RAP (tested 1 per 4 sublots via T164 or T308)

OUTLINE

- Module 2c(1):
  - Binder grading & selection
  - M 332 grades
- Module 2c(2):
  - Testing & evaluation
  - RAP & shingles
  - Mixing & compaction temperatures

DETERMINE MIXING & COMPACTION TEMPERATURES

- Develop the temperature-viscosity curve

Appendix Item# 4
TEMPERATURE - VISCOSITY

- As temperature increases, binder viscosity decreases (it gets thinner)
- This can be plotted.
- Viscosity is important to:
  - pumping
  - spraying
  - aggregate coating in mixing
  - absorption by aggregate
  - laydown and compaction
  - rutting

TEMPERATURE - VISCOSITY, cont'd.

- Establish the curve by running viscosity tests at 2 different temperatures
- Old method: capillary tubes
- New method: Brookfield rotational viscometer
- The curve is used to establish mixing and compaction temperatures necessary to achieve the required viscosity for these operations.
TEMPERATURE-VISCOSITY, cont'd.

- The steepness of the curve is called "temperature sensitivity"—that is, how sensitive is a particular binder to a change in viscosity resulting from a change in temperature.
- We don't like change—so we don't like a sensitive material—we want a relatively flat curve. Modifiers help get the viscosity change under control.

LAB MIXING & COMPACTION TEMPERATURES

- For non-modified binders:
  - Mixing temperature range = what it takes to get a viscosity of 0.17 ± 0.02 Pa·s
  - Compaction temperature range = what it takes to get a viscosity of 0.28 ± 0.03 Pa·s
- For modified binders: follow manufacturer's recommendations.

Plant Mixing & Roadway Compaction Temperatures

- May be different than lab temperatures
- Determine compaction temperature using test strips—typically 275-310°F
- Set plant mixing temperature somewhat higher, say 300-330°F
- Maximum recommended temperature is 338°F, should avoid exceeding 350°F.
ASPHALT CONTENT IGNITION METHOD  
(AASHTO T 308-18) METHOD A  
Asphalt Binder Correction Factor (CF) Determination  
(formerly “aggregate correction factor”)  

1. Run a butter mix through the mixing equipment.  

2. For a given mix, prepare two asphalt binder correction factor (CF) specimens at the design asphalt content using oven dry aggregate. It is recommended that the CF and field verification specimen sizes be the same.  

3. Obtain the tare weight of the baskets, pan, and lid.  

4. Place the hot mix into the sample basket. If the mix has cooled, oven dry at 110 ± 5°C to constant mass prior to placing in the basket. Spread the mix in the basket, being careful to keep the mix away from the sides. Allow at least ¾” clearance.  

5. Test (burn) the specimens as discussed in “Test Procedure.”  

6. If the difference between the measured binder contents of the two replicate specimens is more than 0.15%, test two more specimens. Discard the high and low values.  

7. Calculate the CF by determining the difference between the actual and measured asphalt binder contents [Actual %AC – Measured %AC] for each sample, and averaging the two differences. The “Actual %AC” is the amount weighed out in the batching process, expressed as a percent by weight of the mix.  

8. If the CF exceeds 1.0%, MoDOT Standard Specification Section 403.19.3.1.1 modifies AASHTO T 308-18 in the following manner:  

   A. According to AASHTO T 308-18, if the CF exceeds 1.0% at the typical chamber temperature of 538°C (1000°F), lower the chamber temperature to 482 ± 5°C (900 ± 8°F). If the CF determined at this lower temperature is less than or equal to 1.0%, use that CF for subsequent testing on that particular mix.  

   B. However, according to MoDOT Standard Specification Section 403.19.3.1.1, if the CF determined at 482 ± 5°C (900 ± 8°F) exceeds 1.0%, lower the chamber temperature to 427 ± 5°C (800 ± 8°F). Use the CF obtained at 427°C even if it exceeds 1.0%.
# Asphalt Content Ignition Method (AASHTO T 308-18)
## Method A

### Asphalt Binder Correction Factor ($C_F$) Determination

<table>
<thead>
<tr>
<th>Replicate</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tare (basket, etc.) Mass (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Dry Mass (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Dry Specimen Mass (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss in Weight (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$%AC_{\text{measured}} = M$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$%AC_{\text{actual}} = A$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$%AC_{\text{diff}} (M_1 - M_2)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

> 0.15%? If so, 2 more replicates

$C_F = M - A$

$C_F$, average

%ACdiff ($M_1 - M_2$)
ASPHALT CONTENT IGNITION METHOD  
(AASHTO T 308-18)  
METHOD A

Specimen size: Use the following table. It is recommended that the field verification specimen size be the same as the correction factor specimen size.

<table>
<thead>
<tr>
<th>NMS (mm)</th>
<th>Sieve Size</th>
<th>Minimum Specimen Size* (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>#4</td>
<td>1200</td>
</tr>
<tr>
<td>9.5</td>
<td>3/8&quot;</td>
<td>1200</td>
</tr>
<tr>
<td>12.5</td>
<td>1/2&quot;</td>
<td>1500</td>
</tr>
<tr>
<td>19.0</td>
<td>3/4&quot;</td>
<td>2000</td>
</tr>
<tr>
<td>25.0</td>
<td>1&quot;</td>
<td>3000</td>
</tr>
<tr>
<td>37.5</td>
<td>1 ½&quot;</td>
<td>4000</td>
</tr>
</tbody>
</table>

*Specimen sizes shall not be more than 500g greater than the minimum.

POSSIBLE SETTING CHANGES

1. To change the Stability Threshold:
   
   A. With oven off, press the “Calibration Factor” key while simultaneously pressing the Power Switch “on.”
   
   B. Enter new Stability Threshold value. Observe the Percent Loss window for the new value. Maximum allowable = 0.02.
   
   C. Press the Power Switch “off” then “on” to return oven to normal operation.

2. To change filter (afterburner) temperature (750°C typically):
   
   A. Press #5 key while simultaneously pressing the Power Switch “on.”
   
   B. Enter new temperature.
   
   C. Press “Enter.”
   
   D. New setpoint will be displayed.
MAINTENANCE
1. To check to see if the venting system is clogged, use the “Lift Test” procedure while the oven is at room temperature. With the power on, initiate a test (push “Start” button) without anything in the oven chamber. The blower fan will turn on. Watch the balance display. The display should read between -4 and -6 grams if the venting is adequate.

2. Burn accumulated soot out of the chamber by running the testing procedure at an elevated temperature without a sample.

TEST PROCEDURE
1. To change setpoint (furnace) temperature (538°C is typical):
   A. Press “Temp”
   B. Enter new setpoint
   C. Press “Enter”
   D. Press “Temp” again to verify new setpoint

2. To change the Asphalt Binder Correction Factor (C_F):
   A. Press “Calib. Factor”
   B. Enter new C_F
   C. Press “Enter”
   D. Press “Calib. Factor” again to verify

3. Preheat the oven to the setpoint, typically 538°C.

4. If the moisture content will not be determined, oven-dry the specimen at 110 ± 5°C to a constant mass.

5. Weigh the empty basket, etc. on an external scale to the nearest gram.

6. Place half the sample in the bottom basket and the other half in the top. Keep the specimen at least ¾” away from the basket sides. For larger samples, some operators make a hole in the middle of the mix.

7. Cool the loaded assembly to room temperature.

8. Weigh the loaded assembly. Calculate the mass of the specimen.
9. Press the “Weight” key and enter the specimen mass. Press “Enter.”

10. Press the “Weight” key again to verify specimen mass entry.

11. Press the “0” (zero) key to tare the internal balance.

12. Don your clean gloves, safety face shield, and safety attire.

13. Carefully load the specimen into the oven by inserting the basket until the handle tines touch the back of the oven. Make sure the basket is centered and is not touching the walls. Shut the door.

14. Observe the internal scale reading. The displayed value should check with the external scale value of basket assembly + dry specimen within ± 5 grams.

15. Press the “Start/Stop” key to initiate the ignition procedure.

16. When weight loss stabilizes (the change in %AC readings will not exceed 0.01% for three consecutive minutes), the oven will automatically end the test and print out the results. Depending on the oven setup, an alarm may sound and one may have to press the “Start/Stop” key to unlock the door.

17. Remove the printed results before opening the door as the tape is heat-sensitive.

18. Again don the safety gear, open the door, and remove the basket and mount it on the cooling plate. Cover with the cooling cage and allow to cool to room temperature.

19. Determine and record the final mass of the specimen, M_f.

20. From the total % loss, the oven will automatically subtract the C_F and the Temperature Compensation to give the %AC (by weight of mix). The %AC by weight of aggregate is the “Bitumen Ratio.”

21. Check for unburned asphalt (coke). If present, start with a new specimen.

NOTE: Read the manufacturer’s manual for additional information on safety and more detailed instructions on maintenance and operation.
ASPHALT CONTENT IGNITION METHOD  
(AASHTO T 308-18)  
METHOD A  
Manual Weighing Method

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Job No.</th>
<th>Route</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technician</td>
<td>Date</td>
<td>Sublot No.</td>
<td>Mix No.</td>
</tr>
</tbody>
</table>

Empty Basket Assembly Weight (g), \([T_e]\)

Initial Basket Assembly + Wet (or dry) Sample Weight (g), \([T_i]\)

Initial Wet (or dry) Sample Weight (g), \([W_i = T_i - T_e]\)

Final Basket Assembly + Burned Sample Weight (g), \([T_f]\)

Loss in Weight (g), \([L = T_f - T_i]\)

% Loss, \([P_L = (L / W_i) \times 100]\)

Aggregate Correction (Calibration) Factor (%), \([C_f]\)

Calibrated %AC, \([P_{bcal} = P_L - C_f]\)

% Moisture Content, \([MC]\)

% AC, corrected (by weight of mix), \([P_b = P_{bcal} - MC]\)
Theoretical Maximum Specific Gravity ($G_{mm}$) and Density of Asphalt Mixtures: AASHTO T 209-20

This test method shall be used to determine the maximum specific gravity ($G_{mm}$) of uncompacted asphalt mixtures. However, an option exists to obtain samples from pavement cores (AASHTO R 67) but that procedure is not presented, here.

### APPARATUS

<table>
<thead>
<tr>
<th>MINIMUM SAMPLE SIZE (MoDOT)</th>
<th>NOM. MAX SIZE (in.)</th>
<th>SAMPLE (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance</td>
<td>1</td>
<td>2500</td>
</tr>
<tr>
<td>Container (pycnometer)</td>
<td>¾</td>
<td>2000</td>
</tr>
<tr>
<td>Thermometers</td>
<td>½</td>
<td>2000</td>
</tr>
<tr>
<td>Vacuum Pump/System</td>
<td>3/8</td>
<td>2000</td>
</tr>
<tr>
<td>Water Bath</td>
<td>#4</td>
<td>2000</td>
</tr>
</tbody>
</table>

### PROCEDURE

#### Sample Preparation and Agitation

1. Dry the paving mix to a constant weight (mass repeats within 0.1%) at a temperature of 105 ± 5°C. This drying step shall be combined with any warming of the sample necessary to prepare it for separation.

   **NOTE:** The drying of the mix to constant weight prior to separation may be waived provided AASHTO T 329 shows the moisture content to be less than 0.1%. If the drying step is waived due to T 329 results, this fact must be documented and included in the T 209 results.

2. Separate the particles of the paving mix by hand. A small trowel can be used, but care must be taken not to fracture the mineral aggregate. Continually work the mix while, ultimately, cooling to room temperature. The particles of the fine aggregate portion should not be larger than ¼" at the completion of the separation step. Periodically, shake the pan back and forth to bring the larger clumps to the top.

3. Determine and record the weight of the empty pycnometer (without the lid).
4. When the specimen is at room temperature, place and level the sample in the pycnometer.
5. Determine and record the combined weight of the specimen and pycnometer.
6. Subtract the weight of the pycnometer from the combined weight of the specimen and pycnometer.
7. Record the net dry sample weight (A).
8. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely (≈1 inch).
9. Wet O ring of vacuum lid and secure lid on pycnometer (use vacuum grease if necessary to obtain a good seal).
10. Gradually increase the vacuum and hold 27.5 ± 2.5 mm Hg (3.7 ± 0.3 kPa) absolute vacuum for 15 ± 2 minutes.
11. Agitate the pycnometer and contents using mechanical or manual agitation during the vacuum period. Mechanical agitation is accomplished using a shaker device while manual agitation entails vigorously shaking the pycnometer at intervals of about 2 minutes.

**Mass Determination: Weigh in Air Method:**

1. At the end of the 15 ± 2 minute vacuum period, slowly release the vacuum at a rate not to exceed 60 mm Hg (8 kPa) per second (2.36 in. Hg/sec; gage).
2. Immediately start a 10 ± 1 minute time period. The requirement is to obtain the final weight of the pycnometer, completely filled, within this second time period. It is suggested that the timer be set for 9 minutes. Since the pycnometer is to be placed back in the water bath to bring it and its contents back to 25 ± 1°C, this will allow 2 minutes after the timer goes off to obtain the final weight.
3. Slowly submerge the pycnometer in the 25 ± 1°C water bath, being careful not to expose the sample to the air.
4. Place the capillary lid on the pycnometer ensuring the removal of all air bubbles inside the pycnometer while retaining as many fines as possible.
5. When the timer goes off, carefully remove the pycnometer from the bath. Dry off the exterior of the pycnometer. Add water to the lid weephole to ensure that the pycnometer is full. Dry off the exterior of the pycnometer again.
6. Zero the balance, then obtain and record the combined weight of pycnometer and contents (E).
7. Completely empty the pycnometer and re-submerge the empty pycnometer in the 25 ± 1°C water bath.
8. Again, check for air bubbles clinging to the inside of the pycnometer and the bottom of the capillary lid prior to placement on the pycnometer.
9. Leave it in the water bath for 10 ± 1 minutes of immersion.
10. Remove the pycnometer and dry off the exterior. Add water to the weephole with an eyedropper until seepage occurs around the lid. Dry off the exterior again and obtain the total weight of the pycnometer filled with water (D).

**Mass Determination: Weigh in Water Method:**

A weigh-in-water station should be available that includes a water bath suitable for immersion of the suspended container with its deaerated sample, an overflow outlet for maintaining a default water level, a method for controlling or monitoring water temperature, a balance with a weigh-below capability, and some type of suspended platform on which the pycnometer/flask can be supported while submerged in the water bath. The platform and rod/wires that connect the platform to the balance should displace a minimum amount of water.
1. Prepare and vacuum sample as described earlier. After 15 ± 2 minutes of agitation and vacuum at the specified level, slowly release the vacuum at a rate not to exceed 60 mm Hg (8 kPa) per second (2.36 in. Hg/sec; gage) then disassemble apparatus.

2. The temperature of the water bath should be adjusted to and maintained at 25 ± 1°C, the water level shall be at its default level (full, but not overflowing), then the weigh-in-water system balance shall be zeroed out (tared).

3. Suspend the pycnometer (without the lid) and deaerated sample in the water bath and determine the combined weight (C) after 10 ± 1 minutes of immersion.

4. After recording the combined weight (C), immediately remove the pycnometer from the water bath, completely remove the sample from the pycnometer, and then, without delay, obtain the mass of the empty pycnometer (B) after 10 ± 1 minutes of immersion.

Note: It is important that every weight determination begins by returning the water level to its default position; i.e. the water has just stopped dripping from the overflow.

CALCULATIONS

**Weigh in Air Method:** Calculation of maximum specific gravity is performed in accordance with AASHTO T 209-20, Section 12.1.3.

\[ G_{mm} = \frac{A}{A+D-E} \]

Where:
- \( G_{mm} \) = maximum theoretical specific gravity (reported to three decimal places)
- \( A \) = mass of oven-dry sample in air, (gm)
- \( D \) = mass of pycnometer filled with water, (gm)
- \( E \) = mass of pycnometer filled with water + sample, (gm)

**Weigh in Water Method:** Calculation of maximum specific gravity for this method is performed in accordance with AASHTO T 209-20, Section 12.1.2.

\[ G_{mm} = \frac{A}{A+B-C} \]

Where:
- \( G_{mm} \) = maximum theoretical specific gravity (reported to three decimal places)
- \( A \) = mass of oven-dry sample in air, (gm)
- \( C \) = mass of sample + pycnometer in water, (gm)
- \( B \) = mass of pycnometer in water, (gm)

NOTE: Section 12.2 describes how to calculate a weighted average \( G_{mm} \) for large samples tested a portion at a time, if necessary.
MAXIMUM SPECIFIC GRAVITY: \( G_{mm} \)

AASHTO T 209

PROJECT________________ROUTE________________MIX NO.________________

LOT NO_____________SUBLOT_____________TECHNICIAN_____________

PRE-TEST REQUIREMENT: MIX MOISTURE CONTENT < 0.1%

1) Results from T 329: Moisture Content (%) = ____________________

OR

2) Mass repeats within 0.1% [percent loss < 0.1% (based on 2\textsuperscript{nd} wt. per interval)]:

\[ P_{MC} = \text{Pan weight (g):} \]
\[ T_0 = \text{Initial sample + pan weight (g):} \]
\[ W_0 = T_0 - P_{MC} = \text{Initial sample weight (g):} \]

1\textsuperscript{st} Drying Interval (DI)

\[ T_1 = \text{1\textsuperscript{st} DI sample + pan weight (g):} \]
\[ W_1 = T_1 - P_{MC} = \text{1\textsuperscript{st} DI sample weight (g):} \]
\[ L_1 = W_0 - W_1 = \text{1\textsuperscript{st} Loss in weight (g):} \]
\[ \left( \frac{L_1}{W_1} \right) \times 100 = \text{1\textsuperscript{st} Percent loss (%):} \]

2\textsuperscript{nd} Drying Interval (DI)

\[ T_2 = \text{2\textsuperscript{nd} DI sample + pan weight (g):} \]
\[ W_2 = T_2 - P_{MC} = \text{2\textsuperscript{nd} DI sample weight (g):} \]
\[ L_2 = W_1 - W_2 = \text{2\textsuperscript{nd} Loss in weight (g):} \]
\[ \left( \frac{L_2}{W_2} \right) \times 100 = \text{2\textsuperscript{nd} Percent loss (%):} \]

3\textsuperscript{rd} Drying Interval (DI)

\[ T_3 = \text{3\textsuperscript{rd} DI sample + pan weight (g):} \]
\[ W_3 = T_3 - P_{MC} = \text{3\textsuperscript{rd} DI sample weight (g):} \]
\[ L_3 = W_2 - W_3 = \text{3\textsuperscript{rd} Loss in weight (g):} \]
\[ \left( \frac{L_3}{W_3} \right) \times 100 = \text{3\textsuperscript{rd} Percent loss (%):} \]

4\textsuperscript{th} Drying Interval (DI)

\[ T_4 = \text{4\textsuperscript{th} DI sample + pan weight (g):} \]
\[ W_4 = T_4 - P_{MC} = \text{4\textsuperscript{th} DI sample weight (g):} \]
\[ L_4 = W_3 - W_4 = \text{4\textsuperscript{th} Loss in weight (g):} \]
\[ \left( \frac{L_4}{W_4} \right) \times 100 = \text{4\textsuperscript{th} Percent loss (%):} \]
“DRY-BACK” PROCEDURE: REQUIRED WHEN ANY COARSE AGGREGATE FRACTION HAS AN ABSORPTION greater than 2.0%.
Procedure complete when percent loss < 0.05% based on 2nd wt. per interval [mass repeats within 0.05%]

\[ P_{DB} = \text{Pan weight (g):} \]
\[ T_0 = \text{Initial sample + pan weight (g):} \]
\[ W_0 = T_0 - P_{DB} = \text{Initial sample weight (g):} \]

1st Drying Interval (DI)
\[ T_1 = \text{1st DI sample + pan weight (g):} \]
\[ W_1 = T_1 - P_{DB} = \text{1st DI sample weight (g):} \]
\[ L_1 = W_0 - W_1 = \text{1st Loss in weight (g):} \]
\[ \left( \frac{L_1}{W_1} \right) \times 100 = \text{1st Percent loss (%):} \]

2nd Drying Interval (DI)
\[ T_2 = \text{2nd DI sample + pan weight (g):} \]
\[ W_2 = T_2 - P_{DB} = \text{2nd DI sample weight (g):} \]
\[ L_2 = W_1 - W_2 = \text{2nd Loss in weight (g):} \]
\[ \left( \frac{L_2}{W_2} \right) \times 100 = \text{2nd Percent loss (%):} \]

3rd Drying Interval (DI)
\[ T_3 = \text{3rd DI sample + pan weight (g):} \]
\[ W_3 = T_3 - P_{DB} = \text{3rd DI sample weight (g):} \]
\[ L_3 = W_2 - W_3 = \text{3rd Loss in weight (g):} \]
\[ \left( \frac{L_3}{W_3} \right) \times 100 = \text{3rd Percent loss (%):} \]

4th Drying Interval (DI)
\[ T_4 = \text{4th DI sample + pan weight (g):} \]
\[ W_4 = T_4 - P_{DB} = \text{4th DI sample weight (g):} \]
\[ L_4 = W_3 - W_4 = \text{4th Loss in weight (g):} \]
\[ \left( \frac{L_4}{W_4} \right) \times 100 = \text{4th Percent loss (%):} \]

5th Drying Interval (DI)
\[ T_5 = \text{5th DI sample + pan weight (g):} \]
\[ W_5 = T_5 - P_{DB} = \text{5th DI sample weight (g):} \]
\[ L_5 = W_4 - W_5 = \text{5th Loss in weight (g):} \]
\[ \left( \frac{L_5}{W_5} \right) \times 100 = \text{5th Percent loss (%):} \]
SPECIFIC GRAVITY DETERMINATION: NO “DRY-BACK” PROCEDURE

S = Weight of oven-dry sample & empty flask (g): __________________
P = Weight of empty flask (g): __________________
A = S – P = Weight of oven-dry sample (g): __________________

Weigh-in-air Method

D = Weight of flask filled with water (g): __________________
X = A + D (g): __________________
E = Weight of flask filled with water & sample (g): __________________
Y = X – E (g): __________________
Gmm = A / Y __________________

Weigh-in-water Method

C = Weight of flask & sample under water (g): __________________
B = Weight of flask under water (g): __________________
Q = C – B (g): __________________
Z = A – Q (g): __________________
Gmm = A / Z __________________

SPECIFIC GRAVITY DETERMINATION: WITH “DRY-BACK” PROCEDURE

A = Weight of oven-dry sample (g): __________________
A2 = Weight of surface-dry sample (g): __________________

Weigh-in-air Method

D = Weight of flask filled with water (g): __________________
X = A2 + D (g): __________________
E = Weight of flask filled with water & sample (g): __________________
Y = X – E (g): __________________
Gmm = A / Y __________________

Weigh-in-water Method

C = Weight of flask & sample under water (g): __________________
B = Weight of flask under water (g): __________________
Q = C – B (g): __________________
Z = A2 – Q (g): __________________
Gmm = A / Z __________________
Equipment Information for AASHTO T 312

Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

Equipment

Referenced Documents on Equipment

- M 339/M 339, Thermometers Used in the Testing of Construction Materials

APPARATUS

Superpave Gyratory Compactor—An electrohydraulic or electromechanical compactor with a ram and ram heads as described in Section 4.3. The axis of the ram shall be perpendicular to the platen of the compactor. The ram shall apply and maintain a pressure of 600 ± 18 kPa perpendicular to the cylindrical axis of the specimen during compaction (Note 1). The compactor shall tilt the specimen molds at an average internal angle of 20.2 ± 0.35 mrad (1.16 ± 0.02 degrees), determined in accordance with T 344. The compactor shall gyrate the specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction.

Note 1—This stress calculates to 10 600 ± 310 N total force for 150-mm specimens.

Specimen Height Measurement and Recording Device—When specimen density is to be monitored during compaction, a means shall be provided to continuously measure and record the height of the specimen to the nearest 0.1 mm during compaction once per gyration.

The system may include a connected printer capable of printing test information, such as specimen height per gyration. In addition to a printer, the system may include a computer and suitable software for data acquisition and reporting.
4.1.3. The loading system, ram, and pressure indicator shall be capable of providing and measuring a constant vertical pressure of 600 ± 60 kPa during the first five gyrations, and 600 ± 18 kPa during the remainder of the compaction period.

4.2. *Specimen Molds*—Specimen molds shall have steel walls that are at least 7.5 mm thick and are hardened to at least a Rockwell hardness of C48. The initial inside finish of the molds shall have a root mean square (rms) of 1.60 μm or smoother when measured in accordance with ASME B46.1 (see Note 2). New molds shall be manufactured to have an inside diameter of 149.90 to 150.00 mm. The inside diameter of in-service molds shall not exceed 150.2 mm. Molds shall be at least 250 mm in length. The inside diameter and length of the molds shall be measured in accordance with Annex A.

**Note 2**—One source of supply for a surface comparator, which is used to verify the rms value of 1.60 μm, is GAR Electroforming, Danbury, Connecticut.

4.3. *Ram Heads and End Plates*—Ram heads and end plates shall be fabricated from steel with a minimum Rockwell hardness of C48. The ram heads shall stay perpendicular to their axis. The platen side of each end plate shall be flat and parallel to its face. All ram and end plate faces (the sides presented to the specimen) shall be flat to meet the smoothness requirement in Section 4.2 and shall have a diameter of 149.50 to 149.75 mm.

4.4. *Thermometers*—Thermometers for measuring temperature of aggregates, binder, and asphalt mixtures shall meet the requirements of M 359M/M 359 with a temperature range of at least 10 to 230°C, and an accuracy of ±2.5°C (±4.5°F) (see Note 3).

**Note 3**—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E230/E230M thermocouple thermometer, Type J, any Class, or Type K, Class 1 or 2; IEC 60584 thermocouple thermometer, Type J, any Class, or Type K, Class 1 or 2; ASTM E2877 digital metal stem thermometer; or dial gauge metal stem (bi-metal) thermometer.

4.5. *Balance*—A balance meeting the requirements of M 231, Class G 5, for determining the mass of aggregates, binder, and asphalt mixtures.

4.6. *Oven*—An oven, thermostatically controlled to ±3°C, for heating aggregates, binder, asphalt mixtures, and equipment as required. The oven shall be capable of maintaining the temperature required for mixture conditioning in accordance with R 30.

*Miscellaneous*—Flat-bottom metal pans for heating aggregates, scoop for batching aggregates, containers (grill-type tins, beakers, containers for heating asphalt), large mixing spoon or small trowel, large spatula, gloves for handling hot equipment, paper disks, mechanical mixer (optional), lubricating materials recommended by the compactor manufacturer.

*Maintenance*—In addition to routine maintenance recommended by the manufacturer, check the Superpave gyratory compactor’s mechanical components for wear, and perform repair, as recommended by the manufacturer.
STANDARDIZATION

Items requiring periodic verification of calibration include the ram pressure, angle of gyration, gyration frequency, LVDT (or other means used to continuously record the specimen height), and oven temperature. Verification of the mold and platen dimensions and the inside finish of the mold are also required. When the computer and software options are used, periodically verify the data-processing system output using a procedure designed for such purposes. Verification of calibration, system standardization, and quality checks may be performed by the manufacturer, other agencies providing such services, or in-house personnel. Frequency of verification shall follow the manufacturer’s recommendations.

The angle of gyration refers to the internal angle (the tilt of the mold with respect to the end plate surface within the gyratory mold). The calibration of the internal angle of gyration shall be verified in accordance with T 344.

ANNEX A—EVALUATING SUPERPAVE GYRATORY COMPACTOR (SGC) MOLDS

A2.5. **Infrared Thermometer**—For measuring the temperature of molds, end plates, and equipment, shall meet the requirements of M 339M/M 339 with a D:s ratio of 6:1.
Equipment Information for AASHTO T 209

Theoretical Maximum Specific Gravity (Gmm) and Density of Asphalt Mixtures

Equipment

Referenced Documents on Equipment

- M 339M/M 339, Thermometers Used in the Testing of Construction Materials

5. APPARATUS

5.1. Follow the procedures for performing equipment calibrations, standardizations, and checks that conform to R. 18 and R. 61.

5.2. Vacuum Container:

5.2.1. The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of 0.075-mm (No. 200) wire mesh to minimize the loss of fine material.

5.2.2. The capacity of the vacuum container should be between 2000 and 10 000 mL and depends on the minimum sample size requirements given in Section 6.3. Avoid using a small sample in a large container.

5.2.3. Bowl for Mass Determination in Water Only (Section 11.1)—Either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7 to 10 in.) and a bowl height of at least 160 mm (6.3 in.) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.
5.2.4. *Flask for Mass Determination in Air Only (Section 11.2)*—A thick-walled volumetric glass flask with a factory-inscribed line and a rubber stopper with a connection for the vacuum line.

5.2.5. *Pycnometer for Mass Determination in Air Only (Section 11.2)*—A glass, metal, or plastic pycnometer with a volume defined by means of a glass capillary stopper, capillary lid, or glass plate.

5.3. *Balance*—A balance conforming to the requirements of M 231, Class G 2. The balance shall be standardized at least every 12 months.

5.3.1. For the mass determination-in-water method (Section 11.1), the balance shall be equipped with a suitable apparatus and holder to permit determining the mass of the sample while suspended below the balance. The wire suspending the holder shall be the smallest practical size to minimize any possible effects of a variable immersed length.

5.4. *Vacuum Pump or Water Aspirator*—Capable of evacuating air from the vacuum container to a residual pressure of 3.4 kPa (25 mmHg).

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

5.5. *Vacuum Measurement Device*—Residual pressure manometer\(^1\) or vacuum gauge to be connected directly to the vacuum vessel and capable of measuring residual pressure down to 3.4 kPa (25 mmHg) or less (preferably to zero). The device shall be standardized at least annually and be accurate to 0.1 kPa (1 mmHg). It shall be connected at the end of the vacuum line using an appropriate tube and either a “T” connector on the top of the vessel or a separate opening (from the vacuum line) in the top of the vessel to attach the hose. To avoid damage, the manometer shall not be situated on top of the vessel.

**Note 2**—A residual pressure of 4.0 kPa (30 mmHg) absolute pressure is approximately equivalent to a 97 kPa (730 mmHg) reading on a vacuum gauge at sea level.

**Note 3**—Residual pressure in the vacuum container, measured in millimeters of mercury, is the difference in the height of mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum container.

**Note 4**—An example of a suitable arrangement of the testing equipment is shown in Figure 1. In the figure, the purpose of the train of small filter flasks is to trap water vapor from the vacuum container that otherwise would enter the oil in the vacuum pump and decrease the pump’s ability to provide adequate vacuum.
5.6. **Bleeder Valve**—attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum container.

5.7. **Thermometer** (*Mass Determination in Air*)—For measuring the temperature of the mass determination in air, meeting the requirements of M 339/M 339 with a temperature range of at least 20 to 45°C (68 to 113°F) and an accuracy of ±0.25°C (±0.45°F) (Note 5).

**Note 5**—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E879 thermistor thermometer; ASTM E1137/E1137M Pt-100 RTD platinum resistance thermometer, Class A; or IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, Class AA.

5.8. **Drying Oven**—A thermostatically controlled drying oven capable of maintaining a temperature of 135 ± 5°C (275 ± 9°F) or 105 ± 5°C (221 ± 9°F). The oven(s) for heating and drying shall be capable of operation at the temperatures required as corrected, if necessary, by standardization. More than one oven may be used, provided each is used within its proper operating temperature range. The thermometer for measuring the oven temperature shall meet the requirements of M 339/M 339 with a temperature range of at least 90 to 150°C (194 to 302°F) and an accuracy of ±1.25°C (±2.25°F) (Note 6).

**Note 6**—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E2877 digital metal stem thermometer; ASTM E230/E230M thermocouple thermometer, Type T, Standard Class; or IEC 60584 thermocouple thermometer, Type T, Class 2.

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**Figure 1**—Example of Suitable Arrangement of Testing Apparatus

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**Figure 1**—Example of Suitable Arrangement of Testing Apparatus
5.9. **Water Bath**—Of sufficient size, capable of maintaining a uniform temperature when used within the proper operating temperature range, to determine the mass determination in water at 25 ± 1°C (77 ± 2°F). The thermometer for measuring the temperature of water baths shall meet the requirements of M 339/M 339 with a temperature range of at least 20 to 45°C (68 to 113°F) and an accuracy of ±0.25°C (±0.45°F) (Note 7).

**Note 7**—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E879 thermistor thermometer; ASTM E1137/E1137M Pt-100 RTD platinum resistance thermometer, Class A; or IEC 60751: 2008 Pt-100 RTD platinum resistance thermometer, Class AA.

5.9.1. For bowls, a water bath capable of maintaining a constant temperature between 20 and 30°C (68 and 86°F) is required.
Equipment Information

for

AASHTO T 308

Determining the Asphalt Binder Content of asphalt Mixtures by the Ignition Method

- M 339M/M 339, Thermometers Used in the Testing of Construction Materials

5. APPARATUS

5.1. Ignition Furnace—A forced-air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The convection-type furnace must be capable of maintaining a temperature of 538 ± 5°C (1000 ± 9°F). The furnace chamber dimensions shall be adequate to accommodate a specimen size of 3500 g. The furnace door shall be equipped so that the door cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside and, when set up properly, shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan capable of pulling air through the furnace to expedite the test and reduce the escape of smoke into the laboratory. The ignition furnace shall be capable of operation at the temperatures required, between at least 530 and 545°C (986 and 1013°F), and have a temperature control accurate within ±5°C (±9°F) as corrected, if necessary, by standardization. More than one furnace may be used, provided each is used within its proper operating temperature range. When measuring temperature during use, the thermometer for measuring the temperature of materials shall meet the
requirements of M 339/M 339 with a temperature range of at least 530 to 545°C (986 to 1013°F) and an accuracy of ±1.25°C (±2.25°F) (Note 1).

**Note 1**—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E230/E230M thermocouple thermometer, Type J or K, Special Class; or IEC 60584 thermocouple thermometer, Type J or K, Class 1.

5.1.1. For Method A, the furnace shall also have an internal balance thermally isolated from the furnace chamber and accurate to 0.1 g. The balance shall be capable of weighing a 3500-g specimen in addition to the specimen baskets. A data collection system will be included so that the mass can be automatically determined and displayed during the test. The furnace shall have a built-in computer program to calculate the change in mass of the specimen baskets and provide for the input of a correction factor for aggregate loss. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt binder content (percent), test time, and test temperature. The furnace shall provide an audible alarm and indicator light when the specimen mass loss does not exceed 0.01 percent of the total specimen mass for 3 consecutive min. The furnace shall also allow the operator to change the ending mass loss percentage to 0.02 percent.

5.2. **Specimen Basket Assembly**—Consisting of specimen basket(s), catch pan, and an assembly guard to secure the specimen basket(s) to the catch pan.

5.2.1. **Specimen Basket(s)**—Of appropriate size to allow the specimens to be thinly spread and allow air to flow through and around the specimen particles. Sets with two or more baskets shall be nested. The specimen shall be completely enclosed with screen mesh, perforated stainless steel plate, or other suitable material.

**Note 2**—Screen mesh or other suitable material with maximum and minimum openings of 2.36 mm (No. 8) and 0.600 mm (No. 30), respectively, has been found to perform well.

5.2.2. **Catch Pan**—Of sufficient size to hold the specimen basket(s) so that aggregate particles and melting asphalt binder falling through the screen are caught.

5.3. **Oven**—Capable of maintaining 110 ± 5°C (230 ± 9°F). The oven(s) for heating shall be capable of operation at the temperatures required, between 100 and 120°C (212 and 248°F), within ±5°C (±9°F) as corrected, if necessary, by standardization. More than one oven may be used, provided each is used within its proper operating temperature range. The thermometer for measuring the oven temperature shall meet the requirements of M 339/M 339 with a temperature range of at least 90 to 130°C (194 to 266°F) and an accuracy of ±1.25°C (±2.25°F) (Note 3).

**Note 3**—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E2877 digital metal stem thermometer; ASTM E230/E230M thermocouple thermometer, Type J or K, Special Class, Type T any Class; IEC 60584 thermocouple thermometer, Type J or K, Class 1, Type T any Class; or dial gauge metal stem (bi-metal) thermometer.

5.4. **Balance**—Of sufficient capacity and conforming to the requirements of M 231, Class G 2.

5.5. **Safety Equipment**—Safety glasses or face shield, dust mask, high-temperature gloves, long-sleeved jacket, a heat-resistant surface capable of withstanding 650°C (1202°F), and a protective cage capable of surrounding the specimen baskets during the cooling period.

5.6. **Miscellaneous Equipment**—A pan larger than the specimen basket(s) for transferring the specimen after ignition, spatulas, bowls, and wire brushes.
Glossary
SUMMARY OF DEFINITIONS AND CONVENTIONS

NAMING CONVENTION

\[ G_{sb} \]

\[ \text{volumetric property} \quad \text{material} \quad \text{type} \]

\[ b = \text{bulk} \]
\[ e = \text{effective} \]
\[ m = \text{maximum theoretical} \]
\[ a = \text{apparent (for G) or absorbed (for V and P)} \]

**DEFINITIONS**

\[ V_a = \text{volume of air voids} \]
\[ V_{ba} = \text{volume of binder absorbed} \]
\[ V_{be} = \text{volume of effective binder} \]
\[ G_b = \text{specific gravity of binder} \]
\[ G_{sb} = \text{bulk specific gravity of stone} \]
\[ G_{se} = \text{effective specific gravity of stone} \]
\[ G_{sa} = \text{apparent specific gravity of stone} \]
\[ G_{mb} = \text{bulk specific gravity of mix} \]
\[ G_{mm} = \text{maximum theoretical specific gravity of mix} \]
\[ G_{mc} = \text{bulk specific gravity of the core} \]
\[ V_a = \text{percent air} \]
\[ P_s = \text{percent stone (100 - } P_b) \]
\[ P_b = \text{percent binder} \]
\[ P_{ba} = \text{percent binder absorbed} \]
\[ P_{be} = \text{percent effective binder} \]
\[ W_s = \text{weight of stone} \]
\[ VMA = \text{Voids in Mineral Aggregate} \]
\[ VFA = \text{Voids Filled with Asphalt} \]
# GLOSSARY

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Size</td>
<td>One sieve size larger than the Nominal Maximum Size</td>
</tr>
<tr>
<td>Nominal Max Size</td>
<td>One sieve size larger than the first sieve retaining equal to or more than 10% of the combined gradation</td>
</tr>
<tr>
<td>G&lt;sub&gt;mm&lt;/sub&gt;</td>
<td>D, Maximum Specific Gravity of mix as determined by the Rice Method, AASHTO T 209</td>
</tr>
<tr>
<td>G&lt;sub&gt;mb&lt;/sub&gt;</td>
<td>d, Bulk Specific Gravity: specific gravity including permeable and impermeable voids of aggregates or compacted mix.</td>
</tr>
<tr>
<td>G&lt;sub&gt;mc&lt;/sub&gt;</td>
<td>Bulk Specific Gravity of core.</td>
</tr>
<tr>
<td>G&lt;sub&gt;sb&lt;/sub&gt;</td>
<td>Stone (Aggregate) Bulk Specific Gravity: weighted sum of bulk specific gravities of combined aggregates.</td>
</tr>
<tr>
<td>G&lt;sub&gt;sa&lt;/sub&gt;</td>
<td>Stone Apparent Specific Gravity: weighted sum of apparent specific gravities of combined aggregates. This excludes the water permeable voids.</td>
</tr>
<tr>
<td>G&lt;sub&gt;se&lt;/sub&gt;</td>
<td>Stone Effective Specific Gravity: specific gravity including asphalt permeable voids.</td>
</tr>
<tr>
<td>N&lt;sub&gt;des&lt;/sub&gt;</td>
<td>Gyrations simulating design life of mix to yield 4% air voids.</td>
</tr>
<tr>
<td>N&lt;sub&gt;ini&lt;/sub&gt;</td>
<td>Compaction $\geq$ 89% indicates a tender mix that may rut prematurely.</td>
</tr>
<tr>
<td>N&lt;sub&gt;max&lt;/sub&gt;</td>
<td>Gyrations simulating maximum life of pavement. At $&lt; 2%$ air voids the mix becomes plastic.</td>
</tr>
<tr>
<td>P&lt;sub&gt;b&lt;/sub&gt;</td>
<td>Percent binder in total mix.</td>
</tr>
<tr>
<td>P&lt;sub&gt;s&lt;/sub&gt;</td>
<td>Percent stone in total mix.</td>
</tr>
<tr>
<td>TSR</td>
<td>Tensile Strength Ratio: Result of AASHTO T 283 indicating the indirect tensile strength of wet cured specimens compared to dry cured specimens.</td>
</tr>
<tr>
<td>V&lt;sub&gt;a&lt;/sub&gt;</td>
<td>Percent air voids in compacted mix.</td>
</tr>
<tr>
<td>V&lt;sub&gt;ba&lt;/sub&gt;</td>
<td>Volume of absorbed binder.</td>
</tr>
<tr>
<td>V&lt;sub&gt;be&lt;/sub&gt;</td>
<td>Effective volume of binder not absorbed into the stone.</td>
</tr>
<tr>
<td>VMA</td>
<td>Voids in Mineral Aggregate: percent of voids in the aggregate structure.</td>
</tr>
<tr>
<td>VFA</td>
<td>Voids Filled with Asphalt: percent VMA filled with asphalt cement.</td>
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</tbody>
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