2025 Edition

SUPERPAVE

MoDOT

SUPERPAVE QC/QA

CERTIFICATION COURSE **ESTIMATED** SCHEDULE

2023 Season

Day/Time	Module	Location	Topic	Instructor
Day 1 8:00-8:15	Intro	Class Room	Introduction & Welcome	Huffman
8:15-9:30	1	Class Room	Mix Design Overview	Huffman
9:30-10:15	2	Class Room	QC/QA Overview	Huffman
10:15-10:30			Break	
10:30-11:30	3	Class Room	Plant Operations Overview	Huffman
11:30-12:00	4	Class Room	Aggregate Testing Overview	Huffman
12:00-1:00	Lunch on your own			
1:00-2:15	5	Class Room	Asphalt Sampling Random Numbers Loose Mix Sampling Density Cores	Huffman
2:15-2:30			Break	
2:30-3:00	6	Lab	Sample Reduction Methods Specimen Type/Size Reheat/Aging	Huffman
3:00-3:30	7	Class Room	Gyratory Compactor	Huffman
3:30-4:00	7	Lab	Gyratory Demo	Huffman
Day 2 8:00-8:45	8	Class Room	Max. Specific Gravity (Rice)	Huffman
8:45-9:15	8	Lab	Rice Sp. Gravity (Demo)	Huffman
9:15-10:15	9	Class Room	Binder Content: Ignition Oven	Huffman
10:15-10:30			Break	
10:30-12:00	9 7,8,9	Lab	Ignition Oven demo Practice: Gyro, Rice, Ignition	Huffman +
12:00-1:00	Lunch on your own			
1:00-1:30	10	Class Room	Job Mix Sheet	Huffman
1:30-2:45	11	Class Room	Pay Factors	Huffman
2:45-3:00			Break	
3:00-3:30	12	Class Room	Quality Level Analysis	Huffman
3:30-4:00	13	Class Room	Performance Testing	Huffman

Day/Time	Module	Location	Topic	Instructor
Day 3 8:00-9:00	MoDOT	Class Room	Contract Administration	MoDOT
9:00-11:00		Class Room	Written Exam	
11:00-4:00		Lab	Individual Hands-on Proficiency Testing	

SuperPave - Updates

2025 – Updates

- **Module 6**
  - Added update on Mixture Conditioning Long Term is now AASHTO R121
  - Added a slide R121 Scope
- **Module 10**
  - Added a new JMF with explanations.

2024 – Updates

- **Module 5**
  - Added slide on Truck procedure
- **Module 8**
  - Method up-date 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.

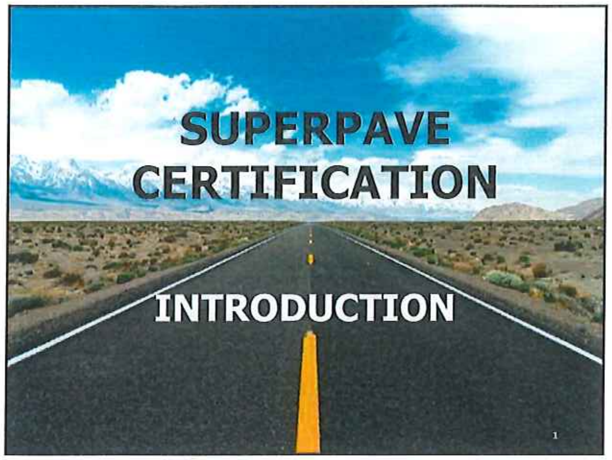
- **Module 8 – Maximum Specific Gravity AASHTO T209 - Updates**
    - Thermometers for measuring temperature See Appendix Item #7 for more information on Thermometers.
    - Vacuum Measurement Device updated, see Appendix Item #7 for more information on Vacuum Measurement Device. Capable of measuring residual pressure down to 25mm Hg.
- **Module 9 – Binder Ignition Oven AASHTO T308- Updates**
    - Thermometers for measuring temperature See Appendix Item #7 for more information on Thermometers.
    - Ignition furnace updates on temperature control, see Appendix Item #7.
- **Appendix** - added Item #7 Equipment

SUPERPAVE

TABLE OF CONTENTS

MoDOT

Introduction to SuperPave


SUPERPAVE
CERTIFICATION
INTRODUCTION

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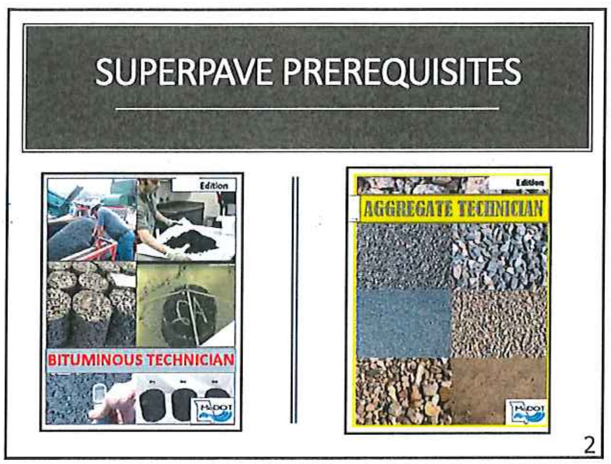
SUPERPAVE PREREQUISITES
BITUMINOUS TECHNICIAN
AGGREGATE TECHNICIAN
2

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QC
QA
Contractor
MODOT
- 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.

3

SUPERPAVE

- SUPERPAVE is the acronym for SUperiorPER forming asphalt PAVEments.
- It is the product of the Strategic Highway Research Program of USA.
- 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.

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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
  - T209 Maximum Specific Gravity (Gmm)
- **SUPERPAVE Items**
  - Job Mix Formula (JMF)
  - Pay Factors
  - Quality Level Analysis (QLA)
  - Performance Testing
  - Contract Administration

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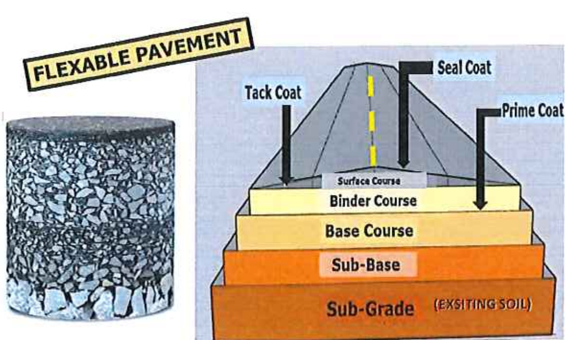
SUPERPAVE LAYERS

Flexible Pavement = Asphalt (SUPERPAVE)



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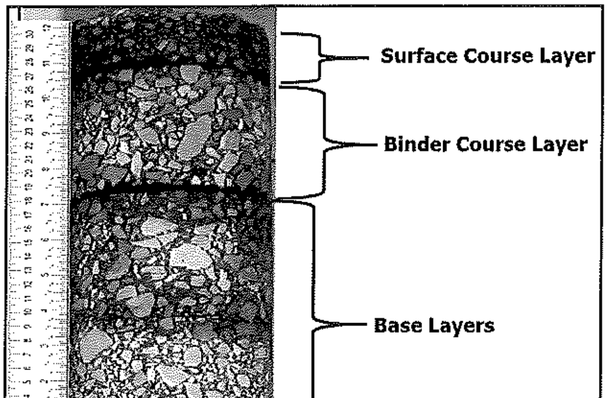

A Core from Missouri Highway.
Core shows a bonding issue.

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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.

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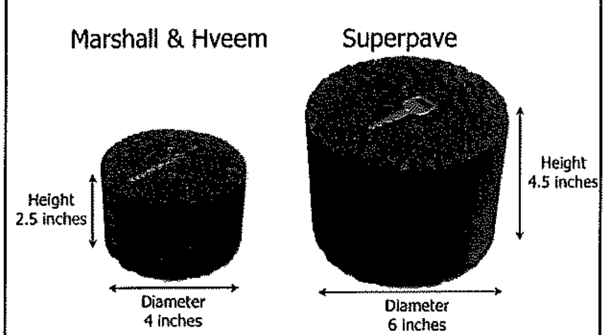
Compacted Samples



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SUPERPAVE | Primarily addresses the following pavement distresses:

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

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

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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.

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Stripping

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

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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.**

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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)

16

16

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

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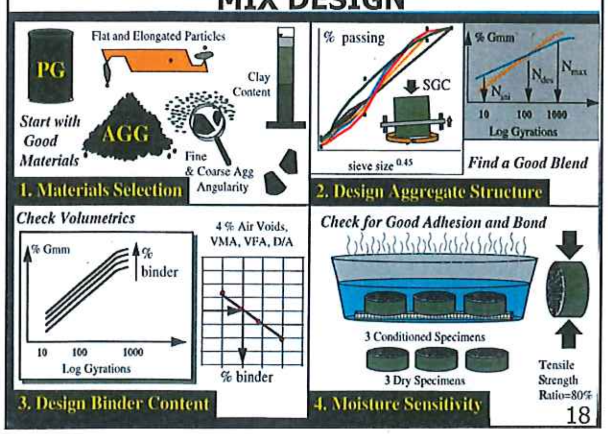
MIX DESIGN



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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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19

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.

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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.

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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
  - Extend 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

22

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.

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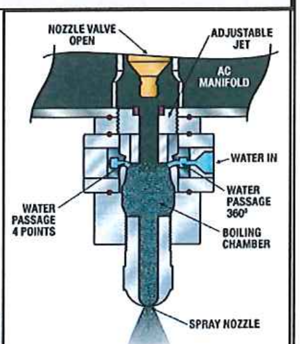
Different Types of WMA

- Foam – addition of water
  - Mechanical – inject water/air, various proprietary configurations
  - Wet aggregate
  - Zeolites – Aspha-Min and Advera
- Organics and chemicals
  - Sasobit, Asphaltan, Licomont, RH, Thiopave, LEADCAP
  - Evotherm, Sasobit Redux, Rediset, Cecabase RT, Zycotherm, SonneWarmix



FOAM NOZZLE OPEN

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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....

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Module 1

Mix Design Overview

MoDOT SUPERPAVE CERTIFICATION COURSE

MODULE 1

MIX DESIGN OVERVIEW

Rev 12/30/2022

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

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.

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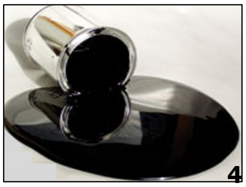
Superpave Language...

- **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.



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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.

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Typical Asphalt Mixture

COMPONENT	% by wt.
Aggregate (Coarse & fine)	90%
Dust (Dust-of-fracture + mineral filler)	5%
Asphalt Binder	5%

Dust = less than -200 sieve

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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

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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.

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Flexible Pavements MoDOT Standard Specs.

Asphalt Mixture	EPG Section
Plant Mix (Bit Base, BP-1, BP-2, BP-3)	401
Surface Leveling	402
Asphalt Concrete (Superpave)	403

EPG = Engineering Policy Guide

Engineering_Policy_Guide (modot.org)

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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)

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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

11

11

Superpave Mixes in Missouri

- **SP048** = #4 NMS surface course
- **SP095** = ⅜" NMS surface course
- **SP125** = ½" NMS surface course
- **SP190** = ¾" NMS binder course
- **SP250** = 1" NMS base course

Examples of Superpave names:

SP250C
SP125CLG

12

12

Material Standard Specs.

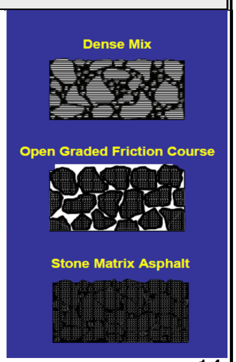
Link: Engineering_Policy_Guide (modot.org)

Item	EPG Section
Aggregate for Asphaltic Concrete	1002
Mineral Filler	1002
Hydrated Lime	1002
PG Binder	1015
Fiber	1071
Anti-Strip	1071
RAP Reclaimed Asphalt Pavement	403
RAS Reclaimed Asphalt Shingles	403
Asphalt Concrete Pavement	403

13

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



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Various Asphalt Mixes

SP = SuperPave
SMA = Stone Mastic (Matrix) Asphalt

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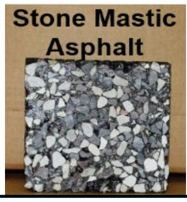
Construction of SMA

- **What is <u>S</u>tone <u>M</u>astic <u>A</u>sphalt?**

- 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%.



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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 **E**quivalent **S**ingle **A**xle **L**oad (**ESAL**)'s.
3. Estimate growth over the design life.
4. Calculate the total design ESAL's:

   Example: 12,000,000 ESAL's

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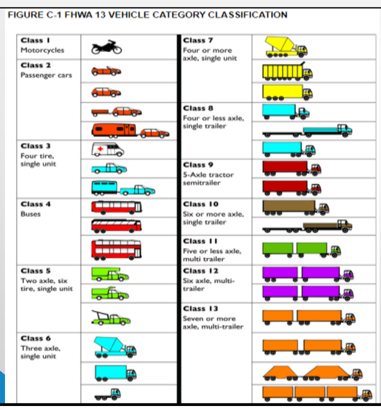
13 MoDOT (AASHTO) Vehicle Classes



Enlarged

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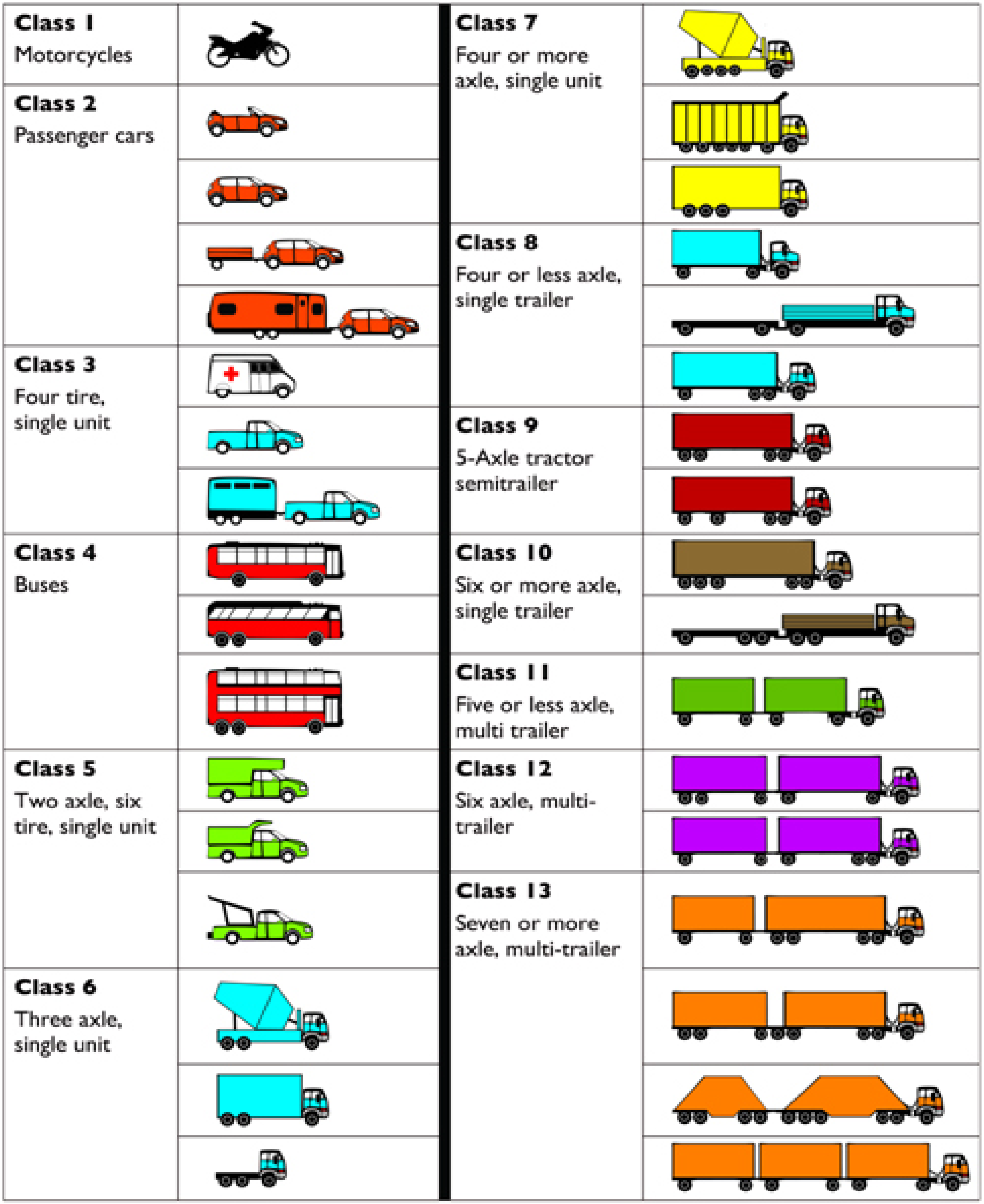
FIGURE C-1 FHWA 13 VEHICLE CATEGORY CLASSIFICATION



Trial Mix Design

Aggregate (+ 4 Material)

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

Aggregate (- 4 Material)

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

19

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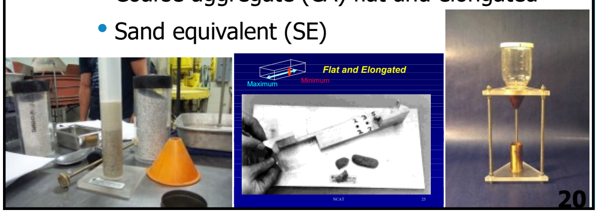
Trial Mix Design

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)



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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 (**Re**claimed **A**sphalt **S**hingles) content
  - RAP (**R**eclaimed **A**sphalt **P**roduct) content

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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.

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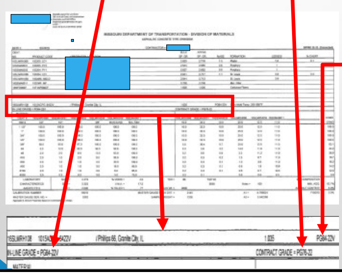
Example JMF Showing Substitution of purchased grade M 332 (PG 64V-22V) for contract grade M 320 (PG 76-22)

Enlarged

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



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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.

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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

[redacted] Digitally signed by Lori Greer
DN: cn=Lori Greer, o=Construction/Materials, ou=Field Office, email=lori.greer@modot.mo.gov, c=US
Date: 2016.04.22 09:49:06 -05'00'

MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP095BSM

DATE = 03/24/16 CONTRACTOR = [redacted] SP 5 16-13 (Corrected)

IDENT. NO	PRODUCT CODE	/ PRODUCER / LOCATION	BULK SP. GR.	APPAR. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
16SLMRH066	100205..LD1	[redacted]	2.625	2.718	1.3	Plattin	7-2	0.1
16SEMA0031	100205..PY2		2.644	2.685	0.6	Porphyry	1	
16SEMA0032	100204..PY1		2.627	2.682	0.8	Porphyry	1	
16SLMRH058	100204..LD1		2.641	2.717	1.1	St. Louis	3-9	0.0
16SLMRH059	1002MS..MSLD		2.644	2.712		St. Louis	3-9	
16SEMA0011	1002MF..MF		2.700	2.700		Min. Filler		
16MFO0007	1071APSMCF		1.000	1.000		Cellulose Fibers		
16SLMRH108	1015ACPG..6422V	/ Phillips 66, Granite City, IL	1.035	PG64-22V		Gyro Mold Temp. 290-300°F		

IN-LINE GRADE = PG64-22V CONTRACT GRADE = PG76-22

MATERIAL IDENT #	16SLMRH066	16SEMA0031	16SEMA0032	16SLMRH058	16SLMRH059	16SEMA0011	16SLMRH066	16SEMA0031	16SEMA0032	16SLMRH058	16SLMRH059	16SEMA0011	COMB GRAD
16013	1/2"	1/2"	3/8"	3/8"	MAN SAND	Min. Filler	10.0	32.0	10.0	25.0	12.0	11.0	
1 1/2"	100.0	100.0	100.0	100.0	100.0	100.0	10.0	32.0	10.0	25.0	12.0	11.0	100.0
1"	100.0	100.0	100.0	100.0	100.0	100.0	10.0	32.0	10.0	25.0	12.0	11.0	100.0
3/4"	100.0	100.0	100.0	100.0	100.0	100.0	10.0	32.0	10.0	25.0	12.0	11.0	100.0
1/2"	100.0	100.0	100.0	100.0	100.0	100.0	10.0	32.0	10.0	25.0	12.0	11.0	100.0
3/8"	50.0	95.0	97.0	100.0	100.0	100.0	5.0	30.4	9.7	25.0	12.0	11.0	93.1
#4	3.0	12.0	32.0	56.0	99.0	100.0	0.3	3.8	3.2	14.0	11.9	11.0	44.2
#8	2.0	2.0	6.0	13.0	93.0	100.0	0.2	0.6	0.6	3.3	11.2	11.0	26.9
#16	2.0	1.0	2.0	5.0	56.0	100.0	0.2	0.3	0.2	1.3	6.7	11.0	19.7
#30	2.0	1.0	1.0	4.0	30.0	100.0	0.2	0.3	0.1	1.0	3.6	11.0	16.2
#50	2.0	1.0	1.0	3.0	16.0	99.0	0.2	0.3	0.1	0.8	1.9	10.9	14.2
#100	2.0	1.0	1.0	3.0	6.0	95.0	0.2	0.3	0.1	0.8	0.7	10.5	12.5
#200	2.0	0.2	0.2	3.0	5.0	75.0	0.2	0.1		0.8	0.6	8.3	9.9

LABORATORY CHARACTERISTICS AASHTO T312				
Gmm = 2.419	% VOIDS = 4.0	TSR = 86	TSR Wt. 3630	MIX COMPOSITION
Gmb = 2.323	V.M.A. = 17.5		Ndes = 100	MIN. AGG 93.7%
Gsb = 2.646	% FILLED = 77	Gyro Wt. = 4600		ASPHALT CONTENT 6.0%

CALIBRATION NUMBER 16016 MASTER GAUGE BACK CNT. = 2145 A1 = -4.766624 FIBER 0.3%

MASTER GAUGE SER. NO. = 2502 SAMPLE WEIGHT = 7200 A2 = 3.342288

Aggregate & Mixture Properties Based on Contractor's Mix Design

16SLMRH108 1015ACPG..6422V / Phillips 66, Granite City, IL 1.035 PG64-22V

IN-LINE GRADE = PG64-22V CONTRACT GRADE = PG76-22

MATERIAL

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.

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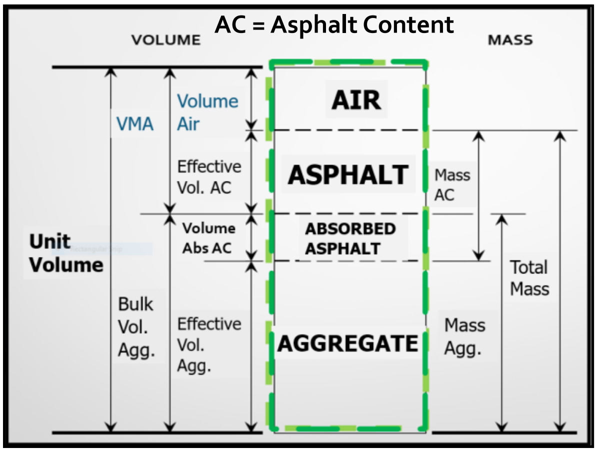

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Aggregate Structure Selection

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.

27

27

Aggregate Structure

(Gradation)

- 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 - is just a reference line.

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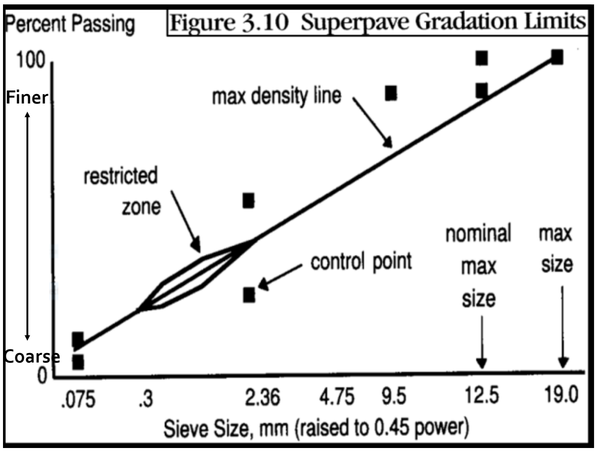

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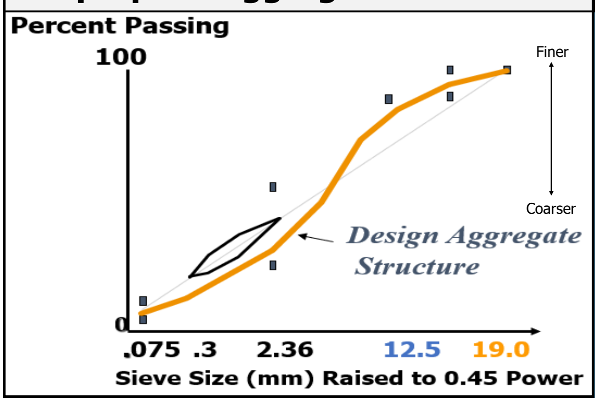
Superpave Aggregate Gradation



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Dust/Binder Ratio

- Ratio of % minus #200 to % effective asphalt content.
- D/P_{be}
  (**D** = Dust, $\mathbf{P_{be}}$ = 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

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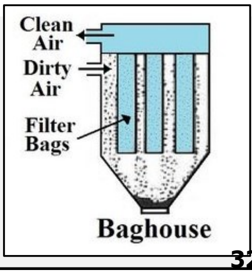
Bag House Dust

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



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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.

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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

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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 ⅜″ 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.

35

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

36

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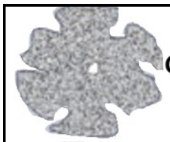
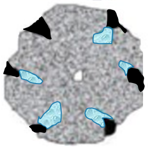


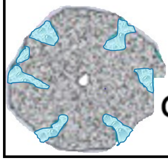
Apparent Specific Gravity

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



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

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

37

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

$$G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$$

38

38

Enlarged

SUMMARY OF VOLUMETRIC EQUATIONS

Mix Design	Bulk Specific Gravity of Aggregate Blend $G_{sb} = G_{sb}\text{(combined)} = \frac{100}{\frac{P_{s1}}{G_{sb1}} + \frac{P_{s2}}{G_{sb2}} + \frac{P_{s3}}{G_{sb3}} + \dots}$
Mix Design	Effective Specific Gravity of Aggregate Blend $G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$
Mix Design	Absorbed Asphalt Content $P_{ba} = 100 \times \left(\frac{G_{se} - G_{sb}}{G_{sb} \times G_{se}}\right) \times G_b$
Mix Design	Effective Asphalt Content $P_{be} = P_b - \left(\frac{P_{ba} \times P_s}{100}\right)$
Mix Design	Ratio of Dust to Effective Asphalt (Sometimes called Dust Proportion) $\frac{P_{0.075}}{P_{be}} = \frac{\%\text{minus}\#200}{P_{be}}$
Mix Design and Field Verification	Air Void Content $V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$
Mix Design and Field Verification	Voids in Mineral Aggregate $VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$
Mix Design and Field Verification	Voids Filled with Asphalt $VFA = \frac{VMA - V_a}{VMA} \times 100$

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SUMMARY OF VOLUMETRIC EQUATIONS

Mix Design	Bulk Specific Gravity of Aggregate Blend $$G_{sb} = G_{sb}\,(\text{combined}) = \frac{100}{\frac{P_{s1}}{G_{sb1}} + \frac{P_{s2}}{G_{sb2}} + \frac{P_{s3}}{G_{sb3}} + \dots}$$
Mix Design	Effective Specific Gravity of Aggregate Blend $$G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$$
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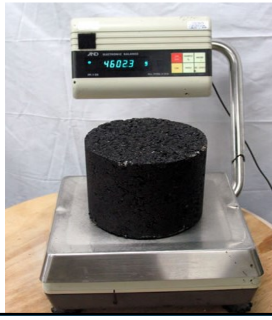
Mix Design and Field Verification	Voids in Mineral Aggregate $$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$$
Mix Design and Field Verification	Voids Filled with Asphalt $$VFA = \frac{VMA - V_a}{VMA} \times 100$$

Bulk Sp. Gravity of Compacted Mix

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



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Theoretical Maximum specific Gravity

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

Creates:
NO Air Voids
or
Zero Air Voids

41

41

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.

42

42

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.

43

43

- 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.

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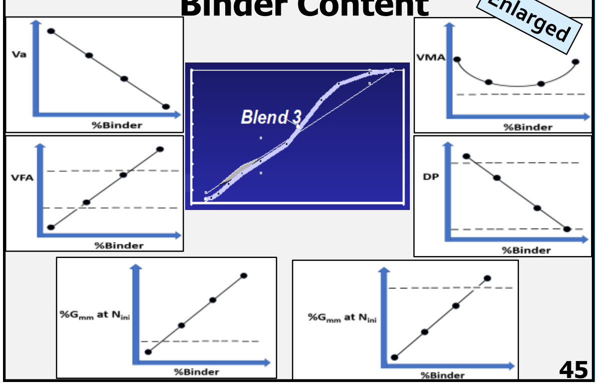
Selection of Design Asphalt Binder Content



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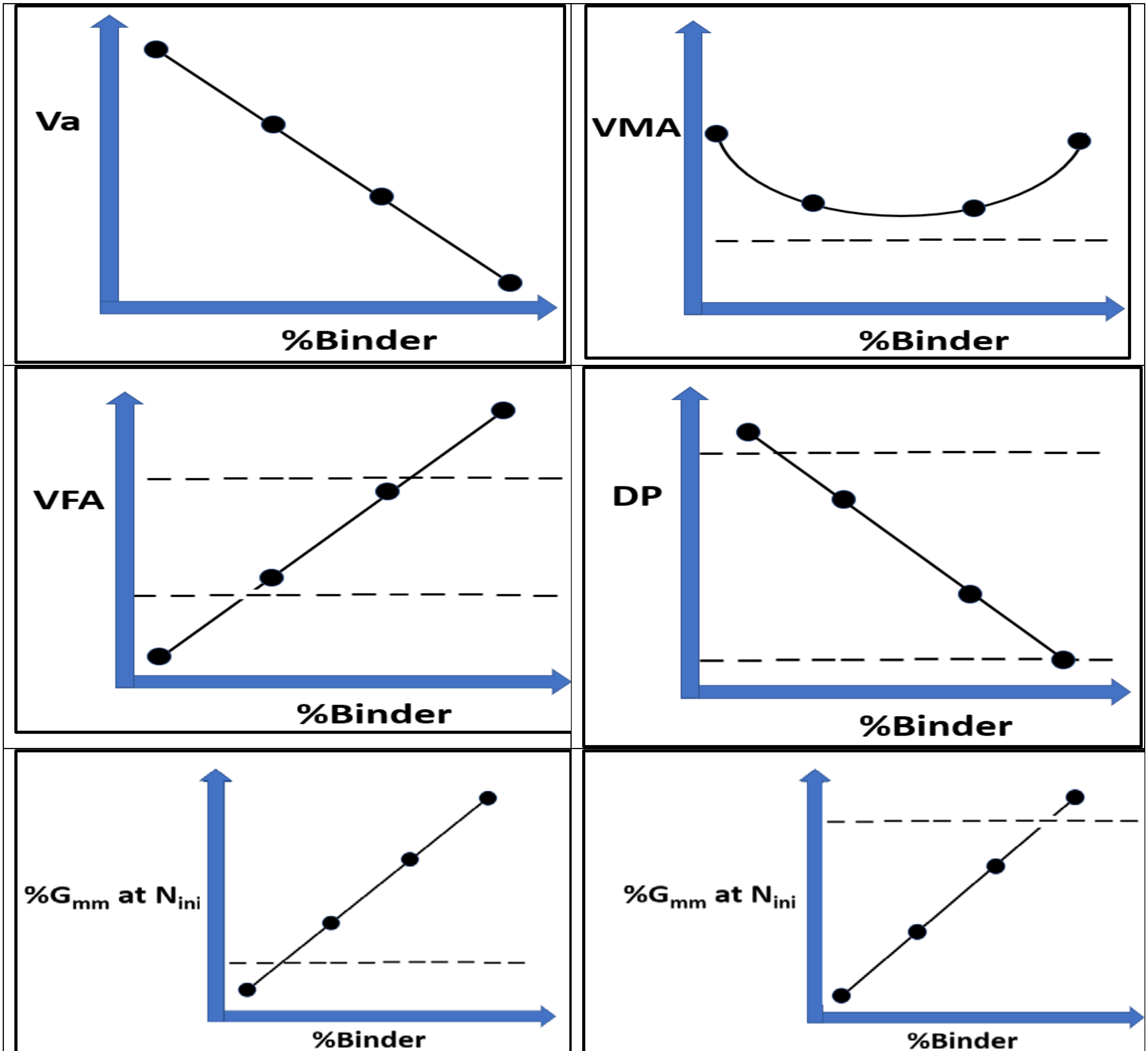
Selection of Design Asphalt Binder Content



Binder Content Selection Steps

1. Using the winning blend, compact more specimens in duplicate to N_{des}, this time varying binder content.

Example : Use 3 different %'s 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.

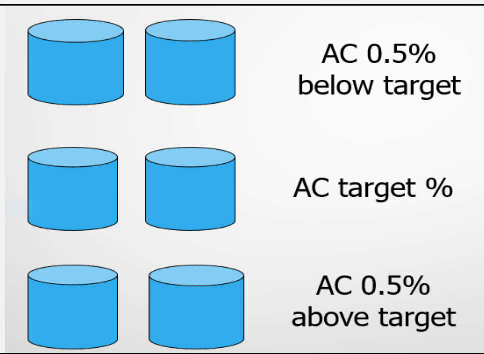
4. Check $\%G_{mm}$ @ N_{ini}

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_{max}; check criteria. **46**

46

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



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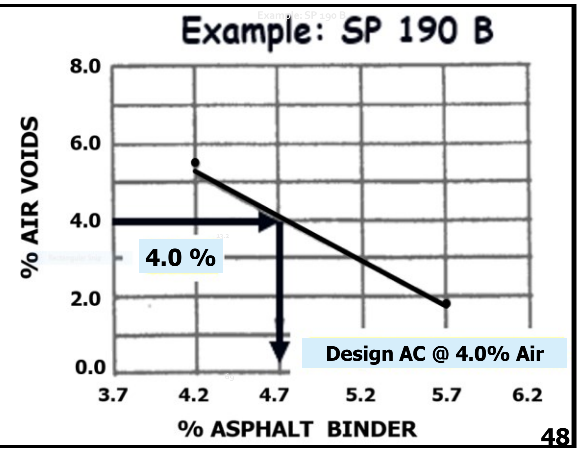

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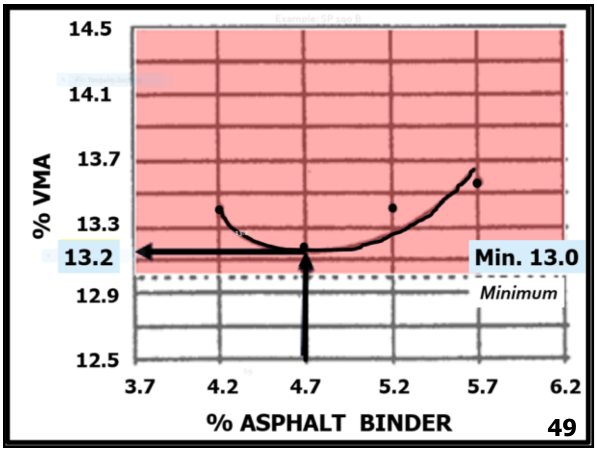

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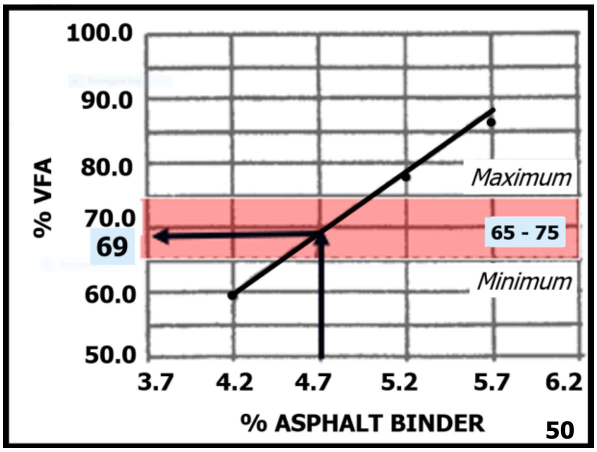

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Compare to ***criteria***.

Choose the blend that best meets criteria, economy, and chance of success.

Factor	Criteria	Reason
Air voids, N_{des}	4.0%	Stability Durability
VMA	≥ 12, 13, 14, 15, 16, 17%	Durability
VFA	70-80 % 65-78% 65-75%	Stability Durability
$\%G_{mm}$ @ N_{ini}	≤ 91.5% ≤ 90.5% ≤ 89.0%	Tenderness
$\%G_{mm}$ @ N_{max}	≤ 98.0%	Stability
Dust/binder	0.8-1.6 0.9-2.0	Compaction Handling

51

51

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

52

52

Module 2

QC/QA Overview

MODULE 2

QC/QA OVERVIEW

Rev 12/28/2022

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

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QC/QA - Who is?

- **Quality Control:**
  - Aggregate Producer
  - Paving Contractor
- **Quality Assurance:**
  - Owner (MoDOT)

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Use of QC/QA

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

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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

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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.

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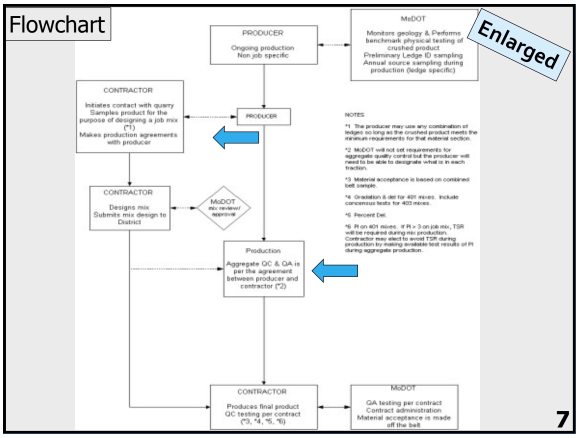

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Flowchart, cont'd.

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.

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8

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.

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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

10

10

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.

11

11

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.

12

12

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.

13

13

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

EPG: Engineering Policy Guide: http://epg.modot.org/index.php?title=Main_Page

14

14

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).

15

15

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.

16

16

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.

17

17

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.

18

18

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.

19

19

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.

20

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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.

21

21

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.

22

22

Example QC Plan

Enlarged

March 17, 2020

Quality Control Plan Superpave SP125CLGLP

Job: J6P5555 Contract I.D. 000716-F05 Route 141 St. Louis and Jefferson Counties Plant: Asphalt Today – Arnold, MO

QC Personnel
Quality Control Contact: Joe McCracken (314) 555-1212
Quality Control Inspector: Kyle Williams (314) 555-1213
Quality Control Inspector: John Jones (573) 555-4949
Quality Control Inspector: Mary Smith (314) 555-1732

Asphalt Testing
The Quality Control testing will be performed by taking samples from random numbers for volumetrics in accordance with the Specifications. On sections of the project with a bonded overlay, sampling will be performed using truck sampling methods.

Asphalt Content Determination
Asphalt content will be determined using the Ignition Oven, AASHTO T-312. Gradations will be performed using the burn-off residue.

Density Cores
Density cores will be cut using a 6 inch diameter core saw. One core will constitute a sample.

Lot and Sub-lot
The mixture with PG 64-22 V will be one lot of 5045 tons in sub-lots of 750 tons. The mixture with PG 64-22 H will have one Lot of 3,000 tons and 750 tons with the remaining Lots of 10,000 tons in sub-lots of 1000 tons.

Third Party Resolution

ACME Testing, LLC
2000 Quarry Road
Linn, MO 65051
(573) 555-1111

23

23

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

24

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.

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Documents On Hand

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

26

26

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

27

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Calibration

Equipment	Requirement	Interval (month)
Gyratory Compactor	Calibrate	12
Gyratory Compactor	Verify	Daily
Gyratory Compactor molds	Dimensions	12
Thermometer	Calibrate	12
Vacuum	Pressure	12
Pycnometer	Calibrate	Daily
Ignition oven	Verify	12 or when moved

28

28

Calibration, Cont'd.

Equipment	Requirement	Interval (month)
Nuclear gage	Drift & stability	1
Shakers	Sieving thoroughness	12
Sieves	Physical condition	12
Ovens	Standardize Thermometric Device	12
Balances	Verify	12 or when moved
Timers	Accuracy	12

29

29

QC Records

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

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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.

31

31

QC/QA Functions at the Asphalt Plant

Engineering Policy Guide (EPG)

Enlarged

AGGREGATE		
FUNCTION:	**LOCATION:**	**FREQUENCY:**
Aggregate Gradation: **3 sieves:** 1 size smaller than NMS_{JMF}: not to exceed 92.0%. #8: Not to exceed 2.0% beyond master spec. #200: within master spec.	**Drum**: Combined cold feed **Batch**: Hot bins **Optional**: T308 Residue	**QC**: 1 per 2 sublots **QA**: 1 per 4 sublots **QA**: QC retained: 1 per week
Consensus Tests: FAA_{spec} -2% CAA_{spec} -5% SE_{spec} -5% $F\&E_{spec}$ +2%	**Drum:** Combined cold feed **Batch:** Combined cold feed	**QC**: 1 per 10,000 tons (min. 1 per project per mix type) **QA**: 1 per project **QA**: QC retained: 1 per project
Deleterious:	**All plants:** cold feed	**QC**: 1 per 2 sublots **QA:** 1 per 4 sublots **QA:** QC retained: 1 per week
RAP: Gradation (T308 or T164 residue) Deleterious Micro-Deval (if necessary) Binder Binder		**QC:** 1 per day 1 per 2 sublots 1 per 1500tons 1 per 4 sublots **QA:** 1 per project **QA**: QC retained: None
Ground Shingles: Gradation		**QC:** 1/10,000 tons (Min. 1 per project) **QA:** 1 per project

32

32

Asphalt		
FUNCTION:	**LOCATION:**	**FREQUENCY:**
Obtain Sample	Behind paver	**QC:** 1 per sublot **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 Calculate average of the two (G_{mb})	QC lab	"
Run Rice specific gravity (G_{mm})	QC lab	"
Calculate % Air Voids (V_a): $V_a=[(G_{mm}-G_{mb}) \div G_{mm}] \times 100$ Compare to spec: 4 ± 1.0% ***This is a pay factor***	QC lab	"
Run asphalt content (P_b), Either nuclear or ignition oven. Compared to spec: $P_{b,JMF}$ ± 0.3% ***This is a pay factor***	QC lab	"
Calculate % aggregate (P_s): $P_s=100 - P_b$	QC lab	"
Calculate VMA: **VMA** $=100 - [(G_{mb} \times P_s) \div G_{sb}]$ G_{sb} from JMF **Compare to Spec**: VMA design minimum [-0.5 to +2.0 %] ***This is a pay factor***	QC lab	"

33

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Asphalt cont...		
FUNCTION:	LOCATION:	FREQUENCY:
Run TSR Compare to spec ***This is a pay adjustment factor***		**QC**: 1 per 10,000 T **QA**: 1 per 50,000 T Minimum: 1 per mix (combination of projects)
Drill pavement cores	Traveled way pavement	**QC**: 1 sample per sublot **QA**: 1 sample per 4 sublots
Determine pavement core density (G_{mc})	Trailer	**QC**: 1 sample per sublot **QA**: 1 sample per 4 sublots

34

34

Additional Testing		
FUNCTION:	LOCATION:	FREQUENCY:
Mix Temperature	Roadway	**QC**: 1 per sublot **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=[(VMA-V_a) ÷ VMA] x 100	Roadway	**QC**: 1 per sublot **QA**: 1 per 4 sublots
Drill unconfined joint cores	Roadway	**QC**: 1 sample per sublot **QA**: 1 sample per 4 sublots
Drill longitudinal joint and shoulder cores	"	(See Module 5 Sampling)
Calculate pavement density: Density= ($G_{mc} \div G_{mm}$) x 100 Compare to Density Pay Adjustment Table if an unconfined joint core ***This is a pay adjustment factor***		(See Module 5 Sampling)

35

35

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

36

36

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)

37

37

QC / QA Functions at the Hot Mix Plant
Engineering Policy Guide (EPG)

AGGREGATE		
FUNCTION:	**LOCATION:**	**FREQUENCY:**
Aggregate Gradation: **3 sieves:** 1 size smaller than NMS_{JMF}: Not to exceed 92.0%. #8: Not to exceed 2.0% beyond master spec. #200: Within master spec.	**Drum**: Combined cold feed **Batch**: Hot bins **Optional**: T308 Residue	**QC**: 1 per 2 sublots **QA**: 1 per 4 sublots **QA**: QC retained: 1 per week
Consensus Tests: FAA_{spec} -2% CAA_{spec} -5% SE_{spec} -5% $F\&E_{spec}$ +2%	**Drum:** Combined cold feed **Batch:** Combined cold feed	**QC**: 1 per 10,000 tons (min. 1 per project per mix type) **QA**: 1 per project **QA**: QC retained: 1 per project
Deleterious:	**All plants:** cold feed	**QC**: 1 per 2 sublots **QA:** 1 per 4 sublots **QA:** QC retained: 1 per week
RAP: Gradation (T308 or T164 residue) Deleterious Micro-Deval (if necessary) Binder Binder		**QC:** 1 per day 1 per 2 sublots 1 per 1500tons 1 per 4 sublots **QA:** 1 per project **QA**: QC retained: None
Ground Shingles: Gradation		**QC:** 1/10,000 tons (Min. 1 per project) **QA:** 1 per project

HMA		
FUNCTION:	**LOCATION:**	**FREQUENCY:**
Obtain Sample	Behind paver	**QC:** 1 per sublot **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 Calculate average of the two (G_{mb})	QC lab	"
Run Rice specific gravity (G_{mm})	QC lab	"
Calculate % Air Voids (V_a): $V_a=[(G_{mm}-G_{mb}) \div G_{mm}] \times 100$ Compare to spec: 4 ± 1.0% ***This is a pay factor***	QC lab	"
Run asphalt content (P_b), Either nuclear or ignition oven. Compare to spec: $P_{b,JMF}$ ± 0.3% ***This is a pay factor***	QC lab	"
Calculate % aggregate (P_s): $P_s=100 - P_b$	QC lab	"
Calculate VMA: **VMA** $=100 - [(G_{mb} \times P_s) \div G_{sb}]$ G_{sb} from JMF **Compare to Spec**: VMA design minimum [-0.5 to +2.0 %] ***This is a pay factor***	QC lab	"

HMA cont...		
FUNCTION:	**LOCATION:**	**FREQUENCY:**
Run TSR Compare to spec ***This is a pay adjustment factor***		**QC**: 1 per 10,000 T **QA**: 1 per 50,000 T Minimum: 1 per mix (combination of projects)
Drill pavement cores	Traveled way pavement	**QC**: 1 sample per sublot **QA**: 1 sample per 4 sublots
Determine pavement core density (G_{mc})	Trailer	**QC**: 1 sample per sublot **QA**: 1 sample per 4 sublots

Additional Testing		
FUNCTION:	**LOCATION:**	**FREQUENCY:**
Mix Temperature	Roadway	**QC**: 1 per sublot **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): $VFA = [(VMA - V_a) \div VMA] \times 100$	Roadway	**QC**: 1 per sublot **QA**: 1 per 4 sublots
Drill unconfined joint cores	Roadway	**QC**: 1 sample per sublot **QA**: 1 sample per 4 sublots
Drill longitudinal joint and shoulder cores	Roadway	See Module 5, Sampling
Calculate pavement density: $Density = (G_{mc} \div G_{mm}) \times 100$ Compare to Density Pay Adjustment Table if an unconfined joint core ***This is a pay adjustment factor***		See Module 5, Sampling

Module 3

Plant Operations Overview

MoDOT

MODULE 3

PLANT OPERATIONS OVERVIEW

1

Outline

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

2

2

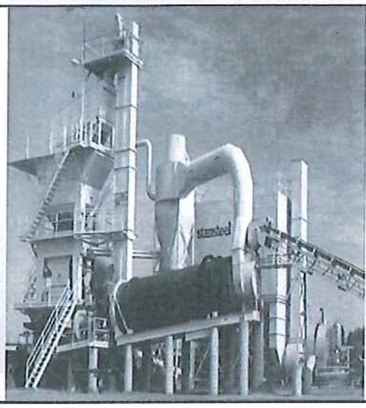
Types of Asphalt Plants

- **Batch Plants**
- **Drum Mix Plants**

3

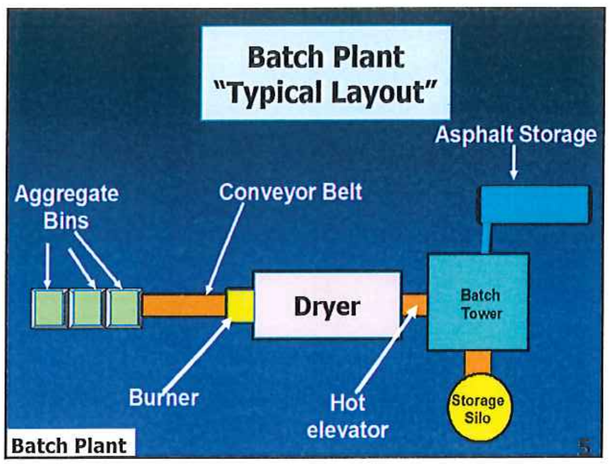
3

Batch Plant



Batch Plant 4

4



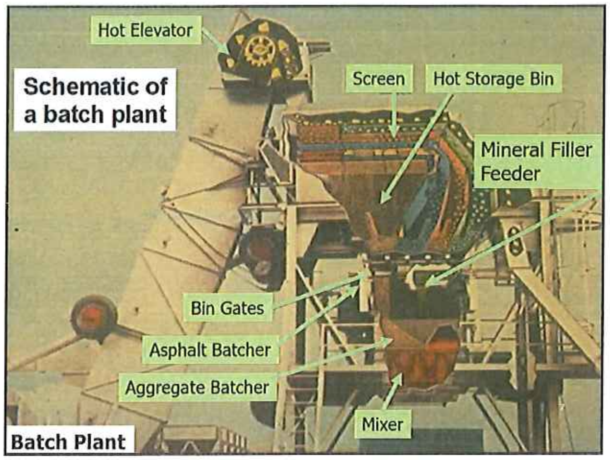
5

Batch Plant

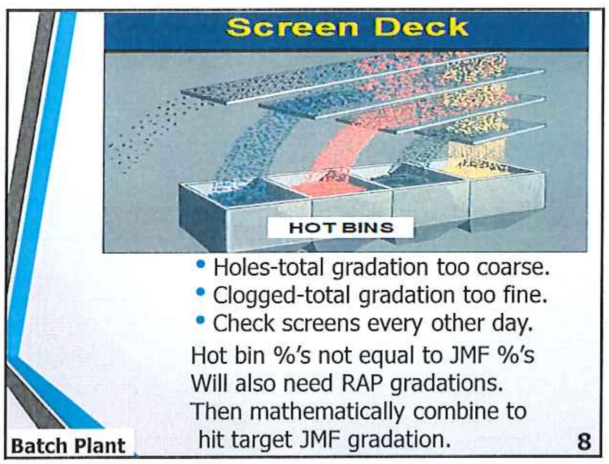
- Aggregate is heated.
  Reduces moisture related problems.
- Aggregate is rescreened.
- Aggregate is batched by weight.
- Batch plants provide a consistent mixture.

Batch Plant 6

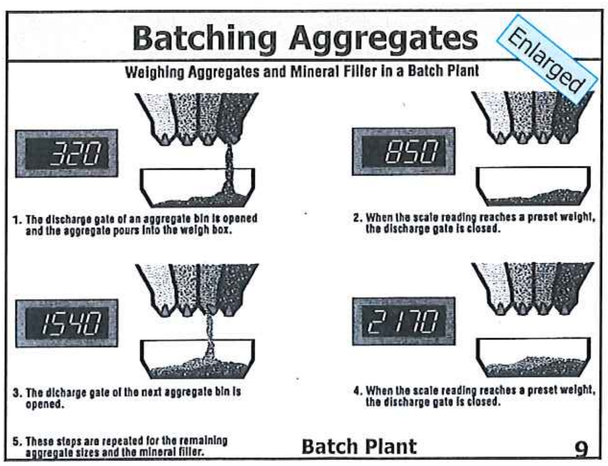
6


Hot Elevator
Schematic of a batch plant
Screen
Hot Storage Bin
Mineral Filler Feeder
Bin Gates
Asphalt Batcher
Aggregate Batcher
Mixer
Batch Plant

7

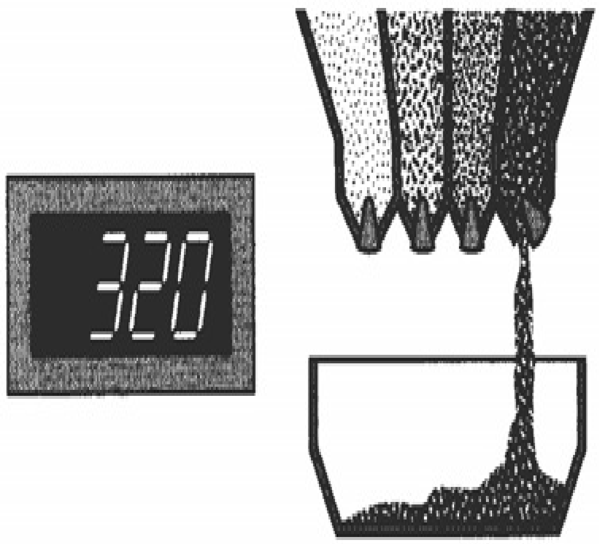

Screen Deck
HOT BINS
• Holes-total gradation too coarse.
• Clogged-total gradation too fine.
• Check screens every other day.
Hot bin %'s not equal to JMF %'s
Will also need RAP gradations.
Then mathematically combine to hit target JMF gradation.
Batch Plant
8

8

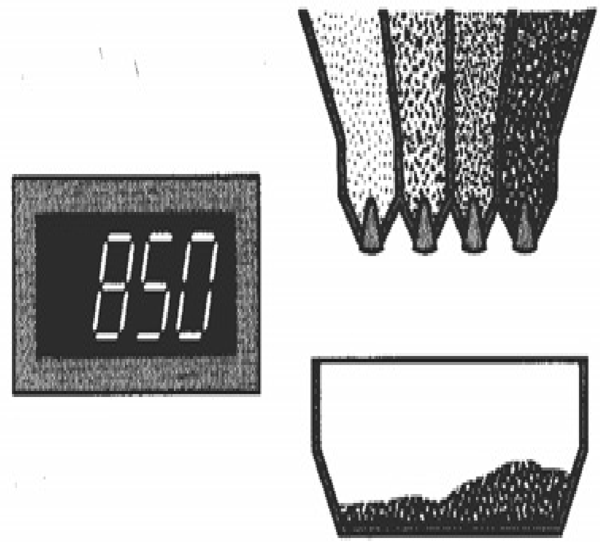

Batching Aggregates
Enlarged
Weighing Aggregates and Mineral Filler in a Batch Plant
320
1. The discharge gate of an aggregate bin is opened and the aggregate pours into the weigh box.
850
2. When the scale reading reaches a preset weight, the discharge gate is closed.
1540
3. The dicharge gate of the next aggregate bin is opened.
2170
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.
Batch Plant
9

9

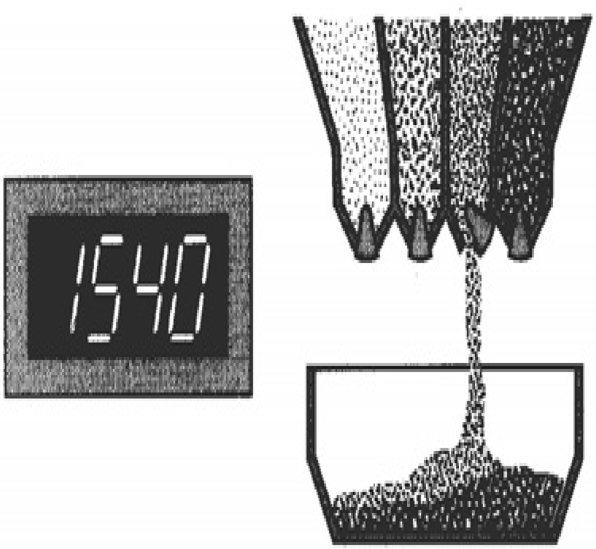
Weighing Aggregates and Mineral Filler in a Batch Plant



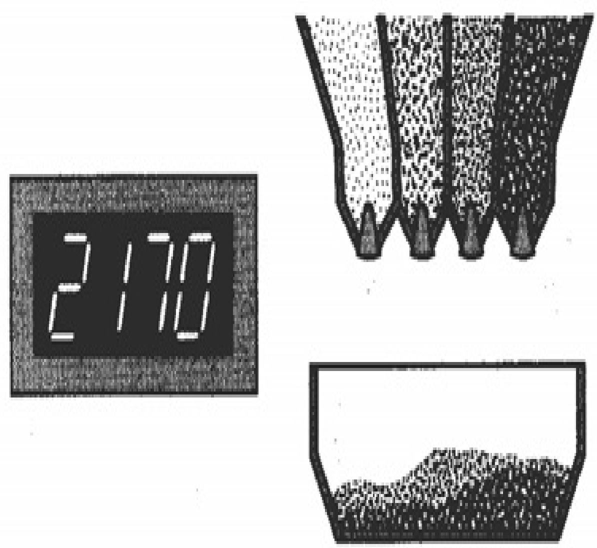
1. The discharge gate of an aggregate bin is opened and the aggregate pours into the weigh box.



2. When the scale reading reaches a preset weight, the discharge gate is closed.



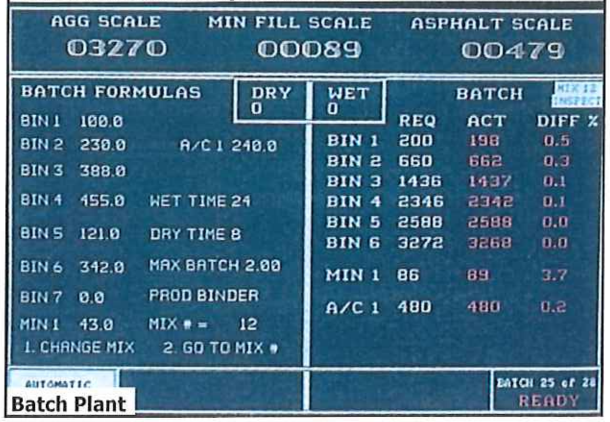
3. The dicharge gate of the next aggregate bin is opened.



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.

Screen from Computerized Batch Automation



Batch Plant

10

Pug Mill

Dry cycle: say 15 sec
Wet cycle: say 20 sec

Inspect paddle wear tolerance weekly, more if traprock

Batch Plant

11

11

Drum Mix Plant

Drum Mix Plant

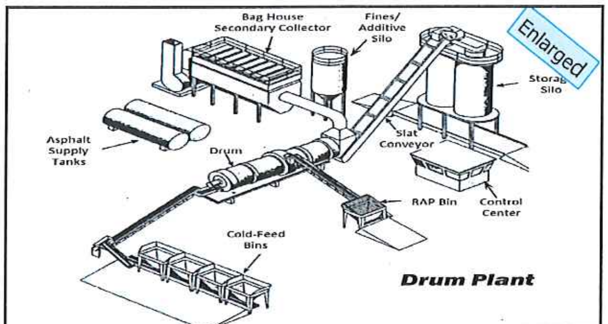
12

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

13



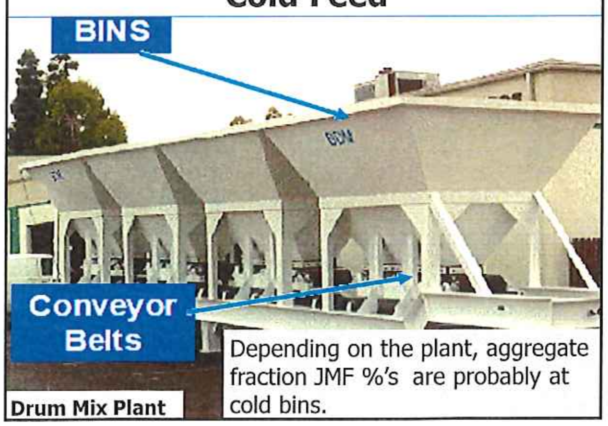
There is an optimum flight configuration for the % RAP to maintain the veil of aggregate that protects the RAP, binder, and baghouse.

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

Drum Mix Plant

14

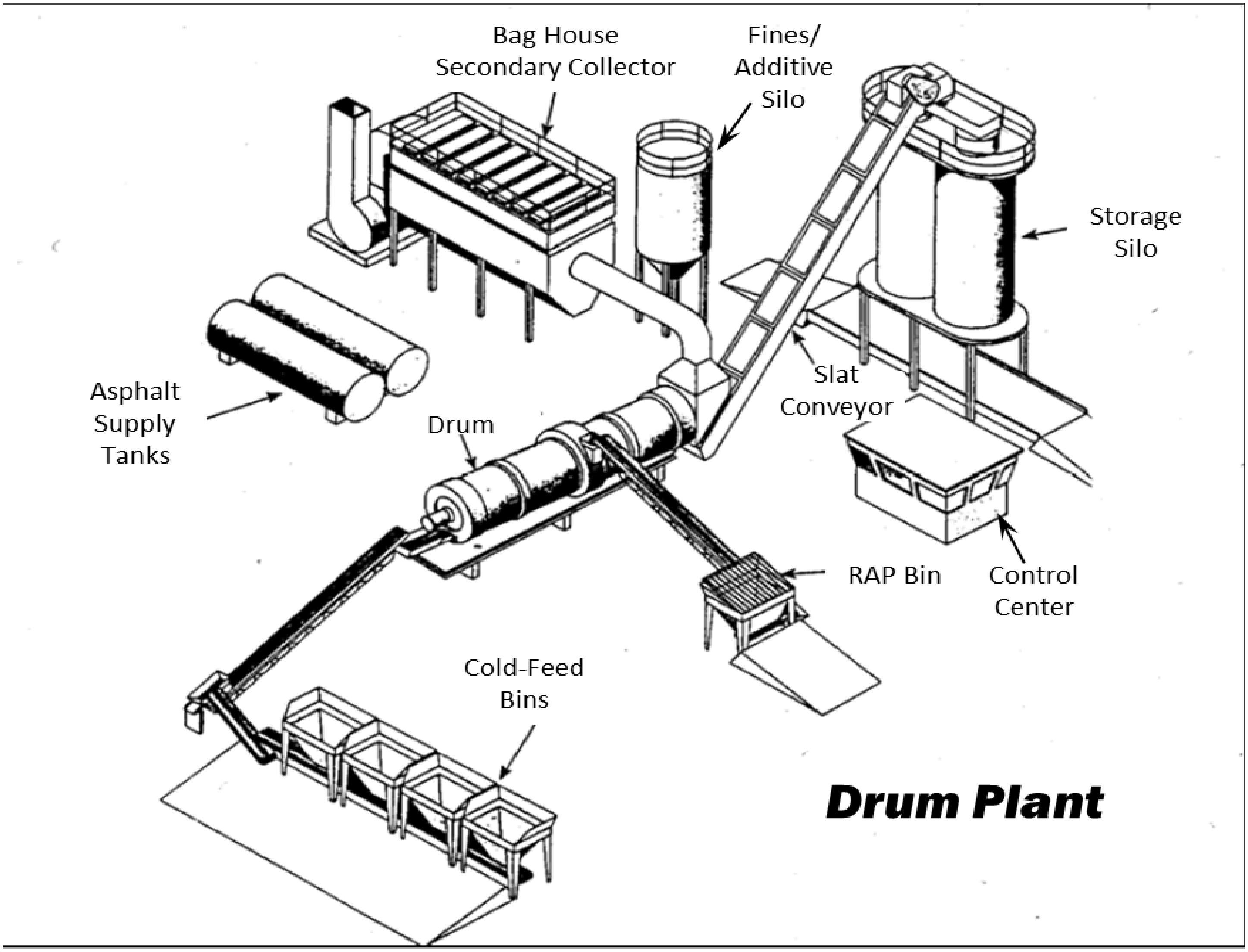
Cold Feed



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

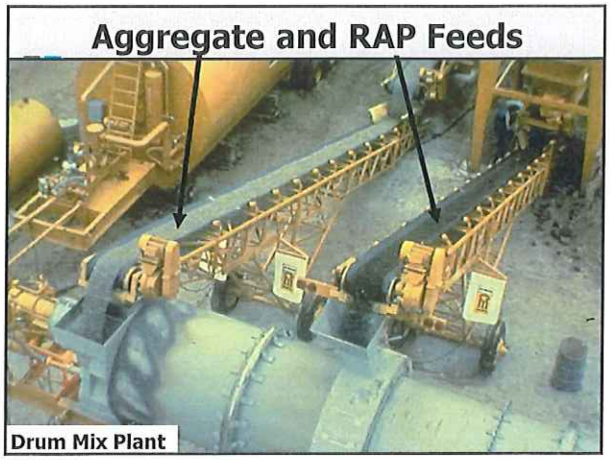
Drum Mix Plant

15



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

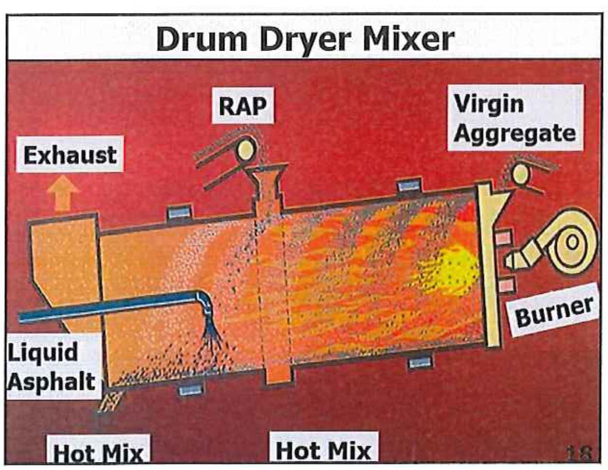
RAP collar ok up to ~20% RAP; problems for greater amounts


Aggregate and RAP Feeds
Drum Mix Plant

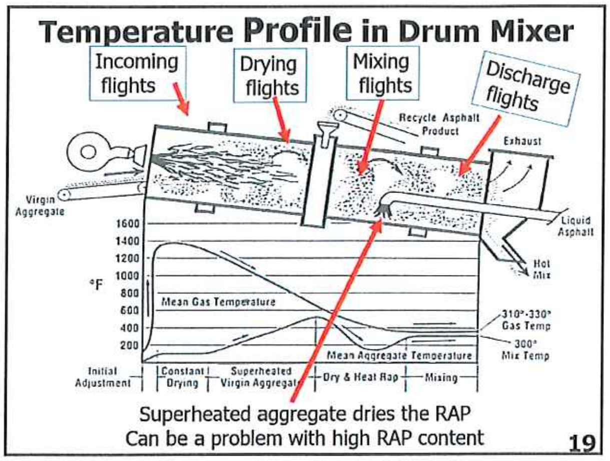
16


Dryer
For Drum Dryer Mix Plant
End of day: shut off oil, run aggregate through to clean out mix to prevent chunks breaking loose
Drum Mix Plant
17

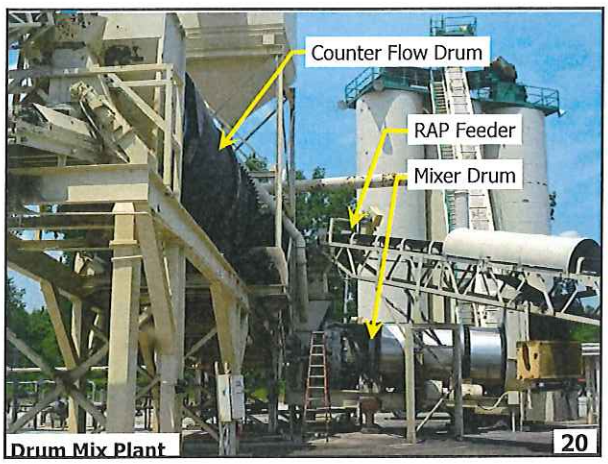
17


Drum Dryer Mixer
RAP
Virgin Aggregate
Exhaust
Burner
Liquid Asphalt
Hot Mix
Hot Mix
18

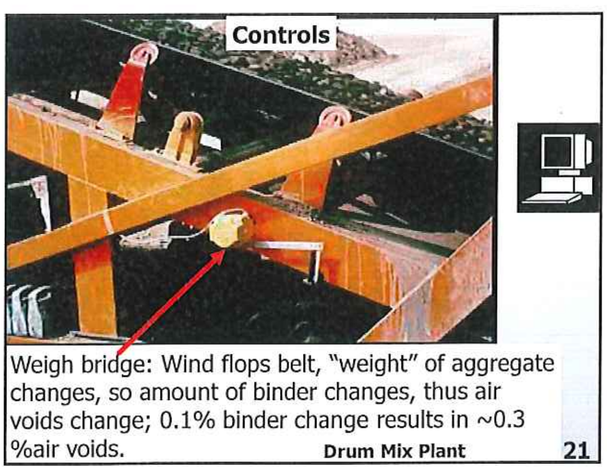
18


Temperature Profile in Drum Mixer
Incoming flights
Drying flights
Mixing flights
Discharge flights
Recycle Asphalt Product
Exhaust
Virgin Aggregate
Liquid Asphalt
Hot Mix
°F
1600
1400
1200
1000
800
600
400
200
Mean Gas Temperature
310°-330° Gas Temp
300° Mix Temp
Mean Aggregate Temperature
Initial Adjustment
Constant Drying
Superheated Virgin Aggregate
Dry & Heat Rap
Mixing
Superheated aggregate dries the RAP
Can be a problem with high RAP content
19

19


Counter Flow Drum
RAP Feeder
Mixer Drum
Drum Mix Plant
20

20


Controls
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.
Drum Mix Plant
21

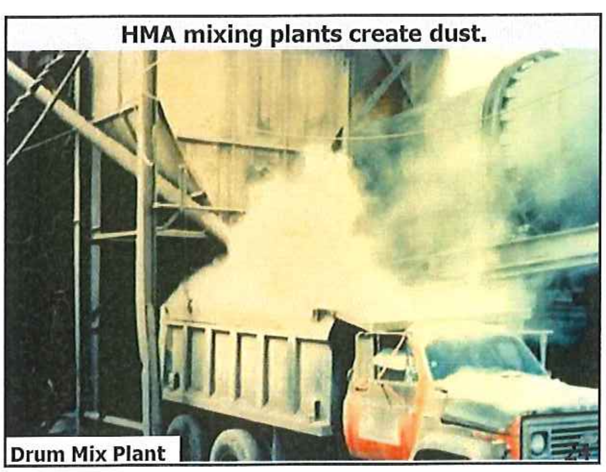
21


Surge Silo
Drum Mix Plant
22

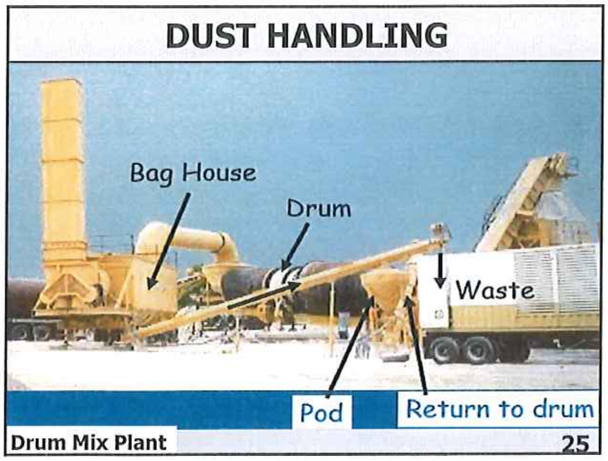
22


Silo
Drum Mix Plant
23

23


HMA mixing plants create dust.
Drum Mix Plant

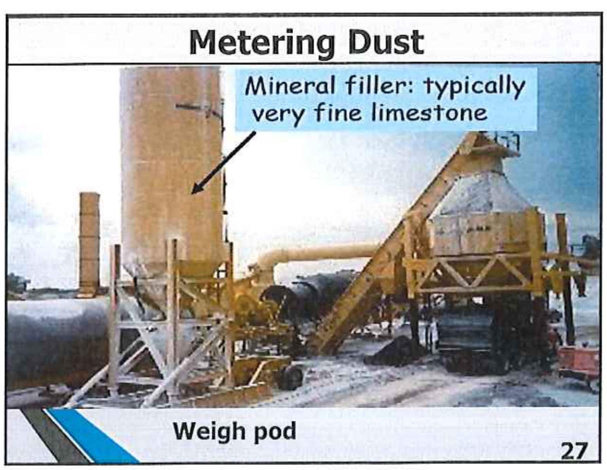
24


DUST HANDLING
Bag House
Drum
Waste
Pod
Return to drum
Drum Mix Plant
25

25


Dust Handling
Waste
Return to drum
26

26


Metering Dust
Mineral filler: typically
very fine limestone
Weigh pod
27

27

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.

28

28

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

29

29

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.

30

30

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.

31

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

32

32

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 ⅜" products).
- Keep an eye on:
  - Gradation
  - Specific gravity for certain products
  - Flat & elongated (crusher wear)

33

33

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.

34

34

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.

35

35

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.

36

36

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.

37

37

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.

38

38

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.

39

39

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 >¾"-poor mixing and coating.

40

40

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 unloads 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.

41

41

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.

42

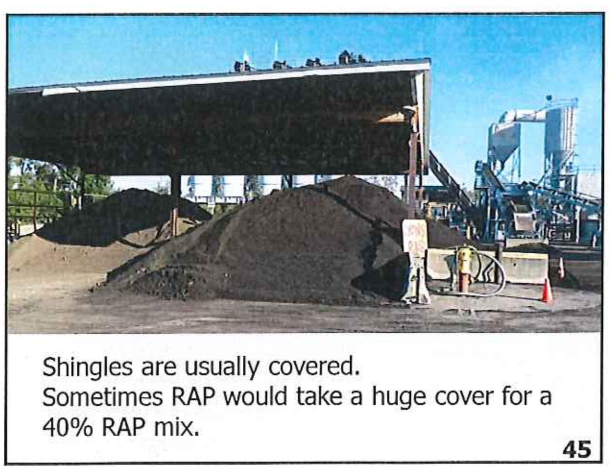
42


Coarse RAP (½ to 1 inch)

43


Fine RAP (minus ½ inch)

44


Shingles are usually covered.
Sometimes RAP would take a huge cover for a 40% RAP mix.
45

45

Module 4

Aggregate Testing Overview

MODULE 4

AGGREGATE TESTING OVERVIEW

1

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.

2

2

Production Aggregate Test

Gradation

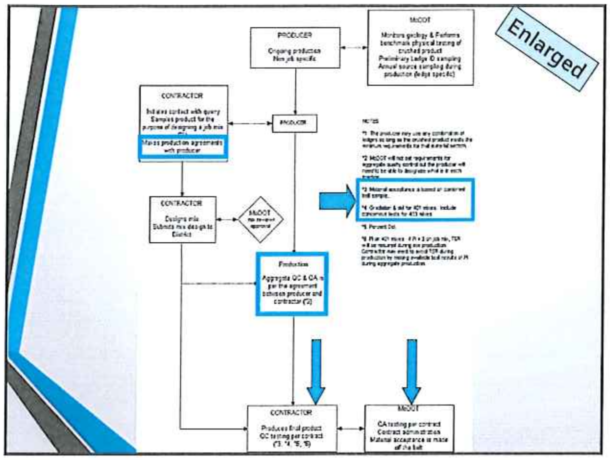
Deleterious

***Consensus tests*:**

- FAA Fine Aggregate Angularity
- CAA Coarse Aggregate Angularity
- SE Sand Equivalency
- F&E Flat & Elongated

3

3



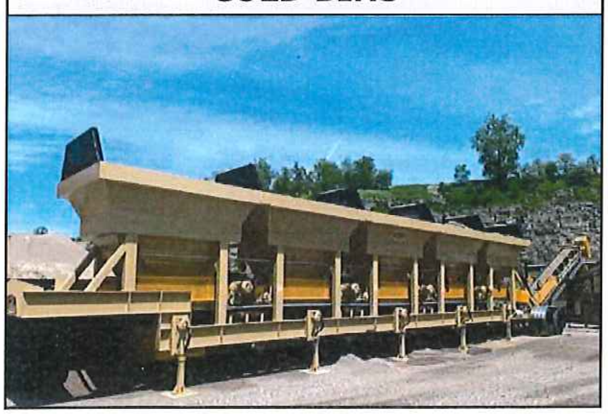
4

SAMPLING: Aggregate

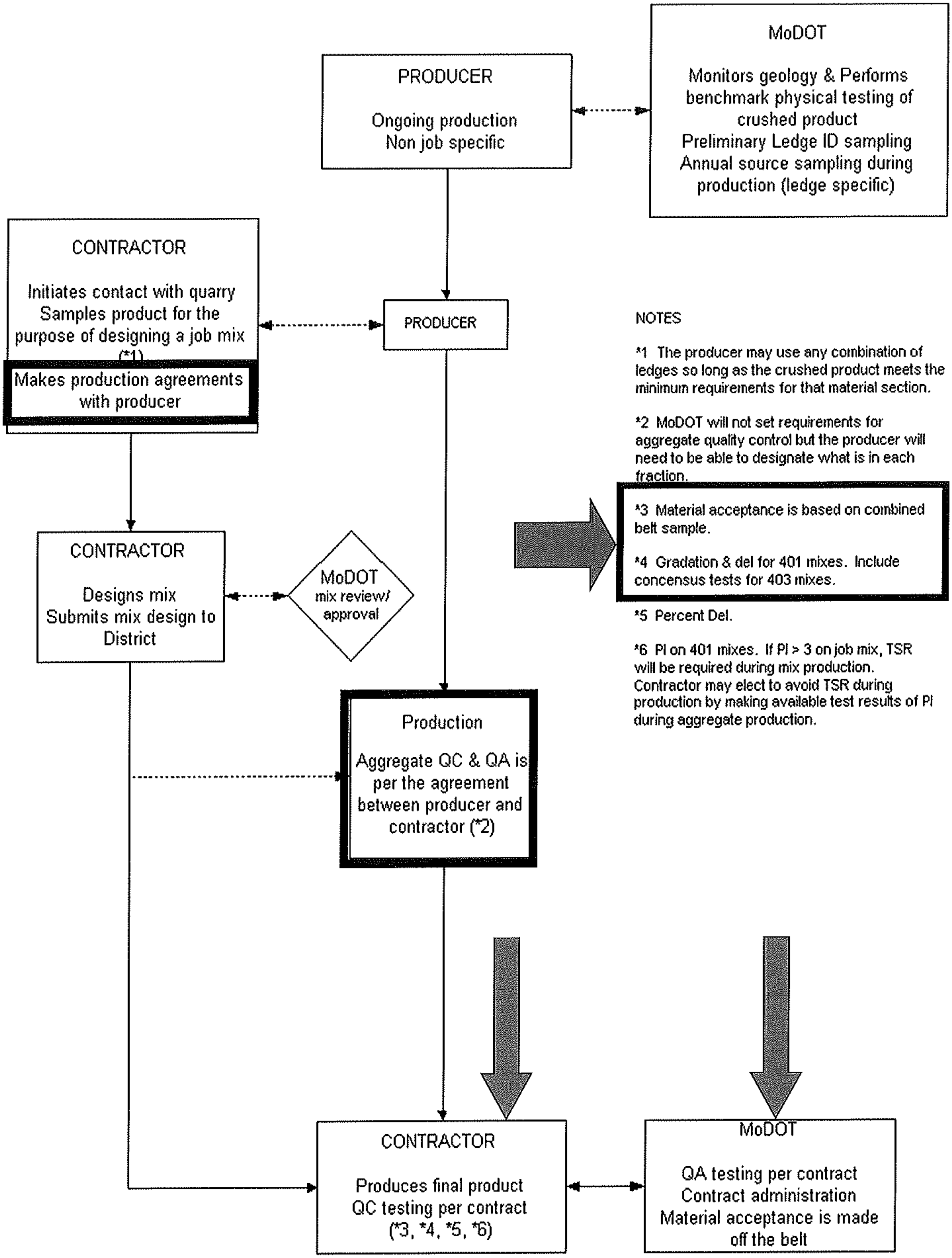
- **Gradation**:
  - Drum - Cold feed belt
  - Batch - Hot bins
  - Can use Asphalt sample - T308 residue
    (Not applicable for dolomite).
  - RAP - T308 residue; combine mathematically with virgin gradation. (Dolomite – will need to extract)
- **Deleterious:**
  - All plants - Cold feed belt
- **Consensus:**
  - All plants - Cold feed belt
- **QC** retains half their sample (after final split) for QA. 5

5

COLD BINS



6


PRODUCER
Ongoing production
Non job specific
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
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 concensus 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.
CONTRACTOR
Designs mix
Submits mix design to District
MoDOT
mix review/ approval
Production
Aggregate QC & QA is per the agreement between producer and contractor (*2)
CONTRACTOR
Produces final product
QC testing per contract
(*3, *4, *5, *6)
MoDOT
QA testing per contract
Contract administration
Material acceptance is made off the belt

Sampling
Drum Plant Methods

- Off the combined cold feed belt
- Diverter

7

7

Sampling Gradation

8

8

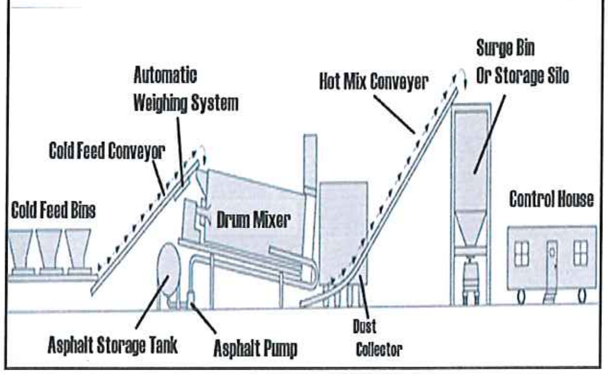
Sampling
Cold Feed Belt

Get equal increments if more than one is not enough.

9

9

Drum Mix Plant



10

Diverter Chute

Diverter chute: Get 3 grabs to combine.

11

11

Sampling - Batch Plant

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

12

12

Sampling - Hot Bins

13

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.

14

14

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

15

15

Sampling & Testing

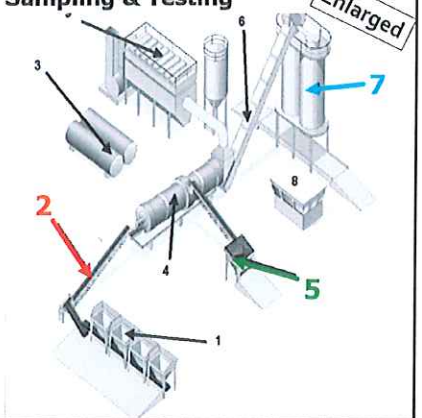
Enlarged

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



16

Aggregate

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

17

17

Unfavorable Comparison

- Has been traced to the splitting operation and equipment that each side was using.

18

18

Sampling & Testing

2: Aggregate Cold feed:

- Deleterious
- Consensus
- Gradation: if dolomite and maybe if limestone

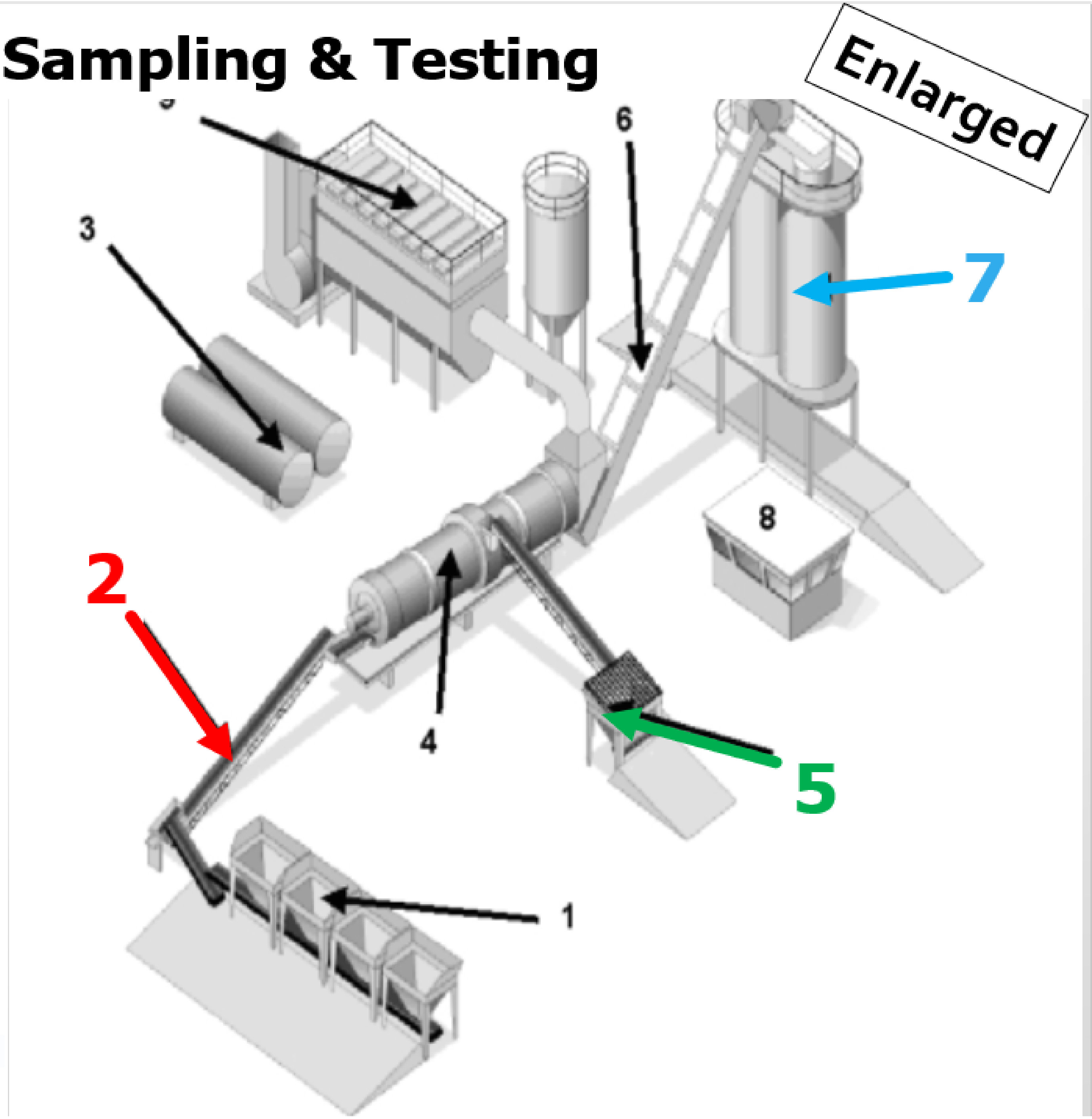
5: RAP

- 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

19

19

SPECIFIED GRADATIONS

Sieve Size	SP250	SP190	SP125	SP095	SP048
1 ½ "	100				
1	90-100	100			
¾	90 max	90-100	100		
½		90 max	90-100	100	
3/8			90 max	90-100	100
#4				90 max	90-100
#8	19-45	23-49	28-58	32-67	
#16					30-60
#30					
#50					
#100					
#200	1-7	2-8	2-10	2-10	7-12

20

20

Field Tolerances

Aggregate ***Gradation*** (Non-SMA)

(3 sieves):

- 1 size smaller than NMS_{JMF} : not to exceed 92.0%
- #8: not to exceed 2.0% beyond master spec.
- #200: within master spec.

21

21

Example

SP 190

Sieve	SP190	Tolerance	Test
1.5	--	---	---
1	100	---	100
¾	90-100	---	99
½	90 max	92 max	91
3/8	--	--	--
#4	--	--	--
#8	23-49	21-51	22
#16	--	--	--
#30	--	--	--
#50	--	--	--
#100	--	--	--
#200	2-8	2-8	5.2

22

22

SMA Tolerances

%'s off JMF Target Gradation

Sieve	SP095	SP125
¾"	---	
½"	---	± 4
⅜"	± 4	± 4
#4	± 3	± 3
#8	± 3	± 3
#200	± 2	± 2

23

23

Minor Deviations

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

24

24

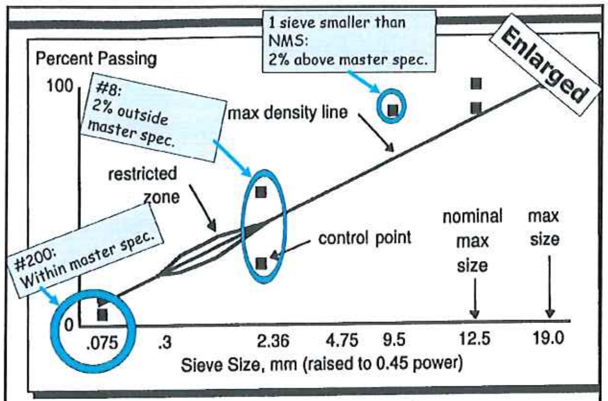


Figure 3.10 Superpave Gradation Limits 25

25

Aggregate

Acceptance:

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

26

26

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.

27

27

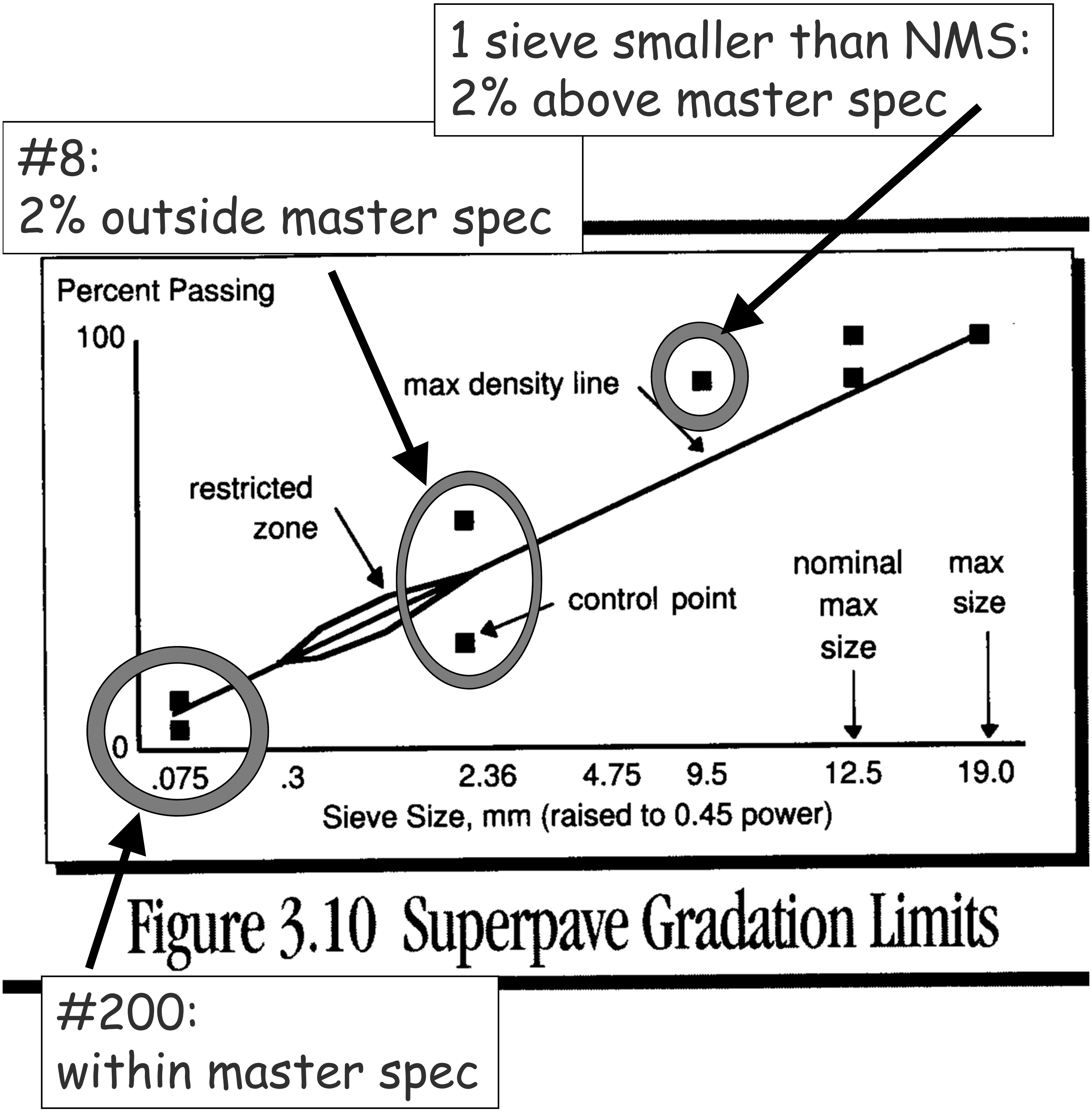


Figure 3.10 Superpave Gradation Limits

Example Comparison

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

28

28

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)

29

29

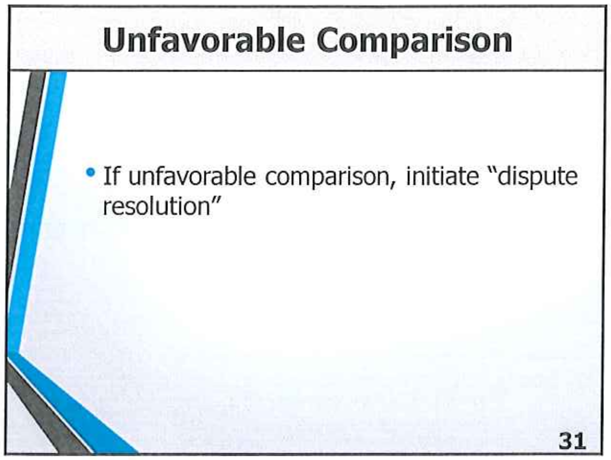
Gradation
on QC retained sample so are running same type of sample.

(Use for Gradation comparisons)

Sieve Size	Percentage points
≥¾"	± 5.0%
½"	± 5.0
3/8"	± 4.0
#4	± 4.0
#8	± 3.0
#10	± 3.0
#16	± 3.0
#20	± 3.0
#30	± 3.0
#40	± 2.0
#50	± 2.0
#100	± 2.0
# 200	± 1.0

30

30


Unfavorable Comparison
• If unfavorable comparison, initiate "dispute resolution"
31

31

Module 5

Asphalt Sampling
Loose Mix & Cores

MODULE 5

ASPHALT SAMPLING
LOOSE MIX & CORES

Rev: 10/02/2023

1

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

2

RESOURCES

403 specification

General provisions & Supplemental Specifications

AASHTO Test Methods:

R 97 Sampling Asphalt Mixtures

R 67 Sampling Asphalt Mixtures (Cores)

Engineering **P**olicy **G**uide (EPG)

FAQ – located in EPG

Superpave Course Notebook

3

3

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.

4

4

Extra or Check Samples

Extra sampling by QA or QC:

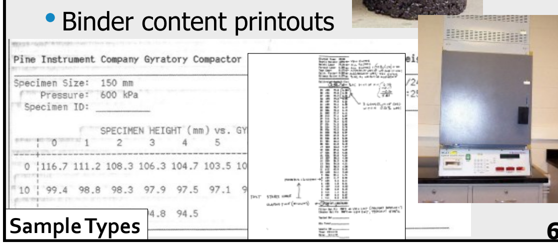
- Check how the mix is doing.
- Investigate problem areas *e.g.,* does a problem exist?
- Determine limits of the problem.
- Can be from truck, plant or roadway
- Not random and can not be used for QLA.
  - **Q**uality **L**evel **A**nalysis (QLA).
- Can be used to define removal limits, but must be "Well - Documented"

5

5

"Well - Documented" The Following are Available:

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



Sample Types

6

6

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.

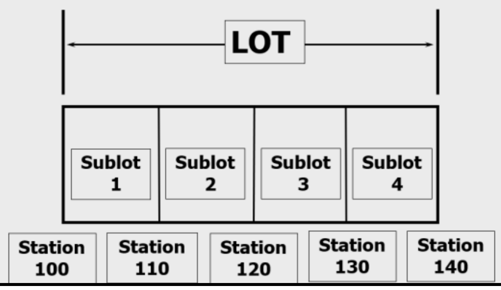
The retained samples can be used for dispute resolution.

Retaining Samples **7**

7

LOTS AND SUBLOTS

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



8

8

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 **9**

9

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.

Lots and Sublots 10

10

- **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.

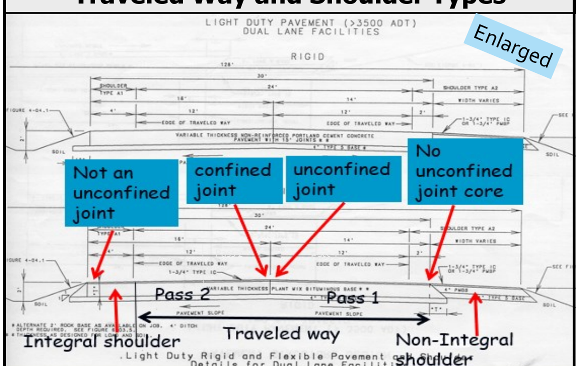
NOTES:

- 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.

Lots and Sublots 11

11

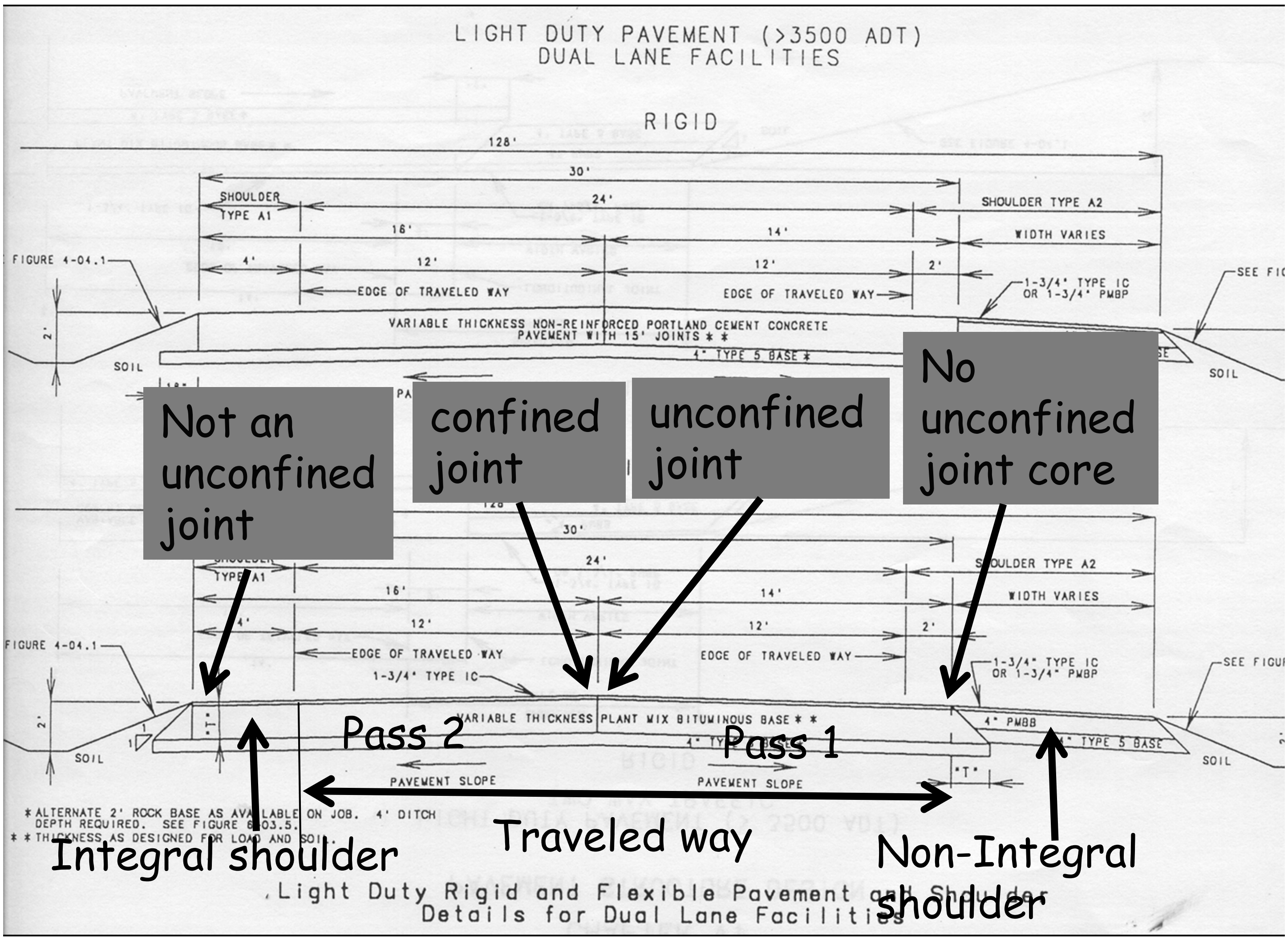
Traveled Way and Shoulder Types



Lots and Sublots 12

12

Traveled Way and Shoulder Types



SAMPLE LOCATION

Random Numbers are used to generate a random location for sampling.

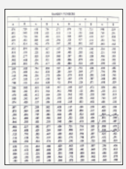
- **Object**: to produce unbiased samples. Sample bias occurs either during construction or during sampling.
  - See ASTM D3665 on Random Samples
- **QC** should provide contingencies in **QC** Plan to handle random numbers in weird locations (does not apply to early tonnage e.g., first 50 tons).

Sample Location 13

13

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 14

14

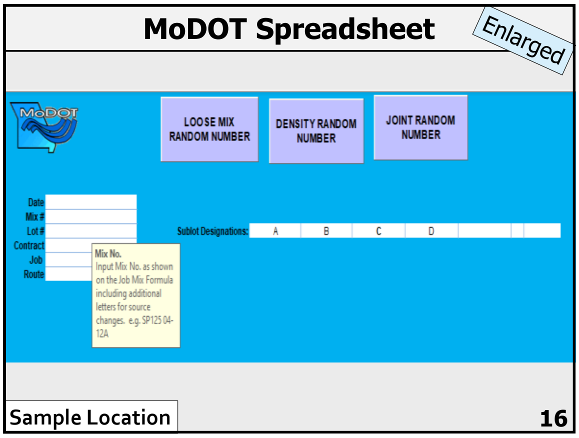
Random Number Generation

- MoDOT spreadsheet is the preferred method.
- Use the "Asphalt Random Location spreadsheet"
- MoDOT internal site:

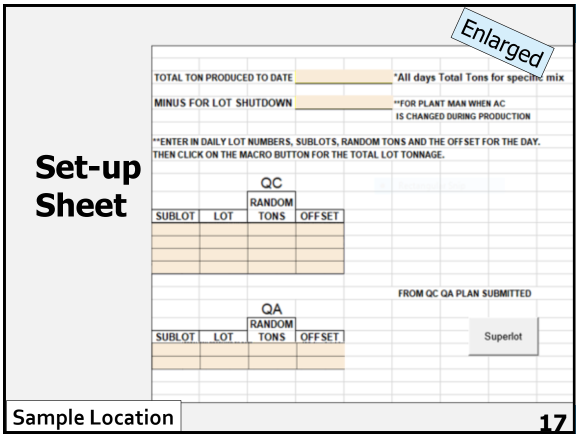
http://eprojects/Template/Forms/AllItems.aspx

Sample Location 15

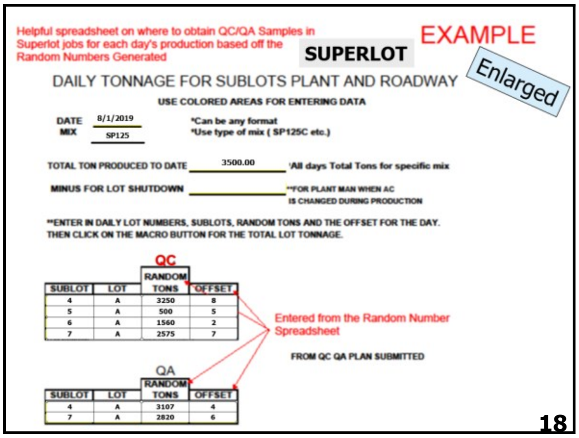
15


MoDOT Spreadsheet
Enlarged
LOOSE MIX RANDOM NUMBER
DENSITY RANDOM NUMBER
JOINT RANDOM NUMBER
Date
Mix #
Lot #
Contract
Job
Route
Sublot Designations:
A
B
C
D
Mix No.
Input Mix No. as shown on the Job Mix Formula including additional letters for source changes. e.g. SP125 04-12A
Sample Location
16

16

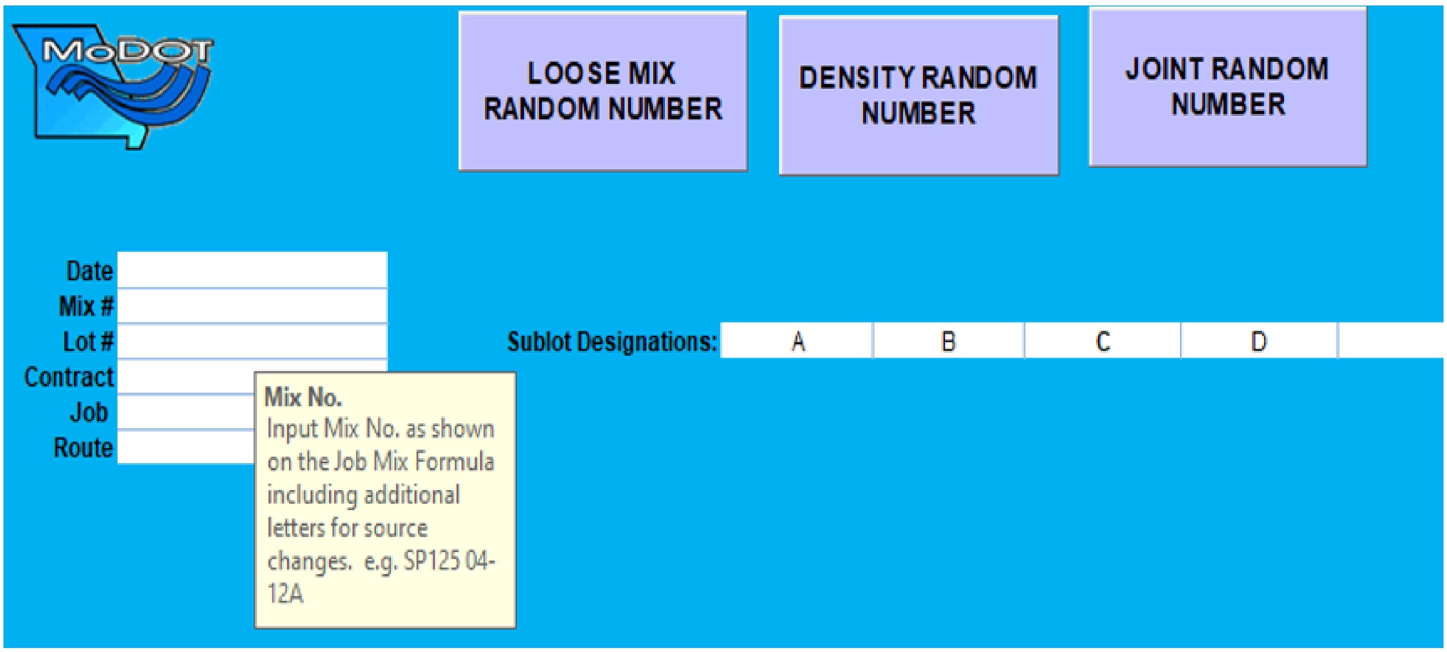

Set-up Sheet
Enlarged
TOTAL TON PRODUCED TO DATE
*All days Total Tons for specific mix
MINUS FOR LOT SHUTDOWN
**FOR PLANT MAN WHEN AC IS CHANGED DURING PRODUCTION
**ENTER IN DAILY LOT NUMBERS, SUBLOTS, RANDOM TONS AND THE OFFSET FOR THE DAY. THEN CLICK ON THE MACRO BUTTON FOR THE TOTAL LOT TONNAGE.
QC
SUBLOT
LOT
RANDOM TONS
OFFSET
FROM QC QA PLAN SUBMITTED
QA
SUBLOT
LOT
RANDOM TONS
OFFSET
Superlot
Sample Location
17

17


Helpful spreadsheet on where to obtain QC/QA Samples in Superlot jobs for each day's production based off the Random Numbers Generated
SUPERLOT
EXAMPLE
Enlarged
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
SUBLOT | LOT | RANDOM TONS | OFFSET
4 | A | 3250 | 8
5 | A | 500 | 5
6 | A | 1560 | 2
7 | A | 2575 | 7
Entered from the Random Number Spreadsheet
FROM QC QA PLAN SUBMITTED
QA
SUBLOT | LOT | RANDOM TONS | OFFSET
4 | A | 3107 | 4
7 | A | 2820 | 6
18

18

MoDOT Spreadsheet



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

SUBLOT	LOT	RANDOM TONS	OFFSET

FROM QC QA PLAN SUBMITTED

QA

SUBLOT	LOT	RANDOM TONS	OFFSET

Superlot

Helpful spreadsheet on where to obtain QC/QA Samples in Superlot 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	*Can be any format
MIX	SP125	*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

SUBLOT	LOT	RANDOM TONS	OFFSET
4	A	3250	8
5	A	500	5
6	A	1560	2
7	A	2575	7

Entered from the Random Number Spreadsheet

FROM QC QA PLAN SUBMITTED

QA

SUBLOT	LOT	RANDOM TONS	OFFSET
4	A	3107	4
7	A	2820	6

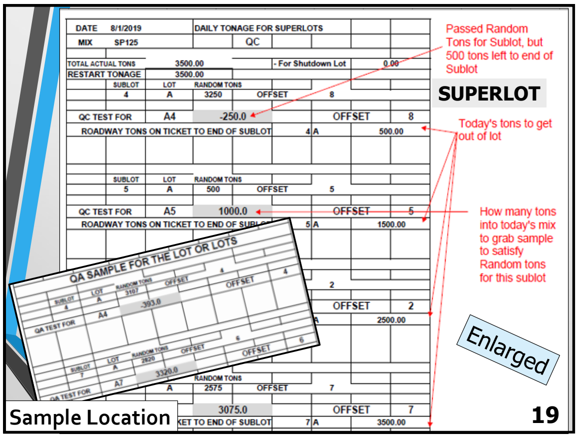
DATE 8/1/2019		DAILY TONAGE FOR SUPERLOTS			
MIX SP125		QC			
TOTAL ACTUAL TONS	3500.00		- For Shutdown Lot		0.00
RESTART TONAGE	3500.00				
SUBLOT	LOT	RANDOM TONS			
4	A	3250	OFFSET	8	
QC TEST FOR	A4	-250.0		OFFSET	8
ROADWAY TONS ON TICKET TO END OF SUBLOT			4	A	500.00
SUBLOT	LOT	RANDOM TONS			
5	A	500	OFFSET	5	
QC TEST FOR	A5	1000.0		OFFSET	5
ROADWAY TONS ON TICKET TO END OF SUBLOT			5	A	1500.00
SUBLOT	LOT	RANDOM TONS			
6	A	1560	OFFSET	2	
QC TEST FOR	A6	2060.0		OFFSET	2
ROADWAY TONS ON TICKET TO END OF SUBLOT			6	A	2500.00
SUBLOT	LOT	RANDOM TONS			
7	A	2575	OFFSET	7	
QC TEST FOR	A7	3075.0		OFFSET	7
ROADWAY TONS ON TICKET TO END OF SUBLOT			7	A	3500.00

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				
SUBLOT	LOT	RANDOM TONS		
4	A	3107	OFFSET	4
QA TEST FOR	A4	-393.0	OFFSET	4
SUBLOT	LOT	RANDOM TONS		
7	A	2820	OFFSET	6
QA TEST FOR	A7	3320.0	OFFSET	6



19

Random Numbers Sample Location

- The pair of random numbers are different for each sample location (Loose Mix or Core) **QC**, or **QA**.

Sample Location 20

20

Loose Mix Sample Location

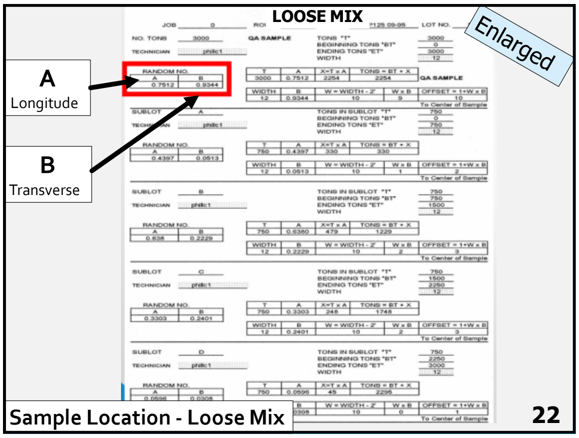
- **Location of a loose mix**:

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**

Sample Location – Loose Mix 21

21



22

Core Sample Location

- **Position of a core**:

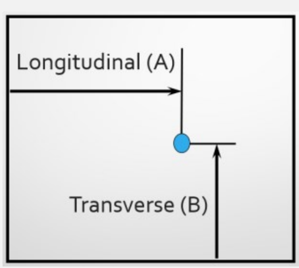
A transverse distance and a longitudinal distance. (stations)

Distances are determined by random numbers one for longitudinal (A), one for transverse (B).

Sample Location – Core 23

23

CORE
Sublot 1- Sample Location



QC QA Sampling Construction

Sampling Location Core 24

24

LOOSE MIX

JOB 0 ROUTE 0 MIX NO. SP125 09-95 LOT NO. 5

NO. TONS 3000

TECHNICIAN phillc1

QA SAMPLE

TONS "T" 3000
BEGINNING TONS "BT" 0
ENDING TONS "ET" 3000
WIDTH 12

RANDOM NO.

A	B
0.7512	0.9344

T	A	X=T x A	TONS = BT + X
3000	0.7512	2254	2254

QA SAMPLE

WIDTH	B	W = WIDTH - 2'	W x B	OFFSET = 1+W x B
12	0.9344	10	9	10

To Center of Sample

SUBLOT A

TECHNICIAN phillc1

TONS IN SUBLOT "T" 750
BEGINNING TONS "BT" 0
ENDING TONS "ET" 750
WIDTH 12

RANDOM NO.

A	B
0.4397	0.0513

T	A	X=T x A	TONS = BT + X
750	0.4397	330	330

WIDTH	B	W = WIDTH - 2'	W x B	OFFSET = 1+W x B
12	0.0513	10	1	2

To Center of Sample

SUBLOT B

TECHNICIAN phillc1

TONS IN SUBLOT "T" 750
BEGINNING TONS "BT" 750
ENDING TONS "ET" 1500
WIDTH 12

RANDOM NO.

A	B
0.638	0.2229

T	A	X=T x A	TONS = BT + X
750	0.6380	479	1229

WIDTH	B	W = WIDTH - 2'	W x B	OFFSET = 1+W x B
12	0.2229	10	2	3

To Center of Sample

SUBLOT C

TECHNICIAN phillc1

TONS IN SUBLOT "T" 750
BEGINNING TONS "BT" 1500
ENDING TONS "ET" 2250
WIDTH 12

RANDOM NO.

A	B
0.3303	0.2401

T	A	X=T x A	TONS = BT + X
750	0.3303	248	1748

WIDTH	B	W = WIDTH - 2'	W x B	OFFSET = 1+W x B
12	0.2401	10	2	3

To Center of Sample

SUBLOT D

TECHNICIAN phillc1

TONS IN SUBLOT "T" 750
BEGINNING TONS "BT" 2250
ENDING TONS "ET" 3000
WIDTH 12

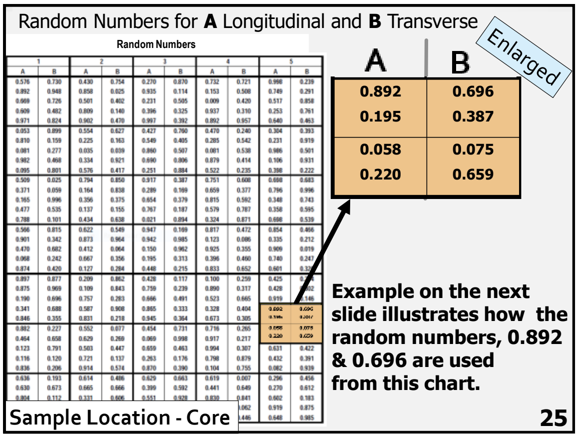
RANDOM NO.

A	B
0.0596	0.0308

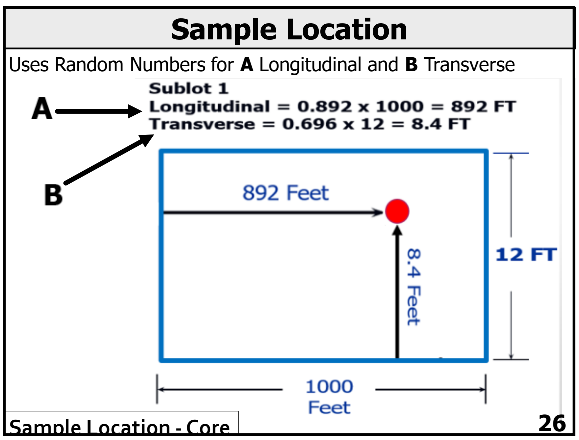
T	A	X=T x A	TONS = BT + X
750	0.0596	45	2295

WIDTH	B	W = WIDTH - 2'	W x B	OFFSET = 1+W x B
12	0.0308	10	0	1

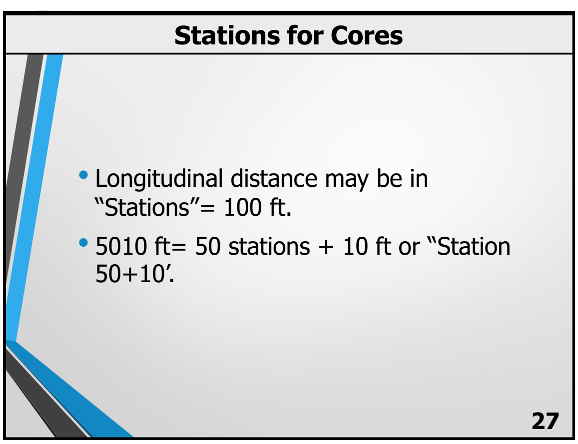
To Center of Sample


Random Numbers for A Longitudinal and B Transverse
Random Numbers
Enlarged
A B
0.892 0.696
0.195 0.387
0.058 0.075
0.220 0.659
Example on the next slide illustrates how the random numbers, 0.892 & 0.696 are used from this chart.
Sample Location - Core
25

25


Sample Location
Uses Random Numbers for A Longitudinal and B Transverse
A
B
Sublot 1
Longitudinal = 0.892 x 1000 = 892 FT
Transverse = 0.696 x 12 = 8.4 FT
892 Feet
8.4 Feet
12 FT
1000 Feet
Sample Location - Core
26

26


Stations for Cores
Longitudinal distance may be in "Stations"= 100 ft.
5010 ft= 50 stations + 10 ft or "Station 50+10'.
27

27

Random Numbers

1		2		3		4		5	
A	B	A	B	A	B	A	B	A	B
0.576	0.730	0.430	0.754	0.270	0.870	0.732	0.721	0.998	0.239
0.892	0.948	0.858	0.025	0.935	0.114	0.153	0.508	0.749	0.291
0.669	0.726	0.501	0.402	0.231	0.505	0.009	0.420	0.517	0.858
0.609	0.482	0.809	0.140	0.396	0.325	0.937	0.310	0.253	0.761
0.971	0.824	0.902	0.470	0.997	0.392	0.892	0.957	0.640	0.463
0.053	0.899	0.554	0.627	0.427	0.760	0.470	0.240	0.304	0.393
0.810	0.159	0.225	0.163	0.549	0.405	0.285	0.542	0.231	0.919
0.081	0.277	0.035	0.039	0.860	0.507	0.081	0.538	0.986	0.501
0.982	0.468	0.334	0.921	0.690	0.806	0.879	0.414	0.106	0.931
0.095	0.801	0.576	0.417	0.251	0.884	0.522	0.235	0.398	0.222
0.509	0.025	0.794	0.850	0.917	0.387	0.751	0.608	0.698	0.683
0.371	0.059	0.164	0.838	0.289	0.169	0.659	0.377	0.796	0.996
0.165	0.996	0.356	0.375	0.654	0.379	0.815	0.592	0.348	0.743
0.477	0.535	0.137	0.155	0.767	0.187	0.579	0.787	0.358	0.595
0.788	0.101	0.434	0.638	0.021	0.894	0.324	0.871	0.698	0.539
0.566	0.815	0.622	0.549	0.947	0.169	0.817	0.472	0.854	0.466
0.901	0.342	0.873	0.964	0.942	0.985	0.123	0.086	0.335	0.212
0.470	0.682	0.412	0.064	0.150	0.962	0.925	0.355	0.909	0.019
0.068	0.242	0.667	0.356	0.195	0.313	0.396	0.460	0.740	0.247
0.874	0.420	0.127	0.284	0.448	0.215	0.833	0.652	0.601	0.326
0.897	0.877	0.209	0.862	0.428	0.117	0.100	0.259	0.425	0.284
0.875	0.969	0.109	0.843	0.759	0.239	0.890	0.317	0.428	0.302
0.190	0.696	0.757	0.283	0.666	0.491	0.523	0.665	0.919	0.146
0.341	0.688	0.587	0.908	0.865	0.333	0.328	0.404	0.892	0.696
0.846	0.355	0.831	0.218	0.945	0.364	0.673	0.305	0.195	0.387
0.882	0.227	0.552	0.077	0.454	0.731	0.716	0.265	0.058	0.075
0.464	0.658	0.629	0.269	0.069	0.998	0.917	0.217	0.220	0.659
0.123	0.791	0.503	0.447	0.659	0.463	0.994	0.307	0.631	0.422
0.116	0.120	0.721	0.137	0.263	0.176	0.798	0.879	0.432	0.391
0.836	0.206	0.914	0.574	0.870	0.390	0.104	0.755	0.082	0.939
0.636	0.193	0.614	0.486	0.629	0.663	0.619	0.007	0.296	0.456
0.630	0.673	0.665	0.666	0.399	0.592	0.441	0.649	0.270	0.612
0.804	0.112	0.331	0.606	0.551	0.928	0.830	0.841	0.602	0.183
0.360	0.193	0.181	0.399	0.564	0.772	0.890	0.062	0.919	0.875
0.183	0.651	0.157	0.450	0.800	0.875	0.205	0.446	0.648	0.985

Stationing Example for Cores

Longitudinal

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

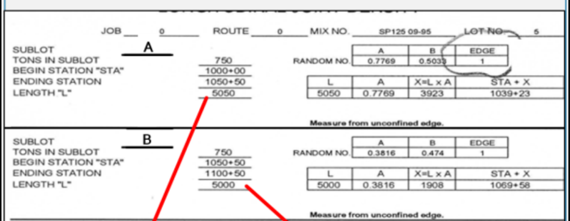
1200+00
52+38
1252+38

Sample Location - Core

28

28

Stationing Example for Cores


JOB 0 ROUTE 0 MIX NO. SP125 09-95 LOT NO. 5

SUBLOT A
TONS IN SUBLOT 750
BEGIN STATION "STA" 1000+00
ENDING STATION 1050+50
LENGTH "L" 5050

	A	B	EDGE
RANDOM NO.	0.7769	0.5033	1

L	A	X=L x A	STA + X
5050	0.7769	3923	1039+23

Measure from unconfined edge.

SUBLOT B
TONS IN SUBLOT 750
BEGIN STATION "STA" 1050+50
ENDING STATION 1100+50
LENGTH "L" 5000

	A	B	EDGE
RANDOM NO.	0.3816	0.474	1

L	A	X=L x A	STA + X
5000	0.3816	1908	1069+58

Measure from unconfined edge.

Sublot A

1000 + 00	Begin. station
+ 50 + 50	Length
= 1050 + 50	Ending Station

Sublot B

1050 + 50	Begin. station
+ 50 + 00	Length
= 1100 + 50	Ending Station

29

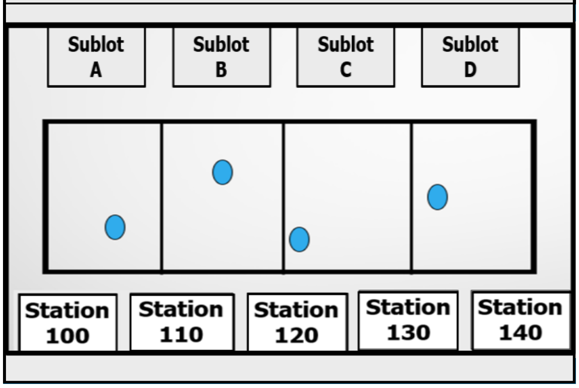
Stratified Random Sampling

- Stratified sampling divides the lot into the desired number of equal sublots and then calls for random samples of each sublot.
- 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.

30

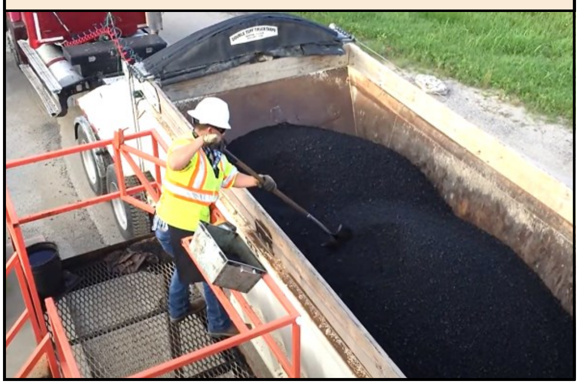
30

Stratified Random Sampling Core



31

SAMPLING ASPHALT - LOOSE MIX



32

Sample Areas for Loose Mix Asphalt

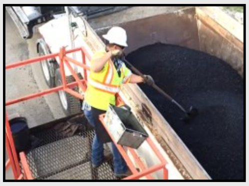
- **Truck**
- **Roadway**
- **Asphalt Stream** - Plant Discharge
- **Mini Stockpile**

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

Loose Mix **33**

33

Truck



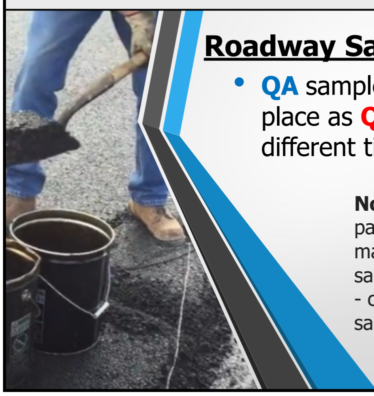
Procedure:

- 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.

(New Slide) 31

34

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.

35

35

Volumetric and % Binder Samples

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.

Loose Mix

QLA = Quality Level Analysis

36

36

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 sublot.***
- 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**.

Loose Mix **37**

37

Volumetric and % Binder Sample

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.**

Loose Mix **38**

38

Volumetric and % Binder Sample

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.**

Loose Mix **39**

39

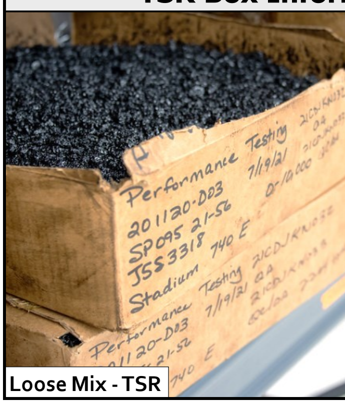
TSR Samples

- **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)

Loose Mix - TSR 40

40

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

Loose Mix - TSR 41

41

TSR Samples

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.

Loose Mix - TSR 42

42

TSR Samples – QC

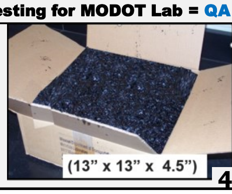
- **QC Location:** Truck sample, At the plant, Roadway behind the paver*.

*Full depth of the course.

- **Random**
- **Size:** 75-125 lbs.

(Plus, another 125 lb. sample retained for **QA**)

4 FULL Boxes needed for TSR testing for MODOT Lab = QA



Loose Mix - TSR

43

43

TSR Samples – QA

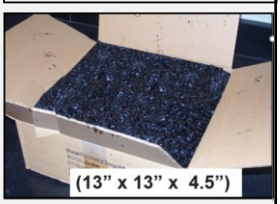
- **QA Location:** Truck sample, At the plant, Roadway behind the paver*.

*Full depth of the course.

- **Random**
- **Size:** 75-125 lbs.

(Plus, another 125 lb. sample retained for **QA**)

4 FULL Boxes needed for TSR testing for MODOT Lab = QA



Loose Mix - TSR

44

44

TSR Samples – At the Plant

- Mini Stockpile
- Plant Discharge

Note: Normally utilized to avoid sampling from a truck due to safety concerns.

Loose Mix - TSR

45

45

"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.

Loose Mix - TSR

46

46

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.

Loose Mix - TSR

47

47

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.

Loose Mix

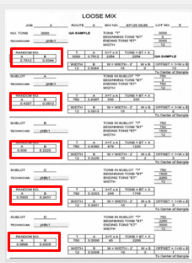
48

48

Loose Mix Sampling Steps Typical Scenario (EPG)

49

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.



50

50

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.

Loose Mix Sampling Steps

51

51

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

52

52

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

53

53

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.

54

54

11. **QC** places sample in insulated containers or boxes, label, and transport containers to mobile lab.

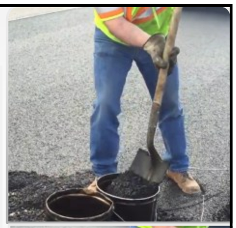
Loose Mix Sampling Steps

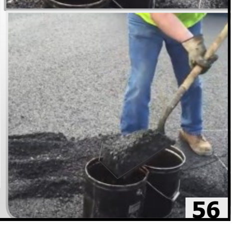
55

55

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

56

56

SAMPLING ASPHALT - CORES

57

57

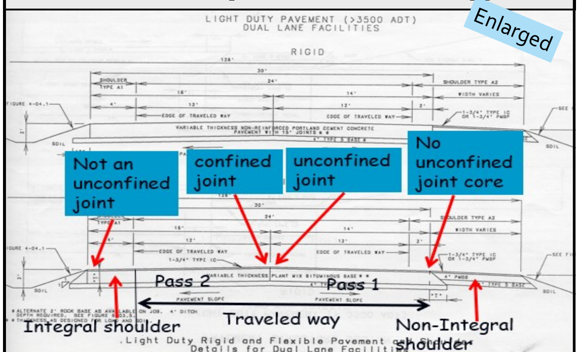
Types of Cores

- **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**

58

Traveled Way and Shoulder Types



Sampling Cores **59**

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

60

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.

61

61

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.

Sampling Cores 62

62

Core Positions

Quality Level Analysis Cores

Sampling Cores 63

63

Coring

Quality Level Analysis Cores

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

Sampling Cores 64

64

Extra QC Cores

Quality Level Analysis Cores

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

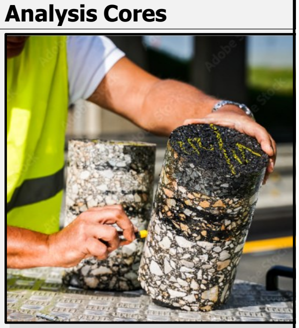
Sampling Cores 65

65

Thick Lifts

Quality Level Analysis Cores

- If mix is placed in lifts ≥ 6 x 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



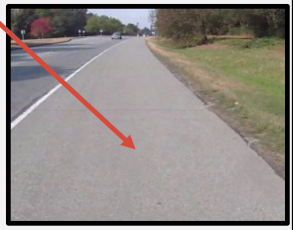
Sampling Cores 66

66

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%].

67

67

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 68

68

Density Pay Adjustment Factor

Non-integral Shoulder Cores

Field Density, % of Gmm	% of Contract Unit Price
92.0 - 97.0	100
91.5 - 91.9 **or** 97.1 - 97.5	90
91.0 - 91.4 **or** 97.1 - 97.5	85
90.5 - 90.9 **or** 97.6 - 98.0	80
90.0 - 90.4 **or** 97.6 - 98.0	75
Below 90.0 **or** above 98.0	Remove & replace

69

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 70

70

Longitudinal Joint

Longitudinal Unconfined Joint

Sampling Cores 71

71

Coring Frequencies

Longitudinal Unconfined Joint Cores

- **QC: 1 sample per sublot**
- **QA: 1 sample per 4 sublots**

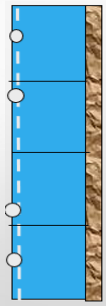
Sampling Cores 72

72

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 sublot).



Sampling Cores

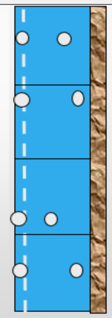
73

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.



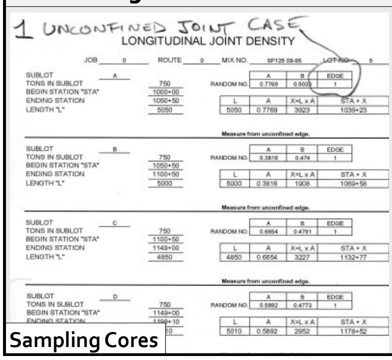
Sampling Cores

74

74

Longitudinal Joint Density

Longitudinal Unconfined Joint Cores



1 UNCONFINED JOINT CASE

LONGITUDINAL JOINT DENSITY

JOB 0 ROUTE 0 MIX NO. SP125 09-95 LOT NO. 5

SUBLOT	A
TONS IN SUBLOT	750
BEGIN STATION "STA"	1000+00
ENDING STATION	1050+50
LENGTH "L"	5050

	A	B	EDGE
RANDOM NO.	0.7769	0.5033	1

L	A	X=L x A	STA + X
5050	0.7769	3923	1039+23

Measure from unconfined edge.

SUBLOT	B
TONS IN SUBLOT	750
BEGIN STATION "STA"	1050+50
ENDING STATION	1100+50
LENGTH "L"	5000

	A	B	EDGE
RANDOM NO.	0.3816	0.474	1

L	A	X=L x A	STA + X
5000	0.3816	1908	1069+58

Measure from unconfined edge.

SUBLOT	C
TONS IN SUBLOT	750
BEGIN STATION "STA"	1100+50
ENDING STATION	1149+00
LENGTH "L"	4850

	A	B	EDGE
RANDOM NO.	0.6654	0.4791	1

L	A	X=L x A	STA + X
4850	0.6654	3227	1132+77

Measure from unconfined edge.

SUBLOT	D
TONS IN SUBLOT	750
BEGIN STATION "STA"	1149+00
ENDING STATION	1199+10
LENGTH "L"	[illegible]10

	A	B	EDGE
RANDOM NO.	0.5892	0.4773	1

L	A	X=L x A	STA + X
5010	0.5892	2952	1178+52

Enlarged

NOTE:
Must alternate sides if have 2 unconfined joints.

Sampling Cores

75

75

LONGITUDINAL JOINT DENSITY

1 UNCONFINED JOINT CASE

LONGITUDINAL JOINT DENSITY

JOB 0 ROUTE 0 MIX NO. SP125 09-95 LOT NO. 5

SUBLOT	A			
TONS IN SUBLOT	750			
BEGIN STATION "STA"	1000+00			
ENDING STATION	1050+50			
LENGTH "L"	5050			

	A	B	EDGE
RANDOM NO.	0.7769	0.5033	1

L	A	X=L x A	STA + X
5050	0.7769	3923	1039+23

Measure from unconfined edge.

SUBLOT	B
TONS IN SUBLOT	750
BEGIN STATION "STA"	1050+50
ENDING STATION	1100+50
LENGTH "L"	5000

	A	B	EDGE
RANDOM NO.	0.3816	0.474	1

L	A	X=L x A	STA + X
5000	0.3816	1908	1069+58

Measure from unconfined edge.

SUBLOT	C
TONS IN SUBLOT	750
BEGIN STATION "STA"	1100+50
ENDING STATION	1149+00
LENGTH "L"	4850

	A	B	EDGE
RANDOM NO.	0.6654	0.4791	1

L	A	X=L x A	STA + X
4850	0.6654	3227	1132+77

Measure from unconfined edge.

SUBLOT	D
TONS IN SUBLOT	750
BEGIN STATION "STA"	1149+00
ENDING STATION	1199+10
LENGTH "L"	5010

	A	B	EDGE
RANDOM NO.	0.5892	0.4773	1

L	A	X=L x A	STA + X
5010	0.5892	2952	1178+52

Measure from unconfined edge.

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: **S**tone-**M**astic (Matrix)- **A**sphalt, 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.

Sampling Cores 76

76

QLA Coring Sampling Steps Typical Scenario

77

QLA Coring for QC

Typical Scenario

1. Roadway inspector marks where each sublot starts.

AASHTO R67

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.

Core Sampling Steps 78

78

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.

Core Sampling Steps

79

79

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.

Core Sampling Steps

80

80

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

81

81

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 82

82

QLA Coring for QC

AASHTO R67

16. Core density (G_{mc}) is determined.

$$Density = (G_{mc} \div G_{mm}) \times 100$$

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

Core Sampling Steps 83

83

Coring Examples

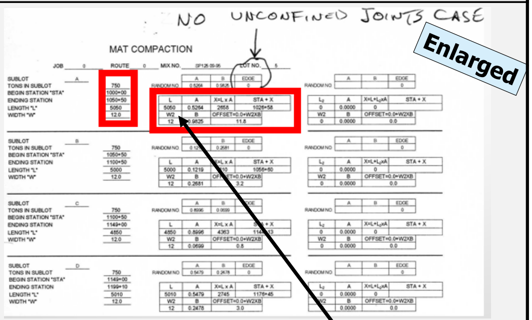
- No unconfined joints
- One unconfined joint
- Two unconfined joints

Sampling Cores 84

84

Compacted Mat Density

No Unconfined Joint Case



Sample full width (12 ft)

Sampling Cores

85

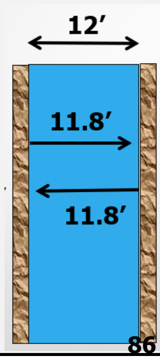
85

Compacted Mat Density

No Unconfined Joints Case

12′ x 0.9825 = 11.8′

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



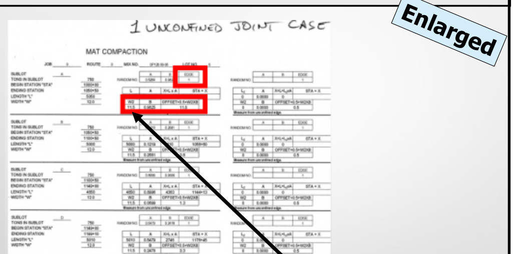
Sampling Cores

86

86

Compacted Mat Density

One Unconfined Joint Case



- Leave out the 6″ strip by the unconfined joint in the calculations (sample 11.5 ft).

Sampling Cores

87

87

COMPACTED MAT DENSITY

No Unconfined Joint Case

NO UNCONFINED JOINTS CASE

MAT COMPACTION

JOB 0 ROUTE 0 MIX NO. SP125 09-95 LOT NO. 5

SUBLOT A
TONS IN SUBLOT 750
BEGIN STATION "STA" 1000+00
ENDING STATION 1050+50
LENGTH "L" 5050
WIDTH "W" 12.0

	A	B	EDGE
RANDOM NO.	0.5264	0.9825	0

L	A	X=L x A	STA + X
5050	0.5264	2658	1026+58
W2	B	OFFSET=0.0+W2XB	
12	0.9825	11.8	

	A	B	EDGE
RANDOM NO.			0

L_2	A	$X=L+L_2xA$	STA + X
0	0.0000	0	
W2	B	OFFSET=0.0+W2XB	
0	0.0000	0.0	

SUBLOT B
TONS IN SUBLOT 750
BEGIN STATION "STA" 1050+50
ENDING STATION 1100+50
LENGTH "L" 5000
WIDTH "W" 12.0

	A	B	EDGE
RANDOM NO.	0.1219	0.2681	0

L	A	X=L x A	STA + X
5000	0.12[illegible]	610	1056+60
W2	B	OFFSET=0.0+W2XB	
12	0.2681	3.2	

	A	B	EDGE
RANDOM NO.			0

L_2	A	$X=L+L_2xA$	STA + X
0	0.0000	0	
W2	B	OFFSET=0.0+W2XB	
0	0.0000	0.0	

SUBLOT C
TONS IN SUBLOT 750
BEGIN STATION "STA" 1100+50
ENDING STATION 1149+00
LENGTH "L" 4850
WIDTH "W" 12.0

	A	B	EDGE
RANDOM NO.	0.8996	0.06[illegible]	0

L	A	X=L x A	STA + X
4850	0.8996	4363	1144+13
W2	B	OFFSET=0.0+W2XB	
12	0.0699	0.8	

	A	B	EDGE
RANDOM NO.			0

L_2	A	$X=L+L_2xA$	STA + X
0	0.0000	0	
W2	B	OFFSET=0.0+W2XB	
0	0.0000	0.0	

SUBLOT D
TONS IN SUBLOT 750
BEGIN STATION "STA" 1149+00
ENDING STATION 1199+10
LENGTH "L" 5010
WIDTH "W" 12.0

	A	B	EDGE
RANDOM NO.	0.5479	0.2478	0

L	A	X=L x A	STA + X
5010	0.5479	2745	1176+45
W2	B	OFFSET=0.0+W2XB	
12	0.2478	3.0	

	A	B	EDGE
RANDOM NO.			0

L_2	A	$X=L+L_2xA$	STA + X
0	0.0000	0	
W2	B	OFFSET=0.0+W2XB	
0	0.0000	0.0	

- Sample full width (12 ft)

COMPACTED MAT DENSITY

One Unconfined Joint Case

1 UNCONFINED JOINT CASE

MAT COMPACTION

JOB 0 ROUTE 0 MIX NO. SP125 09-95 LOT NO. 5

SUBLOT A

TONS IN SUBLOT	750
BEGIN STATION "STA"	1000+00
ENDING STATION	1050+50
LENGTH "L"	5050
WIDTH "W"	12.0

	A	B	EDGE
RANDOM NO.	0.5264	0.9825	1

L	A	X=L x A	STA + X
W2	B	OFFSET=0.5+W2XB	
11.5	0.9825	11.8	

Measure from unconfined edge.

	A	B	EDGE
RANDOM NO.			1

L_2	A	X=L+L_2xA	STA + X
0	0.0000	0	
W2	B	OFFSET=0.5+W2XB	
0	0.0000	0.5	

Measure from unconfined edge.

SUBLOT B

TONS IN SUBLOT	750
BEGIN STATION "STA"	1050+50
ENDING STATION	1100+50
LENGTH "L"	5000
WIDTH "W"	12.0

	A	B	EDGE
RANDOM NO.	0.1219	0.2681	1

L	A	X=L x A	STA + X
5000	0.1219	610	1056+60
W2	B	OFFSET=0.5+W2XB	
11.5	0.2681	3.6	

Measure from unconfined edge.

	A	B	EDGE
RANDOM NO.			1

L_2	A	X=L+L_2xA	STA + X
0	0.0000	0	
W2	B	OFFSET=0.5+W2XB	
0	0.0000	0.5	

Measure from unconfined edge.

SUBLOT C

TONS IN SUBLOT	750
BEGIN STATION "STA"	1100+50
ENDING STATION	1149+00
LENGTH "L"	4850
WIDTH "W"	12.0

	A	B	EDGE
RANDOM NO.	0.8996	0.0699	1

L	A	X=L x A	STA + X
4850	0.8996	4363	1144+13
W2	B	OFFSET=0.5+W2XB	
11.5	0.0699	1.3	

Measure from unconfined edge.

	A	B	EDGE
RANDOM NO.			1

L_2	A	X=L+L_2xA	STA + X
0	0.0000	0	
W2	B	OFFSET=0.5+W2XB	
0	0.0000	0.5	

Measure from unconfined edge.

SUBLOT D

TONS IN SUBLOT	750
BEGIN STATION "STA"	1149+00
ENDING STATION	1199+10
LENGTH "L"	5010
WIDTH "W"	12.0

	A	B	EDGE
RANDOM NO.	0.5479	0.2478	1

L	A	X=L x A	STA + X
5010	0.5479	2745	1176+45
W2	B	OFFSET=0.5+W2XB	
11.5	0.2478	3.3	

Measure from unconfined edge.

	A	B	EDGE
RANDOM NO.			1

L_2	A	X=L+L_2xA	STA + X
0	0.0000	0	
W2	B	OFFSET=0.5+W2XB	
0	0.0000	0.5	

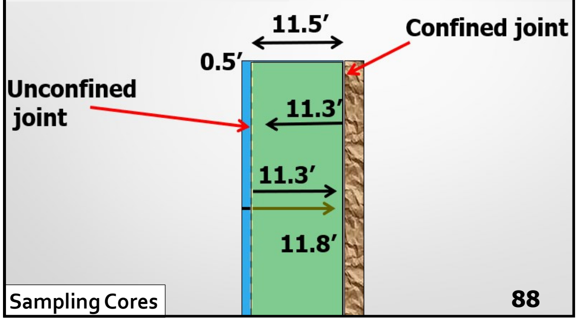
Measure from unconfined edge.

- 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′



Sampling Cores

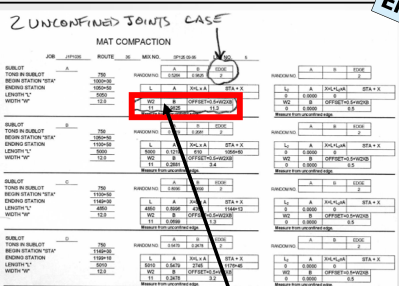
88

88

Compacted Mat Density

Two Unconfined Joint Case

Enlarged



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

Sampling Cores

89

89

Sampling Cores

Enlarged

Where	Who	Core Location Determination	Coring Frequency	Pay Factor Type
Traveled Way	QC	Random Number	1 sample/sublot	QLA Pay Factor
	QA	Random Number	1 sample/ 4 sublots	
Integral shoulder	none			
Non-integral shoulder	Not QLA	Random Number	RE discretion	Density Pay Adjustment Factor
Longitudinal Joint, confined	Considered part of the traveled way			
Longitudinal Joint, unconfined	QC	Random Number	1 sample/sublot	Longitudinal Joint Density Pay Adjustment Factor
	QA	Random Number	1 sample/ 4 sublots	
Base widening, entrances	Not QLA	????	RE discretion	Density Pay Adjustment Factor
Single lift (traveled way)	QC (not QLA)	Random Number	1 Sample/sublot	Density Pay Adjustment Factor

90

90

COMPACTED MAT DENSITY

Two Unconfined Joints Case

2 UNCONFINED JOINTS CASE

MAT COMPACTION

JOB J1P1036 ROUTE 36 MIX NO. SP125 09-95 LOT NO. 5

SUBLOT A

TONS IN SUBLOT	750
BEGIN STATION "STA"	1000+00
ENDING STATION	1050+50
LENGTH "L"	5050
WIDTH "W"	12.0

	A	B	EDGE
RANDOM NO.	0.5264	0.9825	2

L	A	X=L x A	STA + X
[illegible]	[illegible]	[illegible]	[illegible]
W2	B	OFFSET=0.5+W2XB	
11	0.9825	11.3	

Measure from unconfined edge.

	A	B	EDGE
RANDOM NO.			2

L_2	A	$X=L+L_2xA$	STA + X
0	0.0000	0	
W2	B	OFFSET=0.5+W2XB	
0	0.0000	0.5	

Measure from unconfined edge.

SUBLOT B

TONS IN SUBLOT	750
BEGIN STATION "STA"	1050+50
ENDING STATION	1100+50
LENGTH "L"	5000
WIDTH "W"	12.0

	A	B	EDGE
RANDOM NO.	0.1219	0.2681	2

L	A	X=L x A	STA + X
5000	0.1219	610	1056+60
W2	B	OFFSET=0.5+W2XB	
11	0.2681	3.4	

Measure from unconfined edge.

	A	B	EDGE
RANDOM NO.			2

L_2	A	$X=L+L_2xA$	STA + X
0	0.0000	0	
W2	B	OFFSET=0.5+W2XB	
0	0.0000	0.5	

Measure from unconfined edge.

SUBLOT C

TONS IN SUBLOT	750
BEGIN STATION "STA"	1100+50
ENDING STATION	1149+00
LENGTH "L"	4850
WIDTH "W"	12.0

	A	B	EDGE
RANDOM NO.	0.8996	0.0699	2

L	A	X=L x A	STA + X
4850	0.8996	4363	1144+13
W2	B	OFFSET=0.5+W2XB	
11	0.0699	1.3	

Measure from unconfined edge.

	A	B	EDGE
RANDOM NO.			2

L_2	A	$X=L+L_2xA$	STA + X
0	0.0000	0	
W2	B	OFFSET=0.5+W2XB	
0	0.0000	0.5	

Measure from unconfined edge.

SUBLOT D

TONS IN SUBLOT	750
BEGIN STATION "STA"	1149+00
ENDING STATION	1199+10
LENGTH "L"	5010
WIDTH "W"	12.0

	A	B	EDGE
RANDOM NO.	0.5479	0.2478	2

L	A	X=L x A	STA + X
5010	0.5479	2745	1176+45
W2	B	OFFSET=0.5+W2XB	
11	0.2478	3.2	

Measure from unconfined edge.

	A	B	EDGE
RANDOM NO.			2

L_2	A	$X=L+L_2xA$	STA + X
0	0.0000	0	
W2	B	OFFSET=0.5+W2XB	
0	0.0000	0.5	

Measure from unconfined edge.

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

CORING SUMMARY

Where	Who	Core Location Determination	Coring Frequency	Pay Factor Type
Traveled Way	QC	Random Number	1 sample/sublot	QLA Pay Factor
	QA	Random Number	1 sample/ 4 sublots	
Integral shoulder	none			
Non-integral shoulder	Not QLA	Random Number	RE discretion	Density Pay Adjustment Factor
Longitudinal Joint, confined	Considered part of the traveled way			
Longitudinal Joint, unconfined	QC	Random Number	1 sample/sublot	Longitudinal Joint Density Pay Adjustment Factor
	QA	Random Number	1 sample/ 4 sublots	
Base widening, entrances	Not QLA	????	RE discretion	Density Pay Adjustment Factor
Single lift (traveled way)	QC (not QLA)	Random Number	1 Sample/sublot	Density Pay Adjustment Factor

CoringSummary.doc (3-2-16)

Conflict Avoidance

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

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

91

91

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.

Sampling Cores

92

92

Module 6

Sample Reduction and Aging

MODULE 6

SAMPLE REDUCTION AND AGING

Rev 10/07/2024

1

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

2

2

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. 3

3

Preferred methods for reducing sample sizes

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

4

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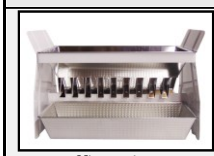
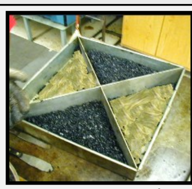
Equipment

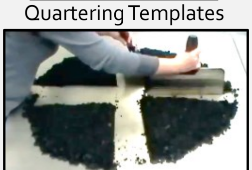


Riffle Splitter



Quartering Templates

Mechanical Splitter Type A



Quartering

5

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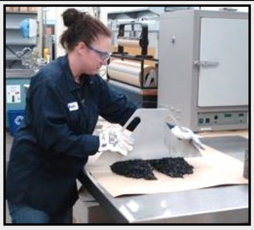
Splitting

Mechanical Splitter Type "A"

6

6

Quartering



For more information Refer to your Bituminous Technician Manual.

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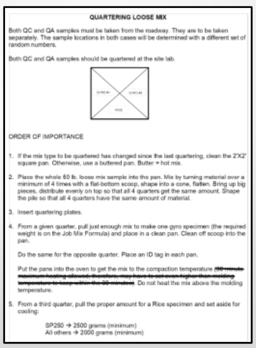
Quartering for Volumetrics

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 60 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)

8

8

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**

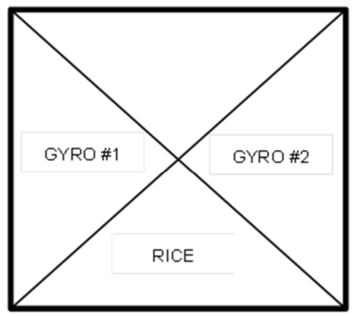
9

9

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.

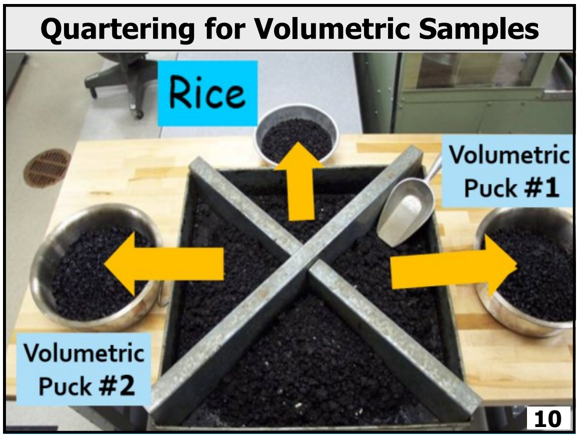
   Compact nuclear sample into the nuclear gage pan while mix is still warm (may have to re-warm).

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

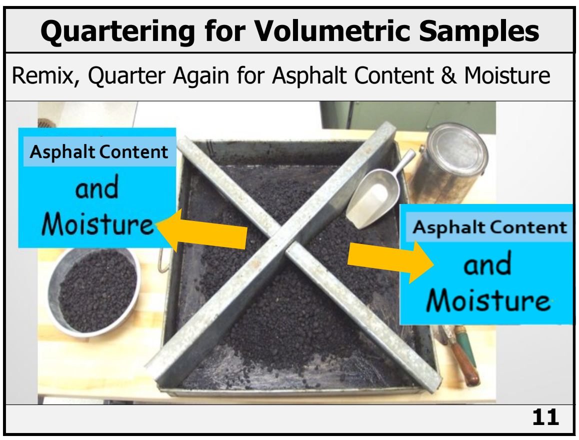
   SP250 → 3000 to 3500 grams
   SP190 → 2000 to 2500 grams
   SP125 → 1500 to 2000 grams
   SP095 and SP048 → 1200 to 1700 grams

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.

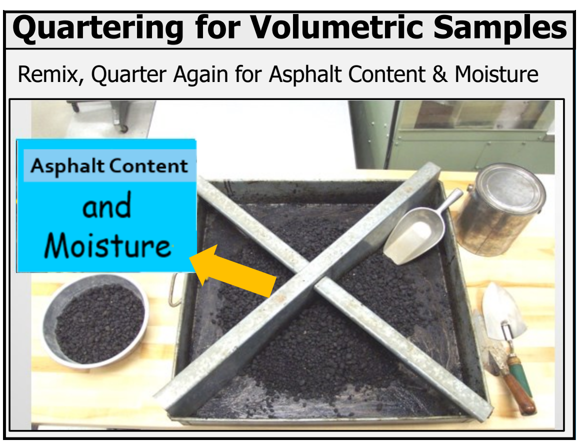
9. Leave the 2′X2′ pan buttered if the type of mix will not change before the next 50 lb. is quartered.


Quartering for Volumetric Samples
Rice
Volumetric Puck #1
Volumetric Puck #2
10

10


Quartering for Volumetric Samples
Remix, Quarter Again for Asphalt Content & Moisture
Asphalt Content and Moisture
Asphalt Content and Moisture
11

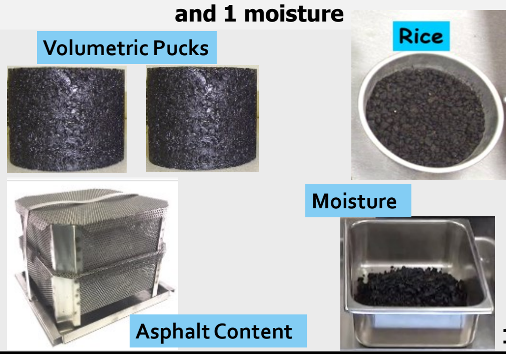
11


Quartering for Volumetric Samples
Remix, Quarter Again for Asphalt Content & Moisture
Asphalt Content and Moisture

12

Volumetric Samples

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



13

13

Quartering for TSR Samples

TSR = Tensile Strength Ratio

- **Get portions for**:
  - **6 – TSR Pucks**
  - **1 - Rice**

    Theoretical Maximum Specific Gravity (Gmm)

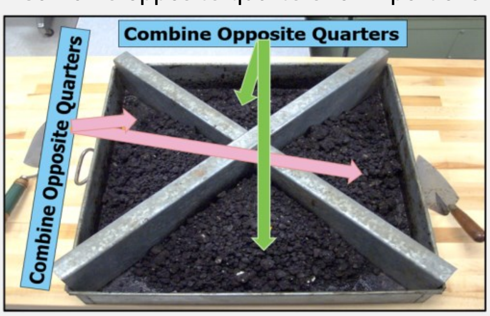
14

14

Quartering for TSR Samples

TSR = Tensile Strength Ratio

Combine opposite quarters for 2 portions.



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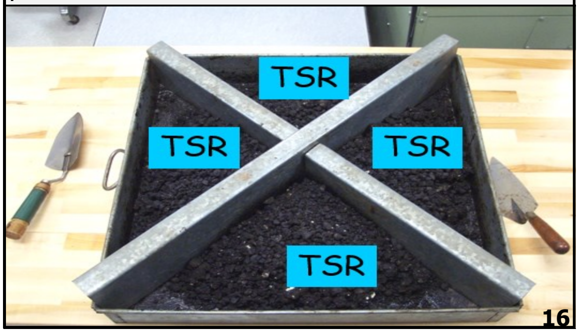
Quartering for TSR Samples

Quarter one of those portions to obtain **4** TSR pucks.

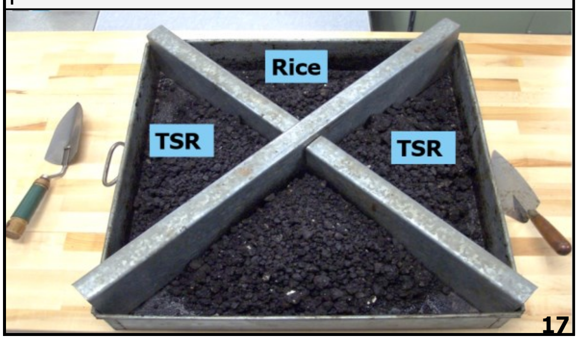


16

16

Quartering for TSR Samples

Quarter the second portion to obtain **2** TSR pucks and **1** Rice.



17

17

TSR Samples

Result = 6 TSR pucks and 1 Rice

18

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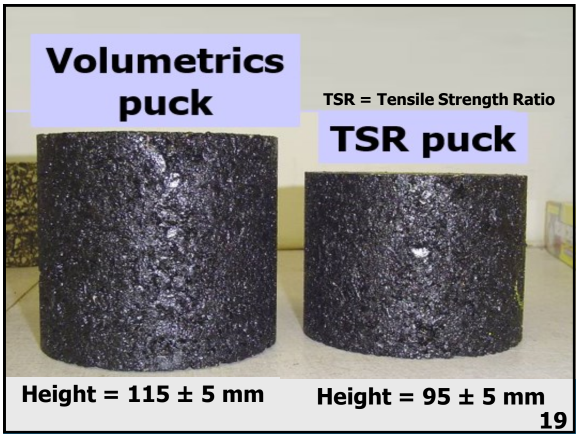


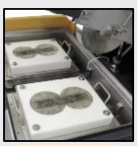
19

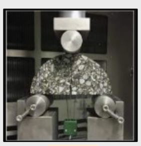
AASHTO R30 and R121

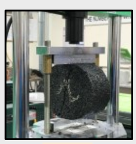
Laboratory Conditioning of Asphalt Mixtures

- 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:


Ideal CT


Hamburg


I-fit


TSR

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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 1-3 years of a pavement's life.

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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.

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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.

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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.

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R30 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.

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R121 Long Term - Mixture Conditioning

- This procedure is for long term aging of compacted specimens AASHTO R121 – Method A.
  - Lab prepared specimens that have been through short term conditioning AASHTO R30.
  - Roadway specimens (cores) that have been cut, trimmed, and dried to a constant mass.
  - Plant-mixed asphalt mixtures.
- 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 for **16+ hrs.**
- Specimens are now ready for testing.

26

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R121 Long Term - Mixture Conditioning

R121 SCOPE:

This standard practice includes 5 long-term mixture conditioning methods, with Method A using compacted mixture specimens and Method B, C, D, and E using uncompacted mixture. The long-term conditioning procedures for mixture mechanical property testing are proceeded by the procedure for short-term conditioning according to R30.

For more information see AASHTO R121.

New Slide

27

27

Module 7

Gyratory Compactor AASHTO T312

MODULE 7

GYRATORY COMPACTOR

AASHTO T312

Rev 10/02/2023

1

MODULE 7 OUTLINE

- Scope
- Referenced Documents
- Significance and Use
- Equipment
- Preparation of Gyratory
- Sample Preparation
- Procedure - Compaction
- Density Procedure
- Calculations & Reporting
- Common Errors

2

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SCOPE

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

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REFERENCED DOCUMENTS

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

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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.

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Uses of the GYRO

GYRO = Gyratory Compactor

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 . .

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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

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Gyratory Compactor

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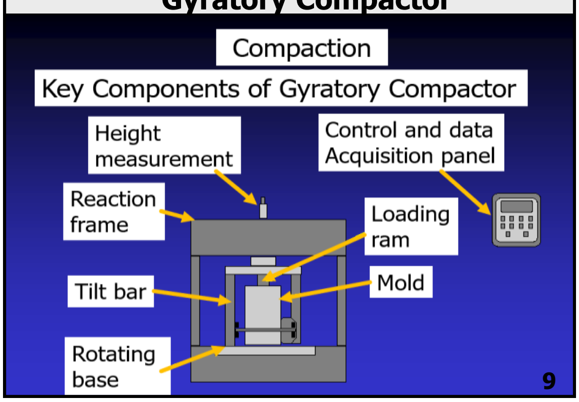
Gyratory Compactor



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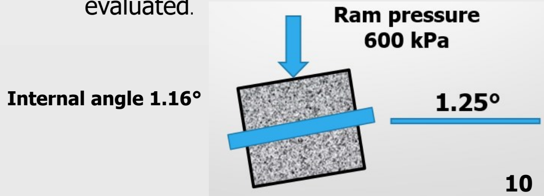
Compaction

- **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.



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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.

11

11

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.

12

12

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

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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.

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Equipment - ID

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

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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.

16

16

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

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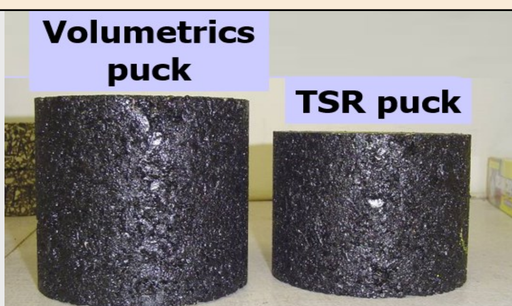
17

SPECIMEN PREPARATION



Height = 115 ± 5 mm Mold to # of gyrations JMF	Height = 95 ± 5 mm Mold to Height

18

Molding 6 TSR Pucks

TSR material sampled from Truck. (Road, Pile, Stream)

For performance test **T**ensile **S**trength **R**atio (TSR) compacted to a ***fixed height*** = 95mm.

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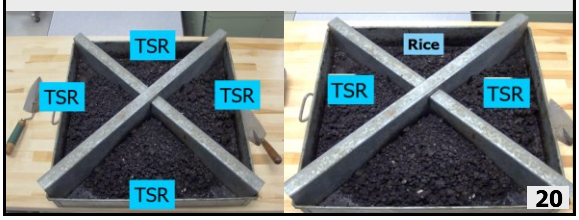
TSR Sample

- 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.



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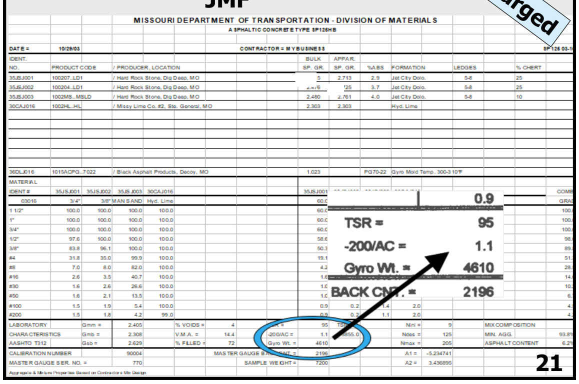
Location of Gyro TSR Puck Weight on JMF

Enlarged



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Location of Gyro Puck Weight on JMF

MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP125HB

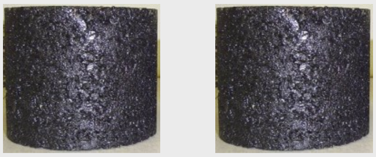
DATE =	10/29/03						CONTRACTOR = MY BUSINESS										SP125 03-16
IDENT.									BULK	APPAR.							
NO.	PRODUCT CODE		/ PRODUCER, LOCATION						SP. GR.	SP. GR.	%ABS	FORMATION		LEDGES		% CHERT	
35JSJ001	100207..LD1		/ Hard Rock Stone, Dig Deep, MO						2.515	2.713	2.9	Jet City Dolo.		5-8		25	
35JSJ002	100204..LD1		/ Hard Rock Stone, Dig Deep, MO						2.476	2.725	3.7	Jet City Dolo.		5-8		25	
35JSJ003	1002MS..MSLD		/ Hard Rock Stone, Dig Deep, MO						2.480	2.761		Jet City Dolo.		5-8		10	
30CAJ016	1002HL..HL		/ Missy Lime Co. #2, Ste. General, MO						2.303	2.303		Hyd. Lime					
36DLJ016	1015ACPG..7022		/ Black Asphalt Products, Decoy, MO						1.023								
MATERIAL																	
IDENT #	35JSJ001	35JSJ002	35JSJ003	30CAJ016					35JSJ0								COMB.
03016	3/4"	3/8"	MAN SAND	Hyd. Lime					6								GRAD
1 1/2"	100.0	100.0	100.0	100.0					6								100.0
1"	100.0	100.0	100.0	100.0					6								100.0
3/4"	100.0	100.0	100.0	100.0					6								100.0
1/2"	97.6	100.0	100.0	100.0					5								98.6
3/8"	83.8	96.1	100.0	100.0					5								89.8
#4	31.8	35.0	99.9	100.0					19.1	4.2	26.0	2.0					51.3
#8	7.0	8.0	82.0	100.0					4.2	1.0	21.3	2.0					28.5
#16	2.6	3.5	40.7	100.0					1.6	0.4	10.[illegible]	2.0					14.6
#30	1.6	2.6	26.6	100.0					1.0	0.3	6.9	2.0					10.2
#50	1.6	2.1	13.5	100.0					1.0	0.[illegible]	3.5	2.0					6.7
#100	1.5	1.9	5.4	100.0					0.9	0.2	1.4	2.0					4.5
#200	1.5	1.8	4.2	99.0					0.9	0.2	1.1	2.0					4.2
LABORATORY		Gmm =	2.405		% VOIDS =	4		TSR =	95	TSR Wt.		Nini =	9		MIX COMPOSITION		
CHARACTERISTICS		Gmb =	2.308		V.M.A. =	14.4		-200/AC =	1.1	38[illegible]0		Ndes =	125		MIN. AGG.		93.8%
AASHTO T312		Gsb =	2.629		% FILLED =	72		Gyro Wt. =	4610			Nmax =	205		ASPHALT CONTENT		6.2%
CALIBRATION NUMBER			90004				MASTER GAUGE BACK CNT. =		2196			A1 =	-5.234741				
MASTER GAUGE SER. NO. =			770					SAMPLE WEIGHT =	7200			A2 =	3.436895				
Aggregate & Mixture Properties Based on Contractors Mix Design																	

0.9
TSR = 95
-200/AC = 1.1
Gyro Wt. = 4610
BACK CNT. = 2196

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 ± 5 mm.

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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).

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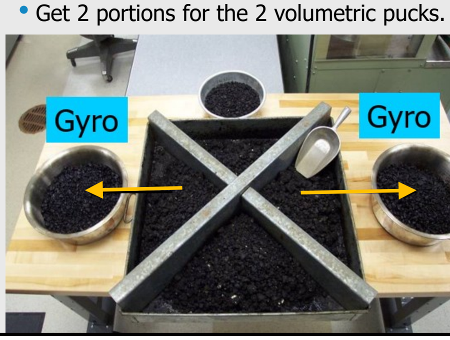
Volumetrics/Binder Content Sample

- Get 2 portions for the 2 volumetric pucks.



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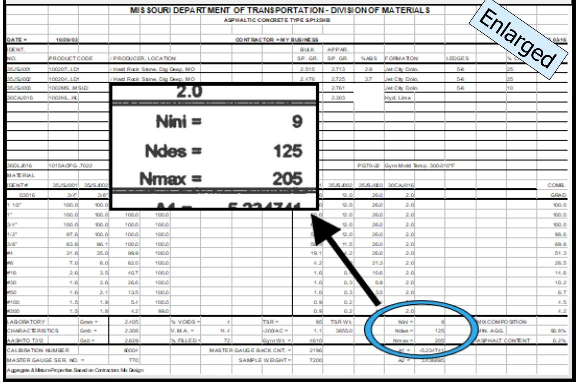
Location of Gyration Info on JMF



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Gyration Levels

Design	$N_{initial}$	N_{design}	$N_{maximum}$
F	--	50	--
E	7	75	115
C	8	80 or 100	160
B	9	125	205

- **C Mixes at 80 gyrations**:
  - no $N_{initial}$ or N_{max} requirements.
- **SMA Mixes:**
  - N_{design}= 100
  - No N_{max} requirement

26

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Number of Gyrations

- N_{ini}, N_{des}, and N_{max} are shown on the JMF.
- ***Samples for field verification of volumetrics should be compacted to N_{des} gyrations.***

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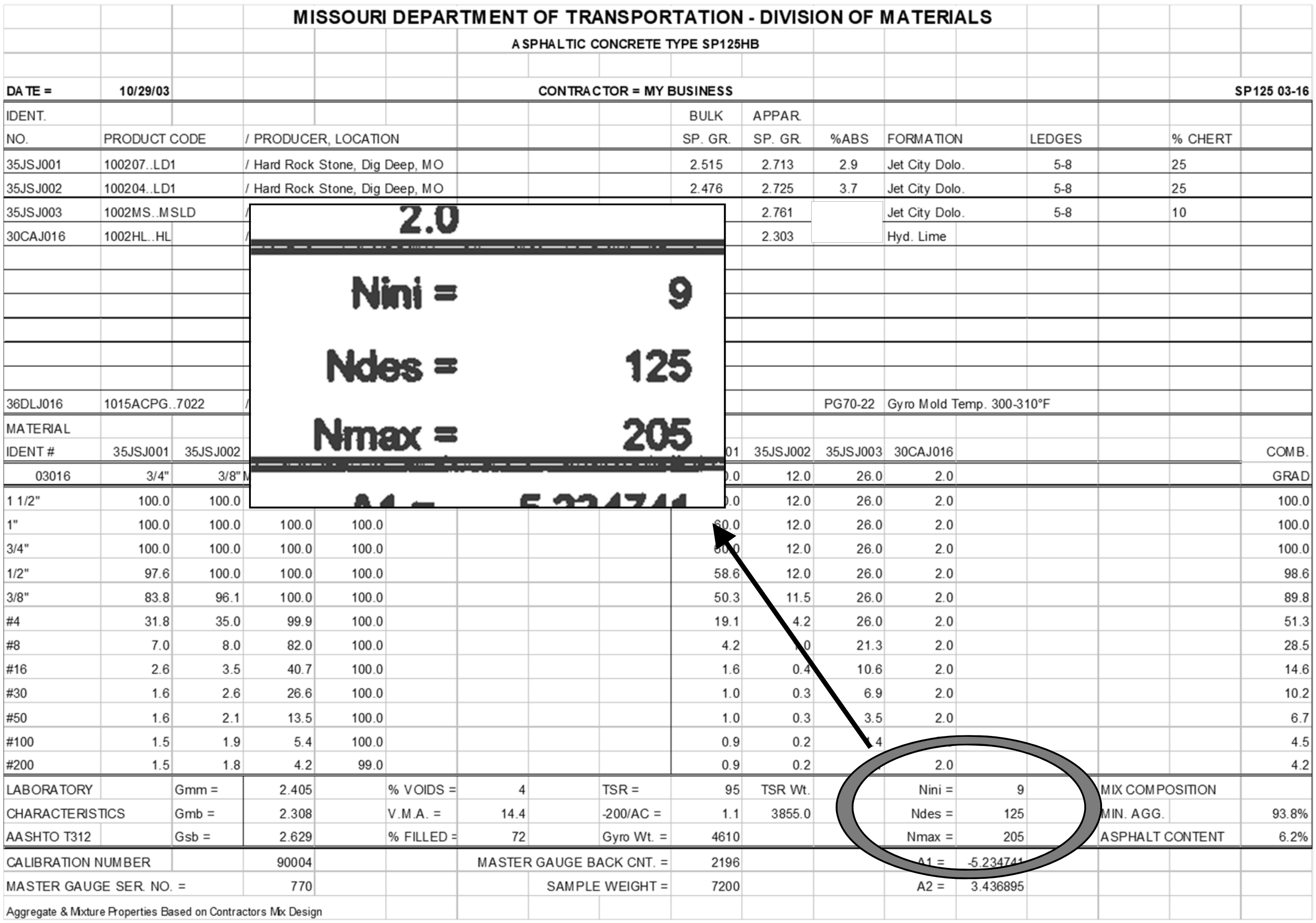
Location of Gyration Info on JMF



MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP125HB

DATE = 10/29/03 **CONTRACTOR = MY BUSINESS** **SP125 03-16**

IDENT. NO.	PRODUCT CODE	/ PRODUCER, LOCATION	BULK SP. GR.	APPAR. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
35JSJ001	100207..LD1	/ Hard Rock Stone, Dig Deep, MO	2.515	2.713	2.9	Jet City Dolo.	5-8	25
35JSJ002	100204..LD1	/ Hard Rock Stone, Dig Deep, MO	2.476	2.725	3.7	Jet City Dolo.	5-8	25
35JSJ003	1002MS..MSLD	/		2.761		Jet City Dolo.	5-8	10
30CAJ016	1002HL..HL	/		2.303		Hyd. Lime		
36DLJ016	1015ACPG..7022	/			PG70-22	Gyro Mold Temp. 300-310°F		

MATERIAL IDENT #	35JSJ001	35JSJ002			01	35JSJ002	35JSJ003	30CAJ016	COMB. GRAD
03016	3/4"	3/8" M			.0	12.0	26.0	2.0	
1 1/2"	100.0	100.0			.0	12.0	26.0	2.0	100.0
1"	100.0	100.0	100.0	100.0	60.0	12.0	26.0	2.0	100.0
3/4"	100.0	100.0	100.0	100.0	[illegible]	12.0	26.0	2.0	100.0
1/2"	97.6	100.0	100.0	100.0	58.6	12.0	26.0	2.0	98.6
3/8"	83.8	96.1	100.0	100.0	50.3	11.5	26.0	2.0	89.8
#4	31.8	35.0	99.9	100.0	19.1	4.2	26.0	2.0	51.3
#8	7.0	8.0	82.0	100.0	4.2	[illegible]	21.3	2.0	28.5
#16	2.6	3.5	40.7	100.0	1.6	0.4	10.6	2.0	14.6
#30	1.6	2.6	26.6	100.0	1.0	0.3	6.9	2.0	10.2
#50	1.6	2.1	13.5	100.0	1.0	0.3	3.5	2.0	6.7
#100	1.5	1.9	5.4	100.0	0.9	0.2	[illegible]		4.5
#200	1.5	1.8	4.2	99.0	0.9	0.2	[illegible]	2.0	4.2

LABORATORY	Gmm =	2.405	% VOIDS =	4	TSR =	95	TSR Wt.	Nini =	9	MIX COMPOSITION
CHARACTERISTICS	Gmb =	2.308	V.M.A. =	14.4	-200/AC =	1.1	3855.0	Ndes =	125	MIN. AGG. 93.8%
AASHTO T312	Gsb =	2.629	% FILLED =	72	Gyro Wt. =	4610		Nmax =	205	ASPHALT CONTENT 6.2%
CALIBRATION NUMBER		90004			MASTER GAUGE BACK CNT. =	2196		A1 =	-5.234741	
MASTER GAUGE SER. NO. =		770			SAMPLE WEIGHT =	7200		A2 =	3.436895	

Aggregate & Mixture Properties Based on Contractors Mix Design

Volumetric pucks

Height = 115 ± 5 mm
Mold to number of gyrations from Job Mix Formula (JMF)

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28

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)

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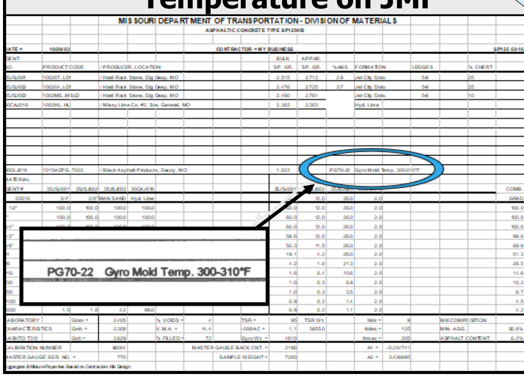
Location of Gyro Molding Temperature on JMF

Enlarged



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Location of Gyro Molding Temperature on JMF

MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP125HB

DATE =	10/29/03	CONTRACTOR = MY BUSINESS						SP125 03-16
IDENT. NO.	PRODUCT CODE	/ PRODUCER, LOCATION	BULK SP. GR.	APPAR. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
35JSJ001	100207..LD1	/ Hard Rock Stone, Dig Deep, MO	2.515	2.713	2.9	Jet City Dolo.	5-8	25
35JSJ002	100204..LD1	/ Hard Rock Stone, Dig Deep, MO	2.476	2.725	3.7	Jet City Dolo.	5-8	25
35JSJ003	1002MS..MSLD	/ Hard Rock Stone, Dig Deep, MO	2.480	2.761		Jet City Dolo.	5-8	10
30CAJ016	1002HL..HL	/ Missy Lime Co. #2, Ste. General, MO	2.303	2.303		Hyd. Lime		
36DLJ016	1015ACPG..7022	/ Black Asphalt Products, Decoy, MO	1.023		PG70-22	Gyro Mold Temp. 300-310°F		

MATERIAL IDENT #	35JSJ001	35JSJ002	35JSJ003	30CAJ016	35JSJ001	35JSJ002	35JSJ003	30CAJ016	COMB.
03016	3/4"	3/8"	MAN SAND	Hyd. Lime	60.0	12.0	26.0	2.0	GRAD
1 1/2"	100.0	100.0	100.0	100.0	60.0	12.0	26.0	2.0	100.0
1"	100.0	100.0	100.0	100.0	60.0	12.0	26.0	2.0	100.0
3/4"	100.0	100.0	100.0	100.0	60.0	12.0	26.0	2.0	100.0
1/2"	[illegible]	[illegible]	[illegible]	[illegible]	58.6	12.0	26.0	2.0	98.6
3/8"	[illegible]	[illegible]	[illegible]	[illegible]	50.3	11.5	26.0	2.0	89.8
#4	[illegible]	[illegible]	[illegible]	[illegible]	19.1	4.2	26.0	2.0	51.3
#8	[illegible]	[illegible]	[illegible]	[illegible]	4.2	1.0	21.3	2.0	28.5
#16	[illegible]	[illegible]	[illegible]	[illegible]	1.6	0.4	10.6	2.0	14.6
#30	[illegible]	[illegible]	[illegible]	[illegible]	1.0	0.3	6.9	2.0	10.2
#50	[illegible]	[illegible]	[illegible]	[illegible]	1.0	0.3	3.5	2.0	6.7
#100	[illegible]	[illegible]	[illegible]	[illegible]	0.9	0.2	1.4	2.0	4.5
#200	1.5	1.8	4.2	99.0	0.9	0.2	1.1	2.0	4.2

PG70-22 Gyro Mold Temp. 300-310°F

LABORATORY	Gmm =	2.405	% VOIDS =	4	TSR =	95	TSR Wt.		Nini =	9	MIX COMPOSITION	
CHARACTERISTICS	Gmb =	2.308	V.M.A. =	14.4	-200/AC =	1.1	3855.0		Ndes =	125	MIN. AGG.	93.8%
AASHTO T312	Gsb =	2.629	% FILLED =	72	Gyro Wt. =	4610			Nmax =	205	ASPHALT CONTENT	6.2%
CALIBRATION NUMBER		90004			MASTER GAUGE BACK CNT. =	2196			A1 =	-5.234741		
MASTER GAUGE SER. NO. =		770			SAMPLE WEIGHT =	7200			A2 =	3.436895		

Aggregate & Mixture Properties Based on Contractors 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.

31

31

Procedure - Compaction

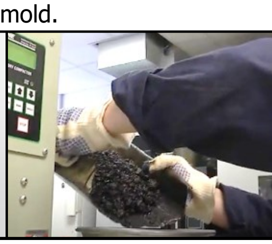
- Pull the mold items out of the oven.
  - Assemble if needed.
- Place a paper disc to the bottom.

32

32

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.



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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.

34

34

Procedure - Compaction

Items to verify:

- Verify 150mm specimen diameter.
- Verify compaction pressure = 600 kPa.
- For Volumetric pucks,
  - Set to # gyrations = Ndes from JMF.
- For TSR pucks,
  - Set specimen height to 95 mm.

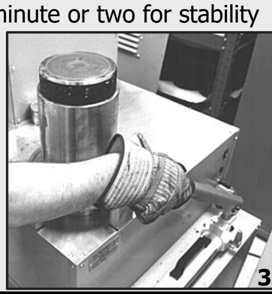
Set up Gyro for Volumetrics

35

35

Procedure - Compaction

- 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.



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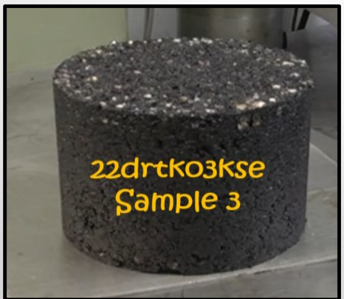
Procedure - Compaction

When cooled enough label the puck on the side.



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DENSITY PROCEDURE

Specific Gravity Gmb

- Once cooled, the resulting specimens are ready to be tested for specific gravity (G_{mb}) or other testing as required.

Note: "AASHTO T166 for Bulk Specific Gravity can be found in your Bituminous Technician Manual

38

38

CALCULATIONS & REPORTING

Bulk Specific Gravity G_{mb}

Specific gravity is used to determine the volumetric properties of a compacted mix relative to the G_{mm}

$$G_{mb} = \frac{A}{(B - C)}$$

A = Dry Mass, 0.1 g
B = SSD Mass, 0.1 g
C = Submerged Mass, 0.1 g

Report Gmb to nearest 0.001

39

39

% Absorption (% Abs)

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

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

A = Dry Mass, 0.1 g

B = SSD Mass, 0.1 g

C = Submerged Mass, 0.1 g

Report absorption to nearest 0.01%

40

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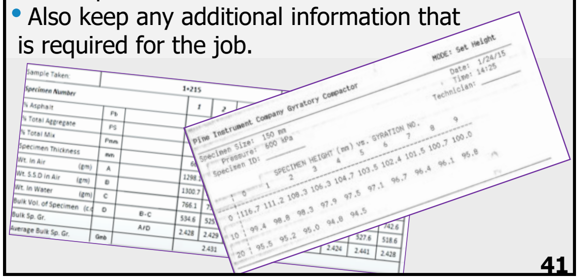
Reporting

- 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.



41

41

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.

42

42

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 in bottom of mold in oven overnight.

43

43

AASHTO T 312: Specimen Compaction

Pre-Verification Checklist: (Note: State operation & frequency).	1	2	R
State required frequency of verification & calibration:			
Verify on a cold (powered up for 10-15 minutes) and clean machine 1) Daily during use, or 2) if gyro is moved			
Calibrate: 1) Annually, or 2) If verification fails			
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 2nd paper disk ASAP			
20. Mark the puck for identification purposes on the side of the sample.			
PASS?			
FAIL?			

Proctor____Date__________________

Reviewer______________________________________Date__________________

Module 8

Maximum Specific Gravity
AASHTO T209

(Gmm), (Rice)

MODULE 8

MAX SPECIFIC GRAVITY "RICE" AASHTO T-209

10/02/2023

1

OUTLINE

- Scope
- Significance and Use
- Equipment
- Sampling
- Sample Preparation
- Procedure – Weigh in Water – Weigh in Air
- Calculation
- Supplemental Procedure
- Report
- Changes in Gmm
- Common Errors

2

2

SCOPE

- This test method covers the determination of the theoretical maximum specific gravity/gravity mix maximum (Gmm) and density of uncompacted asphalt mixture at 25ºC (77ºF).

3

3

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

Scope

4

4

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.

5

5

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

1. Computing **%Air Voids** :
(a pay factor)
   - $V_a = [(G_{mm} - G_{mb}) \div G_{mm}] \times 100$
2. Computing pavement **Density** :
(a pay factor)
   - **Density** = $(G_{mc} \div G_{mm}) \times 100$
   - G_{mc} = core specific gravity

Significance and Use

6

6

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)

7

7

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 ºC, 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)

8

8

SAMPLING

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

9

9

Sample Size For T209 (Rice)

Nominal Maximum Aggregate Size, mm	Minimum Sample Size, g
37.5mm or Greater (1.5")	4000
19 to 25mm (¾ - 1")	2500
12.5 mm (½") or smaller	2000

MODOT NOTES:

SP250 → 2500 grams (minimum)
All others → 2000 grams (minimum)

Sampling

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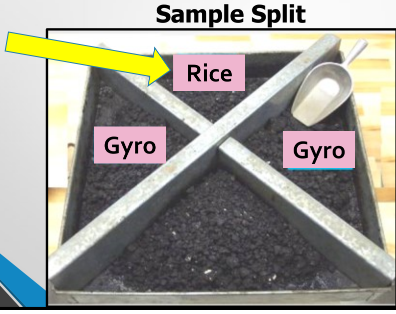
SAMPLE PREPARATION

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

Sample Split



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- Dry specimen to constant weight at 221 ± 9°F (105 ± 5 ºC) 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%).

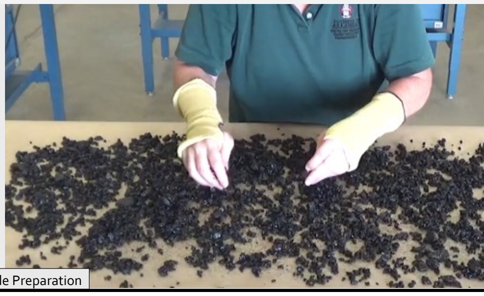
221 ± 9°F

Sample Preparation

12

12

- 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.



Sample Preparation

13

13

PROCEDURE – Weigh in Water

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

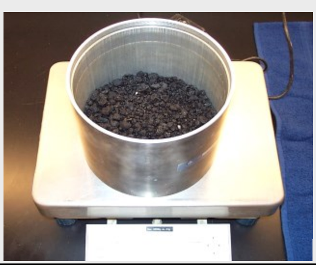
14

14

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)



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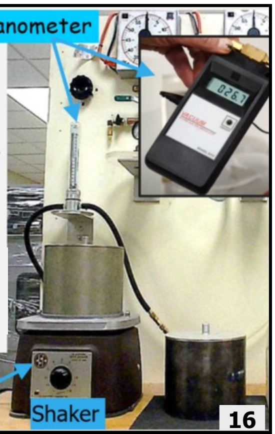
Add sufficient water to cover the sample completely. (~1 inch) De-air the specimen by agitating under vacuum for **15 ± 1 min.**

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



Procedure - Water

16

16

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.

17

17

- After **15 ± 1 min** slowly release the vacuum at a rate of 60mm Hg/sec.
- Disassemble apparatus.

Procedure - Water

18

18

- 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)

Procedure - Water

19

19

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)

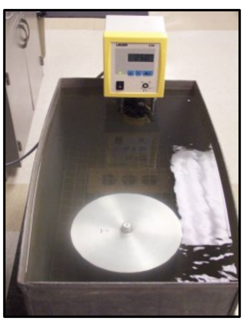
Procedure - Water

20

20

Weigh in Air - PROCEDURE

Fill the pycnometer with water and bring the specimen to test temperature (25 ± 1ºC).



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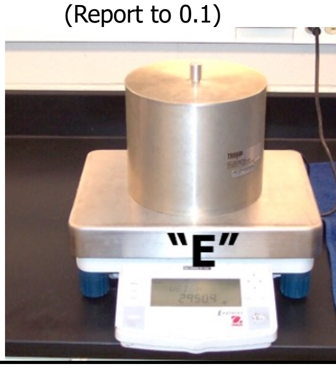
21

After 10 ± 1 min. determine weight of [specimen + pycnometer + water] = **"E"**
(Report to 0.1)



Procedure - Air

22

22

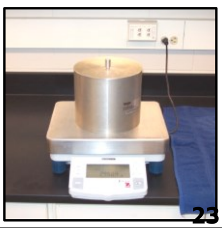
Determine weight of pycnometer full of water to determine its volume. The water is required to be at 25 ± 1.0 ºC.

Report as **"D"**

(Report to 0.1)

"D" will be too high with cold temperature & cloudiness.

"D" will be too low with high temperature.



Procedure - Air

23

23

$$Gmm = \frac{A}{(A + D - E)}$$

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

Report *Gmm* to nearest 0.001

Procedure - Air

24

24

$$Gmm = \frac{A}{(A + D - E)}$$

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

Procedure - Air Answer is 2.564 **25**

25

CALCULATON

Weigh 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 **26**

26

Weight in Water - Sample Calculation

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

Calculate Gmm for Sample **#ACDC**

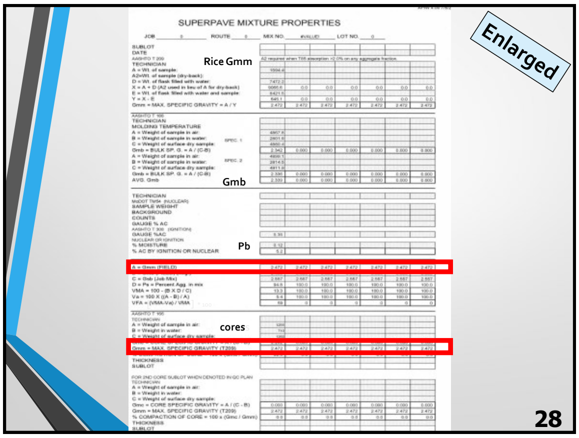
- A = Dry Sample Mass in air = 2,510.5 g
- B = Container & Water = 7,440.8 g
- C = Container, Water & Sample = 8,966.1 g

What is the Gmm? ___________

Report *Gmm* to nearest 0.001

Answer is 2.548 **27**

27



28

Spreadsheet Calculations

Enlarged

AASHTO R 35

A = Gmm (FIELD)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
B = Gmb (FIELD) (Avg.)	2.339	0.000	0.000	0.000	0.000	0.000	0.000
C = Gsb (Job Mix)	2.557	2.557	2.557	2.557	2.557	2.557	2.557
D = Ps = Percent Agg. in mix	94.8	100.0	100.0	100.0	100.0	100.0	100.0
VMA = 100 - (B X D / C)	13.3	100.0	100.0	100.0	100.0	100.0	100.0
Va = 100 X ((A - B) / A)	5.4	100.0	100.0	100.0	100.0	100.0	100.0
VFA = (VMA-Va) / VMA	59	0	0	0	0	0	0

AASHTO T 166

TECHNICIAN							
A = Weight of sample in air:	1255						
B = Weight in water:	710						
C = Weight of surface dry sample:	1260						
Gmc = CORE SPECIFIC GRAVITY = A / (C - B)	2.282	0.000	0.000	0.000	0.000	0.000	0.000
Gmm = MAX. SPECIFIC GRAVITY (T209)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	92.3	0.0	0.0	0.0	0.0	0.0	0.0
THICKNESS							
SUBLOT							

29

29

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.

30

30

SUPERPAVE MIXTURE PROPERTIES

JOB 0 ROUTE 0 MIX NO. #VALUE! LOT NO. 0

SUBLOT							
DATE							
AASHTO T 209 Rice Gmm	A2 required when T85 absorption >2.0% on any aggregate fraction.						
TECHNICIAN							
A = Wt. of sample:	1594.4						
A2=Wt. of sample (dry-back):							
D = Wt. of flask filled with water:	7472.2						
X = A + D (A2 used in lieu of A for dry-back)	9066.6	0.0	0.0	0.0	0.0	0.0	0.0
E = Wt. of flask filled with water and sample:	8421.5						
Y = X - E	645.1	0.0	0.0	0.0	0.0	0.0	0.0
Gmm = MAX. SPECIFIC GRAVITY = A / Y	2.472	2.472	2.472	2.472	2.472	2.472	2.472
AASHTO T 166							
TECHNICIAN							
MOLDING TEMPERATURE							
A = Weight of sample in air: (SPEC. 1)	4867.8						
B = Weight of sample in water:	2801.9						
C = Weight of surface dry sample:	4880.4						
Gmb = BULK SP. G. = A / (C-B)	2.342	0.000	0.000	0.000	0.000	0.000	0.000
A = Weight of sample in air: (SPEC. 2)	4899.1						
B = Weight of sample in water:	2814.5						
C = Weight of surface dry sample:	4911.9						
Gmb = BULK SP. G. = A / (C-B)	2.336	0.000	0.000	0.000	0.000	0.000	0.000
AVG. Gmb (Gmb)	2.339	0.000	0.000	0.000	0.000	0.000	0.000
TECHNICIAN							
MoDOT TM54 (NUCLEAR)							
SAMPLE WEIGHT							
BACKGROUND							
COUNTS							
GAUGE % AC							
AASHTO T 308 (IGNITION)							
GAUGE %AC	5.35						
NUCLEAR OR IGNITION							
% MOISTURE (Pb)	0.12						
% AC BY IGNITION OR NUCLEAR	5.2						
A = Gmm (FIELD)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
[redacted]							
C = Gsb (Job Mix)	2.557	2.557	2.557	2.557	2.557	2.557	2.557
D = Ps = Percent Agg. in mix	94.8	100.0	100.0	100.0	100.0	100.0	100.0
VMA = 100 - (B X D / C)	13.3	100.0	100.0	100.0	100.0	100.0	100.0
Va = 100 X ((A - B) / A)	5.4	100.0	100.0	100.0	100.0	100.0	100.0
VFA = [(VMA-Va) / VMA] * 100	59	0	0	0	0	0	0
AASHTO T 166							
TECHNICIAN							
A = Weight of sample in air: (cores)	1255						
B = Weight in water:	710						
C = Weight of surface dry sample:	1260						
[redacted]							
Gmm = MAX. SPECIFIC GRAVITY (T209)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
[redacted]							
THICKNESS							
SUBLOT							
FOR 2ND CORE SUBLOT WHEN DENOTED IN QC PLAN							
TECHNICIAN							
A = Weight of sample in air:							
B = Weight in water:							
C = Weight of surface dry sample:							
Gmc = CORE SPECIFIC GRAVITY = A / (C - B)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gmm = MAX. SPECIFIC GRAVITY (T209)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
THICKNESS							
SUBLOT							

SPREADSHEET CALCULATIONS

AASHTO R 35

A = Gmm (FIELD)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
B = Gmb (FIELD) (Avg.)	2.339	0.000	0.000	0.000	0.000	0.000	0.000
C = Gsb (Job Mix)	2.557	2.557	2.557	2.557	2.557	2.557	2.557
D = Ps = Percent Agg. in mix	94.8	100.0	100.0	100.0	100.0	100.0	100.0
VMA = 100 - (B X D / C)	13.3	100.0	100.0	100.0	100.0	100.0	100.0
Va = 100 X ((A - B) / A)	5.4	100.0	100.0	100.0	100.0	100.0	100.0
VFA = (VMA-Va) / VMA	59	0	0	0	0	0	0

AASHTO T 166

TECHNICIAN							
A = Weight of sample in air:	1255						
B = Weight in water:	710						
C = Weight of surface dry sample:	1260						
Gmc = CORE SPECIFIC GRAVITY = A / (C - B)	2.282	0.000	0.000	0.000	0.000	0.000	0.000
Gmm = MAX. SPECIFIC GRAVITY (T209)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	92.3	0.0	0.0	0.0	0.0	0.0	0.0
THICKNESS							
SUBLOT							

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.

31

31

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.

32

32

Dry-Back Calculation "A_2"

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

$$Gmm_2 = \frac{A}{(A_2 + B - C)}$$

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

Report *Gmm* to nearest 0.001

33

33

Sample Problem – Dry Back

$$Gmm_2 = \frac{A}{(A_2 + B - C)}$$

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 Gmm_2 ? __________

Report Gmm_2 to nearest 0.001

Updated slide

Answer is 2.545

34

34

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.

35

35

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 Gmm^2 to the nearest 0.001

36

36

CHANGES IN "G_{mm}"
In silo, trucks, MTV

- Time interval at high temperature
- Absorptiveness of aggregate

37

37

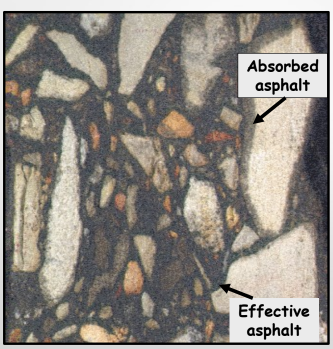
Time at High Temperature

SURGE SILO

38

38

Absorptiveness of Aggregate



39

39

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

40

40

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.

41

41

AASHTO T 209: Theoretical maximum Specific Gravity (Rice Test): "Weigh in Air" Method Rev: 10/02/2023

Pre-Procedure Checklist: (Note: State operation & frequency).	1	2	R
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 either a. Oven drying until mass repeats within 0.1%, or b. Use results of AASHTO T329			
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)**			
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?			

Proctor____________________________________ Date__________________

Reviewer__________________________________ Date__________________

AASHTO T 209: Theoretical Maximum Specific Gravity (Rice Test): "Weigh In Water" Method rev 01/05/2024

	1	2	R
Trial#			
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?			
PASS?			
FAIL?			

Proctor____ Date__________________

Reviewer______________________________________ Date__________________

Module 9

Binder Ignition
AC Content
AASHTO T308

MODULE 9

BINDER IGNITION OVEN AC CONTENT AASHTO T308

Rev 10/10/2023

1

SCOPE

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.

2

2

SIGNIFICANCE AND USE

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.

3

3

EQUIPMENT

- **Ignition Furnace** – A forced air oven that heats by convection or direct IR irradiation. The convection type must be capable of maintaining 538 $\pm$ 5°C (1000 $\pm$ 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.

4

4

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

5

5

Ignition Oven Basics:

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

6

6

CORRECTIONS

1. Moisture
   - Moisture Content "MC"
2. Aggregate Burn Loss
   - Aggregate Correction Factor "Cf"
3. Temperature effects on weighing
   - Temperature Correction Factor "TCF"

7

7

1. Moisture

- Moisture in mix will evaporate.
- This will count as binder unless corrected.
- There are two methods to correct for moisture:

Method 1
- 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.

8

8

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.

9

Calculate the PERCENT CHANGE as follows:

$$\% \text{ Change} = \frac{(A - B)}{A} \times 100$$

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.

10

10

Moisture Content (AASHTO T 329): Method 2

$$\textit{Moisture Content} = \frac{(M_i - M_f)}{M_f} \times 100$$

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%**

Updated slide

11

11

Moisture Content (AASHTO T 329): Method 2

$$\textit{Moisture Content} = \frac{(M_i - M_f)}{M_f} \times 100$$

Classroom Practice

M_i = 1134.9

M_f = 1127.3

% Moisture = ______________ %

Report to the nearest 0.01%

Moisture Content

Ans: 0.67%

Updated slide

12

12

Method 2

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 Content

13

13

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

Moisture Content

14

14

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).

Aggregate Correction

15

15

C_F 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.

Aggregate Correction 16

16

Definitions:

- **M** = mass (g)
- **Mi(dry)** = Mass of mix before burning, dry already.
- **Mf** = Final mass of mix after burning (binder and some aggregate burned off).
- **(Mi(dry) – Mf)** = Binder & aggregate burned off.
- **Magg** = Initial unburned mass of just the aggregate, dry.
- **(Mi(dry) – Mi(agg))** = Mix mass minus aggregate mass is the mass of binder, initially.

Aggregate Correction 17

17

C_F Calculations:

$$C_f = Measured - Actual$$

- Lab-produced sample (dry)

$$C_f = \left[\frac{M_{i(dry)} - M_f}{M_{i(dry)}}\right] - \left[\frac{M_{i(dry)} - M_{i(agg)}}{M_{i(dry)}}\right]$$

- 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%

Aggregate Correction 18

18

Two types of Ovens

Infrared Oven

Convention Oven

New Slide

19

19

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)

Aggregate Correction

20

20

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.

Aggregate Correction

21

21


HOT

Asphalt Binder Correction Factor

(Aggregate Correction Factor)

Data Sheet

Enlarged

ASPHALT CONTENT IGNITION METHOD
AASHTO T 308
METHOD A

Aggregate Correction Factor
[Asphalt Binder Correction Factor] Determination

Sample________________Lab No.________Date______Initials______

Replicate	1	2	3	4
Test Temperature	538	538		
Tare (basket, etc.) Mass (g)	3000.0	3000.0		
Total Dry Mass (g)	5000.1	5005.2		
Initial Dry Specimen Mass (g)	2000.1	2005.2		
Loss in Weight (g)	125.2	126.1		
%AC, measured = M	6.26	6.29		
%AC, actual = A	6.00	6.01		
$\%AC_{diff}$ $(M_1 - M_2)$	0.03	> 0.15%? If so, 2 more replicates		
$C_F = M - A$	0.26	0.28		
C_F Average	0.27			

Total Dry Mass – Tare Basket Mass = Initial Dry Specimen Mass

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

Updated Slide

22

ASPHALT CONTENT IGNITION METHOD
AASHTO T 308
METHOD A

Classroom Practice

Aggregate Correction Factor
[Asphalt Binder Correction Factor] Determination

Sample________________Lab No.________Date______Initials______

Replicate	1	2	3	4
Test Temperature	538	538		
Tare (basket, etc.) Mass (g)	3000.0	3000.0		
Total Dry Mass (g)	4129.2	4123.8		
Initial Dry Specimen Mass (g)				
Loss in Weight (g)	65.7	62.9		
%AC, measured = M				
%AC, actual = A	5.25	5.23		
$\%AC_{diff}$ $(M_1 - M_2)$		> 0.15%? If so, 2 more replicates		
$C_F = M - A$				
C_F, average				

New Slide

23

Asphalt Binder Correction Factor

(Aggregate Correction Factor)

Data Sheet

Key

ASPHALT CONTENT IGNITION METHOD
AASHTO T 308
METHOD A

Aggregate Correction Factor
[Asphalt Binder Correction Factor] Determination

Sample________________Lab No.________Date______Initials______

Replicate	1	2	3	4
Test Temperature	538	538		
Tare (basket, etc.) Mass (g)	3000.0	3000.0		
Total Dry Mass (g)	4129.2	4123.8		
Initial Dry Specimen Mass (g)	1129.2	1123.8		
Loss in Weight (g)	65.7	62.9		
%AC, measured = M	5.82	5.60		
%AC, actual = A	5.25	5.23		
$\%AC_{diff}$ $(M_1 - M_2)$	0.22	> 0.15%? If so, 2 more replicates		
$C_F = M - A$	0.57	0.37		
C_F, average	0.47			

Need 2 more replicates

24

Asphalt Binder Correction Factor

(Aggregate Correction Factor)

Data Sheet

Enlarged

ASPHALT CONTENT IGNITION METHOD
AASHTO T 308
METHOD A

Aggregate Correction Factor
[Asphalt Binder Correction Factor]

Total Dry Mass – Tare Basket Mass = Initial Dry Specimen Mass

Sample________________ Lab No.________ Date______ Initials______

Replicate	1	2	3	4
Test Temperature	538	538		
Tare (basket, etc.) Mass (g)	3000.0	3000.0		
Total Dry Mass (g)	5000.1	5005.2		
Initial Dry Specimen Mass (g)	2000.1	2005.2		
Loss in Weight (g)	125.2	126.1		
%AC, measured = M	6.26	6.29		
%AC, actual = A	6.00	6.01		
$\%AC_{diff}$ $(M_1 - M_2)$	0.03	> 0.15%? If so, 2 more replicates		
$C_F = M - A$	0.26	0.28		
C_F Average	0.27			

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

Updated Slide

ASPHALT CONTENT IGNITION METHOD
AASHTO T 30
METHOD A

Classroom Practice

Aggregate Correction Factor
[Asphalt Binder Correction Factor] Determina

Sample______________________________Lab No.__________Date_______Initials________

Replicate	1	2	3	4
Test Temperature	538	538		
Tare (basket, etc.) Mass (g)	3000.0	3000.0		
Total Dry Mass (g)	4129.2	4123.8		
Initial Dry Specimen Mass (g)				
Loss in Weight (g)	65.7	62.9		
%AC, measured = M				
%AC, actual = A	5.25	5.23		
$\%AC_{diff}$ $(M_1 - M_2)$		> 0.15%? If so, 2 more replicates		
$C_F = M - A$				
C_F, average		New Slide		

Use of Cf :

- Before production, when Cf is the *unknown*:

Cf = Measured Content – Actual Content

- During production, when Actual Content is *unknown*:

Actual = Measured Content – Cf

Aggregate Correction **25**

25

Infrared Burn Profiles:

- **"Default"**
  Most mixes
- **"Option 1"**
  (Less) - For C_f > 1.0% e.g., RAP containing dolomite.
- **"Option 2"**
  (More) – Hard to burn mixes

Aggregate Correction **26**

26

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.

Aggregate Correction **27**

27

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 = Apparent loss in mass due to heating.***

28

28

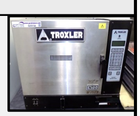
Use of Temperature Correction Factor:

- 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

29

29

Second Generation Infrared oven:



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

30

30

PROCEDURE FOR T308

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

31

31

Test Methods

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

32

32

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.

33

33

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.

Sampling **34**

34

Ignition Oven Specimen Size (TABLE 1)

Mix	NMS, in.	Specimen Size, g
SP048 & BP-3	#4	1200-1700
SP095	3/8	1200-1700
SP125, BP-1 & BP-2	1/2	1500-2000
SP190 & Bit Base	3/4	2000-2500
SP250	1	3000-3500

Sampling **35**

35

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***.

36

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

37

- 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 $weight_{initial}$
\- Empty Basket weight
= Sample $Weight_{initial}$

38

Method A

38

- Input the initial sample weight in whole grams into the ignition furnace controller.
- Enter the ***asphalt correction factor (C_F).***
- Reset the internal scale to zero.

Method A

39

- 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

40

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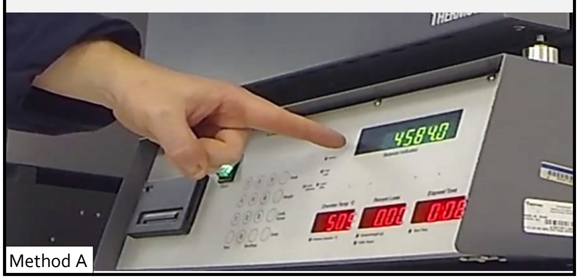
- Verify that the specimen weight is displayed on the furnace scale equals the **total mass**$_{\mathbf{inital}}$ weighed on bench scale **± 5 grams**.
- Start the oven. “Burn”



Method A

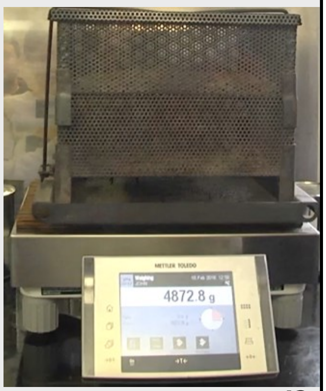
41

- 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.

Method A

42

- 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

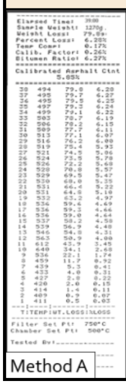


Method A

43

43

CALCULATION/REPORTING

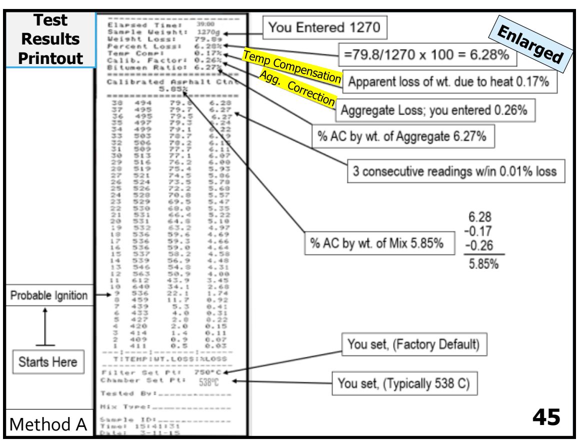


- The furnace will calculate % binder based on the:
  - Original specimen weight entered
  - Total loss
  - Asphalt correction factor (C_F) that you entered.
  - "Temperature Compensation Factor" that the oven calculates = apparent loss in weight due to heating.
- ***You*** must then correct (subtract) for ***moisture*** if started with a wet sample.

Method A

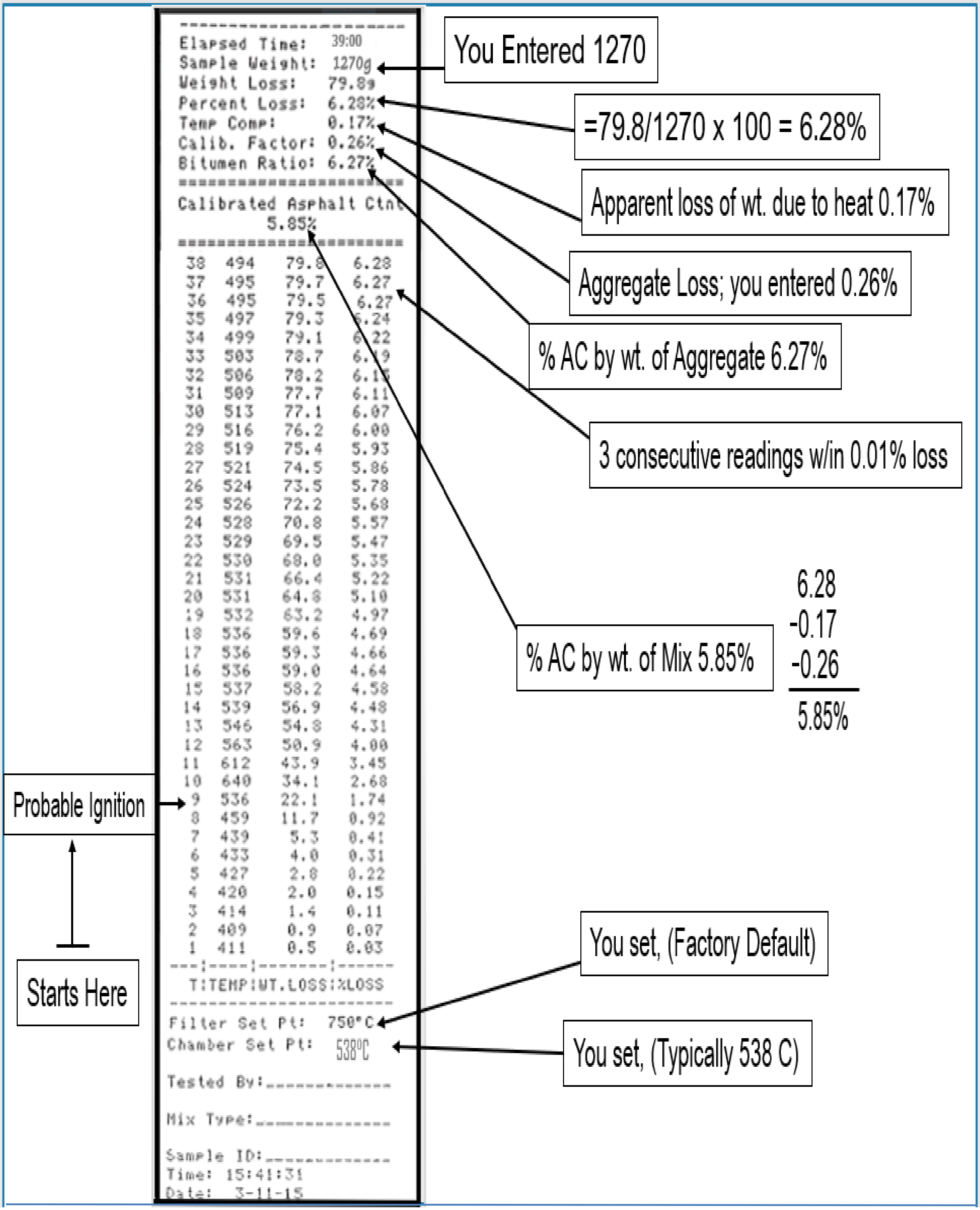
44

44



45

TEST RESULTS PRINT OUT FROM IGINITION OVEN



Elapsed Time: 39:00
Sample Weight: 1270g
Weight Loss: 79.8g
Percent Loss: 6.28%
Temp Comp: 0.17%
Calib. Factor: 0.26%
Bitumen Ratio: 6.27%

Calibrated Asphalt Ctnt
5.85%

T	TEMP	WT.LOSS	%LOSS
38	494	79.8	6.28
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	6.15
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	5.10
19	532	63.2	4.97
18	536	59.6	4.69
17	536	59.3	4.66
16	536	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	43.9	3.45
10	640	34.1	2.68
9	536	22.1	1.74
8	459	11.7	0.92
7	439	5.3	0.41
6	433	4.0	0.31
5	427	2.8	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

Filter Set Pt: 750°C
Chamber Set Pt: 538°C
Tested By:____________
Mix Type:____________
Sample ID:____________
Time: 15:41:31
Date: 3-11-15

ASPHALT CONTENT IGNITION METHOD (AASHTO T 308-10) METHOD A
Reproducing Oven Ticket Values

Revised 12-9-15

*If w_i = wet

Project No.	Job No.	Route	County
Technician	Date	Sublot No.	Mix No.
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, [$P_L = (L / W_i)$ x100]			
Temperature Compensation (%), [C_{tc}] (from tape)			
% AC, uncorrected, [$P_{bu} = P_L - C_{tc}$]			
Aggregate Correction (Calibration) Factor (%), [C_f] (from tape)			
Calibrated %AC (from ignition oven tape), [$P_{bcal} = P_{bu} – C_f$]			
% Moisture Content, [MC] (previous test)*			0.13
% AC, corrected (by weight of mix), [$P_b = P_{bcal} – MC$]*			

Asphalt Content Ignition Method

(AASHTO T 308-10) Method A

Reproducing Oven Ticket Values

Enlarged

Classroom Practice

*If w_i = wet

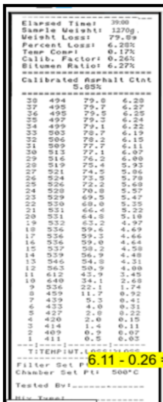
Project No.	Job No.	Route	County
Technician	Date	Sublot No.	Mix No.

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, [$P_L = (L / W_i)$ x100]	
Temperature Compensation (%), [C_{tc}] (from tape)	
% AC, uncorrected, [$P_{bu} = P_L - C_{tc}$]	
Aggregate Correction (Calibration) Factor (%), [C_f] (from tape)	
Calibrated %AC (from ignition oven tape), [$P_{bcal} = P_{bu} - C_f$]	
% Moisture Content, [MC] (previous test)*	0.13
% AC, corrected (by weight of mix), [$P_b = P_{bcal} - MC$]*	

Method A

46

46



6.11 - 0.26 = 5.85

5.85 - 0.13 = 5.72

Asphalt Content Ignition Method

(AASHTO T 308-10) Method A

Reproducing Oven Ticket Values

KEY

*If w_i = wet

Project No.	Job No.	Route	County
Technician	Date	Sublot No.	Mix No.

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), [$W_i = (T_i - T_e)$]	1,270.0
Loss in Weight (g), [L] (from tape)	79.8
Total % Loss, [$P_L = (L / W_i)$ x100] (79.8 / 1270.0) X 100 = 6.289	6.28
Temperature Compensation (%), [C_{tc}] (from tape)	0.17
% AC, uncorrected, [$P_{bu} = P_L - C_{tc}$] 6.28 – 0.17 = 6.11	6.11
Aggregate Correction (Calibration) Factor (%), [C_f] (from tape)	0.26
Calibrated %AC (from ignition oven tape), [$P_{bcal} = P_{bu} - C_f$]	5.85
% Moisture Content, [MC] (previous test)*	0.13
% AC, corrected (by weight of mix), [$P_b = P_{bcal} - MC$]*	5.72

Method A

47

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

48

48

PROCEDURE
Method B

- Note the special heat resistant shirt.

Use SAFETY gear!

Dr. Richardson

49

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.

Method B **50**

50

Method B - No internal scale – Manual Weigh

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

Weight = Mass
Mass = Weight

Method B **51**

51

SUPERPAVE MIXTURE PROPERTIES

JOB 0 ROUTE 0 MIX NO. #VALUE! LOT NO. 0

SUBLOT							
DATE							

AASHTO T 209

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

TECHNICIAN							
A = Wt. of sample:	1594.4						
A2=Wt. of sample (dry-back):							
D = Wt. of flask filled with water:	7472.2						
X = A + D (A2 used in lieu of A for dry-back)	9066.6	0.0	0.0	0.0	0.0	0.0	0.0
E = Wt. of flask filled with water and sample:	8421.5						
Y = X - E	645.1	0.0	0.0	0.0	0.0	0.0	0.0
Gmm = MAX. SPECIFIC GRAVITY = A / Y	2.472	2.472	2.472	2.472	2.472	2.472	2.472

AASHTO T 166

TECHNICIAN								
MOLDING TEMPERATURE								
A = Weight of sample in air:		4867.8						
B = Weight of sample in water:	SPEC. 1	2801.9						
C = Weight of surface dry sample:		4880.4						
Gmb = BULK SP. G. = A / (C-B)		2.342	0.000	0.000	0.000	0.000	0.000	0.000
A = Weight of sample in air:		4899.1						
B = Weight of sample in water:	SPEC. 2	2814.5						
C = Weight of surface dry sample:		4911.9						
Gmb = BULK SP. G. = A / (C-B)		2.336	0.000	0.000	0.000	0.000	0.000	0.000
AVG. Gmb		2.339	0.000	0.000	0.000	0.000	0.000	0.000

Nuclear gage

TECHNICIAN							
MoDOT TM54 (NUCLEAR)							
SAMPLE WEIGHT							
BACKGROUND							
COUNTS							
GAUGE % AC							

Ignition oven

AASHTO T 308 (IGNITION)							
GAUGE %AC	5.35						
NUCLEAR OR IGNITION							
% MOISTURE	0.12						
% AC BY IGNITION OR NUCLEAR	5.2						

AASHTO R 35

A = Gmm (FIELD)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
B = Gmb (FIELD) (Avg.)	2.339	0.000	0.000	0.000	0.000	0.000	0.000
C = Gsb (Job Mix)	2.557	2.557	2.557	2.557	2.557	2.557	2.557
D = Ps = Percent Agg. in mix	94.8	100.0	100.0	100.0	100.0	100.0	100.0
VMA = 100 - (B X D / C)	13.3	100.0	100.0	100.0	100.0	100.0	100.0
Va = 100 X ((A - B) / A)	5.4	100.0	100.0	100.0	100.0	100.0	100.0
VFA = (VMA-Va) / VMA	59	0	0	0	0	0	0

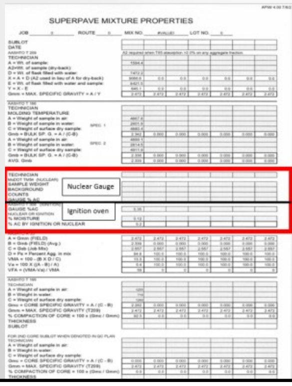
AASHTO T 166

TECHNICIAN							
A = Weight of sample in air:	1255						
B = Weight in water:	710						
C = Weight of surface dry sample:	1260						
Gmc = CORE SPECIFIC GRAVITY = A / (C - B)	2.282	0.000	0.000	0.000	0.000	0.000	0.000
Gmm = MAX. SPECIFIC GRAVITY (T209)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	92.3	0.0	0.0	0.0	0.0	0.0	0.0
THICKNESS							
SUBLOT							

FOR 2ND CORE SUBLOT WHEN DENOTED IN QC PLAN

TECHNICIAN							
A = Weight of sample in air:							
B = Weight in water:							
C = Weight of surface dry sample:							
Gmc = CORE SPECIFIC GRAVITY = A / (C - B)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gmm = MAX. SPECIFIC GRAVITY (T209)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
THICKNESS							
SUBLOT							

Reporting binder content of mix



52

52

Reporting binder content of mix

Binder Portion

Enlarged

TECHNICIAN							
MoDOT TM54 (NUCLEAR)							
SAMPLE WEIGHT							
BACKGROUND							
COUNTS							
GAUGE % AC							
AASHTO T 308 (IGNITION)							
GAUGE %AC	5.35						
NUCLEAR OR IGNITION							
% MOISTURE	0.12						
% AC BY IGNITION OR NUCLEAR	5.2						

53

53

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).

54

54

Binder Portion

TECHNICIAN							
MoDOT TM54 (NUCLEAR)							
SAMPLE WEIGHT							
BACKGROUND							
COUNTS							
GAUGE % AC							
AASHTO T 308 (IGNITION)							
GAUGE %AC	5.35						
NUCLEAR OR IGNITION							
% MOISTURE	0.12						
% AC BY IGNITION OR NUCLEAR	5.2						

Binder content of RAP

RAP & RAS

- 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.

55

55

Aggregate Gradation

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 is determined with ignition oven.

56

56

Aggregate Gradation

RAS Gradation

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

57

57

Aggregate Gradation

RAS Gradation

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

Sieve Size	% Passing
3/8"	100
#4	95
#8	85
#16	70
#30	50
#50	45
#100	35
#200	25

58

58

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.

59

59

When is Aggregate Gradation Correction Factor Required?

60

60

Gradation Samples
Burned and Unburned
Plus #200 Portion

- Determine a difference for each sieve, each replicate, say, for the #4 sieve:

$(\%\text{-}\#4)_{blank} - (\%\text{-}\#4)_{burned\text{, replicate \#1}}$

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

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

61

61

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**:
  - ≥ #8: ± 5.0%
  - ≥ #200 to < #8: ± 3.0%
  - ≤#200 ± 0.5%

62

62

Gradation Samples
Passing the #200 Portion

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

63

63

Example

Enlarged

Adapted From FHWA "Addendum T308"

Sieve	Burned Rep#1	Burned Rep#2	Unburned Blank	Rep#1 Diff	Rep#2 Diff	Avg. Diff= AGCF	Allowable
1"	100.0	100.0	100.0	0.0	0.0	0.0	±5.0
¾"	100.0	100.0	100.0	0.0	0.0	0.0	±5.0
½"	86.5	89.5	89.7	3.2	0.2	1.7	±5.0
3/8"	69.3	72.1	70.4	1.1	-1.7	-0.3	±5.0
#4	52.1	55.6	53.9	1.8	-1.7	0.1	±5.0
#8	38.5	42.3	41.0	2.5	-1.3	0.6	±3.0
#30	32.7	37.0	34.4	1.7	-2.6	-0.5	±3.0
#40	16.1	17.9	18.3	2.2	0.4	1.3	±3.0
#50	12.6	13.4	14.5	1.9	1.1	1.5	±3.0
#200	6.8	7.4	7.1	0.3	-0.3	0.0	±0.5

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"

Sieve	Burned Rep#1	Burned Rep#2	Unburned Blank	Rep#1 Diff	Rep#2 Diff	Avg Diff= AGCF	Allowable
1"	100.0	100.0	100.0	0.0	0.0	0.0	±5.0
¾"	100.0	100.0	100.0	0.0	0.0	0.0	±5.0
½"	86.5	89.5	89.7	3.2	0.2	1.7	±5.0
3/8"	69.3	72.1	70.4	1.1	-1.7	-0.3	±5.0
#4	52.1	55.6	53.9	1.8	-1.7	0.1	±5.0
#8	38.5	42.3	41.0	2.5	-1.3	0.6	±3.0
#30	32.7	37.0	34.4	1.7	-2.6	-0.5	±3.0
#40	16.1	17.9	18.3	2.2	0.4	1.3	±3.0
#50	12.6	13.4	14.5	1.9	1.1	1.5	±3.0
#200	6.8	7.4	7.1	0.3	-0.3	0.0	±0.5

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

- 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

67

67

- 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.

Common Testing Errors

68

68

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).

69

69

Premature Burn Stop

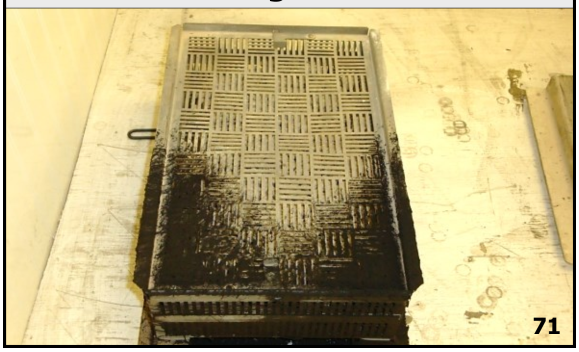
- Vibrations
- Basket or strap up against wall or top of chamber.
- Clogged port
- Used U.S. date, not European date (1998-2000 NCAT models).

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

70

70

Incomplete Burn Pattern: Shingle Mix



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71

Soot

72

72

Coke

73

73

AASHTO T 308: Asphalt Content by Ignition; Method A

Trial#	1	2	R
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 ~½ of hotmix sample in each basket; move mix ~¾" 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			
PASS?			
FAIL?			

Proctor_______________________________________Date_________________

Reviewer_____________________________________Date_________________

Module 10

Job Mix Formula (JMF)

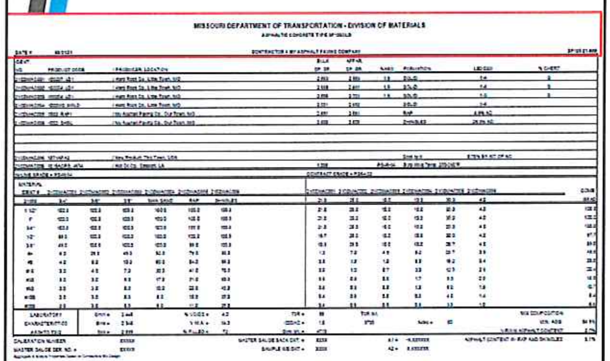
MODULE 10

JOB MIX FORMULA SHEET

(JMF)

1

JMF



2

2

JMF Header

- Contains Type of Mix
- Date Issued
- Contractor Issued to
- Mix Number

3

3

JMF

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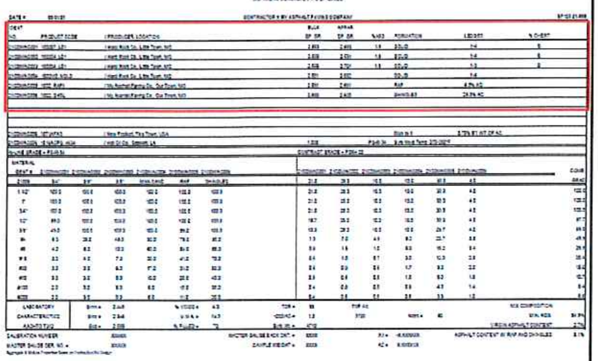

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4

JMF Virgin Aggregate Information

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

5

5

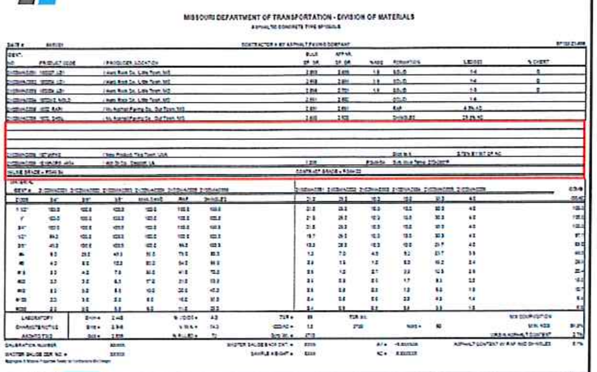
JMF Virgin Aggregate Information

- Each mix design is acceptable to 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

6

6

JMF



7

7

JMF
Binder and Additive Information

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

8

8

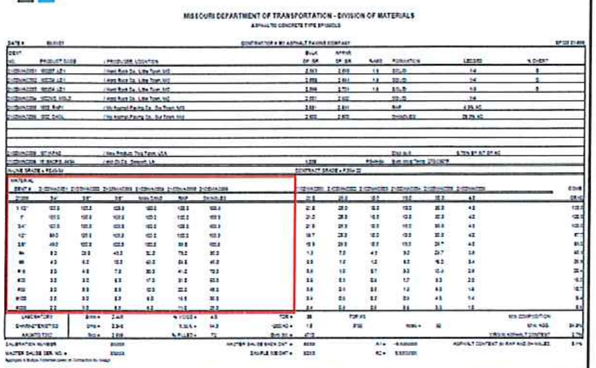
JMF
Binder and Additive Information

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

9

9

JMF



10

10

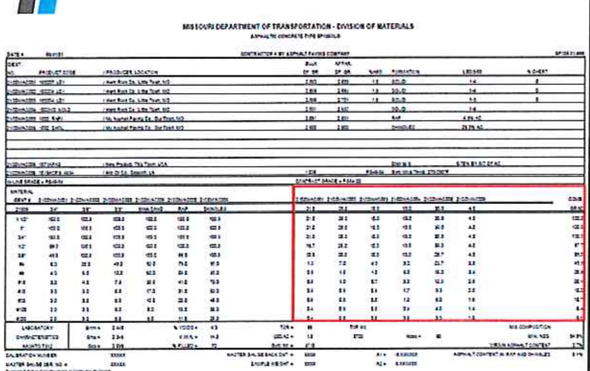
JMF
Individual Aggregate Gradations

- This area contains the gradation of individual aggregate fractions to include RAP & RAS if applicable.

11

11

JMF



12

12

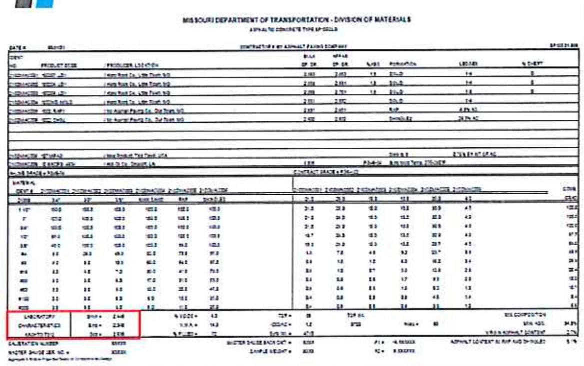
JMF
Weighted and Combined Gradations

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

13

13

JMF



14

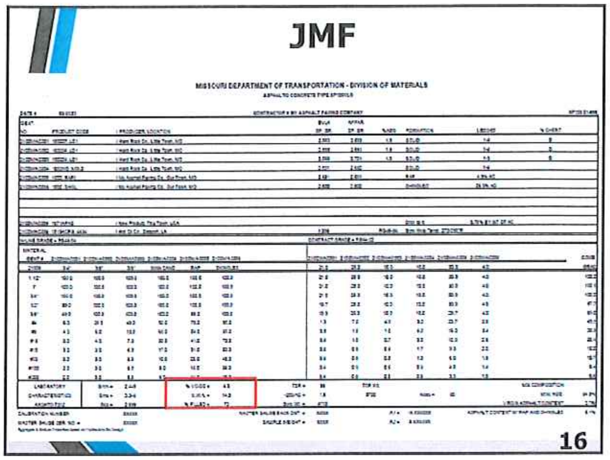
14

JMF
Target Mix Characteristics

- Gmm from mix design phase (Rice).
- Gmb from mix design phase (Puck).
- Gsb Calculated from the combined weighted aggregate bulk gravities.

15

15



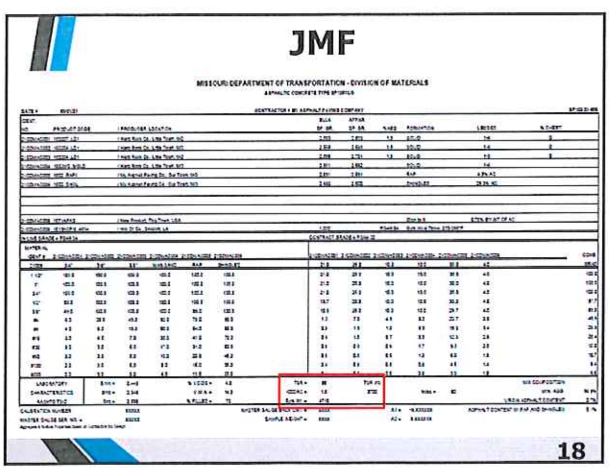
16

JMF
Target Voids, VMA and VFA

- Voids Specified.
- VMA and VFA generated during the mix design phase adhering to specifications.

17

17



18

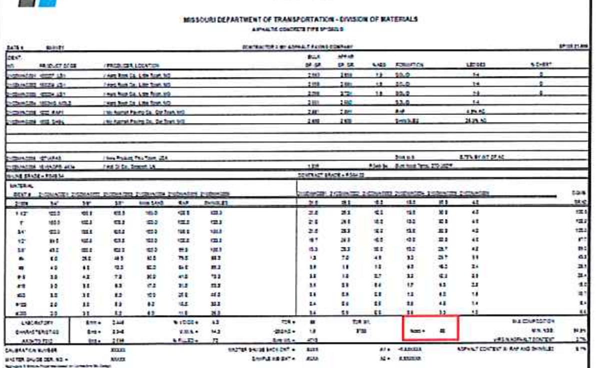
JMF
TSR, Dust/Binder, Specimen Weights

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

19

19

JMF



20

20

JMF
Gyration Levels

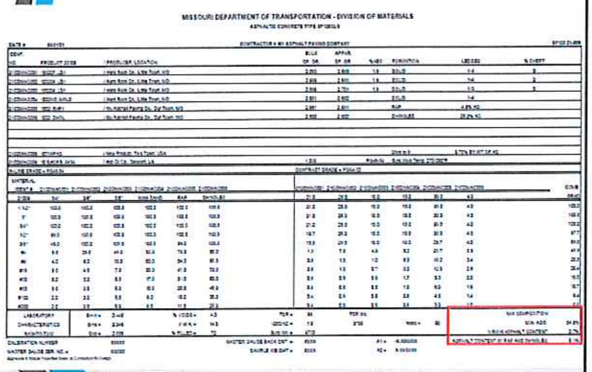
- Number of Gyrations for
  - Nini
  - Ndes
  - Nmax

  Volumetric pucks are made to Ndes during production.
  - LG mixes only specify Ndes gyrations.

21

21

JMF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22

22

JMF
Mix Composition

- Percentages of Aggregate and AC are in this area. If RAP and/or RAS are being used, then the percentage of virgin AC along with the Total AC are provided.

23

23

MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP125CLG

DATE = 03/01/21 **CONTRACTOR = MY ASPHALT PAVING COMPANY** **SP125 21-999**

IDENT. NO.	PRODUCT CODE	/ PRODUCER, LOCATION	BULK SP. GR.	APPAR. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
21CDMAC001	100207..LD1	/ Hard Rock Co., Little Town, MO	2.563	2.693	1.9	SOLID	1-4	0
21CDMAC002	100204..LD1	/ Hard Rock Co., Little Town, MO	2.558	2.691	1.9	SOLID	1-4	0
21CDMAC003	100204..LD1	/ Hard Rock Co., Little Town, MO	2.566	2.701	1.9	SOLID	1-3	0
21CDMAC004	1002MS..MSLD	/ Hard Rock Co., Little Town, MO	2.551	2.682		SOLID	1-4	
21CDMAC005	1002..RAP1	/ My Asphalt Paving Co., Our Town, MO	2.691	2.691		RAP	4.9% AC	
21CDMAC006	1002..SHGL	/ My Asphalt Paving Co., Our Town, MO	2.600	2.600		SHINGLES	26.3% AC	
21CDMAC006	1071APAS	/ New Product, This Town, USA				Stick to It	0.75% BY WT OF AC	
21CDMAC006	1015ACPG..4634	/ Hot Oil Co., Seaport, LA	1.035		PG46-34	Gyro Mold Temp. 270-280°F		

IN-LINE GRADE = PG46-34 CONTRACT GRADE = PG64-22

MATERIAL IDENT #	21CDMAC001	21CDMAC002	21CDMAC003	21CDMAC004	21CDMAC005	21CDMAC006	21CDMAC001	21CDMAC002	21CDMAC003	21CDMAC004	21CDMAC005	21CDMAC006	COMB.
21008	3/4"	3/8"	3/8"	MAN SAND	RAP	SHINGLES	21.0	25.0	10.0	10.0	30.0	4.0	GRAD
1 1/2"	100.0	100.0	100.0	100.0	100.0	100.0	21.0	25.0	10.0	10.0	30.0	4.0	100.0
1"	100.0	100.0	100.0	100.0	100.0	100.0	21.0	25.0	10.0	10.0	30.0	4.0	100.0
3/4"	100.0	100.0	100.0	100.0	100.0	100.0	21.0	25.0	10.0	10.0	30.0	4.0	100.0
1/2"	89.0	100.0	100.0	100.0	100.0	100.0	18.7	25.0	10.0	10.0	30.0	4.0	97.7
3/8"	49.0	100.0	100.0	100.0	99.0	100.0	10.3	25.0	10.0	10.0	29.7	4.0	89.0
#4	6.0	28.0	49.0	92.0	79.0	95.0	1.3	7.0	4.9	9.2	23.7	3.8	49.9
#8	4.0	6.0	10.0	60.0	54.0	85.0	0.8	1.5	1.0	6.0	16.2	3.4	28.9
#16	3.0	4.0	7.0	30.0	41.0	70.0	0.6	1.0	0.7	3.0	12.3	2.8	20.4
#30	3.0	3.0	6.0	17.0	31.0	50.0	0.6	0.8	0.6	1.7	9.3	2.0	15.0
#50	3.0	3.0	5.0	10.0	20.0	45.0	0.6	0.8	0.5	1.0	6.0	1.8	10.7
#100	2.0	3.0	5.0	8.0	15.0	35.0	0.4	0.8	0.5	0.8	4.5	1.4	8.4
#200	2.0	3.0	5.0	6.0	11.0	25.0	0.4	0.8	0.5	0.6	3.3	1.0	6.6

LABORATORY	Gmm =	2.445	% VOIDS =	4.0	TSR =	86	TSR Wt.		MIX COMPOSITION	
CHARACTERISTICS	Gmb =	2.346	V.M.A. =	14.3	-200/AC =	1.5	3700	Ndes = 80	MIN. AGG.	94.9%
AASHTO T312	Gsb =	2.599	% FILLED =	72	Gyro Wt. =	4710			VIRGIN ASPHALT CONTENT	2.7%

CALIBRATION NUMBER XXXXX MASTER GAUGE BACK CNT. = XXXX A1 = -X.XXXXXX ASPHALT CONTENT W/ RAP AND SHINGLES 5.1%

MASTER GAUGE SER. NO. = XXXXX SAMPLE WEIGHT = XXXX A2 = X.XXXXXX

Aggregate & Mixture Properties Based on Contractors Mix Design

MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP125CLG

DATE = 03/01/21 CONTRACTOR = MY ASP SP125 21-999

Job Mix ID
SP = SuperPave
125 = 12.5 agg size mm
21 = year
999 = #ID

IDENT. NO.	PRODUCT CODE	/ PRODUCER, LOCATION	BULK SP. GR.	APPAR. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
21CDMAC001	100207..LD1	/ Hard Rock Co., Little Town, MO	2.563	2.693	1.9	SOLID	1-4	0
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21CDMAC004	1002MS..MSLD	/ Hard Rock Co., Little Town, MO	2.551	2.682		SOLID	1-4	
21CDMAC005	1002..RAP1	/ My Asphalt Paving Co., Our Town, MO	2.691	2.691		RAP	4.9% AC	
21CDMAC006	1002..SHGL	/ My Asphalt Paving Co., Our Town, MO	2.600	2.600		SHINGLES	26.3% AC	

Aggregate Information in the mix
Aggregate Bulk Specific Gravity
Aggregate Apparent Specific Gravity
Aggregate % Absorption
Aggregate Percent Chert from Deleterious testing
RAP = Recycled Asphalt Pavement
SHGL = Recycled Shingles
Percent Binder Oil in RAP 4.9 In Shingles 26.3

21CDMAC006	1071APAS	/ New Product, This Town, USA	...ck to It	0.75% BY WT OF AC
21CDMAC006	1015ACPG..4634	/ Hot Oil Co., Seaport, LA	1.035 PG46-34	Gyro Mold Temp 270-280°F
IN-LINE GRADE = PG46-34			CONTRACT GRADE = PG64-22	

Binder (AC) Specific Gravity
Binder (AC) Performance Grade
Mix and molding temp for gyratory compaction

MATERIAL	1	2	3	4	5	6	P1	P2	P3	P4	P5	P6	
IDENT #	21CDMAC001	21CDMAC002	1CDMAC003	21CDMAC004	21CDMAC005	21CDMAC006	21CDMAC001	21CDMAC002	21CDMAC003	21CDMAC004	21CDMAC005	21CDMAC006	COMB.
21008	3/4"	3/8"	3/8"	MAN SAND	RAP	SHINGLES	21.0	25.0	10.0	10.0	30.0	4.0	GRAD
1 1/2"	100.0	100.0	100.0	100.0	100.0	100.0	21.0	25.0	10.0	10.0	30.0	4.0	100.0
1"	100.0	100.0	100.0	100.0	100.0	100.0	21.0	25.0	10.0	10.0	30.0	4.0	100.0
3/4"	100.0	100.0	100.0	100.0	100.0	100.0	21.0	25.0	10.0	10.0	30.0	4.0	100.0
1/2"	89.0	100.0	100.0	100.0	100.0	100.0	18.7	25.0	10.0	10.0	30.0	4.0	97.7
3/8"	49.0	100.0	100.0	100.0	99.0	100.0	10.3	25.0	10.0	10.0	29.7	4.0	89.0
#4	6.0	28.0	49.0	92.0	79.0	95.0	1.3	7.0	4.9	9.2	23.7	3.8	49.9
#8	4.0	6.0	10.0	60.0	54.0	85.0	0.8	1.5	1.0	6.0	16.2	3.4	28.9
#16	3.0	4.0	7.0	30.0	41.0	70.0	0.6	1.0	0.7	3.0	12.3	2.8	20.4
#30	3.0	3.0	6.0	17.0	31.0	50.0	0.6	0.8	0.6	1.7	9.3	2.0	15.0
#50	3.0	3.0	5.0	10.0	20.0	45.0	[illegible]	[illegible]	[illegible]	1.0	[illegible]	[illegible]	10.7
#100	2.0	3.0	5.0	8.0	15.0	35.0	[illegible]	[illegible]	[illegible]	0.8	[illegible]	[illegible]	8.4
#200	2.0	3.0	5.0	6.0	11.0	25.0	0.4	0.8	[illegible]	[illegible]	[illegible]	[illegible]	6.6

Sieve sizes
Sieve Analysis On each Material
Aggregate Nominal Max Size ½" or 12.5 mm
Total Aggregate Ps Agg
Dust
Percent Asphalt Or Binder 2.7%

LABORATORY CHARACTERISTICS AASHTO T312									
Gmm =	2.445	% VOIDS =	4.0	TSR =	86	TSR Wt.		MIX COMPOSITION	
Gmb =	2.346	V.M.A. =	14.3	-200/AC =	1.5	3700	Ndes = 80	MIN. AGG.	94.9%
Gsb =	2.599	% FILLED =	72	Gyro Wt. =	4710			VIRGIN ASPHALT CONTENT	2.7%
								ASPHALT CONTENT W/ RAP AND SHINGLES	5.1%

TSR Puck TSR = Tensile Strength Raito % = 86
TSR Puck Dust to Asphalt Raito = 1.5
TSR Gyro weight 4710 grams
N-design # of Gyrations = 80
Tensile Strength Raito weight in grams
TSR Puck Gmm= max gravity = 2.446
TSR Puck Gmb= Bulk specific Gravity= 2.346
TSR Puck % Air Voids 4.0%
TSR Puck % Voids in Mineral Agg. = 14.3
TSR Puck % Voids Filled with Asphalt = 72%

Module 11

Pay Factors

MODULE 11

PAY FACTORS

1

Pay Factors

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

2

2

Spec Limits

Factor	Spec Limit
Air voids	4.0 ± 1.0 %
VMA	-0.5 to +2.0% Applied to min. design VMA: 12.0, 13.0, 14.0
Binder content	Design ± 0.3 %
Density Density (SMA)	94.5 ± 2.5 % ≥ 94.0 %

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3

Pay Factors

- **P**ay **F**actors (**PF**s) are numbers that you multiply times the contract unit price to adjust for quality.
- PFs are either *incentives* or *disincentives.*

4

4

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 (PFs)

5

5

Pay Factors

- *Disincentive:*

PF is less than 100%:

Say PF = 80%

Adjusted price =

(0.80-1.00)($43.50)(4000) = -$34,800

Pay Factors (PFs)

6

6

QLA Pay Factors

- **QLA** = **Q**uality **L**evel **A**nalysis
- **PFs** = **P**ay **F**actors
- **QLA PFs** are calculated for each lot, say 3000 tons of mix.
- Next lot, new **PFs.**

Pay **F**actors (**PFs**)

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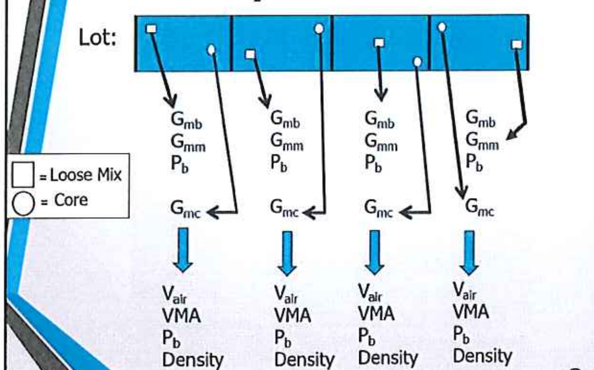
7

Pay Factors



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QLA Pay Factors

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

$$[\ PF_{AC} + PF_{Va} + PF_{VMA} + PF_{Dens}\ ] \div 4$$

Pay Factor Total = PF_T

9

9

QLA Pay Factors

- Each sublot is sampled,(50lbs. 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.

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10

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"*** = $\overline{X}$

11

11

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).***

12

12

Standard Deviation

- Standard deviation:

$$S=\sqrt{\{\Sigma[(x_i-\overline{x})^2]\div(n-1)\}}$$

x_i = Each test value

$\overline{x}$ = Mean

n = Number of test values

(usually = number of sublots)

13

13

QLA Pay Factors

- So now you have the average (***mean***) and ***standard deviation*** for air voids, for VMA, for binder content, and for density for a certain lot:

$\overline{X}_{air}$, S_{air}

$\overline{X}_{VMA}$, S_{VMA}

$\overline{X}_{AC}$, S_{AC}

$\overline{X}_{dens}$, S_{dens}

14

14

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 sublot values. (How large is the **S**)
- So, to get a high pay factor, you want low variability--you want ***CONSISTENCY!***

PFs = **Pay Factors** | **S** = **Standard deviation**

15

15

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

16

16

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 = **Q**uality **L**evel **A**nalysis | **PF**s = **P**ay **F**actors

17

17

QLA Pay Factors

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

18

18

Quality Index (Q)

$$Q_U = \frac{USL - \overline{X}}{S}$$

OR

$$Q_L = \frac{\overline{X} - LSL}{S}$$

- **$\overline{X}$ = Mean**
- **LSL** = **L**ower **S**pec **L**imit
- **USL** = **U**pper **S**pec **L**imit
- **S** = **S**tandard **D**eviation

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

19

19

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.

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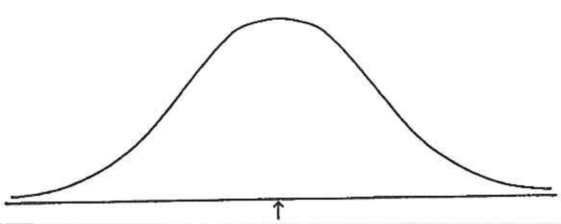
The Normal Distribution is the most important for highway materials



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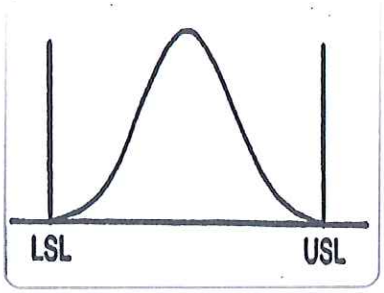
USL and LSL

- 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%

22

22

Acceptable Product



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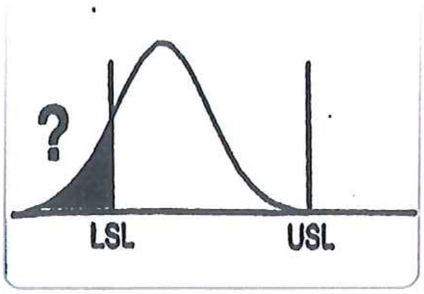
Percent Within Limits

- 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.

24

24

Unacceptable Product



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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)"***

26

26

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.

27

27

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.

28

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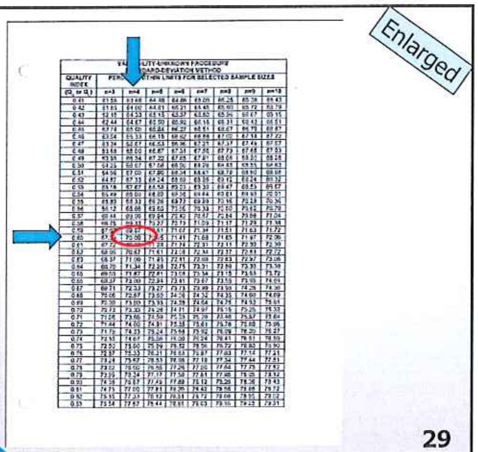

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29

Quality Index (Q)

$$Q_L = \frac{\overline{X} - LSL}{S}$$

OR

$$Q_U = \frac{USL - \overline{X}}{S}$$

30

30

VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD								
QUALITY INDEX	PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES							
(Q_U or Q_L)	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10
0.41	61.56	63.66	64.46	64.86	65.09	65.25	65.36	65.43
0.42	61.85	64.00	64.81	65.21	65.45	65.60	65.72	65.79
0.43	62.15	64.33	65.15	65.57	65.80	65.96	66.07	66.15
0.44	62.44	64.67	65.50	65.92	66.16	66.31	66.43	66.51
0.45	62.74	65.00	65.84	66.27	66.51	66.67	66.79	66.87
0.46	63.04	65.33	66.18	66.62	66.86	67.02	67.14	67.22
0.47	63.34	65.67	66.53	66.96	67.21	67.37	67.49	67.57
0.48	63.65	66.00	66.87	67.31	67.56	67.73	67.85	67.93
0.49	63.95	66.34	67.22	67.65	67.91	68.08	68.20	68.28
0.50	64.25	66.67	67.56	68.00	68.26	68.43	68.55	68.63
0.51	64.56	67.00	67.90	68.34	68.61	68.78	68.90	68.98
0.52	64.87	67.33	68.24	68.69	68.95	69.12	69.24	69.32
0.53	65.18	67.67	68.58	69.03	69.30	69.47	69.59	69.67
0.54	65.49	68.00	68.92	69.38	69.64	69.81	69.93	70.01
0.55	65.80	68.33	69.26	69.72	69.99	70.16	70.28	70.36
0.56	66.12	68.66	69.60	70.06	70.33	70.50	70.62	70.70
0.57	66.44	69.00	69.94	70.40	70.67	70.84	70.96	71.04
0.58	66.75	69.33	70.27	70.73	71.00	71.17	71.29	71.38
0.59	67.07	69.67	70.61	71.07	71.34	71.51	71.63	71.72
0.60	67.39	70.00	70.95	71.41	71.68	71.85	71.97	72.06
0.61	67.72	70.33	71.28	71.74	72.01	72.11	72.30	72.39
0.62	68.05	70.67	71.61	72.08	72.34	72.37	72.63	72.72
0.63	68.37	71.00	71.95	72.41	72.68	72.63	72.97	73.06
0.64	68.70	71.34	72.28	72.75	73.01	72.89	73.30	73.39
0.65	69.03	71.67	72.61	73.08	73.34	73.15	73.63	73.72
0.66	69.37	72.00	72.94	73.41	73.67	73.55	73.95	74.04
0.67	69.71	72.33	73.27	73.73	73.99	73.95	74.28	74.36
0.68	70.05	72.67	73.60	74.06	74.32	74.35	74.60	74.69
0.69	70.39	73.00	73.93	74.38	74.64	74.75	74.93	75.01
0.70	70.73	73.33	74.26	74.71	74.97	75.15	75.25	75.33
0.71	71.08	73.66	74.59	75.03	75.29	75.46	75.57	75.64
0.72	71.44	74.00	74.91	75.35	75.61	75.78	75.88	75.96
0.73	71.79	74.33	75.24	75.68	75.92	76.09	76.20	76.27
0.74	72.15	74.67	75.56	76.00	76.24	76.41	76.51	76.59
0.75	72.50	75.00	75.89	76.32	76.56	76.72	76.83	76.90
0.76	72.87	75.33	76.21	76.63	76.87	77.03	77.14	77.21
0.77	73.24	75.67	76.53	76.95	77.18	77.34	77.44	77.51
0.78	73.62	76.00	76.85	77.26	77.50	77.64	77.75	77.82
0.79	73.99	76.34	77.17	77.58	77.81	77.95	78.05	78.12
0.80	74.36	76.67	77.49	77.89	78.12	78.26	78.36	78.43
0.81	74.75	77.00	77.81	78.20	78.42	78.56	78.66	78.72
0.82	75.15	77.33	78.12	78.51	78.72	78.86	78.95	79.02
0.83	75.54	77.67	78.44	78.81	79.03	79.16	79.25	79.31

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.***

31

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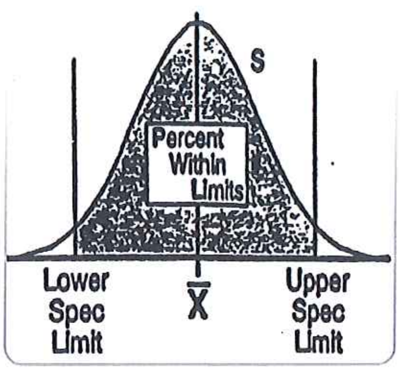

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32

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:
- $PWL_T = (PWL_U + PWL_L) - 100$

33

33

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.

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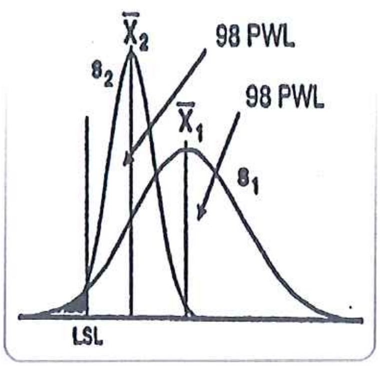

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Percent Within Limits

- 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.

36

36

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.

37

37

QLA Pay Factors

- If $PWL_T < 70\%$:

  $$PF = 2(PWL_T) - 50$$

- If $PWL_T \geq 70\%$:

  $$PF = 0.50(PWL_T) + 55$$

38

38

QLA Pay Factors

- The PFs for each test parameter are then averaged to obtain the total $\mathbf{PF_T}$:

For the traveled way:

$[PF_{AC} + PF_{Va} + PF_{VMA} + PF_{Dens}] \div 4$

For non-integral shoulders:

$[PF_{AC} + PF_{Va} + PF_{VMA}] \div 3$

39

39

EQUATIONS:

$V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$ $P_s = 100 - P_b$ $VMA = 100 - \left[\frac{G_{mb} \times P_s}{G_{sb}}\right]$

$VFA = \frac{VMA - V_a}{VMA} \times 100$ Density $= \frac{G_{mb}}{G_{mm}} \times 100$

MEAN: $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$

Example: n = number of samples = 3 Therefore: $\bar{x} = \frac{x_1 + x_2 + x_3}{3}$

STANDARD DEVIATION: $s = \sqrt{\frac{\sum_{i=1}^{n}(x - \bar{x})^2}{n-1}}$

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

USL = Target + Tolerance LSL = Target − Tolerance

$Q_U = \frac{USL - \bar{x}}{s}$ $Q_L = \frac{\bar{x} - LSL}{s}$

$PWL_T = (PWL_U + PWL_L) - 100$

Pay Factor (PF) IF: $PWL_T < 70\%$ THEN: $PF = 2(PWL_T) - 50$

IF: $PWL_T \geq 70\%$ THEN: $PF = 0.50(PWL_T) + 55$

QA to QC Comparison:

$[QC_{avg} - 2(s)] \leq QA_{avg} \leq [QC_{avg} + 2(s)]$

OUTLIERS:

Highside $t = \frac{x_{max} - \bar{x}}{s}$

Lowside $t = \frac{\bar{x} - x_{min}}{s}$

Enlarged

40

40

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%.**

41

41

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%.

42

42

EQUATIONS:

$$V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100 \qquad P_s = 100 - P_b \qquad VMA = 100 - \left[\frac{G_{mb} \times P_s}{G_{sb}}\right]$$

$$VFA = \frac{VMA - V_a}{VMA} \times 100 \qquad Density = \frac{G_{mc}}{G_{mm}} \times 100$$

MEAN: $$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Example: n = number of samples = 3 Therefore: $\bar{x} = \frac{x_1 + x_2 + x_3}{3}$

STANDARD DEVIATION: $$s = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n-1}}$$

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

USL = Target + Tolerance LSL = Target – Tolerance

$$Q_U = \frac{USL - \bar{x}}{s} \qquad Q_L = \frac{\bar{x} - LSL}{s}$$

$PWL_T = (PWL_U + PWL_L) - 100$

Pay Factor (PF): IF: $PWL_T < 70\%$ THEN: $PF = 2(PWL_T) - 50$

IF: $PWL_T \geq 70\%$ THEN: $PF = 0.50(PWL_T) + 55$

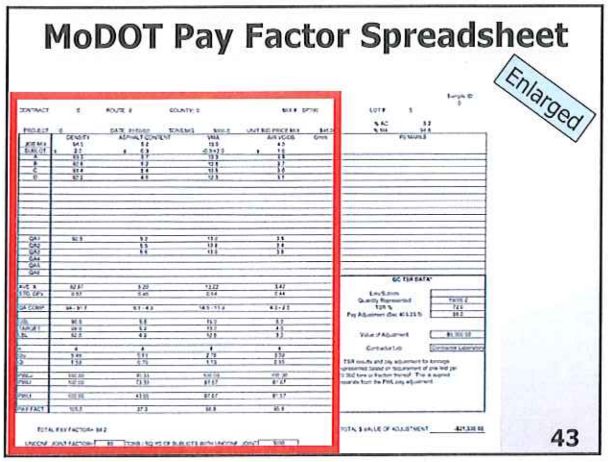
QA to QC Comparison:

$$[QC_{avg} - 2(s)] \leq QA_{avg} \leq [QC_{avg} + 2(s)]$$

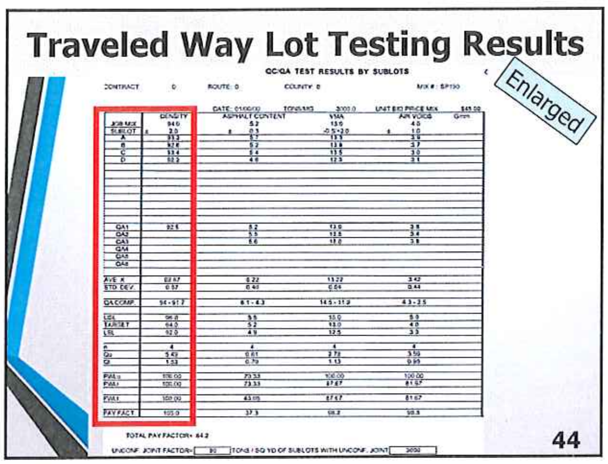
OUTLIERS:

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

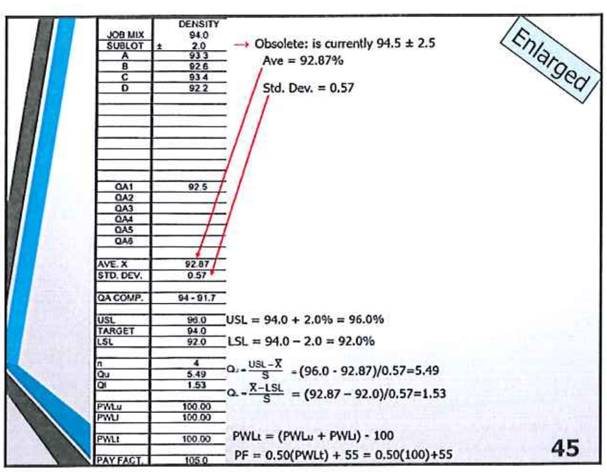
Lowside: $t = \frac{\bar{x} - x_{min}}{s}$


MoDOT Pay Factor Spreadsheet
Enlarged
43

43


Traveled Way Lot Testing Results
QC/QA TEST RESULTS BY SUBLOTS
Enlarged
44

44


DENSITY
JOB MIX 94.0
SUBLOT ± 2.0
A 93.3
B 92.6
C 93.4
D 92.2
QA1 92.5
QA2
QA3
QA4
QA5
QA6
AVE. X 92.87
STD. DEV. 0.57
QA COMP. 94 - 91.7
USL 96.0
TARGET 94.0
LSL 92.0
n 4
Qu 5.49
Ql 1.53
PWLu 100.00
PWLl 100.00
PWLt 100.00
PAY FACT. 105.0
Obsolete: is currently 94.5 ± 2.5
Ave = 92.87%
Std. Dev. = 0.57
USL = 94.0 + 2.0% = 96.0%
LSL = 94.0 − 2.0 = 92.0%
$Q_U = \frac{USL - \bar{X}}{S}$ = (96.0 - 92.87)/0.57=5.49
$Q_L = \frac{\bar{X} - LSL}{S}$ = (92.87 − 92.0)/0.57=1.53
$PWL_t = (PWL_U + PWL_L) - 100$
PF = 0.50(PWLt) + 55 = 0.50(100)+55
Enlarged
45

45

MoDOT Pay Factor Spreadsheet

Pay Factor 5.01 7/6/200

Sample ID
0

CONTRACT: 0 ROUTE: 0 COUNTY: 0 MIX # : SP190 LOT # : 5

PROJECT: 0 DATE: 01/00/00 TONS/MG 3000.0 UNIT BID PRICE MIX $45.0

% AC 5.2
% MA 94.8

	DENSITY	ASPHALT CONTENT	VMA	AIR VOIDS	Gmm	REMARKS
JOB MIX	94.0	5.2	13.0	4.0		
SUBLOT	± 2.0	± 0.3	-0.5/+2.0	± 1.0		
A	93.3	5.7	13.3	3.9		
B	92.6	5.2	13.8	3.7		
C	93.4	5.4	13.5	3.0		
D	92.2	4.6	12.3	3.1		
QA1	92.5	5.2	13.0	3.8		
QA2		5.5	13.8	3.4		
QA3		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		
QA COMP.	94 - 91.7	6.1 - 4.3	14.5 - 11.9	4.3 - 2.5		
USL	96.0	5.5	15.0	5.0		
TARGET	94.0	5.2	13.0	4.0		
LSL	92.0	4.9	12.5	3.0		
n	4	4	4	4		
Qu	5.49	0.61	2.78	3.59		
Ql	1.53	0.70	1.13	0.95		
PWLu	100.00	70.33	100.00	100.00		
PWLl	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		

QC TSR DATA*

Lots/Sublots	
Quantity Represented	10000.0
TSR %	72.0
Pay Adjustment (Sec 403.23.5)	98.0
Value of Adjustment	-$9,000.00
Contractor Lab	Contractor Laboratory

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

TOTAL PAY FACTOR= 84.2

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

TOTAL $ VALUE OF ADJUSTMENT **-$21,330.00**

Traveled Way Lot Testing Results

QC/QA TEST RESULTS BY SUBLOTS

CONTRACT: 0 ROUTE: 0 COUNTY: 0 MIX # : SP190

PROJECT: 0 DATE: 01/00/00 TONS/MG 3000.0 UNIT BID PRICE MIX $45.00

	DENSITY	ASPHALT CONTENT	VMA	AIR VOIDS	Gmm
JOB MIX	94.0	5.2	13.0	4.0	
SUBLOT	± 2.0	± 0.3	-0.5/+2.0	± 1.0	
A	93.3	5.7	13.3	3.9	
B	92.6	5.2	13.8	3.7	
C	93.4	5.4	13.5	3.0	
D	92.2	4.6	12.3	3.1	
QA1	92.5	5.2	13.0	3.8	
QA2		5.5	13.8	3.4	
QA3		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	
QA COMP.	94 - 91.7	6.1 - 4.3	14.5 - 11.9	4.3 - 2.5	
USL	96.0	5.5	15.0	5.0	
TARGET	94.0	5.2	13.0	4.0	
LSL	92.0	4.9	12.5	3.0	
n	4	4	4	4	
Qu	5.49	0.61	2.78	3.59	
Ql	1.53	0.70	1.13	0.95	
PWLu	100.00	70.33	100.00	100.00	
PWLl	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

	DENSITY
JOB MIX	94.0
SUBLOT ±	2.0
A	93.3
B	92.6
C	93.4
D	92.2
QA1	92.5
QA2	
QA3	
QA4	
QA5	
QA6	
AVE. X	92.87
STD. DEV.	0.57
QA COMP.	94 - 91.7
USL	96.0
TARGET	94.0
LSL	92.0
n	4
Qu	5.49
Ql	1.53
PWLu	100.00
PWLl	100.00
PWLt	100.00
PAY FACT.	105.0

→ Obsolete: is currently 94.5 ± 2.5

Ave = 92.87%

Std. Dev. = 0.57

USL = 94.0 + 2.0% = 96.0%

LSL = 94.0 – 2.0 = 92.0%

$Q_U = \frac{USL - \overline{X}}{S}$ = (96.0 - 92.87)/0.57=5.49

$Q_L = \frac{\overline{X} - LSL}{S}$ = (92.87 – 92.0)/0.57=1.53

$PWL_t = (PWL_u + PWL_l) - 100$

$PF = 0.50(PWL_t) + 55 = 0.50(100)+55$

Q_L & PWL_L

QUALITY INDEX (Q_U or Q_L)	VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD							
	PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES							
	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	98.72	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	99.22	97.90	97.27	96.90	96.65	96.48

Qu & PWLu

VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD								
QUALITY INDEX	**PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES**							
(Q_U or Q_L)	**n=3**	**n=4**	**n=5**	**n=6**	**n=7**	**n=8**	**n=9**	**n=10**
2.56	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.57	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.58	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.59	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.60	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.61	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.62	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.63	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.64	100.00	[illegible]	100.00	100.00	100.00	100.00	100.00	100.00
2.65	100.00	100.0[illegible]	100.00	100.00	100.00	100.00	100.00	100.00

Q_L & PWL_L

Enlarged

QUALITY INDEX (Q_U or Q_L)	VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD — PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES 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	90.88	90.66	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	[illegible]	96.57	95.51	95.02	94.73	94.54	94.41
1.53	100.00	100.00	96.76	95.66	95.16	94.86	94.69	94.54
1.54	100.00	[illegible]	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	96.69	96.33	96.10	95.93
1.65	100.00	100.00	98.72	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	99.22	97.90	97.27	96.90	96.65	96.48

46

46

Qu & PWLu

Enlarged

QUALITY INDEX (Q_U or Q_L)	VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD — PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10
2.56	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.57	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.58	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.59	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.60	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.61	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.62	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.63	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.64	100.00	[illegible]	100.00	100.00	100.00	100.00	100.00	100.00
2.65	100.00	100.	100.00	100.00	100.00	100.00	100.00	100.00

47

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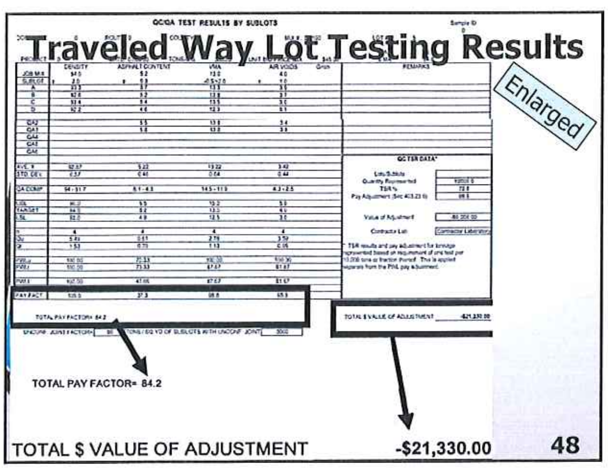


48

Traveled Way Lot Testing Results

Pay Factor 5.01 7/6/200

QC/QA TEST RESULTS BY SUBLOTS

Sample ID 0

CONTRACT: 0 ROUTE: 0 COUNTY: 0 MIX # : SP190 LOT # : 5

% AC 5.2
% MA 94.8

PROJECT: 0 DATE: 01/00/00 TONS/MG 3000.0 UNIT BID PRICE MIX $45.00

	DENSITY	ASPHALT CONTENT	VMA	AIR VOIDS	Gmm	REMARKS
JOB MIX	94.0	5.2	13.0	4.0		
SUBLOT	± 2.0	± 0.3	-0.5/+2.0	± 1.0		
A	93.3	5.7	13.3	3.9		
B	92.6	5.2	13.8	3.7		
C	93.4	5.4	13.5	3.0		
D	92.2	4.6	12.3	3.1		
QA1	92.5	5.2	13.0	3.8		
QA2		5.5	13.8	3.4		
QA3		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		
QA COMP.	94 - 91.7	6.1 - 4.3	14.5 - 11.9	4.3 - 2.5		
USL	96.0	5.5	15.0	5.0		
TARGET	94.0	5.2	13.0	4.0		
LSL	92.0	4.9	12.5	3.0		
n	4	4	4	4		
Qu	5.49	0.61	2.78	3.59		
Ql	1.53	0.70	1.13	0.95		
PWLu	100.00	70.33	100.00	100.00		
PWLl	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		

QC TSR DATA*

Lots/Sublots	
Quantity Represented	10000.0
TSR %	72.0
Pay Adjustment (Sec 403.23.5)	98.0
Value of Adjustment	-$9,000.00
Contractor Lab	Contractor Laboratory

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

TOTAL PAY FACTOR= 84.2

TOTAL $ VALUE OF ADJUSTMENT -$21,330.00

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

TOTAL PAY FACTOR= 84.2

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)

49

49

Unconfined Joint Deductions

- **Example:** For a given lot, if

  PF_{total} = 95% and PAF = 90%

  The 90% controls the whole lot.

- **Example:** For a given lot, if

  PF_{total} = 105% and PAF = 100%

  The 105% controls the whole lot.

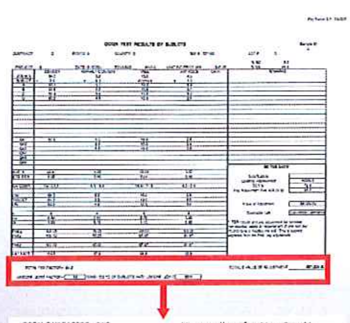
- 403.23.6 and EPG 403.1.21

50

50

Unconfined Joint Factor

Enlarged



TOTAL PAY FACTOR= 84.2 Use smaller of 90% or 84.2%

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

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

TOTAL $ VALUE OF ADJUSTMENT -$21,330.00

51

51

Unconfined Joint Factor

Pay Factor 5.01 7/6/200

QC/QA TEST RESULTS BY SUBLOTS

Sample ID 0

CONTRACT: 0 ROUTE: 0 COUNTY: 0 MIX # : SP190 LOT # : 5

PROJECT: 0 DATE: 01/00/00 TONS/MG 3000.0 UNIT BID PRICE MIX $45.00

% AC 5.2
% MA 94.8

	DENSITY	ASPHALT CONTENT	VMA	AIR VOIDS	Gmm	REMARKS
JOB MIX	94.0	5.2	13.0	4.0		
SUBLOT	± 2.0	± 0.3	-0.5/+2.0	± 1.0		
A	93.3	5.7	13.3	3.9		
B	92.6	5.2	13.8	3.7		
C	93.4	5.4	13.5	3.0		
D	92.2	4.6	12.3	3.1		
QA1	92.5	5.2	13.0	3.8		
QA2		5.5	13.8	3.4		
QA3		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		
QA COMP.	94 - 91.7	6.1 - 4.3	14.5 - 11.9	4.3 - 2.5		
USL	96.0	5.5	15.0	5.0		
TARGET	94.0	5.2	13.0	4.0		
LSL	92.0	4.9	12.5	3.0		
n	4	4	4	4		
Qu	5.49	0.61	2.78	3.59		
Ql	1.53	0.70	1.13	0.95		
PWLu	100.00	70.33	100.00	100.00		
PWLl	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		

QC TSR DATA*

Lots/Sublots	
Quantity Represented	10000.0
TSR %	72.0
Pay Adjustment (Sec 403.23.5)	98.0
Value of Adjustment	-$9,000.00
Contractor Lab	Contractor Laboratory

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

TOTAL PAY FACTOR= 84.2 TOTAL $ VALUE OF ADJUSTMENT -$21,330.00

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

TOTAL PAY FACTOR= 84.2

Use smaller of 90% or 84.2%

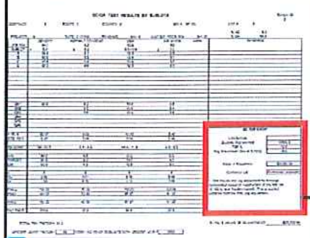
UNCONF. JOINT FACTOR= 90 TONS / SQ YD OF SUBLOTS WITH UNCONF. JOINT 3000

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

TOTAL $ VALUE OF ADJUSTMENT **-$21,330.00**

TSR Results

Enlarged



QC TSR DATA*

Lots/Sublots	
Quantity Represented	10,000.0
TSR %	72.0
Pay Adjustment (Sec 403.23.5)	98.0
Value of adjustment	− $9000.00
Contractor Lab	Contractor Laboratory

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

(0.98-1.00)(10,000 tons)($45/ ton)= -$9000

52

52

Superpave TSR Pay Adjustment

TSR	% of Contract price
≥90	103
75-89	100
70-74	98
65-69	97
<65	Remove

53

53

New Spreadsheets
2016

54

54

TSR Results

Pay Factor 5.01 7/6/200

QC/QA TEST RESULTS BY SUBLOTS

Sample ID
0

CONTRACT: 0 ROUTE: 0 COUNTY: 0 MIX # : SP190 LOT # : 5

% AC 5.2
% MA 94.8

PROJECT: 0 DATE: 01/00/00 TONS/MG 3000.0 UNIT BID PRICE MIX $45.00

	DENSITY	ASPHALT CONTENT	VMA	AIR VOIDS	Gmm	REMARKS
JOB MIX	94.0	5.2	13.0	4.0		
SUBLOT	± 2.0	± 0.3	-0.5/+2.0	± 1.0		
A	93.3	5.7	13.3	3.9		
B	92.6	5.2	13.8	3.7		
C	93.4	5.4	13.5	3.0		
D	92.2	4.6	12.3	3.1		
QA1	92.5	5.2	13.0	3.8		
QA2		5.5	13.8	3.4		
QA3		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		
QA COMP.	94 - 91.7	6.1 - 4.3	14.5 - 11.9	4.3 - 2.5		
USL	96.0	5.5	15.0	5.0		
TARGET	94.0	5.2	13.0	4.0		
LSL	92.0	4.9	12.5	3.0		
n	4	4	4	4		
Qu	5.49	0.61	2.78	3.59		
Ql	1.53	0.70	1.13	0.95		
PWLu	100.00	70.33	100.00	100.00		
PWLl	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		

QC TSR DATA

Lots/Sublots	
Quantity Represented	10000.0
TSR %	72.0
Pay Adjustment (Sec 403.23.5)	98.0
Value of Adjustment	-$9,000.00
Contractor Lab	Contractor Laborato

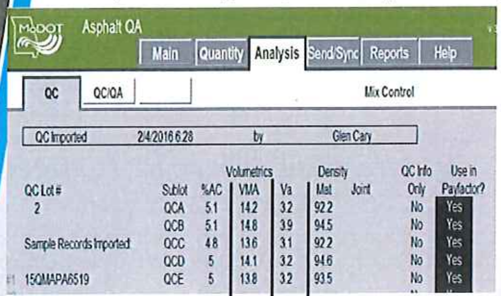
TSR results and pay adjustment for tonnage epresented based on requirement of one test per 0,000 tons or fraction thereof. This is applied eparate from the PWL pay adjustment.

TOTAL PAY FACTOR= 84.2

UNCONF. JOINT FACTOR= 90 TONS / S

(0.98-1.00)(10,000 tons)($45/ ton)= -$9000

"Asphalt QA" / Analysis / QC



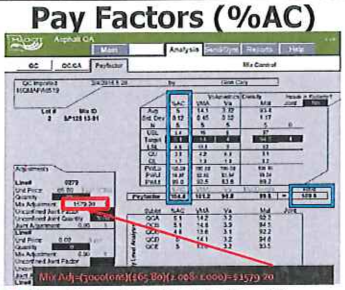
- Average 5.0 | 14.1 | 3.3 | 93.4
- Std Deviation 0.12 | 0.45 | 0.32 | 1.17
- N = 5 (all QC)

55

55

Pay Factors (%AC)

Enlarged



- LSL = Target – Tolerance = 5.1 - 0.3 = ***4.8***

$Q_U = \frac{USL - \bar{X}}{S}$ = (5.4 – 5.0)/0.12 = 3.33 = ***3.3*** → PWL_U = ***100.00***

$Q_L = \frac{\bar{X} - LSL}{S}$ = (5.0 – 4.8)/0.12 = 1.67 = ***1.7*** → 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***

56

56

Enlarged

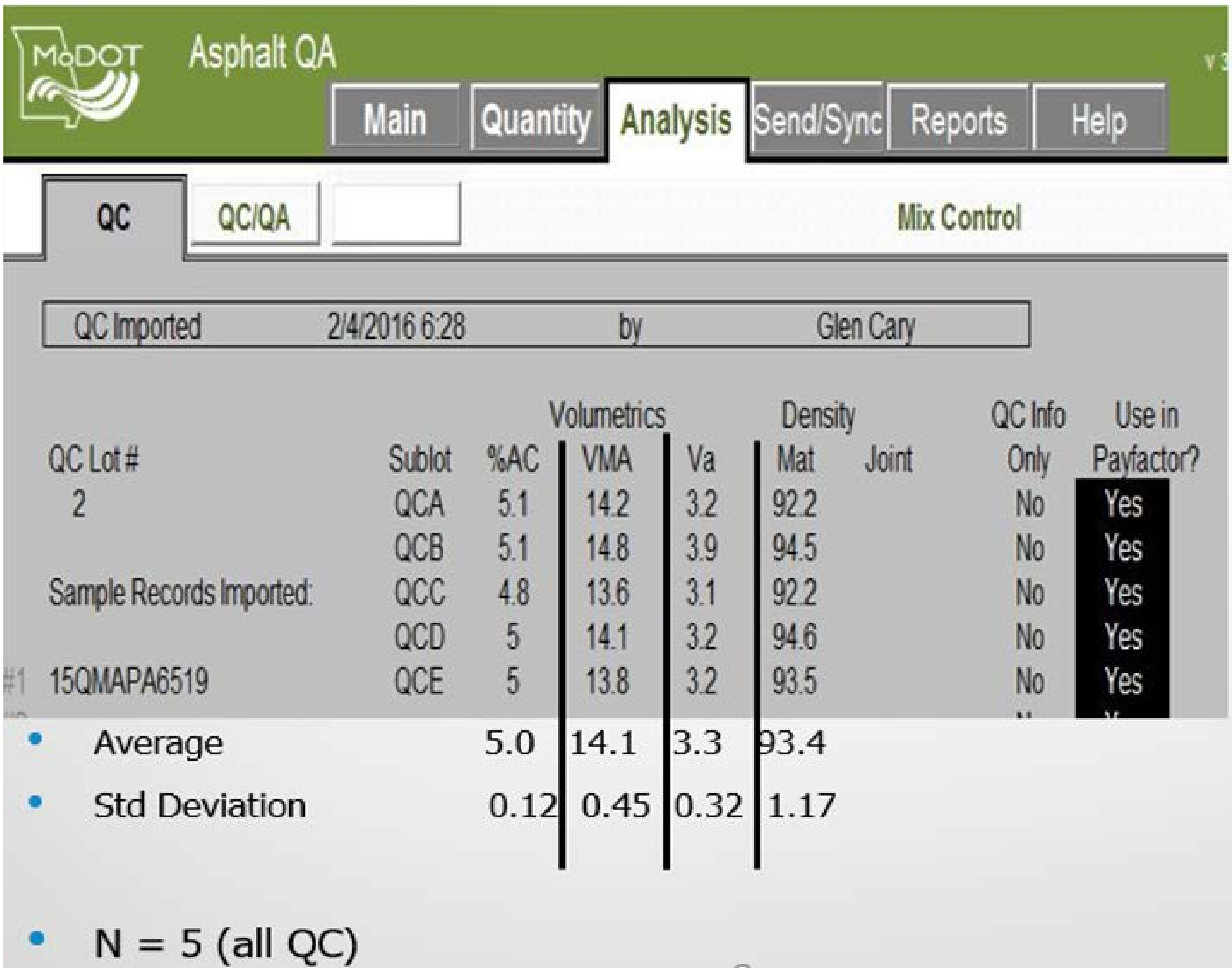
VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD								
QUALITY INDEX	PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES							
(Q_U or Q_L)	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10
2.56	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.57	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.58	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.59	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.60	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.61	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.62	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.63	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.64	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.65	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

- 3.3 → 100.00

57

57

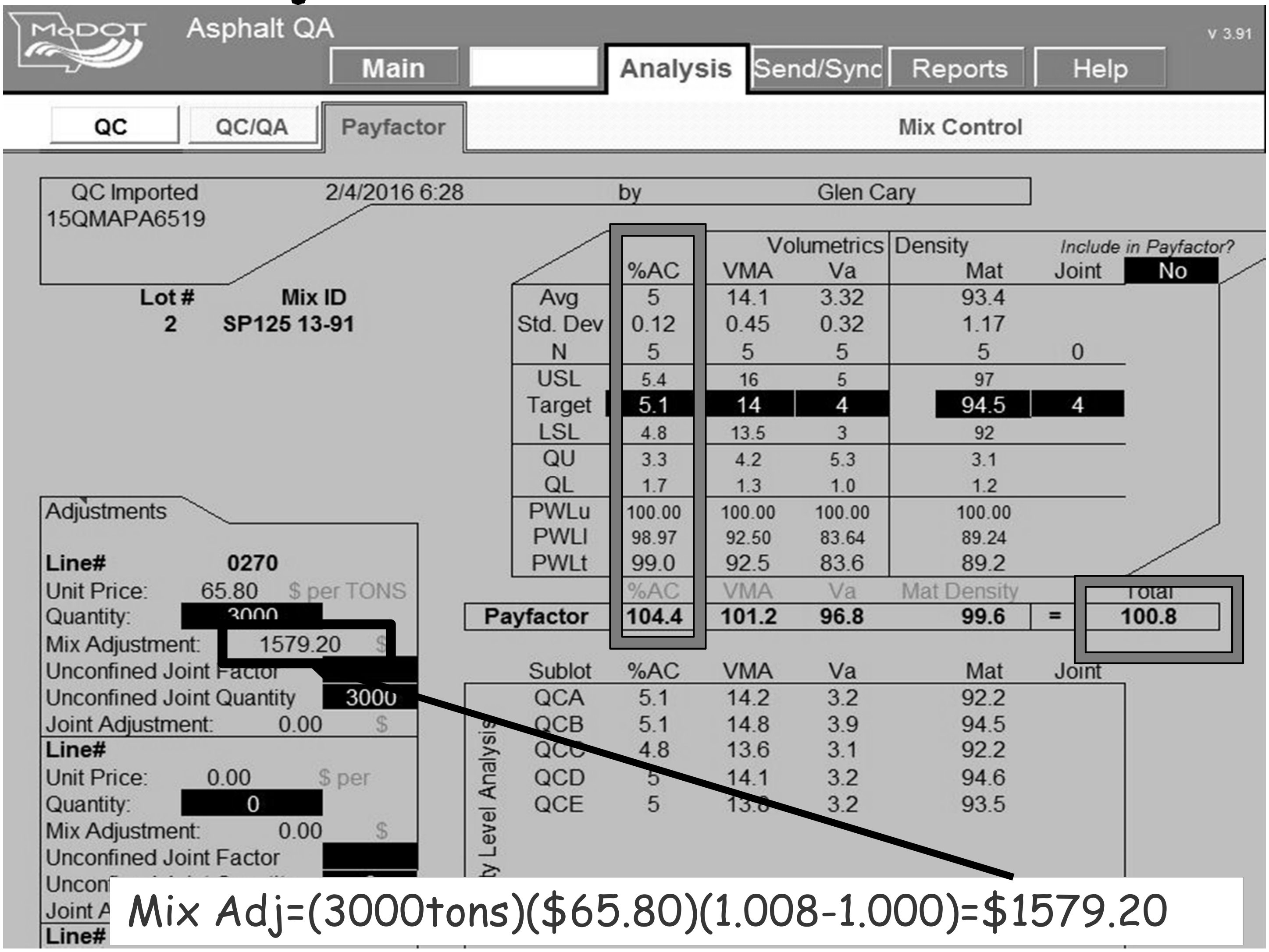
"Asphalt QA" / Analysis / QC



VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD								
QUALITY INDEX	PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES							
(Q_U or Q_L)	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10
2.56	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.57	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.58	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.59	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.60	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.61	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.62	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
2.63	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.64	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.65	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

- 3.3 → 100.00

Pay Factors (%AC)

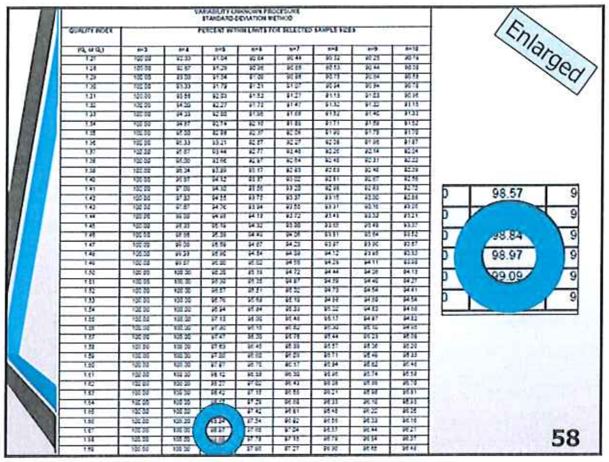


- USL = Target + Tolerance = 5.1 + 0.3 = ***5.4***
- LSL = Target – Tolerance = 5.1 - 0.3 = ***4.8***

$Q_U = \frac{USL - \bar{X}}{S}$ = (5.4 – 5.0)/0.12 = 3.33 = ***3.3*** → PWL_U = ***100.00***

$Q_L = \frac{\bar{X} - LSL}{S}$ = (5.0 – 4.8)/0.12 = 1.67 =***1.7*** → 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***



58

Shoulders

- In the case of a ***non-integral shoulder***, there is no QLA pay factor for density.
- Thus, the total PF is the ***average of the PFs for binder content, air voids, and VMA.***

59

59

VARIABILITY-UNKNOWN PROCEDURE STANDARD-DEVIATION METHOD								
QUALITY INDEX	**PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES**							
(Q_U or Q_L)	**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	[illegible]	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	[illegible]	97.90	97.27	96.90	96.65	96.48

Module 12

Quality Level Analysis (QLA)

MoDOT

MODULE 12

QUALITY LEVEL ANALYSIS (QLA)

Favorable and Unfavorable Comparison

Rev 11/17/2022

1

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.

2

2

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 ($\overline{QC}$) for a lot:

$[\overline{QC}-2(S)] \leq \boldsymbol{QA} \leq [\overline{QC}+2(S)]$

Or

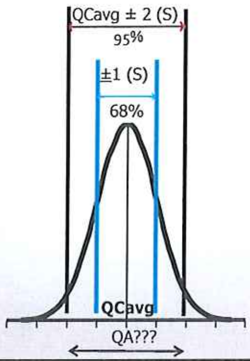
Within ½ of the specification tolerance, whichever is **greater.**

This applies to air voids(Va), VMA, %AC, and mat density.

3

3

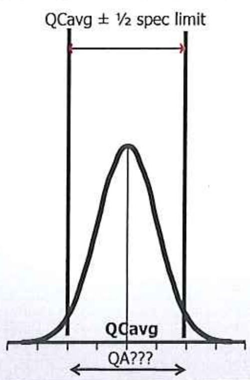
Does QA's result fall somewhere between (QC avg + 2 S) and (QC avg – 2 S) ?



4

4

Does QA's result fall somewhere between (QCavg + ½ spec limit) and (QCavg – ½ spec limit) ?



5

5

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?

6

6

Comparison QA to QC, cont'd.

First, should you use **2 (S)** or **½ the spec.** tolerance to establish the acceptable range??

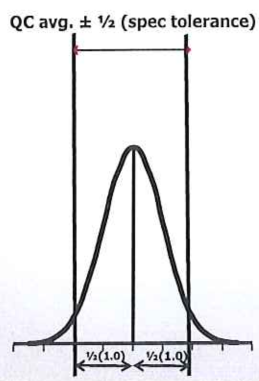
- Allowable range is -1.0% to + 1.0%, so the spec tolerance is 1.0%.
- Half of this is **0.5%.**

On the other hand:

- 2(S) = 2(0.44) = **0.88**

7

7



8

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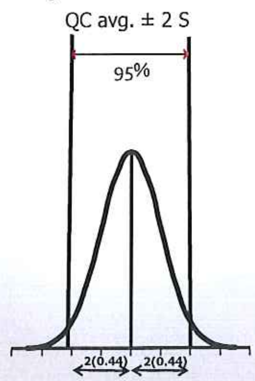
So, use the 2(S) criteria for establishing the allowable range.



9

9

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.

10

10

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

11

11

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 ± 0.6% of the mean of the QC results for a given lot.

12

12

Half Spec Range:

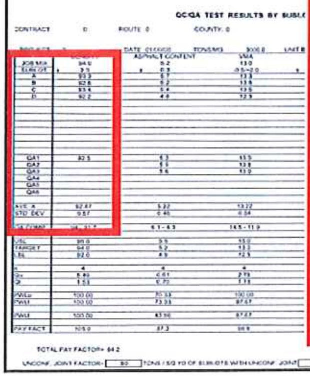
EPG 403.1.21

Parameter	Spec Tolerance (%)	½ Spec Tolerance (%)
Air Voids (Va)	1.0	0.5
Binder Content (Pb)	0.3	0.15
Mat Density	2.5	1.25
VMA	-0.5 to 2.0 = 2.5 (1.25 each "side")	0.6

13

13

QC: QA Comparison

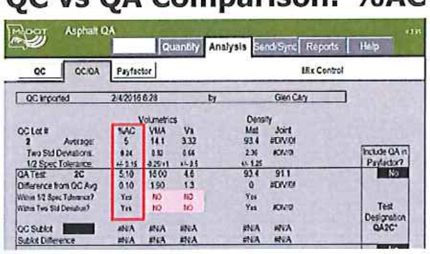


		DENSITY
JOB MIX		94.0
SUBLOT	±	2.0
A		93.3
B		92.6
C		93.4
D		92.2
QA1		92.5
QA2		
QA3		
QA4		
QA5		
QA6		
AVE. X		92.87
STD. DEV.		0.57
QA COMP.		94 - 91.7

91.7 < 92.87 < 94.0
OK

14

QC vs QA Comparison: %AC



- 2 Std Deviations = (2)(0.12) = **0.24**
- ½ Spec Tolerance = (½)(0.3) = **0.15**
- Difference (QA – QC_{avg}) = 5.10 – 5.00 = **0.10**
- Within ½ Spec Tolerance = 0.15? **Yes**
- Within 2 Std Dev = 0.24? **Yes**

15

15

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.

16

16

QLA

QLA = Quality Level Analysis

- What if QA falls outside of the QC range?
- ***"UNFAVORABLE COMPARISON"***
- See FAQ (also in EPG)

17

17

Example: QA Pb is Suspect, First Comparison

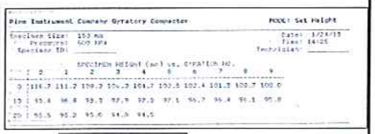
Example 1- QA Pb.xls			Initial QA results:	
			Pb	4.1
			Gmm	2.472
Initial Comparison:			Gmb	2.381
Target Pb=	5.2		Gsb	2.634
QC	5.7		Va	3.7
"	5.2		VMA	13.3
"	5.4			
"	5.2			
QC avg	5.38			
QC S	0.24			
Range,lower	4.90	QCavg - 2 (0.24)		
Range,upper	5.85	QCavg + 2 (0.24)		
QA	4.1			
Fit?	no			
	unfavorable			

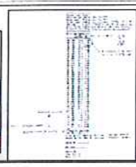
18

18

Unfavorable Comparison:
Case: QA Binder Content (Pb)

Step 1. Check both QC & QA data & calculations, re-weigh pucks, Rice specimens, check spreadsheet cell formulas.





19

19

Unfavorable Comparison
Loose Mix cont'd.

Step 2. If both QA & QC's data 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]

$$Q_L = \frac{\overline{X} - LSL}{S}$$

(Mean & S are now different)

↓

New PWL

↓

New PF

20

20

Add QA P_b, VMA, Air Voids to QC Sets
Re-run PWL's with QA included

	Pb5	VMA5	Va5
n	5	5	5
QC	5.7	13.3	3.9
QC	5.2	13.8	3.7
QC	5.4	13.5	3.0
QC	5.2	12.3	3.1
QA	4.1	13.3	3.7
Avg, n=5	5.12	13.24	3.48
S	0.61	0.56	0.40
USL	5.5	15	5
LSL	4.9	12.5	3
Qu	0.63	3.12	3.78
QL	0.36	1.31	1.19
PWLu	71.95	100	100
PWLL	62.73	92.03	88.97
PWLt	34.68	92.03	88.97
PF	19	101	99

So, choose to re-run QA retained split.

21

21

Unfavorable Comparison Loose Mix cont'd.

Step 3a. Or could jointly test a retained loose mix sample (QA or QC on suspect sublot):

- Run whole suite of tests (G_{mm}, G_{mb}, P_b)

22

22

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

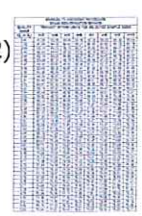
23

23

Unfavorable Comparison Loose Mix cont'd.

- Add QA's independent results to the 3 data sets (Pb, VMA, Va), now n = (4 + 1) = 5
- Re-run all 3 PWL analyses.

(This is shown in Step 2, previous slide 22)



$$Q_L = \frac{\overline{X} - LSL}{S}$$

24

24

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. Re-calculate Va and VMA.

Now you have new QA test values for each parameter (air voids, VMA, binder content).

25

25

Step 3b: QA's Retained Pb Very Different

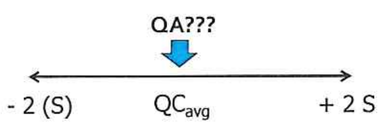
Step 3b:	QA		
	Retained	Original:	Close?
Pb	5.3	4.1	no
Gmm	2.475	2.472	yes
Gmb	2.388	2.381	yes
Va	3.5	3.7	
VMA	14.1	13.3	

26

26

Unfavorable Comparison, Loose Mix cont'd.

For each parameter (Pb, VMA, Va) , re-run the lot comparison of QA vs QC:



- If all 3 are favorable, use these results to re-run PWL (n = 4).

27

27

Comparison Using QA Retained Sample Values

	Pb	VMA	Va
QC	5.7	13.3	3.9
QC	5.2	13.8	3.7
QC	5.4	13.5	3.0
QC	5.2	12.3	3.1
QC avg	5.38	13.2	3.4
S	0.24	0.65	0.44
Range,lower	4.90	11.93	2.54
Range,upper	5.85	14.53	4.31
Retained QA	5.3	14.1	3.5
Fit?	yes	yes	yes
	favorable	favorable	favorable

28

28

If All 3 Are Favorable, Use These Results to Re-run PWL

(n = 4)

	Pb	VMA	Va
n	4	4	4
QC	5.7	13.3	3.9
QC	5.2	13.8	3.7
QC	5.4	13.5	3.0
QC	5.2	12.3	3.1
Avg, n=4	5.38	13.2	3.4
S	0.24	0.65	0.44
USL	5.5	15.0	5.0
LSL	4.9	12.5	3.0
Qu	0.53	2.73	3.56
QL	2.01	1.12	0.96
PWLu	67.67	100	100
PWLL	100	87.33	82
PWLt	67.67	87.33	82
PF	85	99	96

29

29

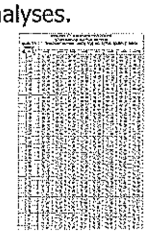
Unfavorable Comparison, Loose Mix cont'd.

- **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.

$$Q_L = \frac{\overline{X} - LSL}{S}$$



30

30

Unfavorable Core Comparison

Rev 10/26/2022 31

31

Example: QA Core is Suspect From First Comparison

QC		93.3
QC		92.6
QC		93.4
QC		92.2
QC avg		92.9
QC S		0.57
Range,lower		91.7
Range,upper		94.0
QA		91.2
Fit?		no
		Unfavorable

32

32

CORES

- **Case:** QA core is taken at the same location as one of the QC core sample locations.
- **Step 1** - check core and G_{mm} 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.

33

33

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.

34

34

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 Gmc for the sublot. Re-compute the sublot's QC % Density
- Re-compute the lot's QC % Density average and standard deviation

35

35

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	(using QC Gmm, no QA Gmm from Lot C)
Also, this is new QC Gmc for sublot C, so %Density =	92.4	(using QC Gmm)

QC	93.3
QC	92.6
new QC	92.4
QC	92.2
new avg	92.63
new S	0.48

36

36

CORES. Cont'd.

- **Step 5** - Re-run the QA vs QC comparison

37

37

Step 5: Re-run the QA vs QC Comparison

QC		93.3
QC		92.6
new QC		92.4
QC		92.2
QC avg		92.63
QC S		0.48
Range,lower		91.67
Range,upper		93.58
QA		92.4
Fit?		yes
		favorable

38

38

Step 6: If Favorable, Run the PWL Analysis with New QC Data

	%Density
n	4
QC	93.3
QC	92.6
new QC	92.4
QC	92.2
Avg, n=4	92.63
S	0.48
USL	97
LSL	92
Qu	9.14
QL	1.31
PWLu	100
PWLL	93.66
PWLt	93.66
PF	102

39

39

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 PWL (n = 5).

40

40

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.

41

41

Outliers

- Lot data may be examined for outliers via ASTM E 178.
- Eligible tests:
  - G_{mb}, G_{mc}, G_{mm}, P_b
- Process is somewhat moot with the advent of the retained split testing procedure now in place.
- See Appendix.

42

42

Dispute Escalation

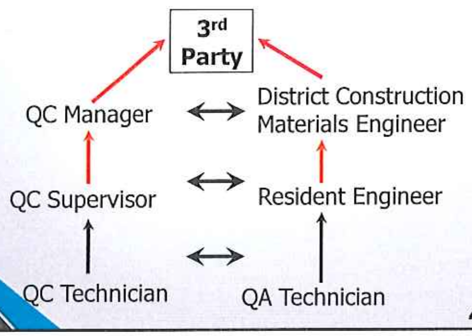
- Look at the QC/QA Checklist—is a hierarchy of resolution levels and associated time frames.
- Make decisions at lowest possible level.

43

43

Conflict Resolution

Example



44

44

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

45

45

Coring Summary

Where	Who	Core Location Determination	Coring Frequency	Pay Factor Type
Traveled Way	QC	Random Number	1 sample/sublot	QLA Pay Factor
	QA	Random Number	1 sample/ 4 sublots	
Integral shoulder	none			
Non-integral shoulder	Not QLA	Random Number	RE discretion	Density Pay Adjustment Factor
Longitudinal Joint, confined	Considered part of the traveled way			
Longitudinal Joint, unconfined	QC	Random Number	1 sample/sublot	Longitudinal Joint Density Pay Adjustment Factor
	QA	Random Number	1 sample/ 4 sublots	
Base widening, entrances	Not QLA	????	RE discretion	Density Pay Adjustment Factor
Single lift (traveled way)	QC (not QLA)	Random Number	1 Sample/sublot	Density Pay Adjustment Factor

46

TSR Pay Adjustment

TSR	% of Contract price
≥90	103
75-89	100
70-74	98
65-69	97
<65	Remove

47

47

Density Pay Adjustment Factor

Field Density, % of Gmm	% of Contract price
92.0-97.0	100
91.5-91.9 or 97.1-97.5	90
91.0-91.4 or 97.1-97.5	85
90.5-90.9 or 97.6-98.0	80
90.0-90.4 or 97.6-98.0	75
Below 90.0 or above 98.0	Remove & replace

48

48

Longitudinal Joint Density Pay Adjustment Factor (PAF)	
Field Density, % of Gmm	**% of Contract Unit Price**
90.0 - 96.0	100
89.5 - 89.9 **or** 96.1 - 96.5	90
89.0 - 89.4 **or** 96.6 - 97.0	85
88.5 - 88.9 **or** 97.1 - 97.5	80
88.0 - 88.4 **or** 97.6 - 98.0	75
Below 88.0 **or** above 98.0	Remove & replace

49

49

Non-Integral shoulders & Small Quantities

- Use the Density Pay Adjustment Table
- Use of the factors for non-integral shoulders is at the Resident Engineer's discretion

50

50

Confined Longitudinal Joint Density Evaluation

- Density in confined joints is handled with the traveled way coring. Required density is same as for the traveled way (94.5 ± 2.5%).

51

51

Smoothness Pay Adjustment (IRI)

Table 1 (> 45 mph)	
IRI (in/mile)	% Contract Price
40.0 or less	105
40.1-54.0	103
54.1-80.0	100
80.1 or greater	100 after correction to 80.0

Correction = diamond grinding

Table 2 (≤45 mph)	
IRI (in/mile)	% Contract Price
70.0 or less	103
70.1-125.0	100
125.1 or greater	100 after correction to 125.0

52

52

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.

53

53

Remove & Replace

- All lots with a PF_T < 50.0
- Any sublot with < 90.0 or >98.0% density
- Any sublot 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.

54

54

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.

55

55

Remove & Replace

- Replacement mix will be sampled & tested to calculate PWL

56

56

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.

57

57

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.

58

58

Record Keeping and Exchange of Data

59

59

** PROCESS REVIEW TEAM NOTED 2008*

60

60

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***

61

61

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.

62

62

Documents On Hand

- ***Job mix***
- ***QC plan***
- ***Current copies of all test method procedures***

63

63

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***

64

64

Calibration

Equipment	Requirement	Interval (month)
Gyro	Calibrate	12
Gyro	Verify	Daily ; when moved
Gyro molds	Dimensions	12
Thermometer	Calibrate	12
Vacuum	Pressure	12
Pycnometer	Calibrate	Daily
Ignition oven	Verify	12 or when moved

65

65

Calibration, Cont'd

Equipment	Requirement	Interval (month)
Nuclear gage	Drift & stability	1
Shakers	Sieving thoroughness	12
Sieves	Physical condition	12
Ovens	Verify settings	12
Balances	Verify	12 or when moved
Timers	Accuracy	12

66

66

QC Records

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

67

67

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.

68

68

Module 13

Performance Testing

MoDOT SUPERPAVE QC/QA TRAINING/CERTIFICATION COURSE

MODULE 13

The Future?

Balanced Mix Design
Performance Testing

1

Balanced Mix Design Performance Testing and Increased Density

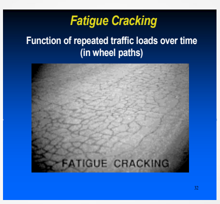
- Moving from ***materials & methods.*** specifications to ***performance*** specifications. (Balanced Mix Design = BMD).
- What properties of the final product are we interested in, rather than some component of the final product.
- Via Job Special Provisions (JSP's) at this point.

2

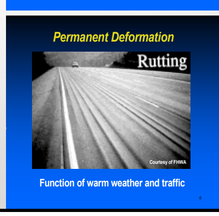
2

Properties of Interest

- ***Fatigue cracking-*** Ideal CT or "CT_{Index}"



- ***Rutting*** (and stripping)- "Hamburg Wheel Tracker"



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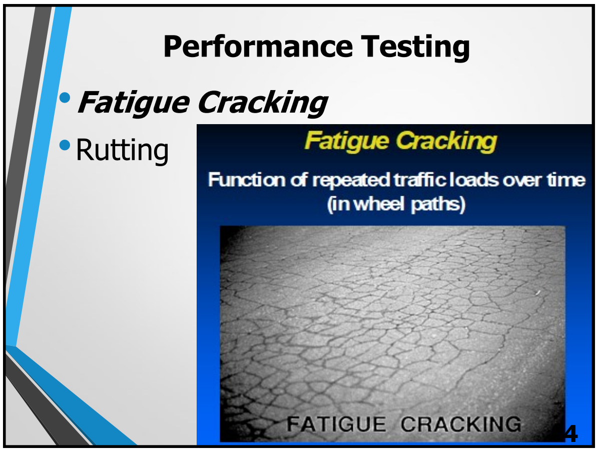
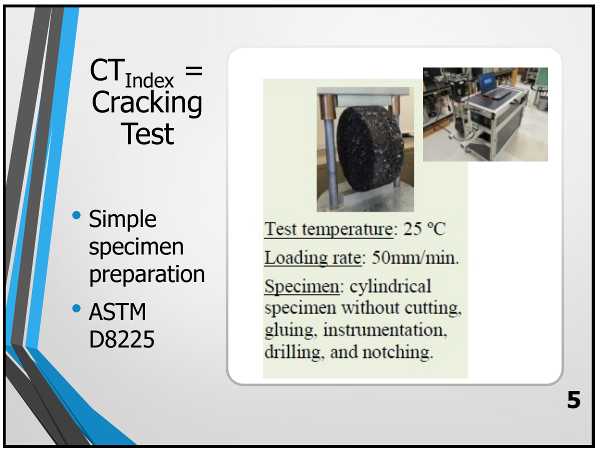
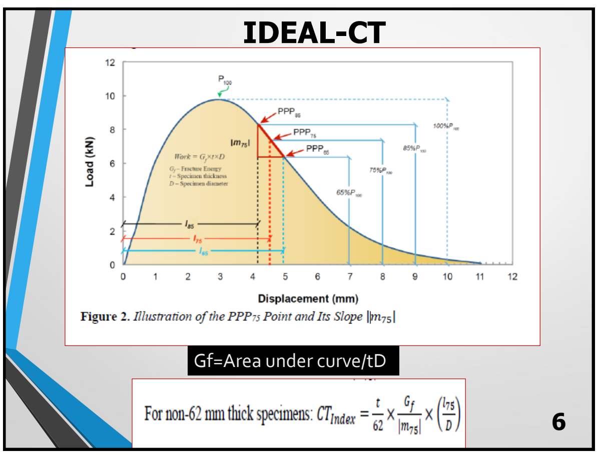

Performance Testing
Fatigue Cracking
Rutting
Fatigue Cracking
Function of repeated traffic loads over time (in wheel paths)
FATIGUE CRACKING
4

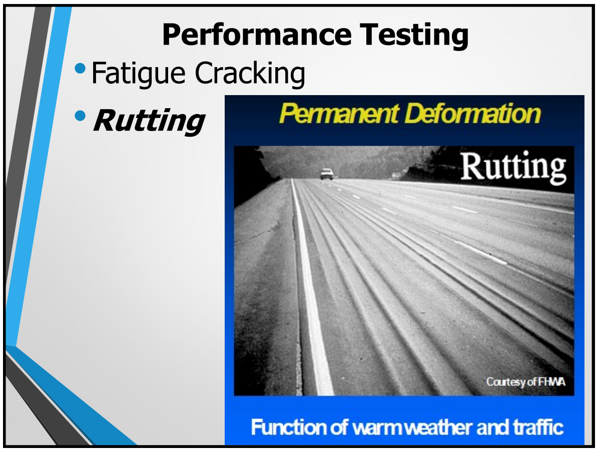
4


CT Index = 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.
5

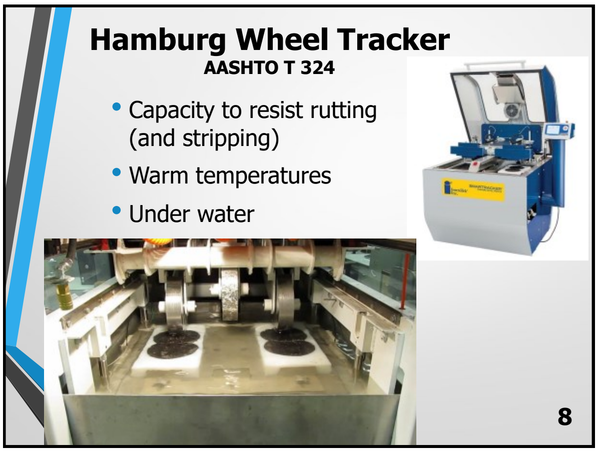
5


IDEAL-CT
Load (kN)
Displacement (mm)
Figure 2. Illustration of the PPP75 Point and Its Slope |m75|
Gf=Area under curve/tD
For non-62 mm thick specimens: $CT_{Index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$
6

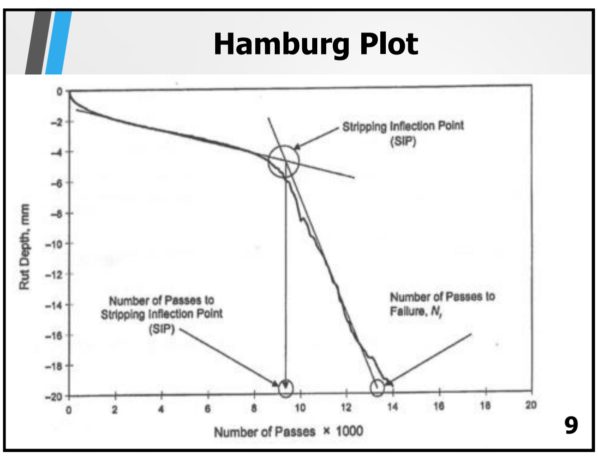
6


Performance Testing
Fatigue Cracking
Rutting
Permanent Deformation
Rutting
Courtesy of FHWA
Function of warm weather and traffic

7


Hamburg Wheel Tracker
AASHTO T 324
Capacity to resist rutting (and stripping)
Warm temperatures
Under water
8

8


Hamburg Plot
Stripping Inflection Point (SIP)
Rut Depth, mm
Number of Passes to Stripping Inflection Point (SIP)
Number of Passes to Failure, N_f
Number of Passes × 1000
9

9

Good Marginal (Barely In-Spec)
Poor (In-Tolerance/Out-of-Spec)

10

10

QC/QA
BMD Projects

- QC: 1 per 10,000 tons
- QA: 1 per 20,000 tons
- ***Up to 3% incentive for CT_{Index} in range and***
- ***Hamburg is <12.5 mm***
- ***1% incentive for greater field density (>94 for non SMA and with unconfined joint density >90.0%).***
- Favorable comparison: QA and QC are within 20%.

11

11

Number and Size of Specimens

Performance Test	Min # of Pucks/Set	Molded Ht. mm
CT_{Index}	3	62
HWT	4	62
AMPT	5	180

Cracking Tolerance Index – CT_{Index}
Hamburg Wheel Track – HWT
AMPT – Samples for Research Purposes

12

12

CT$_{Index}$

Tested according to ASTM D8225 @ 25±1°C

Non SMA Mixtures	
CT$_{Index}$	**% of Contract Price**
< 45	97%
45-97	100%
>97	103%
SMA Mixtures	
CT$_{Index}$	**% of Contract Price**
< 135	97%
135 – 240	100%
➢240	103%

13

13

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.

PG Grade High Temperature *	Minimum Wheel Passes	Maximum Rut Depth (mm)
58S-xx	5,000	12.5
64S-22	7,500	12.5
64H-22	15,000	12.5
64V-22	20,000	12.5

*Determined by the binder grade specified in the contract.

14

14

Design Gyrations

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.

Mixture	Volume of Effective Asphalt (percent)
SP125	11.0
SP095	12.0
SP048	13.0

The minimum gyration level shall be in accordance with the following:

Design	N_{design}
F	35
E	50
C	60
B	65

15

15

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

16

16

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

On the Horizon

17

17

Balanced Mix Design Performance Testing and Increased Density NJSP-20-01B

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_{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_{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_{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:

Performance Test	Minimum Number of Specimens per Set	Molded Specimen Height (mm)
Cracking Tolerance Index (CT_{Index})	3	62
Hamburg Wheel Track (HWT)	4	62
AMPT Samples for Research Purposes	5	180

When QA testing is to be performed, three sets shall be fabricated for CT_{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_{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_{Index}) Testing. The CT_{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_{Index} results are within the incentive range and HWT results are below 12.5 mm.

Non SMA Mixtures	
Cracking Tolerance Index (CT_{Index})	**Percent of Contract Price**
< 45	97%
45 - 97	100%
> 97	103%

SMA Mixtures	
Cracking Tolerance Index (CT_{Index})	**Percent of Contract Price**
< 135	97%
135 - 240	100%
> 240	103%

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.

PG Grade High Temperature *	Minimum Wheel Passes	Maximum Rut Depth (mm)
58S-xx	5,000	12.5
64S-22	7,500	12.5
64H-22	15,000	12.5
64V-22	20,000	12.5

*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.

Mixture	Volume of Effective Asphalt (percent)
SP125	11.0
SP095	12.0
SP048	13.0

The minimum gyration level shall be in accordance with the following:

Design	N_{design}
F	35
E	50
C	60
B	65

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:

Field Density (Percent of Laboratory Max. Theoretical Density)			**Pay Factor (Percent of Contract Unit Price)**
For all SP mixtures other than SMA:			
		92.0 to 97.5 inclusive	100
97.6 to 98.0	or	91.5 to 91.9 inclusive	90
	or	91.0 to 91.4 inclusive	85
	or	90.5 to 90.9 inclusive	80
	or	90.0 to 90.4 inclusive	75
Above 98.0	or	Below 90.0	Remove and Replace
For SMA mixtures:			
		>94.0	100

		93.5 to 93.9 inclusive	90
		93.0 to 93.4 inclusive	85
		92.5 to 92.9 inclusive	80
		92.0 to 92.4 inclusive	75
		Below 92.0	Remove and Replace

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

Superpave QC/QA

Who's Doin' What

1

What is QC/QA?

Quit

Checking

Quit

Asking

2

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.

3

Benefits of Meeting Quality Requirements

- If meet or exceed quality requirements:
  - Pavement/Material will perform satisfactory during its design life.
  - Require less maintenance to maintain.
  - Better use of highway funds.
  - Driver satisfaction.

4

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.

5

Parts of Quality Assurance

Quality Control (QC) | Independent Assurance Samples (IAS) | Quality Acceptance (QA)

6

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.

7

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].

8

Quality Control (QC)

- Activities performed:

1) Testing Material
2) Inspecting Operation

9

Quality Control (QC)

- Testing Material

1) Required Testing

- Minimum number required.
- Samples random & designated by engineer.
- Do not provide to much advance notice about random sample locations.
- Test results shall comply with the specifications.

10

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.

11

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).

12

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.

13

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.)

14

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

15

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.

16

Quality Control (QC)

- Communication is critical
- Advising QA Inspector about:
  - All test results.
  - Mix design adjustments.
  - Production schedules.
  - Changes in production.

17

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.

18

Quality Acceptance (QA)

- Activities Performed:

1) Acceptance Testing
2) Assurance Testing
3) Inspection

19

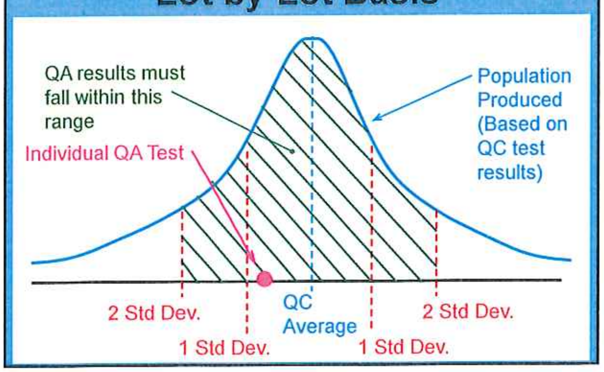
Quality Acceptance (QA)

- Acceptance Testing

- Performing to accept QC test results.
- Test performed on independent samples.
- Minimum number of test required; perform as many test needed to ensure the quality.
- Random sample location.
- Favorable comparison required for each tested sample.

20

Favorable Comparison Lot by Lot Basis



21

Quality Acceptance (QA)

- Acceptance Testing *(continued)*

- If sample(s) do not compare, QC test results may not 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).

22

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 $PWL_t < 70\%$; $PF = (2 * PWL_t) - 50$

23

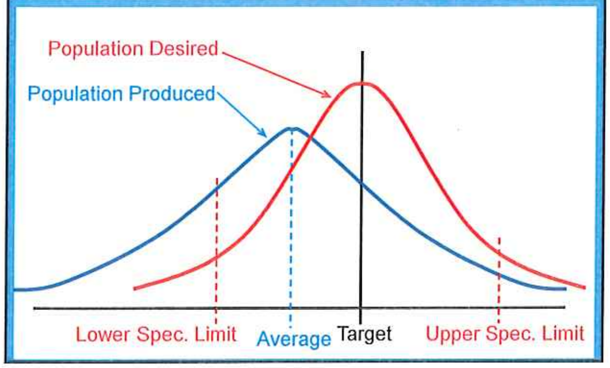
Did you know?

- 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)

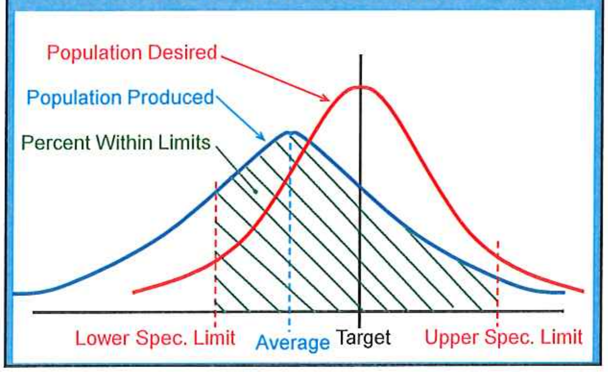
24

Percent Within Limits



25

Percent Within Limits

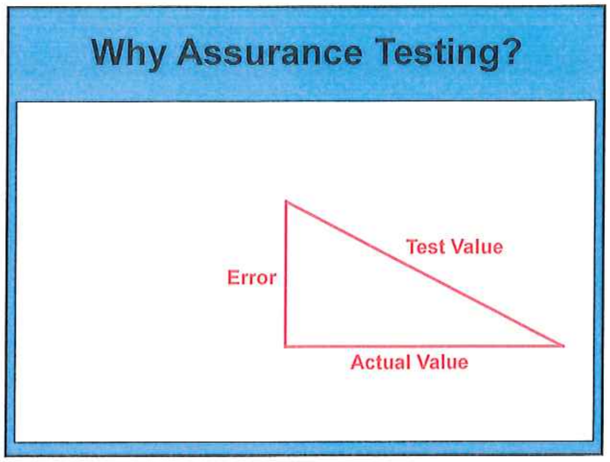


26

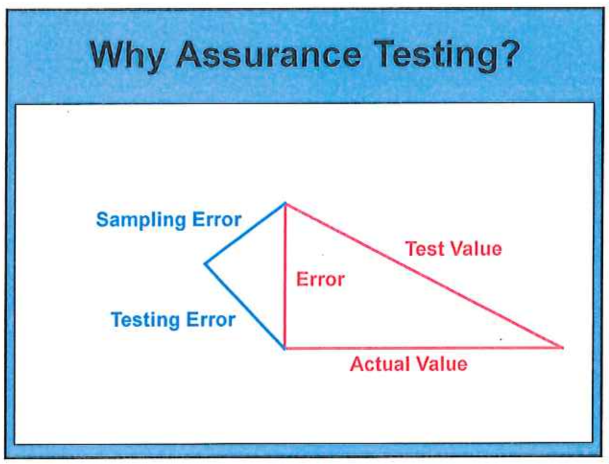
Quality Acceptance (QA)

- 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.

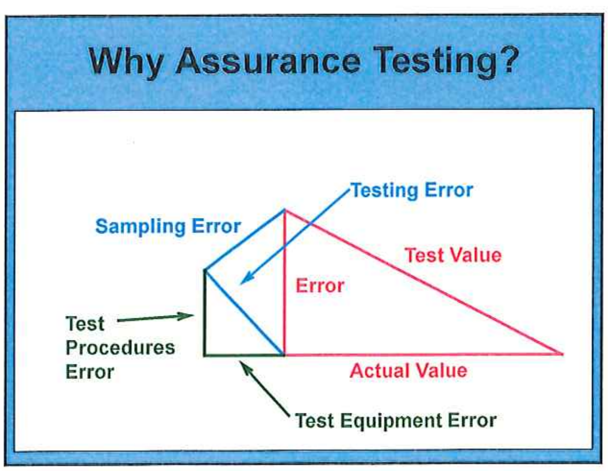
27


Why Assurance Testing?
Test Value
Error
Actual Value

28


Why Assurance Testing?
Sampling Error
Test Value
Error
Testing Error
Actual Value

29


Why Assurance Testing?
Testing Error
Sampling Error
Test Value
Error
Test
Procedures
Error
Actual Value
Test Equipment Error

30

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.

31

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.

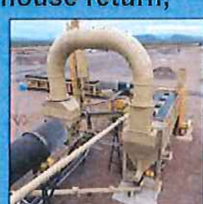
32

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.).

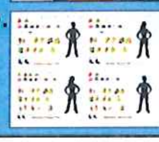


33

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.



34

Quality Acceptance (QA)

- Communication is critical.
- Advising QC Inspector about:
  - All test results.
  - Any items of concerns.
- QA inspector needs to keep Resident Engineer and District Construction & Materials Engineer advised of any problems.

35

QUESTIONS

36

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

MoDOT

Appendix Item #1.

OUTLIER EVALUATION

ASTM E 178

Applies to test values: G_{mm}, G_{mb}, % binder, core sp. gravity

1. If the largest test value (x_{max}) in the set is suspected to be an outlier, calculate the t-statistic:

$$t = \frac{(x_{max} - x_{avg})}{S}$$

Where X_{avg} = average
S = standard deviation

2. If the smallest test value (x_{min}) in the set is suspected to be an outlier, calculate the t-statistic:

$$t = \frac{(x_{avg} - x_{min})}{S}$$

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 sublot:

No. of tests	t @ 5% in tail
3	1.153
4	1.463
5	1.672
6	1.822
7	1.938
8	2.032
9	2.110
10	2.176

If the *calculated t-statistic* is greater than $t_{critical\ (\alpha=5\%)}$, consider the test result to be an outlier. Material from the retained QA or QC sample may be tested to determine a replacement value.

QCQA/OutlierEvalE178.doc (12-18-02; revised 9-23-03; revised 3-2-09; 4-24-09))

ASTM E-178 Dealing with Outlying Observations

Example

G_{mm} – 2.474, 2.478, 2.484, 2.522

$$\bar{x} = 2.490$$

$$s = 0.022$$

max

$$T_n = \frac{(x_n - \bar{x})}{s} = \frac{(2.522 - 2.490)}{0.022} = 1.455 \quad < 1.463$$

min

$$T_1 = \frac{(\bar{x} - x_1)}{s} = \frac{(2.490 - 2.474)}{0.022} = 0.727 \quad < 1.463$$

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.

MoDOT SUPERPAVE QC/QA TRAINING/CERTIFICATION COURSE

MODULE 2C(1)

MIX DESIGN OVERVIEW:

Binder

RAP & Shingles

11-24-06 Revision
11-9-07 Revision, 4-22-09 Revision
11-18-09 Revision, 12-29-09 Revision
11-17-10 Revision, 1-19-11 Revision
3-2-12 Revision, 2-26-13 Revision
12-18-13 Revision, 12-29-14 Revision
2-4-15 Revision, 12-28-16 Revision
2-16-18 Revision, 12-12-18 Revision
12-17-19 Revision, 1-30-20 Revision
1-20-21 Revision

1

OUTLINE

- ***Module 2c(1):***
  - ***Binder grading & selection***
  - M 332 grades
- Module 2c(2):
  - Testing & evaluation
  - RAP & shingles
  - Mixing & compaction temperatures

2

2

ASPHALT (BINDER) GRADING

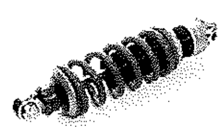
- Binder produced in grades
- Grades based on viscosity-temperature behavior
- Choice of grade depends primarily on climate

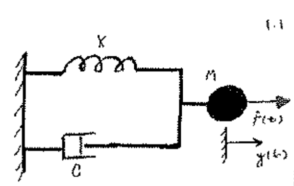
3

3

ASPHALT (BINDER) BEHAVIOR

- Based on ***rheology***
  - Rheology: study of flow and deformation
- Asphalt cement is a ***viscoelastic*** material:
  - Elastic: spring
  - Viscous: dashpot (piston)



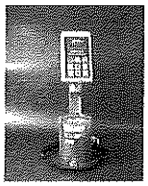


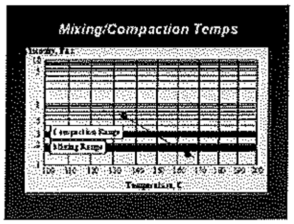
4

4

Binder Behavior

- Asphalt is a ***thermoplastic***
- Behavior depends on:
  - ***Temperature***





  - ***Duration of loading***

  - ***Aging*** (properties change with time)

5

5

SELECTION OF PG BINDER GRADE

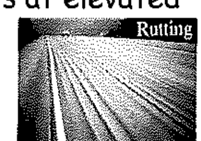
- Based on:
  - ***Climate***
  - Depth in pavement
  - Volume of traffic
  - Vehicle speed
  - Desired level of reliability
  - RAS (shingle) content
  - RAP content

6

6

SELECTION OF PG BINDER GRADE
Climate

- *Grade chosen primarily on temperature expected:*
  - to prevent ***rutting***, based on cumulative hours at elevated temperatures

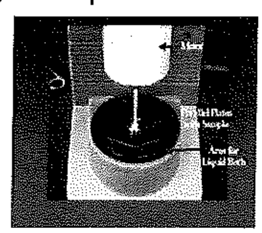


  - to prevent ***cold temperature cracking***, based on average single-day low temperature

7

CONDITIONING/TESTING

- Rutting: High temperature (DSR)



- Fatigue Cracking: Intermediate temperature (DSR)
- Cold-temperature cracking: cold temperature (BBR)

8

8

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)

9

9

AASHTO M320 PG GRADING SYSTEM

- 6 degree increments

Table 3.1 Superpave Binder Grades

High Temperature Grades (Degrees C)	Low Temperature Grades (Degrees C)
PG 46	-34, -40, -46
PG 52	-10, -16, -22, -28, -34, -40, -4(
PG 58	-16, -22, -28, -34, -40
PG 64	-10, -16, -22, -28, -34, -40
PG 70	-10, -16, -22, -28, -34, -40
PG 76	-10, -16, -22, -28, -34
PG 82	-10, -16, -22, -28, -34

10

10

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

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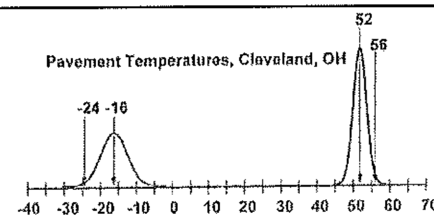

Figure 5.3 Example High and Low Pavement Temperature Variations

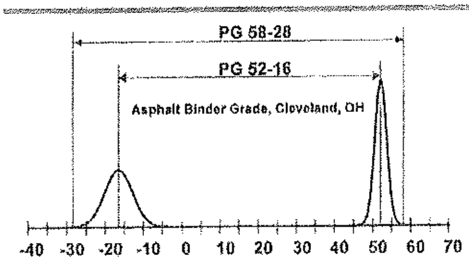

Figure 5.4 Superpave Binder Grade Selections for Cleveland

12

12

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

13

13

TO MODIFY
Optional Materials

- Polymer (eg. elastomeric polymer)
- Polyphosphoric acid (PPA)
- REOB = Re-refined engine oil bottoms
- Air-blown asphalt
- Others

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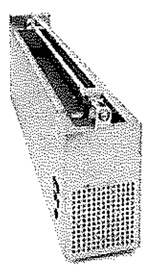
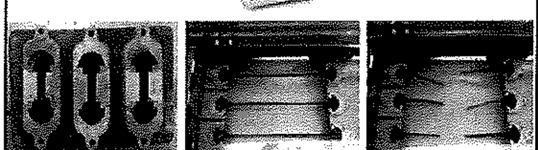
14

DO I REALLY HAVE POLYMER IN MY BINDER?

- M320 has the Elastic Recovery test- MoDOT has this in the 1015 spec



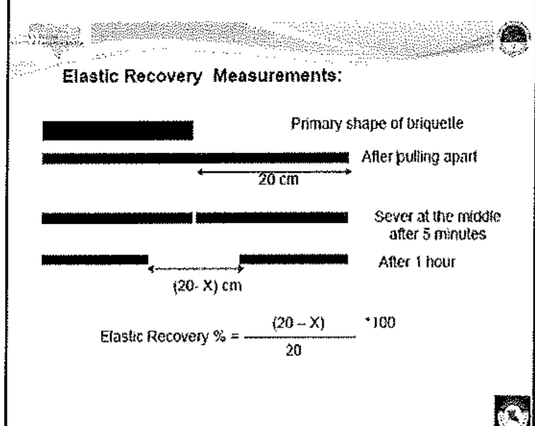


(a) (b) (c)

15

15

Elastic Recovery (%)



- *Greater %ER is better*

16

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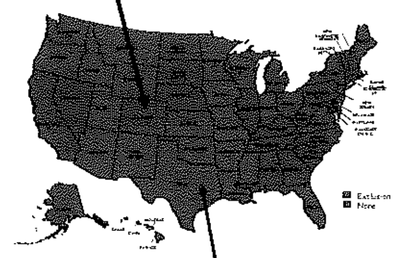
Section 1015.10.3

Grade	ER, min. %
PG 64-22, 58-22, 58-28	--------
PG 70-22	55
PG 76-22	65

17

17

State DOTs with Binder "Exclusions" (don't allow): (PPA, REOB, Air Blown Asphalt, Other)



Other DOTs handle the problem in different ways

18

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

19

19

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

20

20

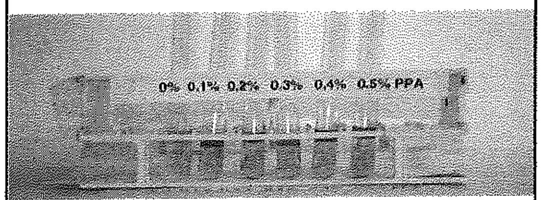
PPA
Possible Issues, cont'd.

- Good communication with contractor regarding potential use of amine-based LAS
  - Ensure compatibility with WMA & LAS

21

21

Simple Test to Detect PPA in Asphalt



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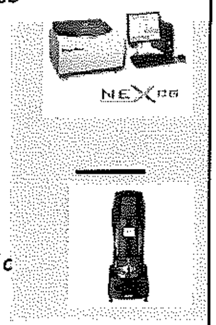
Other Analysis Methods

- To detect PPA in Asphalt
  - XRF - detect presence of phosphorous
  - 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 - REOBs can contain a heat stabilizing additives that can contain up 8% Phosphorous, 8.5% Zinc



23

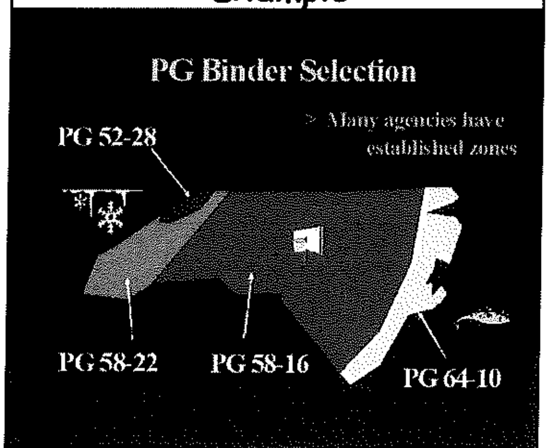
SELECTION OF PG BINDER GRADE
Climate

- 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

24

24

MATCH GRADE TO CLIMATE-
Example



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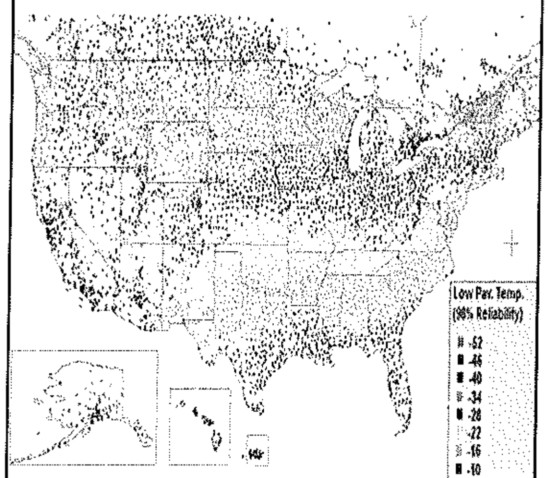
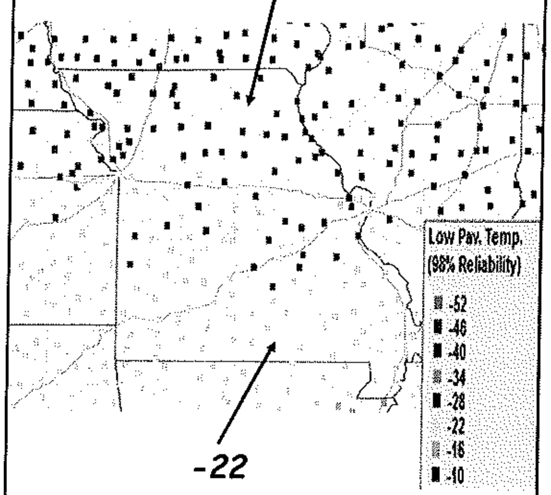
LTPPBind Program
Lower PG Number
(Low Temperature Values)



26

-28



-22

27

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

28

28

SELECTION OF PG BINDER GRADE
Depth in Pavement

- Place better binder ("modified" binder) in surface mix and first underlying layer (top 4")

29

29

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

30

30

Binder Grading Specs

- The following slides refer to traditional M 320 binder grades (not M 332 "MSCR") unless noted

31

31

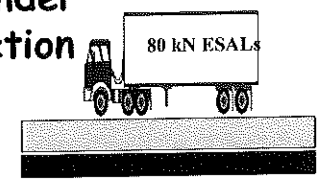
SELECTION OF A BINDER GRADE

- *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*

32

32

Effect of Traffic Amount on Binder Selection



- 10 to 30 x 10^6 ESAL
  - Consider increasing - - one high temp grade
- ≥ 30 x 10^6 + ESAL
  - Recommend increasing - - one high temp grade

> **<u>E</u>quivalent <u>S</u>ingle <u>A</u>xle <u>L</u>oads**

33

33

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

34

34

Vehicle Speed

- Slower → increased rutting
- Stopped → worst case for rutting

Why?

- Longer duration of load

35

35

Effect of Loading Rate (*Vehicle Speed*) on Binder Selection

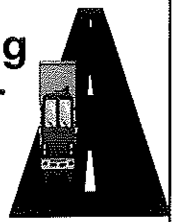
- Can bump up a grade (increase high temperature number) for slow moving (less than 35 mph) traffic [MoDOT uses 12-45 mph]
- MoDOT bumps 2 grades for <12 mph
- Grade bumps apply to the surface mix and the top lift of the underlying mixture
- Grade bumping: no effect on low temp grade

36

36

Effect of Loading Rate on Binder Selection

under revision



90 kph

- Example
  - for toll road PG 64-22
  - for toll booth PG 70-22
  - for weigh stations PG 76-22

Slow

Stopping

37

37

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

38

38

SELECTION OF PG BINDER GRADE *Reliability*

- 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 is typically chosen for more critical situations
- Some DOT's choose 98% reliability for all binder grades

39

39

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***

40

40

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

41

41

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

42

42

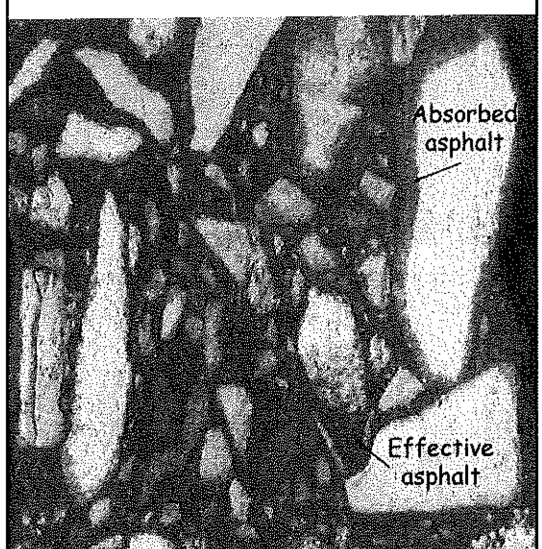
"Effective Binder"

- When dealing with recycled materials, interested in "***effective binder***", not total binder

43

43

ABSORPTIVENESS OF AGGREGATE



44

Appendix Item #3

BINDER CONTENT

Conceptually:

- $P_b = P_{ba} + P_{be}$
  - P_b= total binder content
  - P_{ba} = absorbed binder
  - P_{be} = effective binder

45

45

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%

46

46

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)

47

47

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

48

48

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

49

49

MoDOT Binder Selection- Depth, Traffic Volume, Vehicle Speed

Corridor	Layer	Binder Grade
Interstates	Surface= SP125 or SMA & 1st underlying lift Remaining lifts	PG76-22 PG64-22
Major Routes Heavy Volume	Surface= SP125 & 1st underlying lift Remaining lifts	PG70-22 PG64-22
Major Routes Medium or Low Volume	Surface= SP125 or BP-1 Underlying lifts	PG64-22 PG64-22
Minor Routes	All (generally BP-1 surface)	PG64-22

50

50

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)

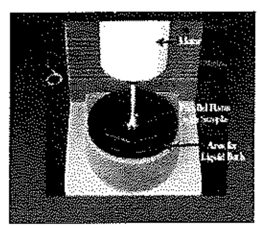
51

51

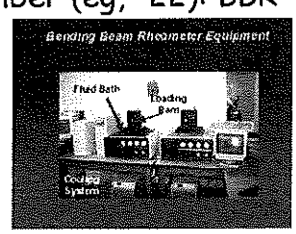
BINDER TESTING

PG 64-22

- Upper PG number (eg, 64): DSR



- Lower PG number (eg, -22): BBR



52

OUTLINE

- ***Module 2c(1):***
  - Binder grading & selection
  - *M 332 grades*
- Module 2c(2):
  - Testing & evaluation
  - RAP & shingles
  - Mixing & compaction temperatures

53

53

ALTERNATE GRADING SYSTEMS

- Original: ***M 320***
- ~New (MSCR): ***M 332***

54

54

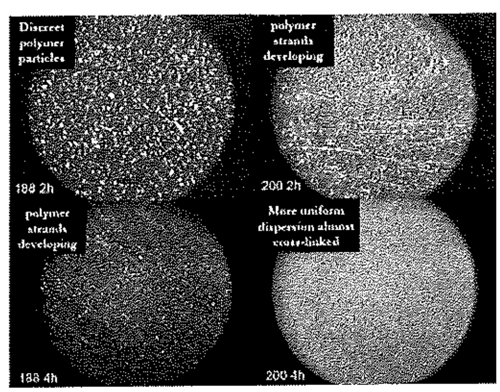
AASHTO M 320 Issues and the M 332 Solution

- **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.**

55

Polymer Modification

- Same polymer, same amount of polymer, but different behavior
- Not well characterized with M320 and PG+ tests



56

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.

57

57

Type of Modification

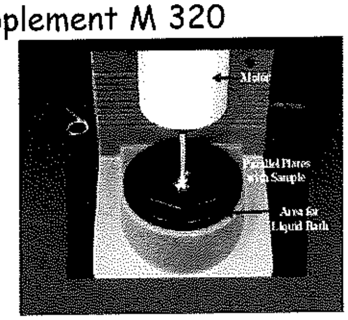
- M332 (MSCR) is blind to the *type* of modifier (because the test is physical, not chemical)

58

58

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



59

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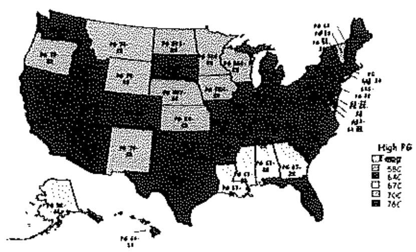
M 332 Binder Grades
Section 1015.10.3.1

- Introduces "traffic grades" increasing ***S*** → ***H*** → ***V***→ ***E***
- Before M332, to bump a grade for more traffic, raise upper PG number (eg, PG 64 → PG 70)
- New: Stay in climate grade (PG 64-22 for Missouri), but bump up by traffic

M 320	M 332
64-22	64-22 Grade S
70-22	64-22 Grade H
76-22	64-22 Grade V

60

"Workhorse" Binder Grades



61

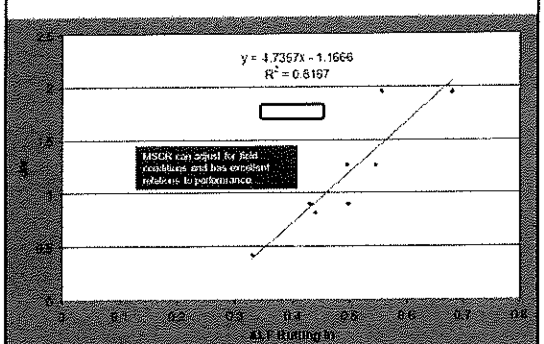
M 332 (MSCR) System

- 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 → H → V), lower the maximum allowable J_{nr}
- To do that, must add more modifier

62

62

Relationship Between J_{nr} and Rutting



63

M 332 Grades

Grade	Traffic/ Speed	MoDOT Class
S (Standard)	<10 million ESALS *AND* > 44 mph	F, E, some C
H (Heavy)	10-30 million ESALs *OR* 12 - 44 mph	Some C
V (Very Heavy)	>30 million ESALS *OR* < 12 mph ("standing")	B
E (Extra Heavy)	>30 million ESALS *AND* "standing"	B

64

64

MoDOT SUPERPAVE QC/QA TRAINING/CERTIFICATION COURSE

MODULE 2C(2)

MIX DESIGN OVERVIEW:

Testing & Evaluation

RAP & Shingles

Mixing & Compaction Temperatures

11-24-06 Revision
11-9-07 Revision, 4-22-09 Revision
11-18-09 Revision, 12-29-09 Revision
11-17-10 Revision, 1-19-11 Revision
3-2-12 Revision, 2-26-13 Revision
12-18-13 Revision, 12-29-14 Revision
2-4-15 Revision, 12-28-16 Revision
2-16-18 Revision, 12-12-18 Revision
12-17-19 Revision, 1-30-20 Revision
1-20-21 Revision

1

OUTLINE

- Module 2c(1):
  - Binder grading & selection
  - M 332 grades
- ***Module 2c(2):***
  - ***Testing & evaluation***
  - RAP & shingles
  - Mixing & compaction temperatures

2

2

M 332 Spec DSR Tested at 64° C

Traffic Level	Max. Allowable Jnr, kPa-1
S	4.5
H	2.0
V	1.0
E	0.5

Note: decreasing max. allowable Jnr for more severe traffic conditions

3

3

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]

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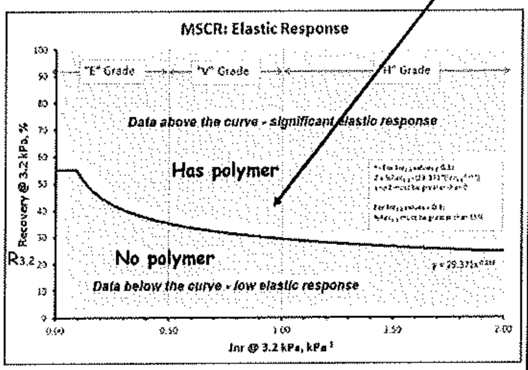
M 332 APPENDIX
MSCR % Recovery

- 2 bits of data from your MSCR test: MSCR % Recovery ($R_{3.2}$) & Jnr
- Plot: see where your point falls



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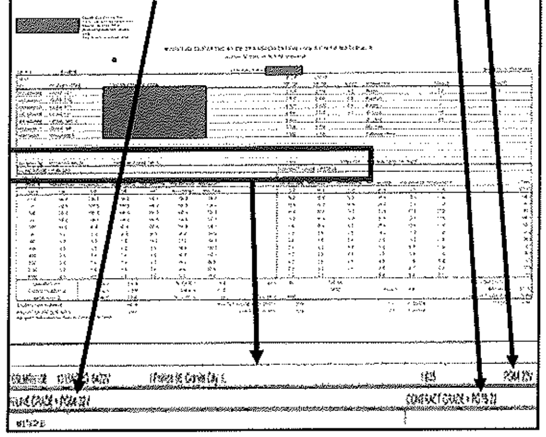
Example JMF Showing Substitution of purchased grade M 332 (PG 64-22V) for contract grade M 320 (PG 76-22)

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



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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-strip, etc.) eg. PG 58-28
- ***"In-line Grade"*** = Purchased grade + ***modifier*** (rejuvenator) eg. PG 52-28

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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

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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***

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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)

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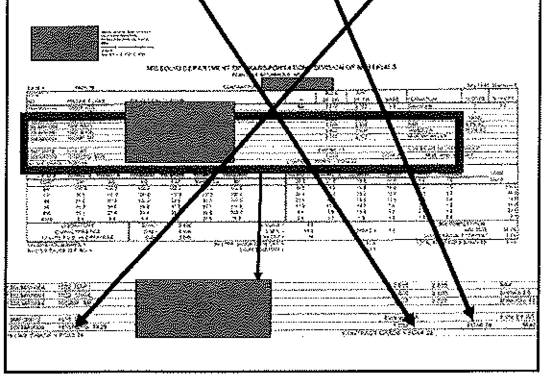
Example of Contract Grade, Purchased Grade, In-Line Grade (after additives/modifiers)

- Has RAP/RAS
- Has modifier
- Contract > Purchased > In-Line
- PG 64-22 > PG 58-28 > PG 52-28



11

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 332 binder, penalties will be assessed ***based on the Jnr*** (except Grade S-test as if M320)

12

12

M 320 Binder
Tested On Non-Aged ("Original") Condition
Example: PG 64

Spec	DSR Testing	Penalty
DSR ≥ 1.00 kPa	DSR > 0.90 kPa	No penalty
	If sample fails:	
Spec temp	**Hi-Temp True Grade Temp**	**Penalty**
64°	< 2° low	No penalty
64°	> 2° & < 4° low	3% of mix unit price
64°	> 4° & < 6° low	10% of mix unit price
64°	> 6° low	16% of mix unit price

13

13

M332 Binder
Tested On RTFO-Aged Condition
For *Grade H*

Spec	Jnr Tested	Penalty
Jnr ≤ 2.0 kPa-1	≤ 2.2 kPa-1	No penalty
Jnr ≤ 2.0 kPa-1	> 2.1 & < 2.7	3% of mix unit price
Jnr ≤ 2.0 kPa-1	> 2.7 & < 4.0	10% of mix unit price
Jnr ≤ 2.0 kPa-1	> 4.0	16% of mix unit price

14

14

M332 Binder
Tested On RTFO-aged Condition
For *Grade V*

Spec	Jnr Tested	Penalty
Jnr ≤ 1.0 kPa-1	≤ 1.1 kPa-1	No penalty
Jnr ≤ 1.0 kPa-1	> 1.1 & < 1.3	3% of mix unit price
Jnr ≤ 1.0 kPa-1	> 1.3 & < 2.0	10% of mix unit price
Jnr ≤ 1.0 kPa-1	> 2.0	16% of mix unit price

15

15

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%

16

16

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

17

17

OUTLINE

- Module 2c(1):
  - Binder grading & selection
  - M 332 grades
- ***Module 2c(2):***
  - Testing & evaluation
  - ***RAP & shingles***
  - Mixing & compaction temperatures

18

18

RECYCLED ASPHALT PAVEMENT (RAP): Considerations

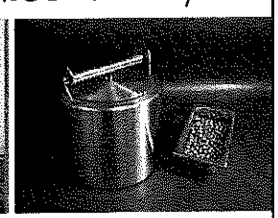
- OK in all mixes except SMA
- Can use a maximum of 30% virgin effective binder replacement without changing the binder grade
- >30% effective binder replacement can be from RAP+RAS if binder testing (use of blending charts) shows that the combined binder meets the contract specified grade
- Aggregate must meet deleterious spec 1002 (1004 if a 401 mix)
- Aggregate must pass Micro-Deval test spec (waived if RAP is from a MoDOT project)

19

19

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



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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

21

21

Re-Calculation of RAP/RAS Binder

- The % effective virgin binder replacement content P_{bv} 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)

22

22

OUTLINE

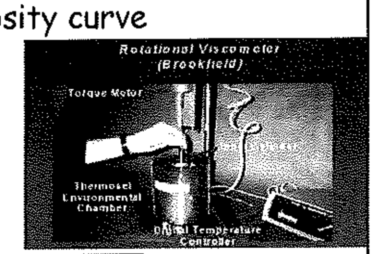
- Module 2c(1):
  - Binder grading & selection
  - M 332 grades
- ***Module 2c(2):***
  - Testing & evaluation
  - RAP & shingles
  - ***Mixing & compaction temperatures***

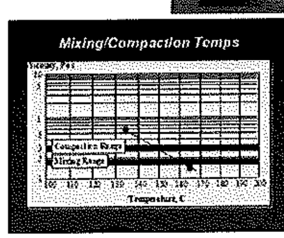
23

23

DETERMINE MIXING & COMPACTION TEMPERATURES

- Develop the temperature-viscosity curve





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24

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

25

25

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.

26

26

27

27

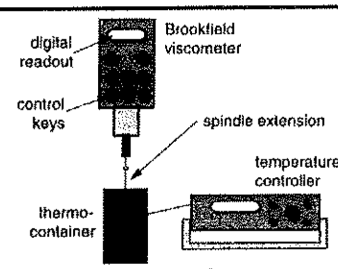


Figure 3.10 Rotational Viscometer

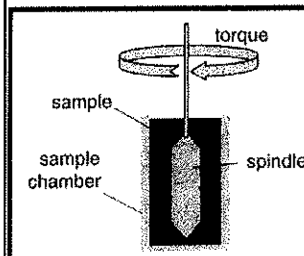


Figure 3.11 Rotational Viscometer Operation

28

28

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.

29

29

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.

30

30

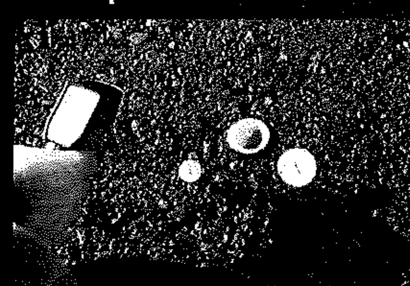
Plant Mixing & Roadway Compaction Temperatures

- May be different than lab temperatures
- Determine compaction temperature using test strips-- typically 275-310F
- Set plant mixing temperature somewhat higher, say 300-330F
- Maximum recommended temperature is 338F, should avoid exceeding 350F.

31

31

Temperature is critical

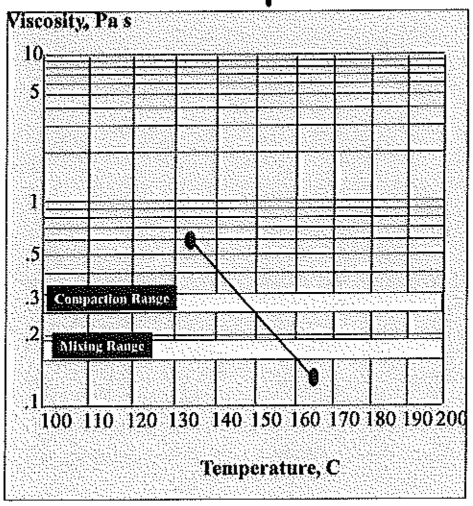


NCAT 19

32

32

Mixing/Compaction Temps



33

33

ASPHALT CONTENT IGNITION METHOD
(AASHTO T 308-18) METHOD A
Asphalt Binder Correction Factor (C_F) 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 (C_F) specimens at the design asphalt content using oven dry aggregate. It is recommended that the C_F 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 C_F 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 C_F 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 C_F 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 C_F determined at this lower temperature is less than or equal to 1.0%, use that C_F for subsequent testing on that particular mix.

   B. However, according to MoDOT Standard Specification Section 403.19.3.1.1, if the C_F determined at 482 ± 5°C (900 ± 8°F) exceeds 1.0%, lower the chamber temperature to 427 ± 5°C (800 ± 8°F). Use the C_F 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

Sample____________________Lab No.________Date______Initials______

Replicate	1	2	3	4
Test Temperature				
Tare (basket, etc.) Mass (g)				
Total Dry Mass (g)				
Initial Dry Specimen Mass (g)				
Loss in Weight (g)				
%AC, measured = M				
%AC, actual = A				
$\%AC_{diff}$ ($M_1 – M_2$)		> 0.15%? If so, 2 more replicates		
C_F = M – A				
C_F, average				

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.

NMS (mm)	Sieve Size	Minimum Specimen Size* (g)
4.75	#4	1200
9.5	3/8”	1200
12.5	1/2”	1500
19.0	3/4"	2000
25.0	1”	3000
37.5	1 ½”	4000

*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

Project No.	Job No.	Route	County
Technician	Date	Sublot No.	Mix No.
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), [$L = T_i - T_f$]			
% Loss, [$P_L = (L / W_i)$ x100]			
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]			

Ignition Ovens Forms.doc (11-24-06;12-28-06;12-12-08;3-9-10;12-14-10;4-14-11; 12-18-13; 4-22-15;12-9-15; 12-28-16; 12-26-18)

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	MINIMUM SAMPLE SIZE (MoDOT)	
	NOM. MAX SIZE (in.)	SAMPLE (g)
Balance	1	2500
Container (pycnometer)	¾	2000
Thermometers	½	2000
Vacuum Pump/System	3/8	2000
Water Bath	#4	2000

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 2nd wt. per interval)]:

P_{MC} = Pan weight (g): ___________

T_0 = Initial sample + pan weight (g): ___________

$W_0 = T_0 - P_{MC}$ = Initial sample weight (g): ___________

<u>1st Drying Interval (DI)</u>

T_1 = 1st DI sample + pan weight (g): ___________

$W_1 = T_1 - P_{MC}$ = 1st DI sample weight (g): ___________

$L_1 = W_0 - W_1$ = 1st Loss in weight (g): ___________

$(L_1 / W_1) \times 100$ = 1st Percent loss (%): ___________

<u>2nd Drying Interval (DI)</u>

T_2 = 2nd DI sample + pan weight (g): ___________

$W_2 = T_2 - P_{MC}$ = 2nd DI sample weight (g): ___________

$L_2 = W_1 - W_2$ = 2nd Loss in weight (g): ___________

$(L_2 / W_2) \times 100$ = 2nd Percent loss (%): ___________

<u>3rd Drying Interval (DI)</u>

T_3 = 3rd DI sample + pan weight (g): ___________

$W_3 = T_3 - P_{MC}$ = 3rd DI sample weight (g): ___________

$L_3 = W_2 - W_3$ = 3rd Loss in weight (g): ___________

$(L_3 / W_3) \times 100$ = 3rd Percent loss (%): ___________

<u>4th Drying Interval (DI)</u>

T_4 = 4th DI sample + pan weight (g): ___________

$W_4 = T_4 - P_{MC}$ = 4th DI sample weight (g): ___________

$L_4 = W_3 - W_4$ = 4th Loss in weight (g): ___________

$(L_4 / W_4) \times 100$ = 4th 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} = Pan weight (g): ____________

T_0 = Initial sample + pan weight (g): ____________

$W_0 = T_0 - P_{DB}$ = Initial sample weight (g): ____________

<u>1st Drying Interval (DI)</u>

T_1 = 1st DI sample + pan weight (g): ____________

$W_1 = T_1 - P_{DB}$ = 1st DI sample weight (g): ____________

$L_1 = W_0 - W_1$ = 1st Loss in weight (g): ____________

$(L_1 / W_1) \times 100$ = 1st Percent loss (%): ____________

<u>2nd Drying Interval (DI)</u>

T_2 = 2nd DI sample + pan weight (g): ____________

$W_2 = T_2 - P_{DB}$ = 2nd DI sample weight (g): ____________

$L_2 = W_1 - W_2$ = 2nd Loss in weight (g): ____________

$(L_2 / W_2) \times 100$ = 2nd Percent loss (%): ____________

<u>3rd Drying Interval (DI)</u>

T_3 = 3rd DI sample + pan weight (g): ____________

$W_3 = T_3 - P_{DB}$ = 3rd DI sample weight (g): ____________

$L_3 = W_2 - W_3$ = 3rd Loss in weight (g): ____________

$(L_3 / W_3) \times 100$ = 3rd Percent loss (%): ____________

<u>4th Drying Interval (DI)</u>

T_4 = 4th DI sample + pan weight (g): ____________

$W_4 = T_4 - P_{DB}$ = 4th DI sample weight (g): ____________

$L_4 = W_3 - W_4$ = 4th Loss in weight (g): ____________

$(L_4 / W_4) \times 100$ = 4th Percent loss (%): ____________

<u>5th Drying Interval (DI)</u>

T_5 = 5th DI sample + pan weight (g): ____________

$W_5 = T_5 - P_{DB}$ = 5th DI sample weight (g): ____________

$L_5 = W_4 - W_5$ = 5th Loss in weight (g): ____________

$(L_5 / W_5) \times 100$ = 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 ____________

Appendix Item #7
Revised on 10/20/2022

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 339M/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 339M/M 339 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.

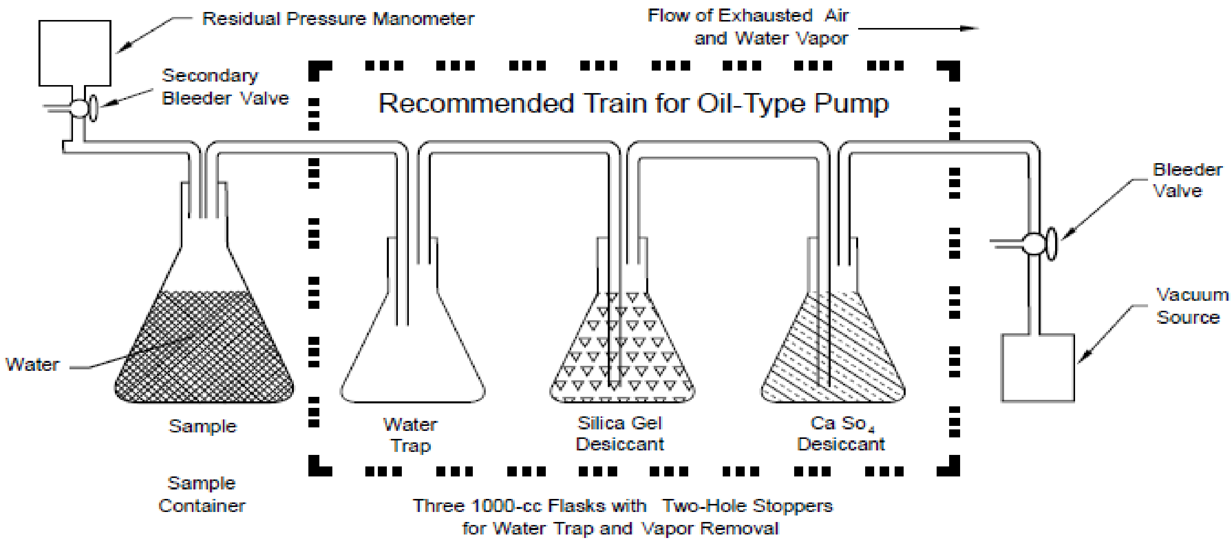


Figure 1—Example of Suitable Arrangement of Testing Apparatus

Figure 1—Example of Suitable Arrangement of Testing Apparatus

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 339M/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 339M/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.

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 339M/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

TS-2c T 308-2 AASHTO

requirements of M 339M/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 339M/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.

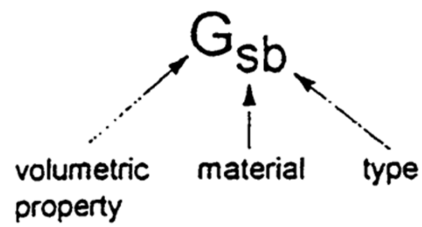
5.5. *Safety Equipment*—Safety glasses or face shield, dust mask, high-temperature gloves, long-sleeved jacket, a heat-resistant surface capable of withstanding 650°C (1202°F), and a protective cage capable of surrounding the specimen baskets during the cooling period.

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



		b = bulk
		e = effective
G = specific gravity	s = stone	m = maximum theoretical
V = volume	b = binder	a = apparent (for G) *or*
	m = mix	a = absorbed (for V and P)

DEFINITIONS

V_a = volume of air voids

V_{ba} = volume of binder absorbed

V_{be} = volume of effective binder

G_b = specific gravity of binder

G_{sb} = bulk specific gravity of stone

G_{se} = effective specific gravity of stone

G_{sa} = apparent specific gravity of stone

G_{mb} = bulk specific gravity of mix

G_{mm} = maximum theoretical specific gravity of mix

G_{mc} = bulk specific gravity of the core

V_a = percent air

P_s = percent stone (100 - P_b)

P_b = percent binder

P_{ba} = percent binder absorbed

P_{be} = percent effective binder

W_s = weight of stone

VMA = Voids in Mineral Aggregate

VFA = Voids Filled with Asphalt

GLOSSARY

Maximum Size	One sieve size larger than the Nominal Maximum Size
Nominal Max Size	One sieve size larger than the first sieve retaining equal to or more than 10% of the combined gradation
G_{mm}	D, Maximum Specific Gravity of mix as determined by the Rice Method, AASHTO T 209
G_{mb}	d, Bulk Specific Gravity: specific gravity including permeable and impermeable voids of aggregates or compacted mix.
G_{mc}	Bulk Specific Gravity of core.
G_{sb}	Stone (Aggregate) Bulk Specific Gravity: weighted sum of bulk specific gravities of combined aggregates.
G_{sa}	Stone Apparent Specific Gravity: weighted sum of apparent specific gravities of combined aggregates. This excludes the water permeable voids.
G_{se}	Stone Effective Specific Gravity: specific gravity including asphalt permeable voids.
N_{des}	Gyrations simulating design life of mix to yield 4% air voids.
N_{ini}	Compaction ≥ 89% indicates a tender mix that may rut prematurely.
N_{max}	Gyrations simulating maximum life of pavement. At < 2% air voids the mix becomes plastic.
P_b	Percent binder in total mix.
P_s	Percent stone in total mix.
TSR	Tensile Strength Ratio: Result of AASHTO T 283 indicating the indirect tensile strength of wet cured specimens compared to dry cured specimens.
V_a	Percent air voids in compacted mix.
V_{ba}	Volume of absorbed binder.
V_{be}	Effective volume of binder not absorbed into the stone.
VMA	Voids in Mineral Aggregate: percent of voids in the aggregate structure.
VFA	Voids Filled with Asphalt: percent VMA filled with asphalt cement.