MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Department of Civil, Architectural, and Environmental Engineering

MoDOT SUPERPAVE QC/QA TRAINING/CERTIFICATION COURSE

Rev. 2-01-01; 10-10-01; 10-18-01
Rev. 9-23-03
Rev. 1-30-04; 11-19-04
Rev.3-10-05; 3-18-05; 4-1-05; 11-1-05
Rev. 2-10-06; 11-24-06; 12-6-06; 12-28-06
Rev. 11-9-07
Rev. 1-2-09; 4-22-09; 11-18-09
Rev. 2-26-10; 11-17-10
Rev. 1-19-11
Rev. 3-2-12
Rev. 3-5-13
Rev. 12-18-13
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Rev. 12-29-14
Rev. 2-5-15
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Rev. 12-14-15
Rev. 3-2-16
Rev. 12-28-16
Rev. 3-7-18
Rev. 12-12-18
Rev. 2-20-19
Rev. 2-25-19
Rev. 3-15-19
Rev. 12-17-19

COURSE OBJECTIVE

To bring together the diverse standpoints in a paving project to share in a common training program that shows not only *how* but *why* the various QC/QA procedures are performed.

WHY IS THE COURSE SET UP THE WAY IT IS?

Q **Why do we cover so many aspects of the work?**

QC/QA plan: hotmix plant
Job mix formula
hotmix plant inspection
hotmix roadway inspection

A **Because attendees bring all kinds of backgrounds to the course—we have to train everybody.**

Q **Why do I have to learn about other peoples work?**

A **You can make better decisions if you have the whole picture.**

You can have more realistic expectations if you know what the other person's constraints are.

You might change jobs (or have your job description changed for you!).

Q **Why are quarry operations mentioned in the course?**

A **If the aggregate's not right, the hotmix won't be right. It is extremely important that the quarry people and the MoDOT quarry inspectors understand that what each party does really impacts the mix.**

It is also important that the hotmix side understands the quarry operations that can affect their hotmix.

SUPERPAVE QC/QA
TRAINING/CERTIFICATION PROGRAM

TABLE OF CONTENTS

SUPERPAVE QC/QA
CERTIFICATION RENEWAL COURSE
2019-2020 Season

Day/Time	Module	Location	Topic	Instructor
Day 1 8:00-10:35	Intro 1-4	Rm. 110	Intro/welcome Overview of Changes	Richardson
10:35-11:30	5	Rm. 110	Sampling Review: Random Numbers Loose Mix Sampling Coring	Richardson
11:30-11:45	6	Rm. 110	Gyratory Compactor Review	Richardson
11:45-12:00	7	Rm. 110	Rice Gravity Review	Richardson
12:00-1:00	Lunch on your own			
1:00-1:50	10	Rm. 110	Pay Factors	Richardson
1:50-2:00	11	Rm. 110	Record Keeping Review	Richardson
2:00-2:50	12	Rm. 110	Contract Administration	MoDOT
2:50-3:40	8	Rm. 110	Ignition Oven Review	Richardson
3:40-3:50	9	Rm. 110	TSR Review	Richardson
3:50-4:00	Break			
4:00-5:00	5-9	Lab	Lab Refresher: Class observes demos: 1. Gyro verification/puck compaction 2. Ignition oven	 Lusher Lusher
Day 2 8:00-10:15	1-12	Rm. 110	Homework/Course Review	Richardson
10:15-10:25	Break			
10:25-11:00		Lab	Rice Spec. Gravity Demo	Lusher
11:00-11:15		Lab	Lab Methods Review	Lusher
11:15-12:30		Lab	Hands-on practice/ proficiency testing	Staff
12:30-1:00	Catered Lunch			
1:00-? (3:00)		Rm. 110	Written Test	Richardson
Begins upon completion written exam		Lab	Proficiency practice/testing continues	Staff

Recert Schedule 3-16-17 (3-7-18) V.2 (4-25-18)(2-20-19)(4-2-19)(12-17-19).docx

SUPERPAVE QC/QA TRAINING/CERTIFICATION COURSE
EVALUATION

DATE: __________

Job Description/Affiliation (Please check one)

Paving Contractor ___ Quarry Operator ___ MoDOT ___ Other___

On a scale from one to five, with one being the lowest and five the highest, rate A.) the instructor and, B.) the material presented for each module. Please circle your selection.

	LOW HIGH
MODULE 1 – INTRODUCTION TO SUPERPAVE	
A.) Instructor: Richardson	1 2 3 4 5
B.) Material presented	1 2 3 4 5
Comments:	
MODULE 2 – MIX DESIGN OVERVIEW	
A.) Instructor: Richardson	1 2 3 4 5
B.) Material presented	1 2 3 4 5
Comments:	
MODULE 3 – PLANT OPERATIONS	
A.) Instructor: _________	1 2 3 4 5
B.) Material presented	1 2 3 4 5
Comments:	

MODULE 4 – CONTRACTOR'S QUALITY CONTROL PLAN

A.) Instructor: _______ 1 2 3 4 5

B.) Material presented 1 2 3 4 5

Comments:

MODULE 5 - SAMPLING HOT MIX / CORES

A.) Instructor: Richardson (lecture) 1 2 3 4 5
Lusher (lab) 1 2 3 4 5

B.) Material presented 1 2 3 4 5

Comments:

MODULE 6 - GYRATORY COMPACTOR OPERATIONS

A.) Instructor: Richardson (lecture) 1 2 3 4 5
Lusher (lab) 1 2 3 4 5

B.) Material presented 1 2 3 4 5

Comments:

MODULE 7 – MAXIMUM SPECIFIC GRAVITY

A.) Instructor: Richardson (lecture) 1 2 3 4 5
Lusher (lab) 1 2 3 4 5

B.) Material presented 1 2 3 4 5

Comments:

MODULE 8 – IGNITION OVEN

A.) Instructor:	Richardson (lecture)	1 2 3 4 5
	Lusher (lab)	1 2 3 4 5
B.) Material presented		1 2 3 4 5

<u>Comments</u>:

MODULE 9 – TENSILE STRENGTH RATIO

A.) Instructor:	Richardson (lecture)	1 2 3 4 5
B.) Material presented		1 2 3 4 5

<u>Comments</u>:

MODULE 10 – QUALITY LEVEL ANALYSIS

A.) Instructor:	Richardson	1 2 3 4 5
B.) Material presented		1 2 3 4 5

<u>Comments</u>:

MODULE 11 - RECORD KEEPING & EXCHANGE OF DATA/TEST RESULTS

A.) Instructor:	Richardson	1 2 3 4 5
B.) Material presented		1 2 3 4 5

<u>Comments</u>:

MODULE 12 - CONTRACT ADMINISTRATION

A.) Instructor:_____ 1 2 3 4 5

B.) Material presented 1 2 3 4 5

Comments:

Please circle your answer for the following questions.

Were the training facilities and materials adequate?

Yes No Other

Comments:

Was the time spent on training adequate?

Too long About Right Too short

Comments:

Rate overall training.

Poor Excellent

1 2 3 4 5

General Comments:

WHY TEST?

AGGREGATE

Gradation	Provides a check to assure that we are close to the optimum aggregate skeleton that will give the maximum stability yet provide sufficient void space to avoid instability and durability problems. Specs: Sieve tolerance limits Dust/asphalt ratio
Specific Gravity	Asphalt mixes are produced "by weight" but behave "by volume". Specific gravity is the link between weight and volume: if you know weight and specific gravity, you can calculate volume--and thus predict behavior. Necessary for mix design. Spec: VMA calculation needs aggregate bulk specific gravity and puck specific gravity.

Consensus Tests

Fine Aggregate Angularity	The more angular the particles, the more interlocking, the more stable the mix will be. Spec: Fine Aggregate Particle Shape
CA Fractured Face Count	Same as for fine aggregate angularity Spec: Fractured Face Count
Sand Equivalent	Indicator of clay content of the aggregate. Clay can cause problems with stripping and raveling Spec: Clay Content (Sand Equivalent)

Thin/Elongated Thin and elongated particles have tendency to break down during construction and service

Spec: Thin/Elongated

Source Tests

Deletereous Soft, non-durable particles tend to cause problems of durability in-service and breaking down during construction; absorptive and hold moisture

Spec: Deletereous Material

LA Abrasion General indicator of aggregate quality; indication of how well aggregate will hold up during handling, construction, and service; measure of toughness

Spec: LAA

Soundness Indicator of resistance to weathering; aggregates with lower soundness may also break down during gyratory compaction and result in low VMA

Spec: Sulfate Soundness

HOT MIX

Air Voids Excessive air voids cause problems with consolidation rutting, stripping, raveling, and freeze/thaw damage. Insufficient air voids leads to plastic rutting and bleeding

Spec: air voids

VMA	**The wrong combination of air voids and effective AC content can lead to either plastic rutting or durability problems, and under certain circumstances, tender mix behavior** **Spec: VMA**
AC Content	**Excessive %AC can cause problems with instability; insufficient %AC leads to cohesion problems, raveling, stripping, and cracking** **Specs: % AC content** **Dust/asphalt ratio**
Rice Specific Gravity	**Necessary for calculation of air voids**
Puck Specific Gravity	**Necessary for calculation of VMA and air voids**
Cores	**Spec: pavement density**
Dust/Asphalt	**The dust (-#200)-to-effective asphalt ratio affects compactability and cohesion of the mix**
TSR	**The moisture sensitivity of the aggregate affects how prone the mix is to stripping** **Spec: TSR (Tensile Strength Ratio)**

RECENT CHANGES IN QC/QA & SUPERPAVE
Chronological Order

- Recognition by MoDOT of self-tests (check samples)

- TSR sampling allowed at plant discharge or from truck (as well as off roadway).

- Aggregate acceptance has shifted to the mixing facility

- More sampling off the aggregate combined cold feed or hot bins:
    - Consensus tests
    - Deleterious

- RAP allowed in Superpave

- More RAP sampling & testing

- More emphasis on SMA

- "Favorable comparison" between QA and QC is now defined.

- QA must also retain a split

- Acid Insoluble spec for Superpave mix B

- Creation of SP095 and SP095xSM

- Allowance of ignition oven sample for gradation purposes

- Dry-back procedure mandatory for mixes with any coarse aggregate with absorptions greater than 2.0%

- Adoption of AASHTO R 47 (previously designated as T 328) for hotmix sample splitting

- Adoption of AASHTO T 329 for moisture in hotmix

- Shingles (RAS) allowed in Superpave
- Creation of SP095xSM(R) [Rural]
- Creation of SP125xSM(R) [Rural]
- Creation of BP-3
- New TSR bonus/deduct table
- Gradual replacement of MoDOT test methods with AASHTO methods
- Superpave QC/QA course prerequisites; Aggregate Technician + Bituminous Technician
- Creation of Engineering Policy Guide (EPG)
- Creation of Task Force “guidelines” (“FAQ”)
- Gyratory compactor angle ***calibration*** now specified to be performed using an internal angle device, but can still use external device for ***verification.***
- TSR dry pucks held an additional 24 hrs after bulk specific gravity determination.
- Re-warming of mix for ignition oven testing now to be accomplished in an oven set at 110 instead of 125 degrees Celsius.
- Manual agitation of the Rice specimen was taken out of the latest version of AASHTO T 209. The spec only refered to mechanical agitation in section 9.4 of the test method. However, MoDOT is going to reinstate the manual method.
- RAP/RAS binder content sampling/testing required for hot mix plant samples.
- Change in allowable %RAP based on ***effective*** binder content

- Allowance of Warm Mix
- Traffic level "C": allowable change from 100 to 80 gyrations with removal of Ninitial and Nmaximum requirements
- Change in Superpave density spec, allowing greater density (94.5±2.5%)
- SP048 (50 gyration)= old BP-3, no Ninitial or Nmax requirement
- Sand Equivalent comparison: QC to QA: ± 8
- Small quantities now 4000 tons
- QA now tests its own core
- T166 specific gravity of pucks/cores: if absorption exceeds 2%, must use Corelok or paraffin
- Rice test-minor change in start of timing
- Binder availability factor removed from MoDOT's RAP worksheet
- D/B ratio is 0.9-2.0 for SP048 mix
- Standardized JMF submittal spreadsheet available
- For high absorption pucks/cores, liquid paraffin not allowed; Parafilm or Corelok required
- Inertial Profiler has replaced profilograph and is in Sect 610; smoothness pay factors based on IRI, not profile Index
- T 329 Moisture Content is defined in reference to wet weight of mix
- T 329 Moisture Content definition of constant mass is no change greater than 0.05%

- T 166 Bulk Sp Grav of Pucks surface blotting dry time has changed to ≤ 15 sec.

- T 329-15 Moisture Content is defined in reference to ***dry*** weight of mix

- T329-15 Moisture Content oven temperature "shall fall within the JMF mixing temperature range." If not supplied, use 325 ± 25 F

- QA cores not in possession of QA shall be sealed in tamper-proof chain-of-custody bags

- Mix and core sampling frequency for QA: one per 4 sublots instead of one per lot

- Ground shingle shingle testing frequency added (QC: 1/10,000 tons, minimum one per project)

- Gradation and deleterious sampling frequency for QC: one per 2 sublots instead of two per lot; QA: one per 4 sublots instead of one per lot

- RAP sampling frequency for QC: one per 4 sublots; for QA: one per project

- Small quantities defined as 4000 tons

- New spreadsheets implemented for submittal of QC (CRE2O) and QA data and for calculation of Pay Factors and Favorable Comparison

- Changes in minimum mat thicknesses for: SP048, BP-2, and leveling courses

- Introduction of an alternate binder grading system to M 320: M 332 (MSCR)

- Increased use of technology to deal with RAP/RAS total binder stiffness; increased use of binder additives and modifiers

- Emphasis on binder contract grade, purchased grade, in-line grade, and true grade
- Implementation of binder deficiency deducts
- Performance testing (Flexibility Index and Hamburg Wheel Tracker) being implemented on a trial basis
- Verification frequency changed from daily to monthly
- JSP change for performance testing (2019)-includes disincentives
- Optional lower gyrations and air voids, higher VMA and field density
- ***New! Test procedure changes T 209 (Rice Specific Gravity)***
- ***New! JSP change for performance testing (2019)***
- ***New! Ideal CT test allowed in lieu of Illinois Flexibility Index Test***
- ***New! Brand-new AASHTO R 96: Operation of Ignition Furnaces***
- ***New! Brand-new mix sampling spec R 97 replaces T 168***

TEST PROCEDURE CHANGES
(2003-2004 to 2019-2020 Training/Certification Seasons)
Chronological Order

AASHTO T 283-14 (2018): Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage.

This test procedure, commonly referred to as the Tensile Strength Ratio (TSR) test, was added as a Level 2 Bituminous (now Superpave QC/QA) proficiency exam requirement during the 2003-2004 training season. It was implemented as part of the transition to performance specifications. The material specification of requiring non-plastic aggregates in Superpave mixes was dropped, and the TSR, a performance specification, was put in force to address stripping potential of the HMA.

<u>NOTE: As of March 2005, the TSR test procedure is no longer part of the Superpave QC/QA Training/Certification but is handled as a separate course, and is held here at Missouri S&T.</u>

- As of the summer of 2007, the MoDOT Central Lab stores the "dry" subset of pucks for another 24 ± 3 hours ***after*** determining the bulk specific gravity (G_{mb}), and ***before*** bagging them and putting them in the room-temperature water bath.

- Changes during the 2014-2015 season (AASHTO T 283-14) were 1) adding T 167 (Compressive Strength of Hot Mix Asphalt) as one of the allowable specimen compaction methods, 2) adding Note 4 to section 10.3.1 which allows some tolerance in the time and/or vacuum level required to reach the specified saturation, and 3) removing ASTM D 2041 as a method to determine G_{mm}.

- 2015-2016 Season: No changes in T 283 since the 2014 version.
- 2016-2017 Season: No changes in T 283 since the 2014 version.
- 2017-2018 Season: No changes in T 283 since the 2014 version.
- 2018-2019 Season: T 283 reconfirmed; no procedural changes since the 2014 version.
- ***2019-2020 Season: No changes in T 283 since the 2018 (2014 reconfirmed) version***.

AASHTO T 308-18: Determining the Asphalt Binder Content of Asphalt Mixtures by the Ignition Method.

NOTE: Wording on this page has been updated to reflect terminology changes first introduced in the 2008 version of T 308 (T 308-08). The changes are as follows:

1. The "correction factor," generally referred to as the 'aggregate correction factor,' and input into the Method A (NCAT) convection-type oven using the 'Calib. Factor' function button, is now referred to as the "asphalt binder correction factor" in T 308-10.
2. The "aggregate gradation correction factor," as last defined in T 308-05, is now to be presented as the "aggregate (gradation) correction factor," where the parenthesis are ours.

To address problematic dolomites:

- When setting asphalt binder correction factors with the Method A (NCAT) convection-type oven, MoDOT specifications (Section 403) require that the ignition temperature be lowered to 427°C (800°F) if the asphalt binder correction factor still exceeds 1.0% at the AASHTO T 308 required lower temperature of 482°C (900°F).
- The infrared (direct irradiation) oven is allowable in AASHTO T 308.

As of the beginning of the 2006-2007 season, MoDOT now allows the use of the burned sample for gradation purposes. If used, an aggregate (gradation) correction factor determination must be performed according to T 308.

- 2015-2016 Season: No procedural changes in T 308 since the 2010 version. However, clarification of the definition of "moisture content" within T 329-15 (now referenced to dry weight of mix) has implications in binder content calculations and they are reflected in the documents used during this training course.
- 2016-2017 Season: Some editorial revisions (e.g. dual temperature units) but no procedural changes in T 308 since the 2010 version.
- 2017-2018 Season: No changes in T 308 since the 2016 version.
- 2018-2019 Season: No procedural changes in T 308-18 since the 2016 version. Minor editorial changes, only.
- ***2019-2020 Season: No changes in T 308 since the 2018 version.***

AASHTO T 209-19: Theoretical Maximum Specific Gravity (G_{mm}) and Density of Asphalt Mixtures.

- The second time period (10 ± 1 minute) in the weigh-in-air method now begins _after_ the vacuum has been released.
- The vacuum manometer must be hooked directly into the top of the vacuum vessel.
- More contractors are using the "weigh-in-water" method. The Central Lab is using it for their routine Rice testing. The 4500 ml metal pycnometer typically used by the industry is now allowed under T 209 for the weigh-in-water method.
- A major change in MoDOT's requirements within T 209 is the assurance of a dry sample (less than 0.1% moisture) before running the Rice. This is done by either 1) documenting AASHTO T329 (moisture determination) results as showing less than 0.1% moisture or 2) drying the sample at 105 ± 5°C and repeatedly weighing until mass repeats are within 0.1%.
- If any coarse aggregate fraction has absorption > 2.0%, the "dry back" procedure (outlined in Section 11 of T 209) must be performed. This could add a couple of hours to the test.
- The vacuum specification was officially cited in T 209-05 as 27.5 ± 2.5 mm Hg absolute pressure (25 – 30 mm Hg absolute) and remains as such today.
- NOTE: MoDOT Field Office says that if a contractor wants to use the CoreLok® device to run the Rice, they would probably allow it upon having first discussed it with the contractor. For some guidance, see AASHTO T 331-13 (or ASTM D 6752).
- 2015-2016 Season: No procedural changes in T 209 since the 2012 version.
- 2016-2017 Season: Reconfirmed for 2016 publication with minor editorial changes, but no technical changes in T 209 since the 2012 version.
- 2017-2018 Season: No changes in T 209 since the 2016 version.
- 2018-2019 Season: No changes in T 209 since the 2016 version.
- ***2019-2020 Season: Considerable changes in the new 2019 version.***
    - ***Obtaining and recording the weight of the empty pycnometer to use in calculating oven-dry specimen weight.***
    - ***Water baths used in both methods must be controlled at 25±1°C.***
    - ***Check (daily verification/calibration) and Standardization (less frequent, but repeated measurements) of the pycnometer for mass determinations in both methods under review by MoDOT.***

AASHTO T 312-19: Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor.

- Pre- 2012-2013 Season: The calibration of the internal angle of gyration should be verified in accordance with AASHTO TP 71. However, daily verification (as required by MoDOT) can still be performed using external angle determinations and then comparing them with equivalent external angles determined during calibration of the internal angle.

- 2012-2013 Season: TP 71 has been fully accepted as T 344 in the new 2012 version of T 312.

- 2013-2014 Season: No procedural changes in T 312 since the 2012 version.

- 2014-2015 Season: Added guidance in the annexes of the new 2014 version about evaluating the molds.

- 2015-2016 Season: The new 2015 version has revisions in Section 4.1.3 about ram pressure constancy.

- 2016-2017 Season: No procedural changes in T 312 since the 2015 version.

- 2017-2018 Season: No changes in T 312 since the 2015 version.

- 2018-2019 Season: No changes in T 312 since the 2015 version. However, MoDOT changed the frequency of calibration verification from daily to monthly.

- ***2019-2020 Season: No significant procedural changes in T 312-19 since the 2015 version. Minor editorial changes, only.***

PRELIMINARY MODULE

11-24-06 Revision
11-9-07 Revision
11-17-10 Revision
3-2-12 Revision
12-18-13 Revision

PRELIMINARY MODULE

11-24-06 Revision
11-9-07 Revision
11-17-10 Revision
3-2-12 Revision
12-18-13 Revision

Superpave QC/QA Prerequisites

- Aggregate Technician
  - Aggregate Sampling
  - Sample Size Reduction
  - Gradation
  - Moisture Content
  - Deleterious Material
  - Flat & Elongated

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Superpave QC/QA Prerequisites

- Bituminous Technician
  - Sampling Binder
  - Sampling Mix
  - Sample Size Reduction
  - HMA Puck/Cores Sp Grav
  - HMA Moisture Content (Oven)
  - HMA Binder Content (nuclear)
  - Air Voids
  - Temperature

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SUPERPAVE QC/QA TOPICS

Module	Topic
1	Introduction
2	Mix Design Overview
3	Plant Operations
4	HMA QC Plan
5	Sampling
6	Gyratory Compactor
7	Rice Sp Gravity
8	Ignition Oven

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TOPICS, Cont'd.

Module	Topic
9	TSR
10	Quality Level Analysis
11	Record keeping
12	Contract Administration

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CERTIFICATION REQUIREMENTS

- Full Attendance
- Lab procedure proficiency test:
  (pass all test procedures)
- Written test:
  (≥80%)

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LAB TESTS

- Instructors Will ***Demo/Discuss:***
  - HMA splitting
  - Consensus tests
  - HMA moisture
  - HMA aging
  - TSR

7

LAB TESTS

- Attendees will ***perform and be evaluated on:***
  - Gyro verification
  - Gyro compaction
  - Rice specific gravity
  - Ignition oven binder content

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CERTIFIED-WHO?

- Paving contractor
- MoDOT inspectors
- How many? –No longer specified

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INSPECTION/ ACCEPTANCE

- ***Aggregate***
- Binder
- Mix
- Mat

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AGGREGATE

- *CA= coarse aggregate, typically plus #4*
- FA= fine aggregate, typically minus #4

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TESTS-Traditional

- MoDOT Initial & Annual Source Approval
- During mix design
- During HMA production

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Initial Source Approval

- Coarse Aggregate:
  - Specific gravity & absorption
  - LA Abrasion

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Annual Source Approval

- Coarse Aggregate:
  - Gradation
  - Specific gravity & absorption
  - LA Abrasion
  - Deleterious Materials
- Fine Aggregate:
  - Gradation
  - Specific gravity
  - Clay lumps & shale
  - Lightweight pieces

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Trial Mix Design

- Coarse Aggregate:
  - Gradation
  - Specific gravity & absorption
  - Deleterious materials
  - Sand equivalent
  - Uncompacted voids
  - PI (as required)
- Fine Aggregate:
  - Gradation
  - Specific gravity
  - Clay lumps & shale
  - Lightweight pieces
  - PI (as required)

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HMA Production

- Gradation
- Deleterious
- Consensus properties

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TESTS
Superpave Consensus

- Coarse Aggregate
  - Fractured Face Count
  - Flat & Elongated
- Fine Aggregate
  - Fine Aggregate particle Shape
  - Sand Equivalent

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INSPECTION/ ACCEPTANCE

- Aggregate
- ***Binder***
- Mix
- Mat

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Sample binder

Asphalt binder is sampled randomly during Production.

QC/QA

- **Quality Control** – Contractor
- **Quality Assurance** – Specifying Agency
  - MoDOT Bituminous Plant Inspector
  - MoDOT Construction Inspector
    - Roadway

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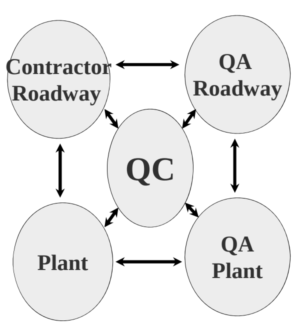
Communication



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INSPECTION/ ACCEPTANCE

- Aggregate
- Binder
- ***Mix***
- Mat

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MIX ACCEPTANCE

- Temperature-min, max
- Asphalt Content (P_b)
- Volumetrics
  - % air voids
  - VMA
- TSR

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INSPECTION/ ACCEPTANCE

- Aggregate
- Binder
- Mix
- ***Mat***

24

MAT ACCEPTANCE

- Appearance
- Density
- Thickness
- Smoothness

25

Pay Factors

- Percent Within Limits
  - ***Asphalt Content***
  - ***VMA*** *- Voids in the Mineral Aggregate*
  - ***Air Voids***
  - **Density**

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Pay Adjustments

- **Inertial Profiler** - Smoothness
- **Tensile Strength Ratio** - Stripping
- **Unconfined Joint Core Density**

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MODULE 1

INTRODUCTION to SUPERPAVE and QC/QA

12-15-06 Revision
1-29-07 Revision
11-9-07 Revision
4-22-09 Revision
11-18-09 Revision
12-29-09 Revision
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12-12-18 Revision

MODULE 1

INTRODUCTION to SUPERPAVE and QC/QA

12-15-06 Revision
1-29-07 Revision
11-9-07 Revision
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3-2-16 Revision
12-28-16 Revision
2-16-18 Revision
12-12-18 Revision

SUPERPAVE VS. QC/QA

- Superpave ≠ QC/QA
- ***Superpave= mix design***
- QC/QA= contract administration

2

SUPERPAVE

- A SHRP product (1993)
- ***SU***perior ***PER***forming asphalt ***PAVE***ments
- New way of specifying binders and aggregates, and a new mix design method
- Tied to pavement performance

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SUPERPAVE

- PG asphalt binder specifications
- Consensus properties of aggregates
- Hot mix design and analysis system (includes new test equipment, methods and criteria)
- Computer software

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PERFORMANCE BEHAVIOR-Major

- ***Permanent distortion***
  - Rutting
  - Shoving
  - Corrugations
- Fatigue cracking
- Cold temperature cracking
- Moisture sensitivity (stripping)

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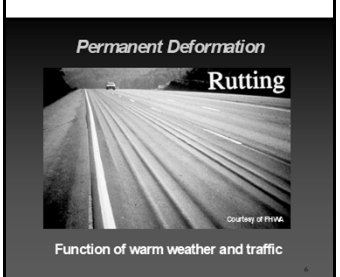
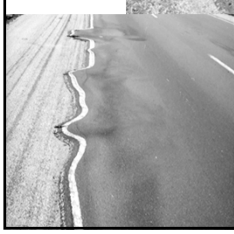


6

Rutting

SHOVING



PERFORMANCE BEHAVIOR-Major

- Permanent distortion
  - Rutting
  - Shoving
  - Corrugations
- ***Fatigue cracking***
- Cold temperature cracking
- Moisture sensitivity (stripping)

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Fatigue Cracking

Function of repeated traffic loads over time (in wheel paths)

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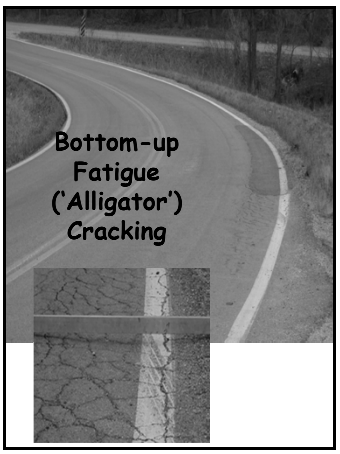

PERFORMANCE BEHAVIOR-Major

- Permanent distortion
  - Rutting
  - Shoving
  - Corrugations
- Fatigue cracking
- ***Cold temperature cracking***
- Moisture sensitivity (stripping)

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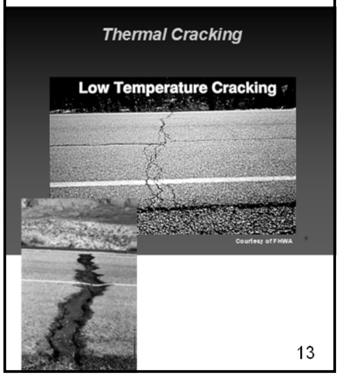
COLD TEMPERATURE CRACKING



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PERFORMANCE BEHAVIOR-Major

- Permanent distortion
  - Rutting
  - Shoving
  - Corrugations
- Fatigue cracking
- Cold temperature cracking
- ***Moisture sensitivity (stripping)***

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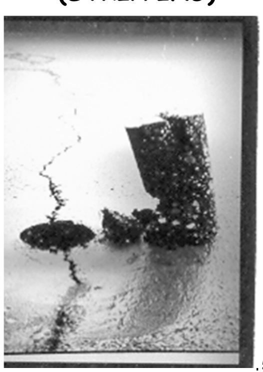
MOISTURE DAMAGE (STRIPPING)



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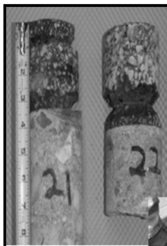

PERFORMANCE BEHAVIOR-Others

- Raveling
- Bleeding
- Reflective cracking
- Slippage cracks
- Lane cracks
- Aggregate polishing

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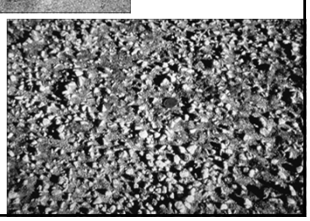
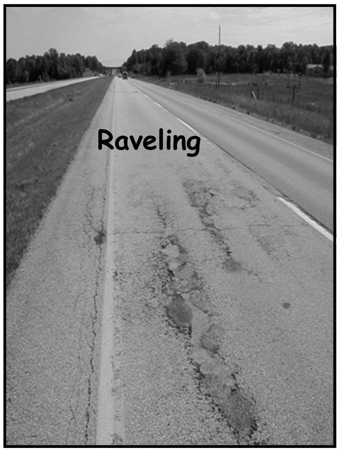
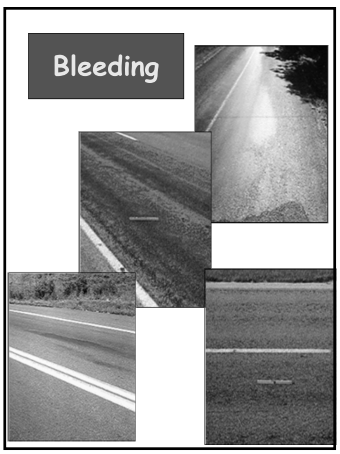
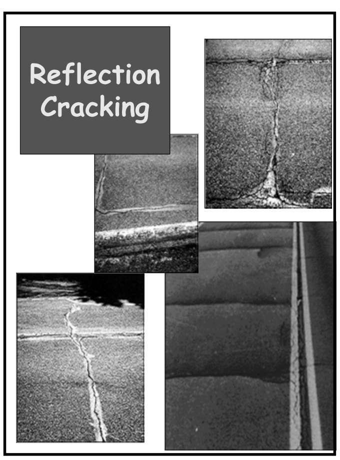
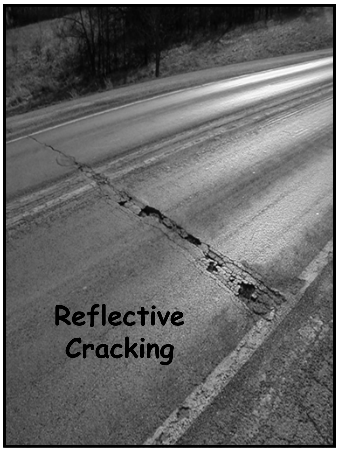
RAVELING


Raveling


Bleeding


Reflection
Cracking



SLIPPAGE CRACKS

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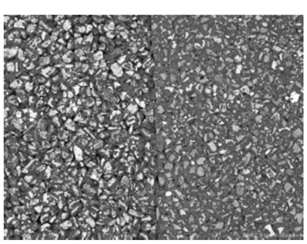
POLISHING



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TESTING/ SPECIFICATION

- ***Binder***
- Aggregate
- Hotmix

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BINDER

- "Asphalt cement"
- "Asphalt"
- Black, sticky stuff

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PG BINDER SYSTEM

- 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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BINDER

- Binder behavior depends on:
  - Temperature
  - Duration load
  - Age-hardening

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PERFORMANCE BEHAVIOR

- ***Permanent distortion***
- Fatigue cracking
- Cold temperature cracking
- Moisture sensitivity

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CAUSES OF DISTORTION: Mix Related

- Excessively soft ***binder*** for the climate/traffic
- Over-asphalted
- Low air voids
- Rounded/smooth aggregate
- Poor gradation

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CAUSES OF DISTORTION: Non-Mix Related

- High pavement temperature
- Sustained loads:
  - Slow moving vehicles
  - Stopped vehicles
- Shear loads:
  - Intersections
  - Curves

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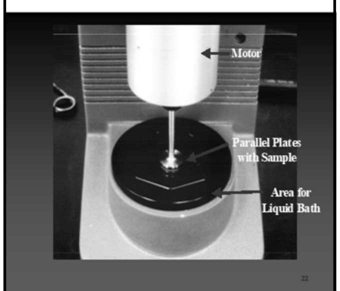
Testing & Specification of Binder: Permanent Distortion

Dynamic Shear Rheometer (DSR)

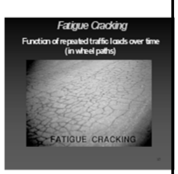
Tested At High Temperature

- Un-aged and "Plant"-aged



PERFORMANCE BEHAVIOR

- Permanent Distortion
- ***Fatigue cracking***
- Cold temperature cracking
- Moisture sensitivity



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Causes of Fatigue Cracks

- ***Binder*** too stiff (brittle):
  - Virgin grade too stiff
  - Recycle-additives/modifiers-virgin binder combo too stiff
  - Aging
- Under-asphalted
- Poor air void system
- Pavement too thin

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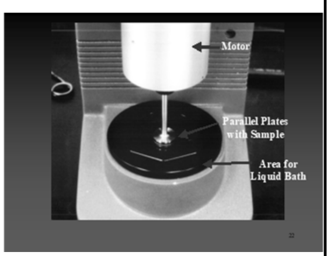
FATIGUE CRACKING
Dynamic Shear Rheometer (DSR)
Tested At Intermediate Temperature
"Plant" Aged plus "Long-term" Aged



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AGING

- Short term = "Plant"
  - At plant
  - During construction process
- Long term
  - Over life of pavement (in-service)
- Aging:
  - More brittle
  - Loses adhesion
- **CRACKS & RAVELS**

TYPE OF CRACKS

- Fatigue

- Cold Temperature

- Shrinkage

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AGING

AGE-HARDENING MECHANISMS:

Oxidation= AC combining with oxygen

Volatilization= lighter molecules "evaporating"

Polymerization= smaller, lighter molecules combining to form larger, heavier molecules

Age-hardening leads to brittleness, then cracking of all types plus loss of adhesion and cohesion, leading to stripping and raveling

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AGING

HEATING AT THE HOTMIX PLANT

TOO COOL: (AC viscosity too high)

Insufficient particle coating: leads to stripping, raveling

Mix too stiff to compact: results in high air voids which leads to consolidation rutting and durability problems (stripping, raveling)

TOO HOT:

Accelerated age-hardening of AC: premature brittleness leads to fatigue, cold-weather, etc, cracking and loss of adhesion and cohesion….leading to raveling and stripping

AC too "thin": mix difficult to compact because it is tender leading to high air voids leading to consolidation rutting and durability problems

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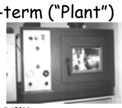
ALLOWABLE TEMPERATURES

- Maximum = 350 °F
- Minimum = vibratory rollers must be operated in static mode below 225 °F (200 °F for Warm Mix)

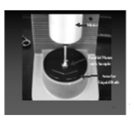
SPECIFICATION TESTING

- Pre-conditioning binder:
  - Short-term ("Plant")



  - Long-term

- Testing, DSR



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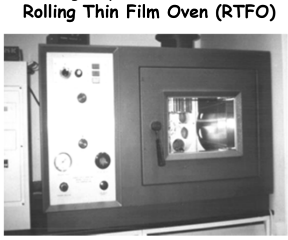
FATIGUE CRACKING TESTING/SPECIFICATION OF *BINDER*

Conditioning step: SHORT TERM AGING: Rolling Thin Film Oven (RTFO)



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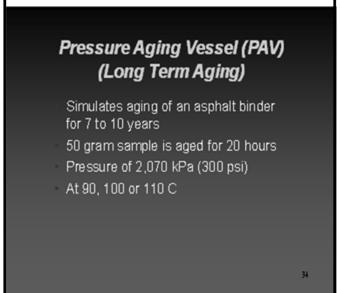
LONG TERM AGING



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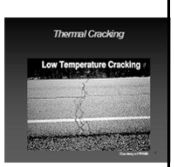
PERFORMANCE BEHAVIOR

- Permanent Distortion
- Fatigue cracking
- ***Cold temperature cracking***
- Moisture sensitivity



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Cold Temperature Cracking Cause

- ***Binder*** not suitable for climate

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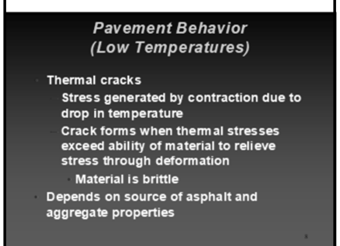

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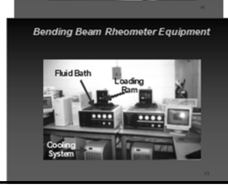
Cold Temperature Cracking

Testing/Specification of *Binder*

Bending Beam Rheometer (BBR)

Tested at Low Temperature

RTFO plus PAV Aged



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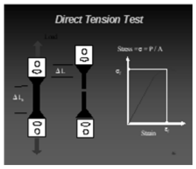
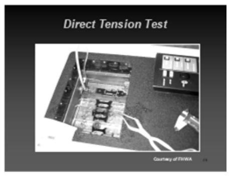
Additional/Alternative Binder Test





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PERFORMANCE BEHAVIOR

- Permanent distortion
- Fatigue cracking
- Cold temperature cracking
- ***Moisture sensitivity (stripping)***

Moisture Sensitivity

- See "Aggregate" testing

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TESTING/ SPECIFICATION

- Binder
- ***Aggregate***
- Hotmix

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AGGREGATE Superpave

- Consensus tests:
  - Used existing methods
  - New application limits

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Stripping Prevention

- Check aggregate cleanliness (Sand Equivalent, PI)

- Check aggregate for moisture sensitivity (TSR)

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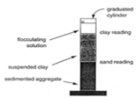
LOW SAND EQUIVALENT

- Harms bonding of asphalt to aggregate ---***stripping***



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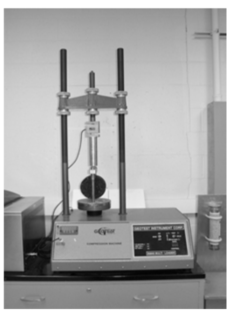
Tensile Strength Ratio (TSR)

AASHTO T 283



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TESTING/ SPECIFICATION

- Binder
- Aggregate
- ***Hotmix***

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DESIGN CRITERIA

- Binder must meet specs for handling, rutting, fatigue cracking, aging, cold temperature cracking
- Aggregate must meet specs for shape and cleanliness
- Gradation limits
- Dust/asphalt ratio

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SUPERPAVE MIXES IN MISSOURI

- SP048= #4 NMS surface course
- SP095= $\frac{3}{8}$" NMS surface course
- SP125= $\frac{1}{2}$" NMS surface course
- SP190= $\frac{3}{4}$" NMS binder course
- SP250= 1" NMS base course
- Traffic levels: B, C, E, F
- Extensions:
  - SM= stone mastic
  - SM(R)= stone mastic (rural)
  - NC= non-carbonate
  - LP= limestone-porphyry
  - LG= low gyration

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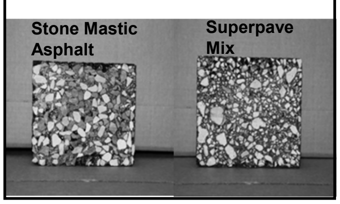
Construction of SMA

- What is SMA

- 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%



STONE MASTIC USES

- SMA—Interstates in commercial zones
- SMR– Rural interstates

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SUPERPAVE VS. QC/QA

- Superpave ≠ QC/QA
- Superpave= mix design
- ***QC/QA= contract administration***

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QC/QA What is it?

- QC…Contractor provides control of the process
- QA…Owner provides assurance that control is working

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QC/QA
Who?

- 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 major change in the way contracts are structured and administered
- 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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QC/QA

- "QC" side becomes involved earlier in the process
- "QC" side becomes more knowledgeable about its product and the influence of the process on mix behavior
- "QA" side, through field verification, becomes more involved with the whole process

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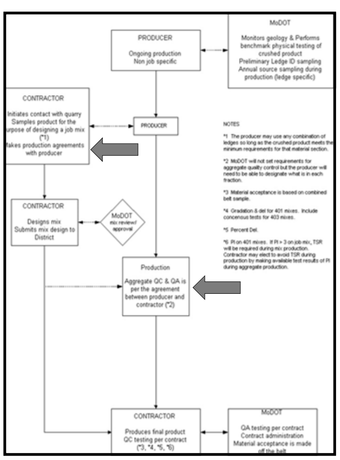
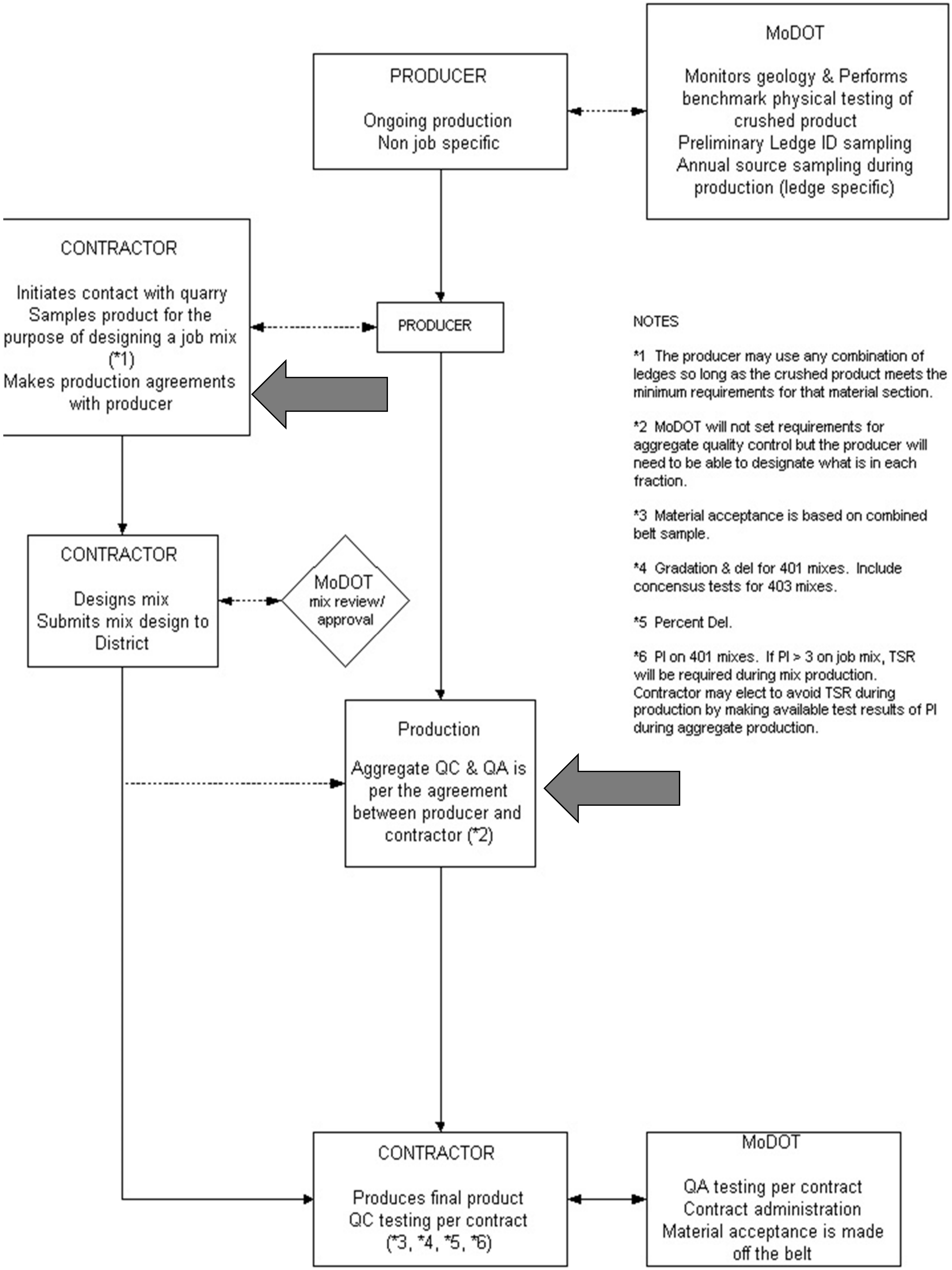
PROJECT FLOWCHART

- 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. Samples aggregate for mix design (often, this is done earlier)





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.

FLOWCHART, cont'd.

- 4. Paving contractor submits mix design info (Job Mix Formula=JMF) to MoDOT through the district.
- 5. MoDOT Central Lab will verify the mix if QC lab not AMRL accredited. JMF approval granted (still have to sample aggregate if running nuclear gage so MoDOT can calibrate)
- 6. Aggregate production begins (actually, Superpave rock is more common now)
- 7. Hot mix production begins. See "Hotmix Production."

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

HOTMIX INSPECTION

- QC and QA perform tests, compare to each other and to:
  - Job Special Provisions
  - Standard Specifications
  - EPG guidelines
  - Task Force (FAQ) guidelines
- Pay factors are computed ("Best Management Practice" says at the end of each lot, now)

QC/QA FUNCTIONS AT THE HOT MIX PLANT

Engineering Policy Guide

FUNCTION	LOCATION	FREQUENCY
Aggregate:		
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% $T\&E_{spec}$ +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

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Hot Mix:		
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}	"	"
Run pucks specific gravity Calculate average of the two (G_{mb})	"	"
Run Rice specific gravity (G_{mm})	"	"
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***	"	"
Run asphalt content (P_b), either nuclear or ignition oven Compare to spec: $P_{b,JMF} \pm 0.3\%$ ***This is a pay factor***	"	"
Calculate % aggregate (P_s): $P_s=100 - P_b$	"	"
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***	"	"

Hot Mix, cont'd.:		
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	"
Calculate pavement density: Density= $(G_{mc} \div G_{mm}) \times 100$ Compare to spec: 94.5 ± 2.5% of G_{mm} ***This is a pay factor***	"	"

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Additional Testing:		
Mix Temperature		QC: 1 per sublot QA: 1 per day
Temperature base & air	Roadway	As-needed
Binder content of RAP/RAS	RAP/RAS feed	QC: 1 per 4 sublots QA: 1 per project
Calculate Voids Filled (VFA): VFA=[(VMA-V_a) ÷ VMA] x 100	QC lab	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
Calculate pavement density: Density= (G_{mc} ÷ G_{mm}) x 100 Compare to Density Pay Adjustment Table if an unconfined joint core ***This is a pay adjustment factor***	"	"

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SMALL QUANTITIES
Individual 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

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SMALL QUANTITIES

- 403.23.7.4.1
- QLA & PWL not required (no PF's) but mix must be within spec
- Still have VMA, V_a, P_b, density spec limits
- TSR still required
- Density: PF-adjustment table (see Module 5)

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QC/QA FUNCTIONS
AT THE HOT MIX PLANT
Engineering Policy Guide

FUNCTION	LOCATION	FREQUENCY
Aggregate:		
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% $T\&E_{spec}$ +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

Hot Mix:		
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}	“	“ “
Run pucks specific gravity Calculate average of the two (G_{mb})	“	“
Run Rice specific gravity (G_{mm})	“	“
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***	“	“
Run asphalt content (P_b), either nuclear or ignition oven Compare to spec: $P_{b,JMF}$ ± 0.3% ***This is a pay factor***	“	“
Calculate % aggregate (P_s): $P_s=100 - P_b$	“	“
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***	“	“

Hot Mix, cont'd.:		
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	"
Calculate pavement density: Density= ($G_{mc} \div G_{mm}$) x 100 Compare to spec: 94.5 ± 2.5% of G_{mm} ***This is a pay factor***	"	"

Additional Testing:		
Mix Temperature		QC: 1 per sublot QA: 1 per day
Temperature base & air	Roadway	As-needed
Binder content of RAP/RAS	RAP/RAS feed	QC: 1 per 4 sublots QA: 1 per project
Calculate Voids Filled (VFA): $VFA=[(VMA-V_a) \div VMA] \times 100$	QC lab	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
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***	“	“

MODULE 2A

MIX DESIGN OVERVIEW:

Mix Design/Pavement Structure Design

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

2-8-19 Revision

MODULE 2A

MIX DESIGN OVERVIEW:

Mix Design/Pavement Structure Design

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
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12-18-13 Revision
12-29-14 Revision
2-4-15 Revision
12-28-16 Revision
2-16-18 Revision
12-12-18 Revision
2-8-19 Revision

AASHTO TEST METHODS & SPECIFICATIONS

- R35 Volumetric Design Practice
- M323 Volumetric Design Specs
- R30 Mix Conditioning
- T 312 Gyro operation
- T 166 Bulk Sp Gravity of gyro pucks
- T 209 Max Sp Gravity of Voidless Mix (Rice)
- T 283 Moisture Sensitivity

2

Typical Bituminous Mixture

COMPONENT	% by wt.
Aggregate (coarse & fine)	90
Dust (dust-of-fracture + mineral filler)	5
Binder (asphalt cement or tar)	5

3

Hot Mix Asphalt Concrete (HMA)
Mix Design Methods

- Objective:
  - Develop an economical blend of aggregates and asphalt that meet design requirements
- Historical mix design methods
  - Marshall
  - Hveem
- New
  - Superpave gyratory

4

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

5

HOT MIX STANDARD SPECS

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

6

MIX SELECTION

Corridor	Traffic	Mixture
Interstates		Superpave
Major Routes	>600 ADTT	Superpave
Major Routes	<600 ADTT	BP-1
Minor Routes	>600 ADTT	Superpave
Minor Routes	ADT>3500 <600 ADTT	BP-1
Minor Routes	ADT<3500 <600 ADTT	BP-1 or BP-2

7

SUPERPAVE™ & MoDOT MIXES

MoDOT Designation	NMS mm (in.)	Max. size mm (in.)
N/A	37 (1 ½)	50 (2)
SP250	25 (1)	37 (1 ½)
SP190	19 (¾)	25 (1)
SP125	12.5 (½)	19 (¾)
SP095	9.5 (⅜)	12.5 (½)
SP 048	4.75 (#4)	9.5 (⅜)

MINIMUM THICKNESSES

Superpave & Plant Mixes

Mix	Minimum Thickness (in.)
SP048, BP-3	1.0
SP095 BP-2*	1.25 1.5
SP125, BP-1	1.75
SP190	2.0
SP250, PMBB	3.0

NJSP: If BP-2 is placed in a 1.25" lift, %Passing 0.5" is reduced to 99-100.

9

Minimum Thickness for Leveling Courses

Mix	Thickness, in.
SP 125, BP-1	1.5
SP 095, BP-2	1
SP 048, BP-3	¾

10

MATERIAL STANDARD SPECS

Aggregate (403) Aggregate (401)	1002 1004
PG Binder	1015
Mineral Filler	1002
Hydrated Lime	1002
Fiber	1071
Anti-Strip	1071
Filler (RAP)	403
RAP	403
RAS	403

11

MIX DESIGN STEPS

- ***I. Material selection (Module 2A-2D)***
- II. Aggregate structure selection: *(Module 2E)*
- III. Design binder content selection: *(Module 2F)*
- IV. Evaluation of moisture sensitivity (stripping): *(Module 2G)*

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I. MATERIAL SELECTION

- 1. ***Determine design traffic***
- ***2.*** Select aggregate sources
- 3. Select PG binder grade (in contract documents)
- 4. Select RAP (optional)
- 5. Select RAS (optional)

13

1. DESIGN TRAFFIC

- 1. Determine traffic data for the project site
- 2. Convert the traffic levels for the mix of vehicle types to 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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ESAL's

- Conversion of damage from a given *axle load* to an equivalent number of passes of an 18,000 lb load on a single axle (equal damage)
- For instance, one pass of a 22,000 lb single axle is equivalent in damage to 2.2 passes of an 18,000 lb single axle load
- Not linear

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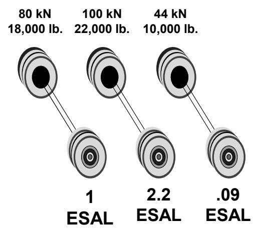
ESAL Comparison



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ESAL's

Another way…

- Conversion of a given ***vehicle*** to an equivalent number of passes of an 18,000 lb load on a single axle (equal damage)
- For instance, one pass of a certain 6-tire truck is equivalent in damage to 0.49 pass of an 18,000 lb single axle load

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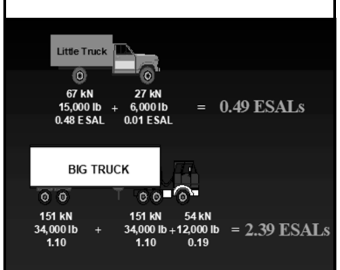

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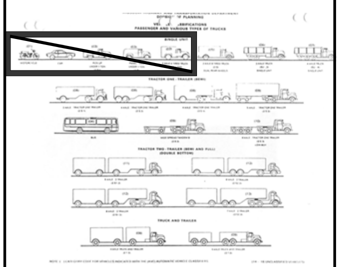
13 MoDOT (AASHTO) Vehicle Classes

"Trucks" = #4 - #13

6+ tires



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MoDOT: 13 VEHICLE CATAGORIES

Examples:

- Cat 1= Motorcycles
- Cat 3= cars & 4 tire pickups
- Cat 9= 18 wheelers

20

USE OF ESAL's IN MATERIAL SELECTION

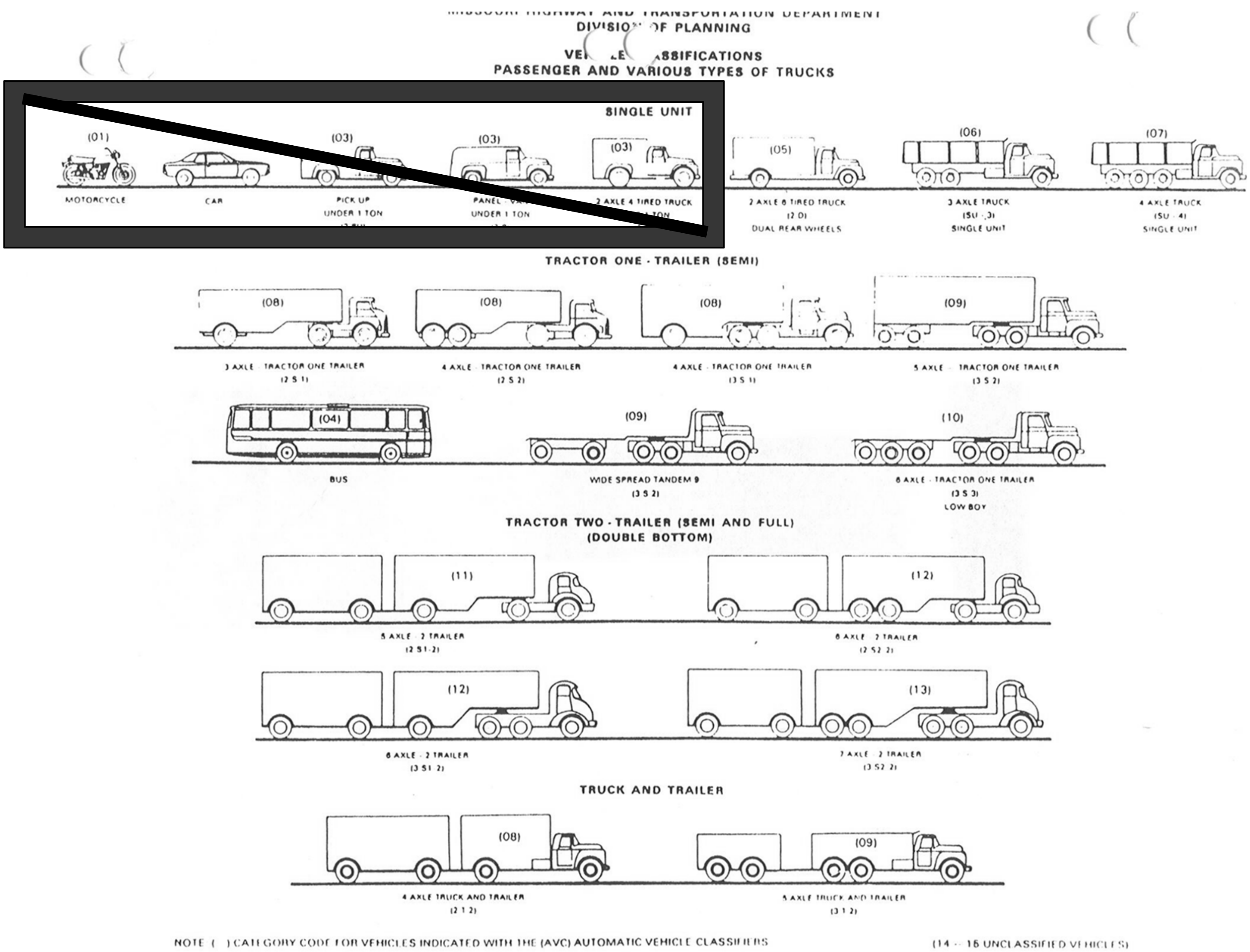
- ***Level of aggregate quality*** is ***tied to level of traffic***; for instance, the greater the design traffic, the more angular and cleaner the aggregate has to be.
- The choice of ***PG binder grade is tied to traffic level***; for instance, the greater the design traffic, the more rut resistant the binder must be.

21

13 MoDOT (AASHTO) Vehicle Classes

"Trucks" = #4 - #13

6+ tires



MoDOT Traffic Levels

Design Levels	Design Traffic (ESALS)
F	< 300,000
E	300,000 to < 3,000,000
C	3,000,000 to < 30,000,000
B	≥ 30,000,000

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CONSENSUS REQUIREMENTS on blended aggregate

Traffic Level	CAA	FAA	SE	F&E*
F	55/none	--	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

*SMA ≤ 20% @ 3:1 and ≤ 5% @ 5:1

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MODULE 2B

MIX DESIGN OVERVIEW:

Aggregate Quality

11-24-06 Revision
11-9-07 Revision
4-22-09 Revision
11-18-09 Revision
12-29-09 Revision
11-17-10 Revision
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MODULE 2B

MIX DESIGN OVERVIEW:

Aggregate Quality

11-24-06 Revision
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12-12-18 Revision
2-8-19 Revision

SELECTION OF AGGREGATE SOURCES

- The individual aggregate sources must meet agency (MoDOT) criteria:
  - Coarse Aggregate:
    - Deleterious material
    - LA abrasion
    - Absorption
    - Gradation
    - (Acid insoluble residue)
  - Fine Aggregate:
    - Deleterious material
    - Gradation

2

MoDOT 1002 SPECIFICATIONS

Coarse Aggregate or Combined

- LAA:……………………..………≤ 50%
- Deletereous Material (CA):
  - Deletereous Rock…………. ≤8.0 %
  - Shale…………………………… ≤1.0 %
  - Other Foreign Material.. ≤0.5 %
  - Total…………………………… ≤8.0 %
- Absorption:
  - Crushed stone………………… ≤4.0 %
  - Gravel………………………… ≤5.5 %
- Acid Insoluble………………≥85 %

3

MoDOT SPECIFICATIONS Fine Aggregate

- Clay Lumps & Shale…… ≤1.0 %
- Total Lightweight……….≤0.5 %
- Other Deleterious………≤0.1 %

4

SMA

- LAA………………………………≤ 40%
- Absorption………………. ≤ 3.5%

5

AGGREGATE CHARACTERISTICS

- Gradation, parent material quality, and contamination affect:
  - Constructability
  - Strength
  - Durability

6

AGGREGATE

- Parent material
- Deleterious material

7

GRADATION

8

SOURCE PROPERTIES

- ***Toughness***= ability to resist breakdown from handling, processing, compaction
- ***Soundness***= ability to resist breakdown from weathering
- ***Skid Resistance***

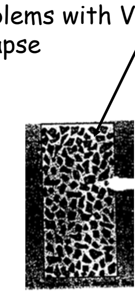
9

LA ABRASION
Toughness

10

TOUGHER AGGREGATE

- Less breakdown, less problems with VMA collapse



11

SODIUM OR MAGNESIUM SOUNDNESS

12

SKID RESISTANCE

- For "B" surface mixes and all SP095 and SP048NC containing limestone
- Must contain *some* (see table) hard ***non-carbonate materials*** (traprock, most gravels, steel slag, flint chat, with AIR ≥ 85%), or…
- Limestone must have AIR ≥ 30% (see TM76)

Coarse Aggregate (+#4)	**Minimum Non-carbonate By Volume**
Limestone, LA≤30	30% Plus #4
Limestone, LA>30	20% Minus #4*
Dolomite	No requirement

13

CONTAMINATION FROM:

- Inclusion of non-durable material during quarrying (e.g., shale, soft rock, etc.)
- Poor stockpile management techniques (e.g., mud, dust, etc.)
  - Quarry
  - Hot Mix Plant
- During delivery (e.g., contaminated truck beds)

14

DELETEREOUS MATERIAL

15

SHALE

- Inter-bedded with limestone
- Will break down easier than harder rock
- Much will end up in fines

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SELECTION OF AGGREGATE SOURCES

- Blended aggregate must also meet Superpave "Consensus" criteria:
  - Fine aggregate angularity
  - Coarse aggregate fractured face count
  - Course aggregate flat and elongated
  - Sand equivalent




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MoDOT Traffic Levels

Design Levels	Design Traffic (ESALS)
F	< 300,000
E	300,000 to < 3,000,000
C	3,000,000 to < 30,000,000
B	≥ 30,000,000

18

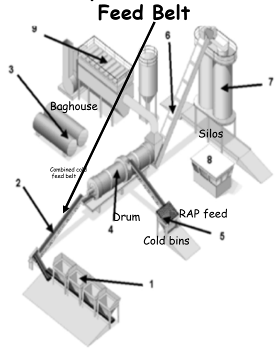
CONSENSUS REQUIREMENTS
on blended aggregate

Traffic Level	CAA	FAA	SE	F&E*
F	55/none	--	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

*SMA ≤ 20% @ 3:1 and ≤ 5% @ 5:1

19

Consensus Test Material Must Be Sampled from the Cold Feed Belt



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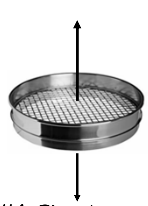
Split Over #4 Sieve

Plus #4: Coarse Aggregate (CA):
- CAA
- F&E



Minus #4: Fine Aggregate (FA):
- FAA
- SE

21

CONSENSUS TESTS

- ***Coarse Aggregate Angularity***
- Fine Aggregate Angularity
- Sand Equivalent
- Flat & Elongated

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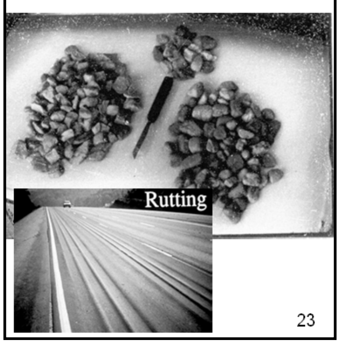
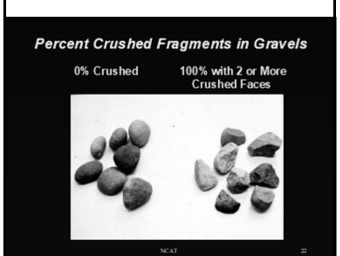
COARSE AGGREGATE ANGULARITY (CAA)
[Fractured Face Count (FFC)]



23

CAA
(Plus #4 on Aggregate Blend)



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CONSENSUS TESTS

- Coarse Aggregate Angularity
- ***Fine Aggregate Angularity***
- Sand Equivalent
- Flat & Elongated

25

FINE AGGREGATE ANGULARITY (FAA)

[Fine Aggregate Particle Shape (FAPS)]

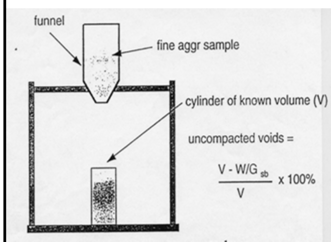
26

FINE AGGREGATE ANGULARITY

(Minus #4 on Aggregate Blend)

27

FAA



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MORE ANGULAR FINE AGGREGATE: Tradeoff

- Better interlocking (thus, greater stability)
- Higher VMA
- But…
  - Higher cost
  - Less compactibility

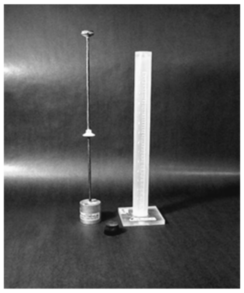
29

CONSENSUS TESTS

- Coarse Aggregate Angularity
- Fine Aggregate Angularity
- ***Sand Equivalent***
- Flat & Elongated

30

"SAND" EQUIVALENT [Clay Content)]



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LOW "SAND" EQUIVALENT
(Really Minus #4 on the Aggregate Blend)

- Harms bonding of asphalt to aggregate ---***stripping***

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"SAND" EQUIVALENT [Clay Content)]

- Shaking methods hierarchy:
  - Mechanical: not mandated
  - Manual: most common
  - Hand

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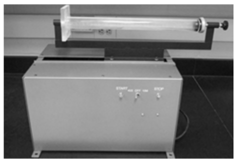
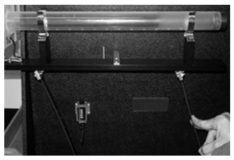
MECHANICAL & "MANUAL" SHAKERS





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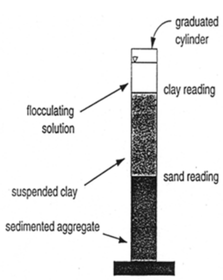
"SAND" EQUIVALENT [Clay Content)]

35



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CONSENSUS TESTS

- *Coarse Aggregate Angularity*
- *Fine Aggregate Angularity*
- *Sand Equivalent*
- ***Flat & Elongated***

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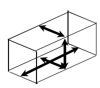
FLAT (THIN) & ELONGATED
(Plus #4 on Aggregate Blend)

- ASTM D4791
  - Flat
  - Elongated
  - Total flat and elongated



- Superpave
  - Flat and Elongated
  - Maximum to minimum dimension
    - ***5:1***
    - 3:1
    - 2:1

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PROBLEMS WITH FLAT & ELONGATED

- Increased breakage-
  - Finer gradation
  - Creates fines
  - Uncoated broken surfaces → stripping
- Compacts flat-lower VMA
- Increased problems with placing & compacting

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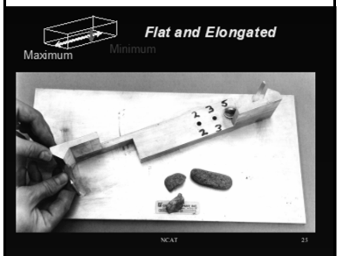
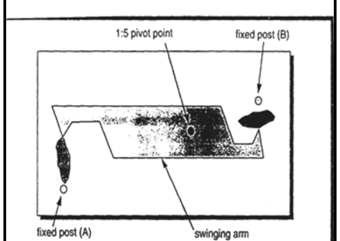
THIN & ELONGATED



40

THIN & ELONGATED

41



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MODULE 2C

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

MODULE 2C

MIX DESIGN OVERVIEW:
Binder
RAP & Shingles

11-24-06 Revision
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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

OUTLINE

- ***Binder grading & selection***
- M 332 grades
- Testing & evaluation
- RAP & shingles
- Mixing & compaction temperatures

2

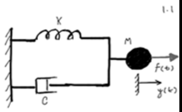
ASPHALT (BINDER) GRADING

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

3

ASPHALT (BINDER) BEHAVIOR

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



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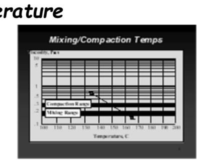
Binder Behavior

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



  - ***Duration of loading***

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

5

SELECTION OF PG BINDER GRADE

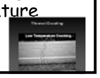
- Based on:
  - ***Climate***
  - Depth in pavement
  - Volume of traffic
  - Vehicle speed
  - Desired level of reliability
  - RAS (shingle) content
  - RAP content

6

SELECTION OF PG BINDER GRADE
Climate

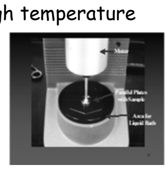
- Grade chosen primarily on temperature expected:
  - to prevent ***rutting***, based on cumulative hours at elevated temperatures

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

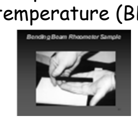


CONDITIONING/TESTING

- Rutting: High temperature (DSR)



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

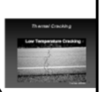


8

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

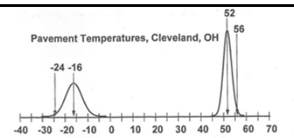


Figure 5.3 Example High and Low Pavement Temperature Variations

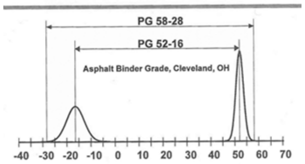


Figure 5.4 Superpave Binder Grade Selections for Cleveland

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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 º C*
- Average low pavement temperature is *-16 º 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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AASHTO M320 PG GRADING SYSTEM

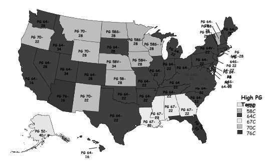
- 6 degree increments

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, -46
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

12

"Workhorse" Binder Grades



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

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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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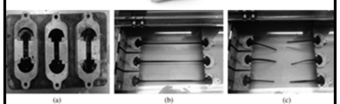
DO I REALLY HAVE POLYMER IN MY BINDER?

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



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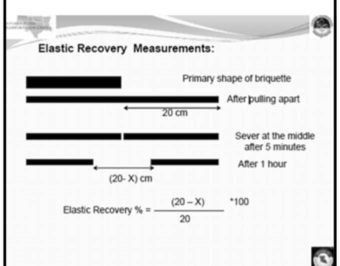
Elastic Recovery (%)



- Greater %ER is better

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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

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

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

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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

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PPA
Possible Issues, cont'd.

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

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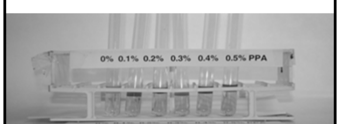
Simple Test to Detect PPA in Asphalt



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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

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

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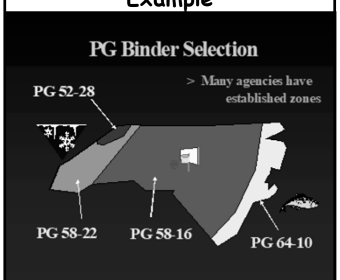
MATCH GRADE TO CLIMATE-
Example



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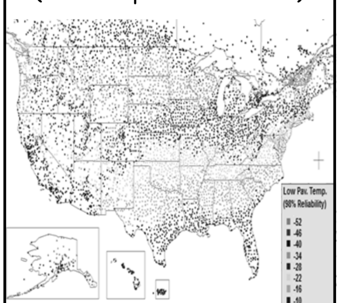
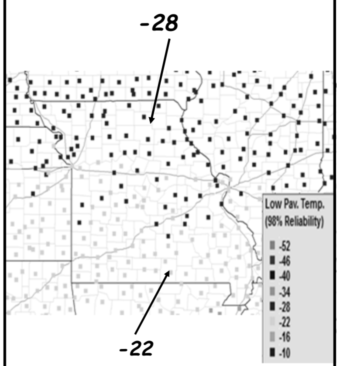
LTPPBind Program
Lower PG Number
(Low Temperature Values)





SELECTION OF PG BINDER GRADE

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

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SELECTION OF PG BINDER GRADE
Depth in Pavement

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

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SELECTION OF PG BINDER GRADE

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

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Binder Grading Specs

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

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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*

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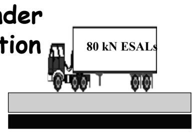
Effect of Traffic Amount on Binder Selection



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

> **E**quivalent **S**ingle **A**xle **L**oads

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SELECTION OF PG BINDER GRADE

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

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Vehicle Speed

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

Why?

- Longer duration of load

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

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

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Effect of Loading Rate on Binder Selection
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

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SELECTION OF PG BINDER GRADE

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

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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

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SELECTION OF PG BINDER GRADE

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

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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

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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

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"Effective Binder"

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

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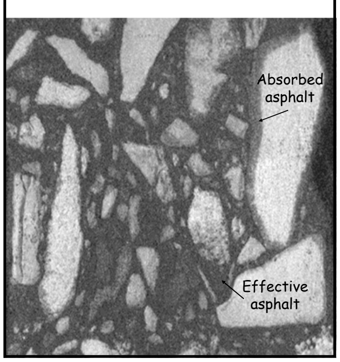
ABSORPTIVENESS OF AGGREGATE



BINDER CONTENT

Conceptually:

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

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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%

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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)

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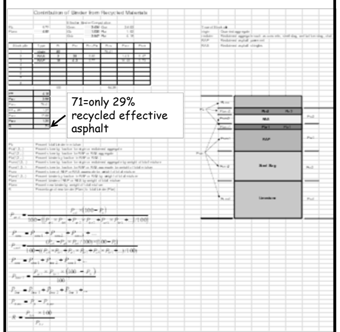
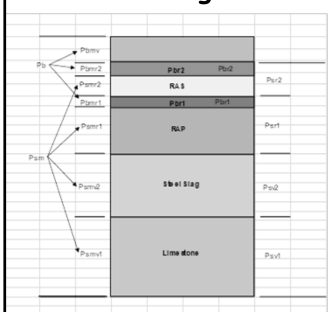
MoDOT Reclaimed Binder Worksheet



Block Diagram



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

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MoDOT Reclaimed Binder Worksheet

Contribution of Binder from Recycled Materials

		Effective Binder Computation			
Pb	5.70	Gmm	2.434	Gse	2.653
Pbmv	4.50	Gb	1.030	Pba	1.52
		Gsb	2.547	Pbe	4.18

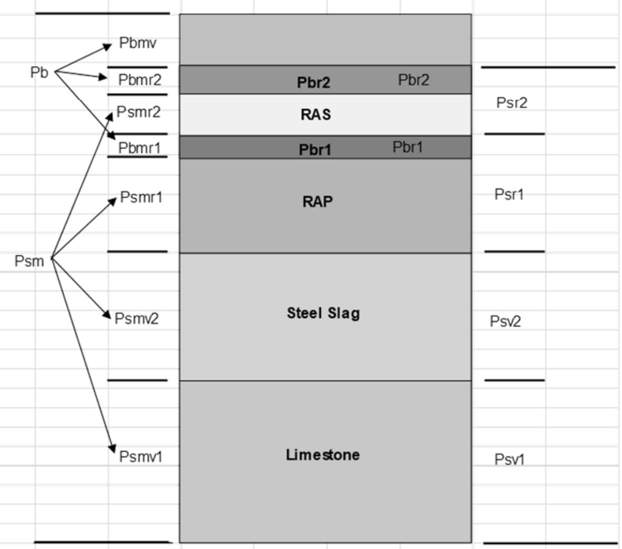
Type of Stockpile

virgin	- Quarried aggregate
reclaim	- Reclaimed aggregate such as concrete, steel slag, wet bottom slag, chat
RAP	- Reclaimed asphalt pavement
RAS	- Reclaimed asphalt shingles

Stockpile	Type	P_s	P_{br}	$P_{sr} \times P_{br}$	P_{smv}	P_{smr}	P_{bmr}
1	virgin	80			76.41		
2	RAS	2	25	0.50		1.43	0.47
3	RAP	18	4.3	0.77		16.45	0.73
4							
5							
6							
7							
8							
		100			94.29		

P_{be}	4.18
P_{bev}	2.98
P_{smv}	76.41
$P_{sr} \times P_{br}$	1.27
P_{smr}	17.88
P_{bmr}	1.20
R	71

71=only 29% recycled effective asphalt



Pb	- Percent total binder in mixture
Psv(1,2,..)	- Pecent stone by fraction for virgin or reclaimed aggregate
Psr(1,2,..)	- Pecent stone by fraction for RAP or RAS aggregate
Pbr(1,2,..)	- Percent binder by fraction in RAP or RAS
Psmv(1,2,..)	- Pecent stone by fraction for virgin or reclaimed aggregate by weight of total mixture
Psmr(1,2,..)	- Pecent stone by fraction for RAP or RAS aggregate by weight of total mixture
Psmr	- Pecent stone of RAP or RAS aggregate by weight of total mixture
Pbmr(1,2,..)	- Percent binder by fraction in RAP or RAS by weight of total mixture
Pbmr	- Percent binder of RAP or RAS by weight of total mixture
Pbmv	- Pecent new binder by weight of total mixture
R	- Percentage of new binder (Pbev) to total binder (Pbe)

$$P_{smv1} = \frac{P_{sv1} \times (100 - P_b)}{100 - ((P_{sr1} \times P_{br1} + P_{sr2} \times P_{br2} + P_{sr3} \times P_{br3} + \ldots)/100)}$$

$$P_{smv} = P_{smv1} + P_{smv2} + P_{smv3} + \ldots$$

$$P_{smr1} = \frac{(P_{sr1} - P_{sr1} \times P_{br1}/100) \times (100 - P_b)}{100 - ((P_{sr1} \times P_{br1} + P_{sr2} \times P_{br2} + P_{sr3} \times P_{br3} + \ldots)/100)}$$

$$P_{smr} = P_{smr\,1} + P_{smr\,2} + P_{smr\,3} + \ldots$$

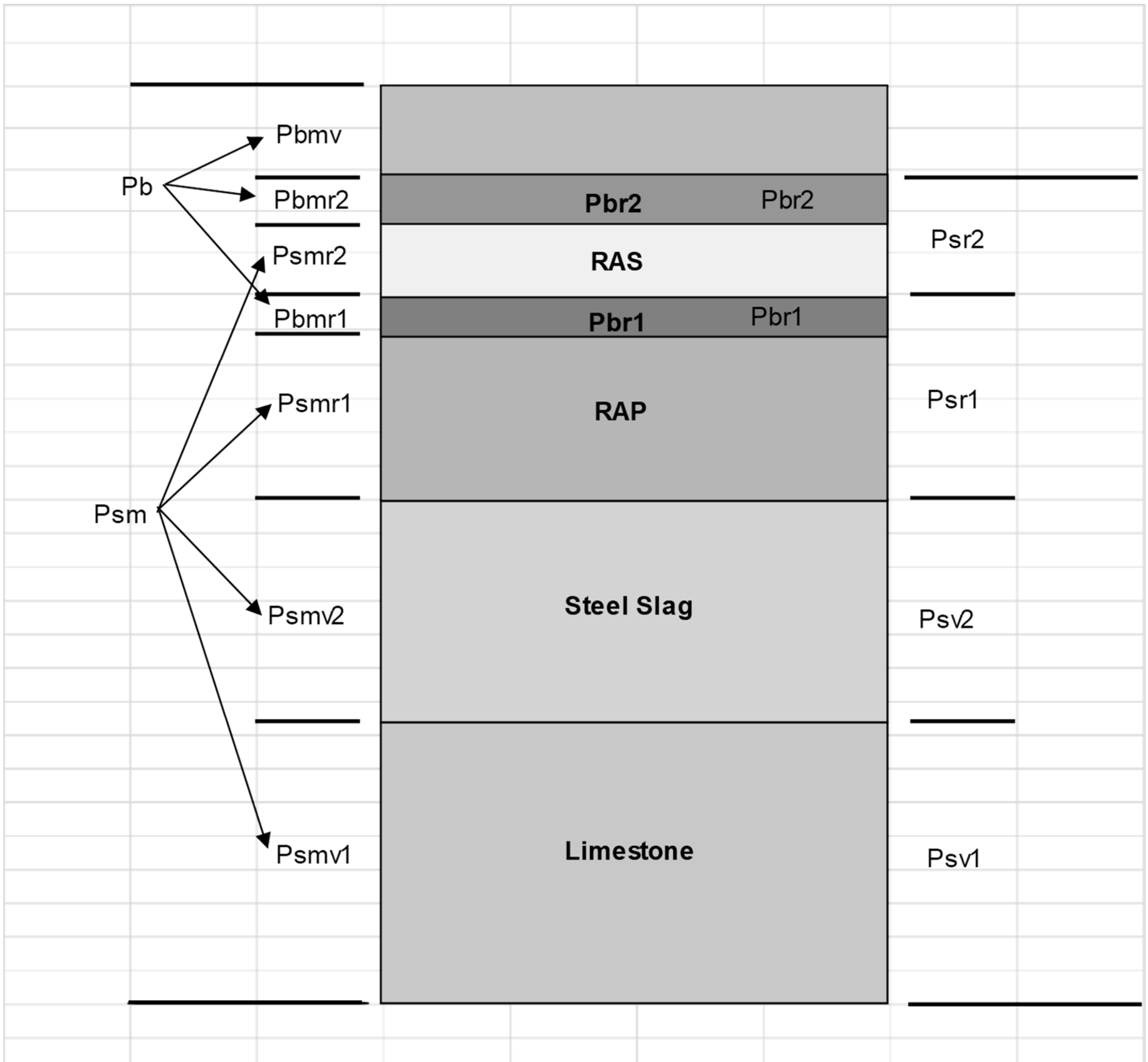
$$P_{bmr\,1} = \frac{P_{sr\,1} \times P_{br\,1} \times (100 - P_b)}{100^2}$$

$$P_{bmr} = P_{bmr\,1} + P_{bmr\,2} + P_{bmr\,3} + \ldots$$

$$P_{bmv} = P_b - P_{bmr}$$

$$R = \frac{P_{bev} \times 100}{P_{be}}$$

Block Diagram



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

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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

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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)

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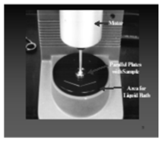
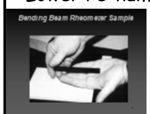
BINDER TESTING
PG 64-22

- Upper PG number (eg, 64): DSR



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



OUTLINE

- Binder grading & selection
- ***M 332 grades***
- Testing & evaluation
- RAP & shingles
- Mixing & compaction temperatures

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ALTERNATE GRADING SYSTEMS

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

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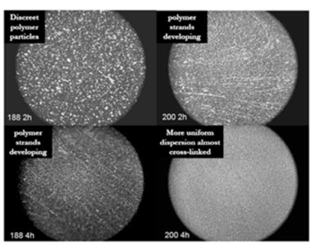
AASHTO M 320 Issues and the M 332 Solution

- **M 320 was developed based on neat asphalts and does not do PMAs justice**
  - **Therefore some Agencies have added "Plus Tests", such as % Elastic Recovery (% ER).**
  - **However empirical tests such as % ER only show the presence of, but not the effectiveness of polymer-modification.**

Polymer Modification

- Same polymer, same amount polymer
- Not well characterized with M320 and PG+ tests



AASHTO M 320 Issues and the M 332 Solution

- **The MSCR specification M332 corrects the M320 deficiencies by testing at the project climate temperatures and at the stress level commensurate with the expected traffic.**
  - **M332 uses the non-recoverable compliance % (Jnr) and % Recovery to better qualify the type of modification.**

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Type of Modification

- M332 (MSCR) is blind to the type of modifier

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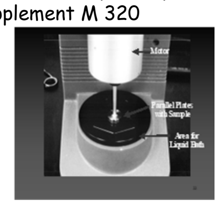
M 332 (MP 19) Binder Test/Specification

- MSCR = Multiple Stress Creep Recovery test
- Extra DSR test
- Alternate AASHTO binder specification (M 332) to supplement M 320



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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

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

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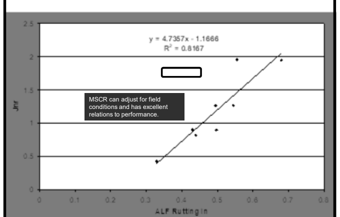
Relationship Between J_{nr} and Rutting



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

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OUTLINE

- Binder grading & selection
- M 332 grades
- ***Testing & evaluation***
- RAP & shingles
- Mixing & compaction temperatures

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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

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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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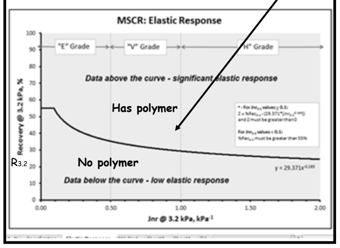
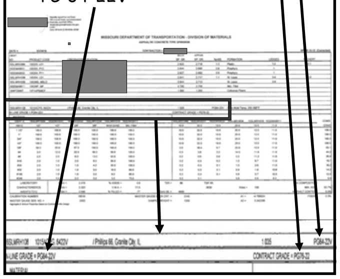
M 332 APPENDIX
MSCR % Recovery

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



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

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



What's My Grade?
Different Example

- ***"Contract Grade"*** = the PG grade in the contract, eg. PG 70-22
- ***"Purchased Grade"*** = what contractor buys from supplier (terminal), eg. PG 58-28 (if RAP/RAS will be used)
- ***"In-line Grade"*** = Purchased grade + ***additive*** (warm mix, anti-strip, etc.)
  eg. PG 58-28
- ***"In-line Grade"*** = Purchased grade + ***modifier*** (rejuvenator)
  eg. PG 52-28

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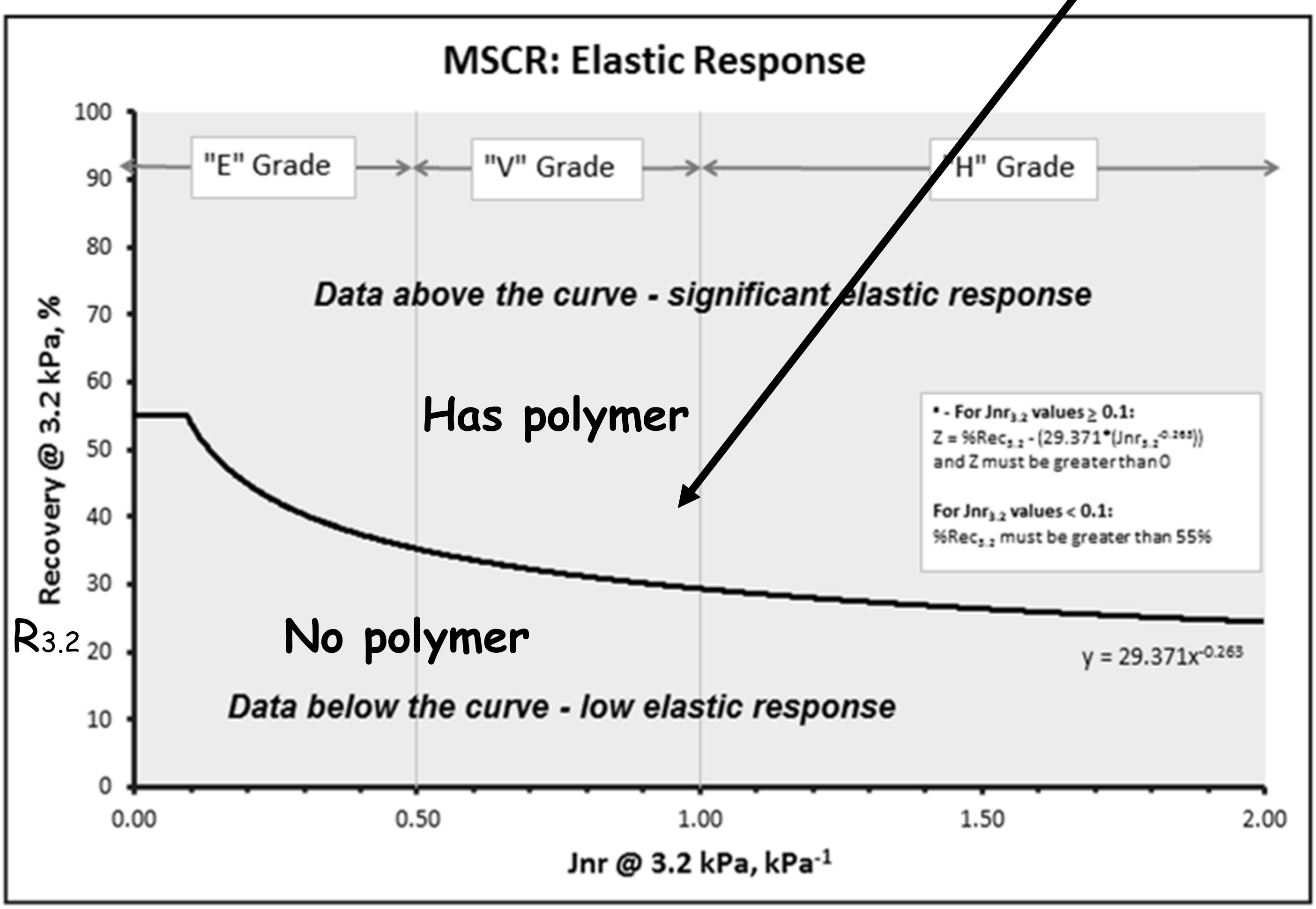
M 332 APPENDIX MSCR % Recovery

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



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 6 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	/ Phill 66, Granite City, IL	1.035		PG64-22V	o Mold Temp. 290-300°F		

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

MATERIAL IDENT #	16SLMRH066	16SEMA0031	16 MA0032	16SLMRH058	16SLMRH059	16SEMA0011	16SLMRH066	16SEMA0031	16SEMA0032	16SLMRH058	16SLMRH059	16SEMA0011	COMB
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	GRAD
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	mm =	2.419	% VOIDS =	4.0	TSR =	86	TSR Wt.		X COMPOSITIO	
CHARACTERISTICS	mb =	2.323	V.M.A. =	17.5			3630	Ndes = 100	MIN. AG	93.7%
AASHTO T312	Gsb =	2.646	% FILLED =	77	Gyro Wt. =	4600			PHALT CONTEN	6.0%

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

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

Aggregate & Mixture Properties Based on Contrac Mix Design

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

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

MATERIAL

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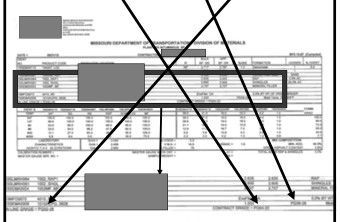
Example of Contract Grade, Purchased Grade, In-Line Grade (after additives/modifiers)

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



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)

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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

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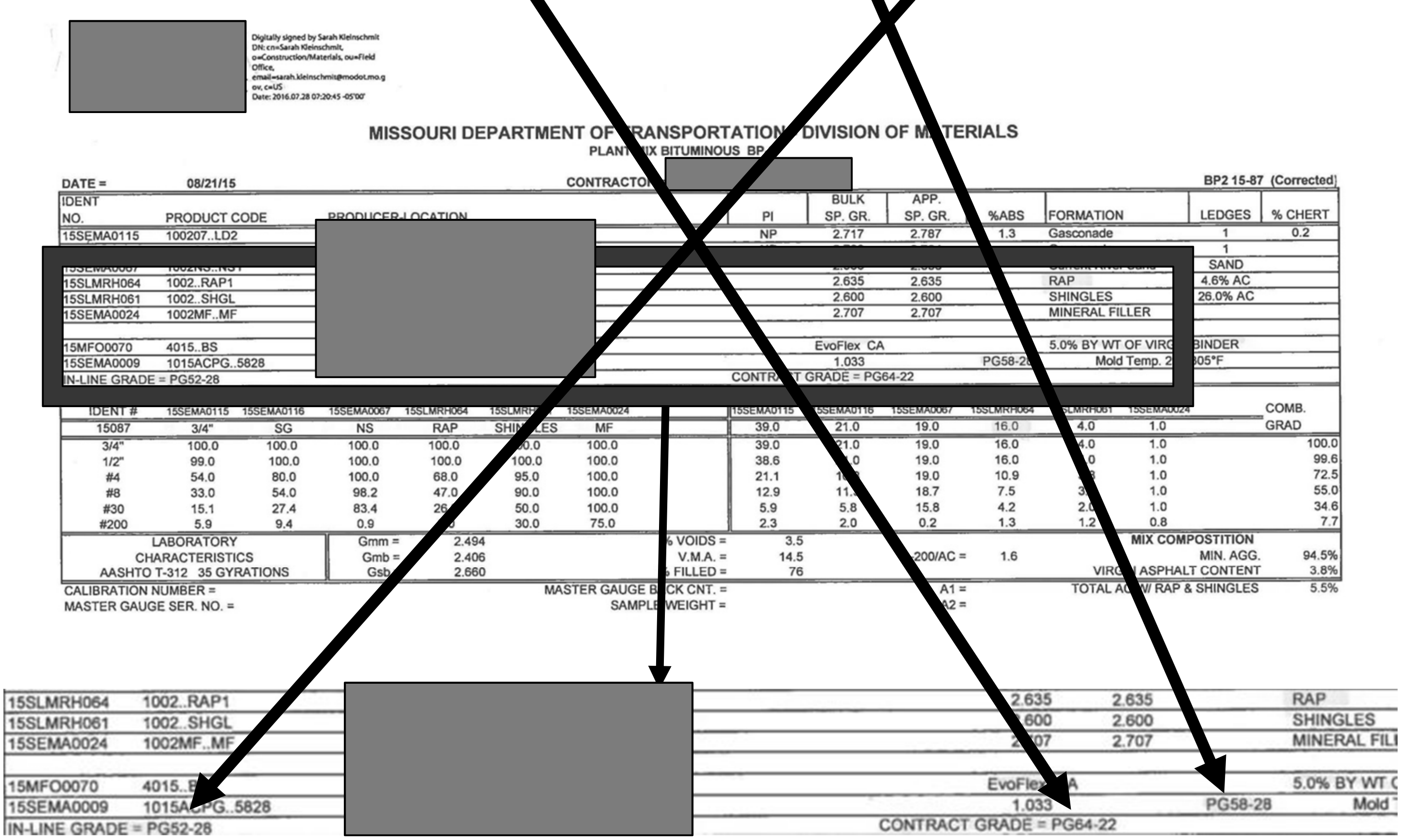
Example of Contract Grade, Purchased Grade, In-Line Grade (after additives/modifiers)

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



[redacted] Digitally signed by Sarah Kleinschmit DN: cn=Sarah Kleinschmit, o=Construction/Materials, ou=Field Office, email=sarah.kleinschmit@modot.mo.gov, c=US Date: 2016.07.28 07:20:45 -05'00'

MISSOURI DEPARTMENT OF [illegible]RANSPORTATION [illegible] DIVISION OF M[illegible]TERIALS
PLANT [illegible]IX BITUMINOUS BP[illegible]

DATE = 08/21/15 CONTRACTO[illegible] [redacted] BP2 15-87 (Corrected)

IDENT NO.	PRODUCT CODE	PRODUCER-LOCATION	PI	BULK SP. GR.	APP. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
15SEMA0115	100207..LD2	[redacted]	NP	2.717	2.787	1.3	Gasconade	1	0.2
								1	
								SAND	
15SLMRH064	1002..RAP1			2.635	2.635		RAP	4.6% AC	
15SLMRH061	1002..SHGL			2.600	2.600		SHINGLES	26.0% AC	
15SEMA0024	1002MF..MF			2.707	2.707		MINERAL FILLER		
15MFO0070	4015..BS			EvoFlex CA			5.0% BY WT OF VIRG[illegible] BINDER		
15SEMA0009	1015ACPG..5828			1.033		PG58-2[illegible]	Mold Temp. 2[illegible]305°F		

IN-LINE GRADE = PG52-28 CONTR[illegible]T GRADE = PG64-22

IDENT #	15SEMA0115	15SEMA0116	15SEMA0067	15SLMRH064	15SLMRH[illegible]	15SEMA0024	15SEMA0115	[illegible]5SEMA0116	15SEMA0067	15SLMRH064	[illegible]SLMRH061	15SEMA0024	COMB. GRAD
15087	3/4"	SG	NS	RAP	SHIN[illegible]LES	MF	39.0	21.0	19.0	16.0	4.0	1.0	
3/4"	100.0	100.0	100.0	100.0	[illegible]0.0	100.0	39.0	[illegible]1.0	19.0	16.0	[illegible]4.0	1.0	100.0
1/2"	99.0	100.0	100.0	100.0	100.0	100.0	38.6	[illegible].0	19.0	16.0	[illegible].0	1.0	99.6
#4	54.0	80.0	100.0	68.0	95.0	100.0	21.1	1[illegible]	19.0	10.9	[illegible]	1.0	72.5
#8	33.0	54.0	98.2	47.0	90.0	100.0	12.9	11.[illegible]	18.7	7.5	3[illegible]	1.0	55.0
#30	15.1	27.4	83.4	26[illegible]	50.0	100.0	5.9	5.8	15.8	4.2	2.[illegible]	1.0	34.6
#200	5.9	9.4	0.9	[illegible]	30.0	75.0	2.3	2.0	0.2	1.3	1.2	0.8	7.7

LABORATORY CHARACTERISTICS AASHTO T-312 35 GYRATIONS
Gmm = 2.494 [illegible]% VOIDS = 3.5
Gmb = 2.406 V.M.A. = 14.5 [illegible]200/AC = 1.6
Gsb[illegible] 2.660 [illegible]% FILLED = 76

MIX COMPOSTITION
MIN. AGG. 94.5%
VIRG[illegible] ASPHALT CONTENT 3.8%
TOTAL AC[illegible]W/ RAP & SHINGLES 5.5%

CALIBRATION NUMBER = MASTER GAUGE B[illegible]CK CNT. = A1 =
MASTER GAUGE SER. NO. = SAMPLE[illegible]WEIGHT = [illegible]A2 =

15SLMRH064	1002..RAP1	[redacted]	2.635	2.635	RAP	
15SLMRH061	1002..SHGL		[illegible]600	2.600	SHINGLES	
15SEMA0024	1002MF..MF		2.[illegible]07	2.707	MINERAL FIL[illegible]	
15MFO0070	4015..B[illegible]		EvoFle[illegible]A		5.0% BY WT [illegible]	
15SEMA0009	1015A[illegible]PG..5828		1.033	PG58-28	Mold [illegible]	

IN-LINE GRADE = PG52-28 CONTRACT GRADE = PG64-22

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

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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

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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%

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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

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OUTLINE

- Binder grading & selection
- M 332 grades
- Testing & evaluation
- ***RAP & shingles***
- Mixing & compaction temperatures

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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)

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RAP
Micro Deval
AASHTO TP 58

- 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

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

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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)

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OUTLINE

- Binder grading & selection
- M 332 grades
- Testing & evaluation
- RAP & shingles
- ***Mixing & compaction temperatures***

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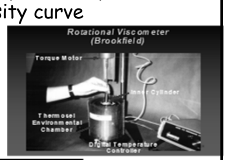
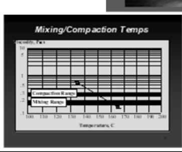
DETERMINE MIXING & COMPACTION TEMPERATURES

- Develop the temperature-viscosity curve





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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

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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.

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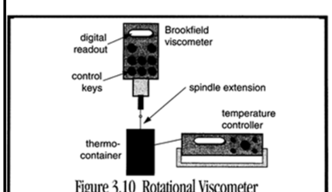

Figure 3.10 Rotational Viscometer

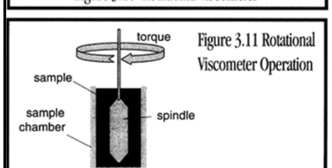

Figure 3.11 Rotational Viscometer Operation

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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.

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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.

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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.

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Temperature is critical

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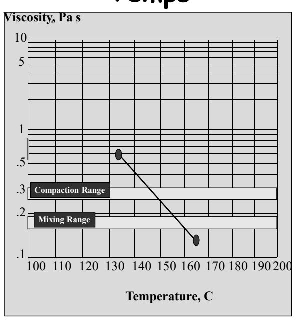
Mixing/Compaction Temps



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MODULE 2D

MIX DESIGN OVERVIEW:

Volumetrics

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
2-8-19 Revision
12-17-19 Revision

MODULE 2D

MIX DESIGN OVERVIEW:
Volumetrics

11-24-06 Revision
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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
2-8-19 Revision
12-17-19 Revision

OUTLINE

- ***Volumetrics***
- Gradation
- Dust
- Particle shape
- Aggregate absorption
- Aggregate specific gravity
- Maintaining VMA
- Mix bulk specific gravity
- Mix maximum specific gravity
- Calculation of volumetrics

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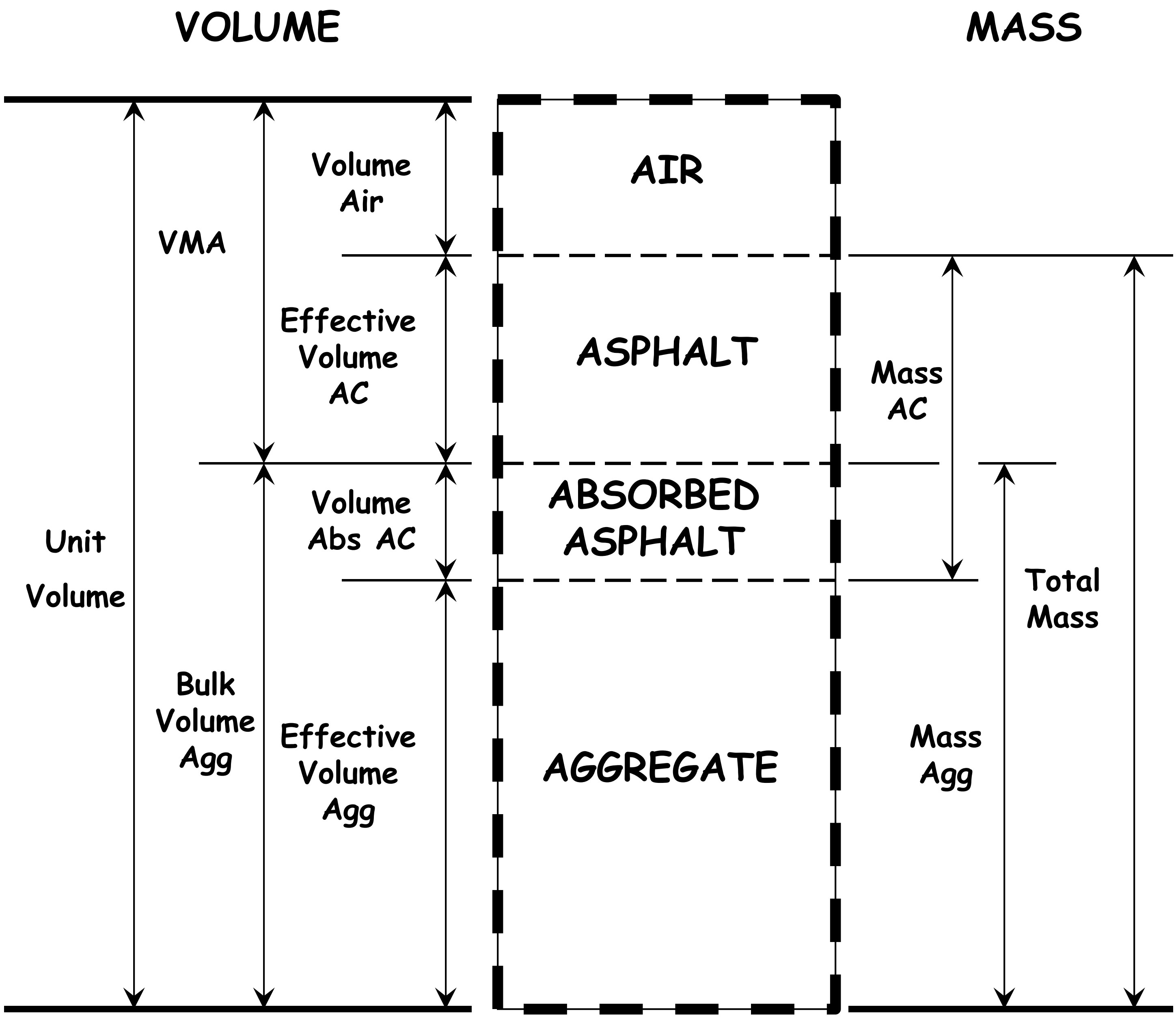
VOLUMETRICS

- "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 air voids are obtained.
- Space is dependent on aggregate gradation, particle shape, aggregate toughness, and aggregate absorption.

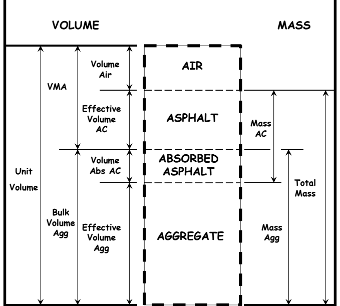
3



VOLUME
MASS
Volume Air
VMA
AIR
Effective Volume AC
ASPHALT
Mass AC
Volume Abs AC
ABSORBED ASPHALT
Unit Volume
Total Mass
Bulk Volume Agg
Effective Volume Agg
AGGREGATE
Mass Agg

VOLUMETRICS

- ***Air voids***
- VMA
- VFA



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Air Voids

- Proper ***% air voids*** content "V_a" (4.0 ± 1.0%)

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AIR VOIDS

- Low % air voids (<3%)
  - Plastic rutting
  - Bleeding
- High air voids (>5%)
  - Consolidation rutting
  - Durability problems (mat is more permeable)

VOLUMETRICS

- Air voids
- ***VMA***
- VFA

VMA

- The total void content is called "VMA"= Voids in the Mineral Aggregate
- VMA=air voids +***effective*** asphalt

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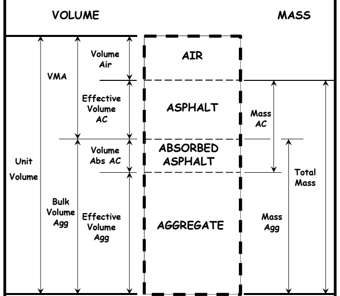

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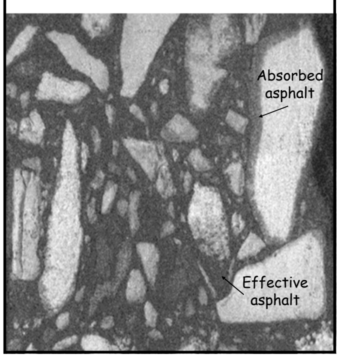
ABSORPTIVENESS OF AGGREGATE



BINDER CONTENT

Conceptually:

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

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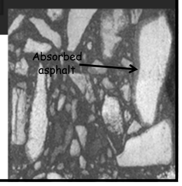
TIME AT HIGH TEMPERATURE: Absorption may continue and change Volumetrics

SURGE SILO



AGGREGATE STRUCTURE

- Insufficient VMA means:
  - Under-asphalted mix thus non-durable, or
  - Low air void content (less than 3%) which may result in "plastic rutting"
- VMA is one of the most difficult parameters to hit

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VMA Design Requirements (Criteria)

MIX	Minimum % VMA
SP 250	12.0
SP 190	13.0
SP 125	14.0
SP 095	15.0
SP 048	16.0
SP095xSM(R) SP125xSM(R)	17.0

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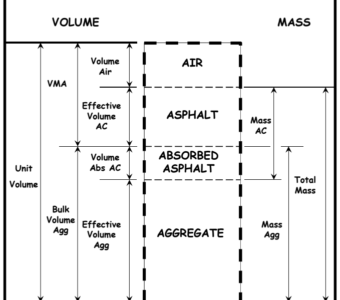
VOLUMETRICS

- Air voids
- VMA
- ***VFA***



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VOIDS FILLED WITH ASPHALT "VFA"

- VFA = % of VMA filled with effective asphalt

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% VOIDS FILLED Requirements (Criteria)

Design Level	VFA (%)[a]
F	70-80
E	65-78
C	65-75[b]
B	65-75[b]

a: SMA and SP048: min. 75%
b: SP095 max 76% and SP048 max 78%

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OUTLINE

- Volumetrics
- ***Gradation***
- Dust
- Particle shape
- Aggregate absorption
- Maintaining VMA
- Aggregate specific gravity
- Mix bulk specific gravity
- Mix max. specific gravity
- Calculation of volumetrics

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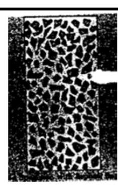

The real purpose in establishing and controlling aggregate gradation is to provide and maintain a proper void content in the aggregate. This is called voids in the mineral aggregate or VMA and is illustrated in this slide.

The VMA must be large enough to allow each particle to be coated with asphalt and still maintain a proper air void content in the final compacted mix. Minimum VMA requirements vary directly with top aggregate size.

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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

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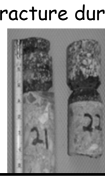
SUPERPAVE & MoDOT MIXES

MoDOT Designation	NMS mm (in.)	Max. size mm (in.)
N/A	37 (1 ½)	50 (2)
SP250	25 (1)	37 (1 ½)
SP190	19 (¾)	25 (1)
SP125	12.5 (½)	19 (¾)
SP095	9.5 (⅜)	12.5 (½)
SP 048	4.75 (#4)	9.5 (⅜)

Gradation
Considerations

- Larger max size:
  - Improves skid resistance
  - Improves rut resistance
  - Increases problem with segregation of particles
  - Increases chance of aggregate fracture during compaction



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Gradation
Considerations

- NMS < 1/3 AC lift thickness (<¼ would be better)
- NMS vs Lift Thickness:

Want ratio NMS/Lift thickness <0.333

Mix	NMS (in.)	Min. Lift Thickness (in.)	Ratio	OK?
SP048	0.187	1.0	0.19	OK
SP095	0.375	1.5	0.25	OK
SP125	0.50	1.75	0.29	OK
SP190	0.75	2.0	0.38	No
SP250	1.0	3.0	0.33	OK

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Gradations
Considerations

- Smaller max size:
  - Reduces segregation
  - Reduces road noise
  - Decreases tire wear
  - Increases sweepability
  - Decreases possibility of aggregate breakage during compaction and possible stripping
  - More likely to be available than NMS of 1" and greater
  - MoDOT allows changing from SP250 to SP190

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Some of the effects of aggregate gradation on the mixture have been determined by experience as follows:

a. Too much coarse aggregate produces a harsh mix which tends to segregate easily.

b. Too much sand produces a soft mix which becomes too tender to properly compact.

c. Too much filler produces a harsh stiff mix.

d. Too little filler produces a mix with low cohesion.

e. Crushed aggregate produces a mix with high interparticle friction.

f. Smooth aggregate produces a mix with lower interparticle friction.

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

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403 SPECIFIED GRADATIONS

Sieve	SP125xSM(R)	SP095xSM(R)
1.5	--	--
1	--	--
¾	100	--
½	90-100	100
3/8	50-80	70-95
#4	20-35	30-50
#8	16-24	20-30
#16	--	21 max
#30	--	18 max
#50	--	15 max
#100	--	---
#200	8.0-11.0	8.0-12.0

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RAS Gradation

- Ground to minus 3/8 in.
- 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

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AGGREGATE STRUCTURE

- The aggregate structure must result in sufficient voids between the particles to contain:
  - sufficient asphalt film thickness on particles
  - proper ***% air voids*** content "V_a" (4.0 ± 1.0%)

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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

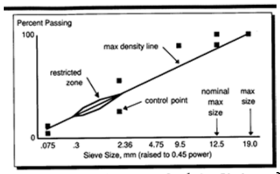


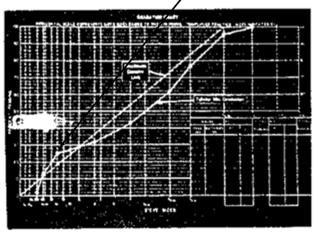
Figure 3.10 Superpave Gradation Limits

2

The maximum density line can also be used as a guide to adjust the mineral voids and the air voids of the mix. The more the slope of the mix gradation varies from the slope of the maximum density line the more mineral aggregate voids are provided in the mix. In some materials, especially limestone mixes, gap grading may be necessary to provide adequate voids.

33

Upon development of the .45 power gradation chart, several problem mixes were studied to see if this chart could be used to identify the problem. This slide shows the gradation of one of the mixes that was identified as tender in the field during construction. These tender mixes will generally be identified by the hump near the #30 sieve.



Restricted Zone

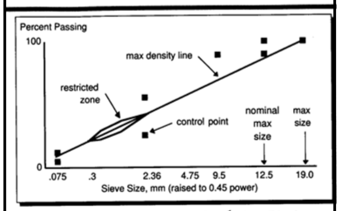


Figure 3.10 Superpave Gradation Limits

35

RESTRICTED ZONE

- The ***restricted zone*** is an area that the gradation line must not enter to avoid tender mix problems (especially if the aggregate contains rounded natural sand).
- This was a requirement of Job Special Provision MSP-95-03Z. This requirement has been removed in the 2004 and later versions of the Standard Specifications, Section 403.

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Restricted Zone

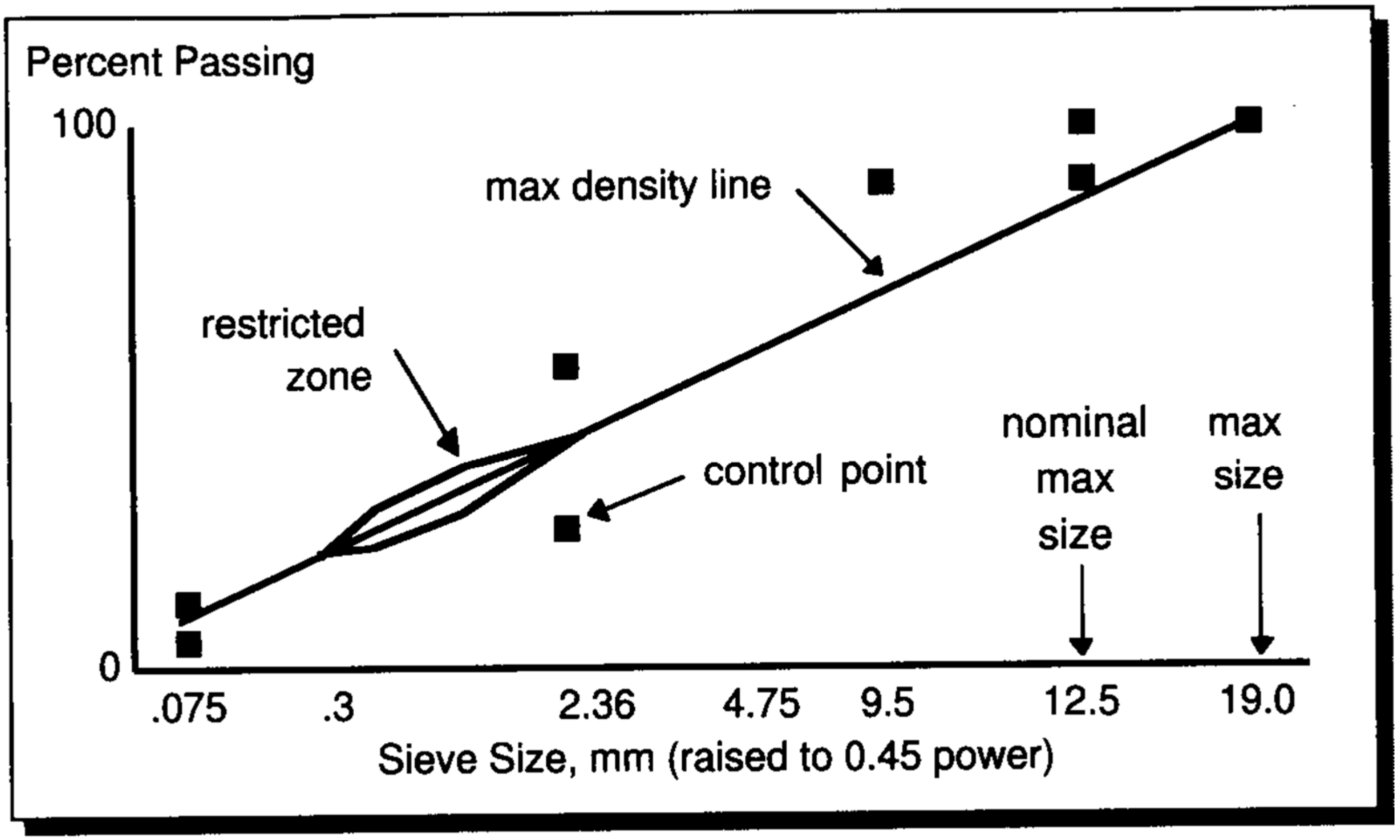
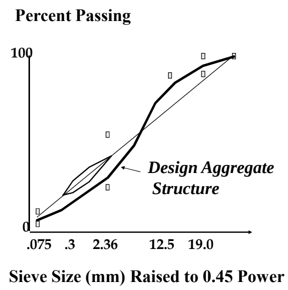


Figure 3.10 Superpave Gradation Limits

Superpave Aggregate Gradation



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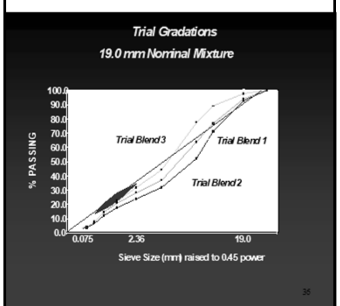

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AGGREGATE STRUCTURE

- Gradations above the MDL and the restricted zone are "fine" and those below are "coarse". Most Missouri mixes are coarse.

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OUTLINE

- Volumetrics
- Gradation
- ***Dust***
- Particle shape
- *Aggregate absorption*
- *Maintaining VMA*
- *Aggregate specific gravity*
- *Mix bulk specific gravity*
- *Mix max. specific gravity*
- *Calculation of volumetrics*

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DUST (Minus #200)

Types:

- Mineral Filler (MF)
- Dust from aggregate:
  - Surface dust
  - Breakdown dust

DUST / BINDER RATIO

- Ratio of % minus #200 to % effective asphalt content
- D/P_{be}
- 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

42

DUST

- Softer aggregates will break down during compaction and VMA “collapses” (fills in)

43

BREAKDOWN DUST

- Must account for in mix design:
  - Show bag house fines % on the Standardized JMF Submittal spreadsheet and indicate which aggregate fraction to add the % dust during production
  - Could run aggregate through drum to estimate amount of breakdown dust generated

BAGHOUSE DUST

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

OUTLINE

- Volumetrics
- Gradation
- Dust
- ***Particle shape***
- Aggregate absorption
- Maintaining VMA
- Aggregate specific gravity
- Mix bulk specific gravity
- Mix max. specific gravity
- Calculation of volumetrics

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Particle Shape

- Angularity of fine aggregate
- Flat & elongated coarse aggregate particles

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TO INCREASE VMA:
Use a More Angular Sand

- More angular aggregate will provide more voids for a given gradation
- Replace some natural sand with manufactured sand

48

TO INCREASE VMA:
Reduce the Effect of the F&E Fraction

- Reduce the % of the aggregate fraction that has a higher % F&E
- Add an intermediate size that is more cubical
- Adjust the crushing operation (feed rate, cone settings, type of crusher)

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OUTLINE

- Volumetrics
- Gradation
- Dust
- Particle shape
- ***Aggregate absorption***
- Maintaining VMA
- Aggregate specific gravity
- Mix bulk specific gravity
- Mix max. specific gravity
- Calculation of volumetrics

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TO INCREASE VMA:
Use a Lower Absorption Fraction

- Replace a more absorptive material with a less absorptive one (at the same total binder content, the effective binder will increase, thus increasing VMA)

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OUTLINE

- Volumetrics
- Gradation
- Dust
- Particle shape
- Aggregate absorption
- Aggregate specific gravity
- ***Maintaining VMA***
- Mix bulk specific gravity
- Mix maximum specific gravity
- Calculation of volumetrics

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VMA Production

- Want to keep VMA close to design value during production

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TO INCREASE VMA

- Change gradation
- Use a more angular sand
- Reduce minus #200
- Reduce effect of flat & elongated
- Use a lower absorption fraction

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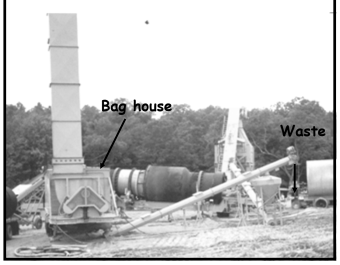
TO INCREASE VMA: Change Gradation

- Gap-grade (increase a coarse sieve, decrease next 2 smaller sieves
- Replace some of the most coarse-graded fraction with a higher % (or introduction of) a finer coarse aggregate
- Move gradation away from the MDL (maximum density line)

55

TO INCREASE VMA: Lower Minus #200

- Reduce mineral filler content
- Reduce fines from aggregate:
  - Waste more dust from baghouse



TO INCREASE VMA: Lower Minus #200, cont'd.

- 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 (eg. replace some ½" minus material with a clean ⅜" chip)
  - Replace some screenings with a less dusty graded fraction

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TO INCREASE VMA: Lower Minus #200, cont'd.

- Replace some of the source material that is breaking down with a harder aggregate
- Wash the source material that is the source of fines

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OUTLINE

- Volumetrics
- Gradation
- Dust
- Particle shape
- Aggregate absorption
- Maintaining VMA
- ***Aggregate specific gravity***
- Mix bulk specific gravity
- Mix max. specific gravity
- Calculation of volumetrics

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SPECIFIC GRAVITIES

- Necessary for calculation of volumes from weights
- For mix design and QC

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Example: VMA

Voids in Mineral Aggregate

$$VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}$$

VMA is an indication of film thickness on the surface of the aggregate

$$G_{sb,\,blend} = \frac{P1 + P2 + P3}{\frac{P1}{G_{sb1}} + \frac{P2}{G_{sb2}} + \frac{P3}{G_{sb3}}}$$

P_s=% aggregate
P_s=100 - P_b
P_b=% binder
G_{sb}= bulk sp. gravity of the aggregate blend

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AGGREGATE SPECIFIC GRAVITY

- For each aggregate, there are three types of specific gravity:
  - Bulk sp gravity (G_{sb})
  - Apparent sp gravity (G_{sa})
  - Effective sp gravity (G_{se})

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SPECIFIC GRAVITY, G

- Ratio of the mass to volume of an object to that of water at the same temperature

$$G = \frac{\dfrac{\text{Mass,solid}}{\text{Volume}}}{\dfrac{\text{Mass,Water}}{\text{Volume}}}$$

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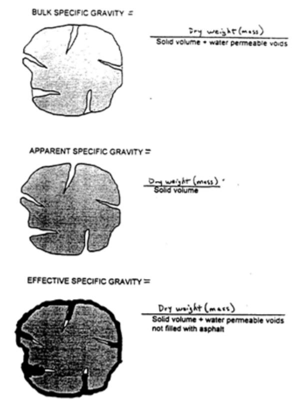

Testing for Spec. Gravity

- G_{sb} and G_{sa} from water displacement tests (T84, T85)
- G_{se} back-calculated from G_{mm} test on HMA mixture (Rice) (T209)

$$Gse = \frac{100 - Pb}{\frac{100}{Gmm} - \frac{Pb}{Gb}}$$

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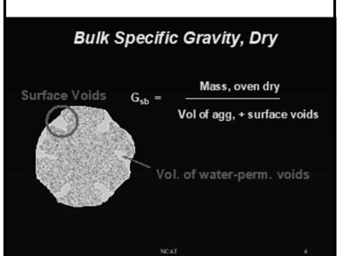

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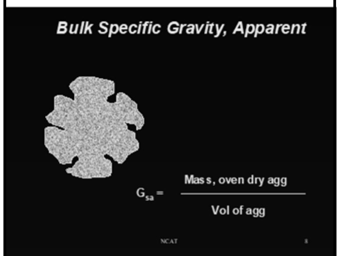

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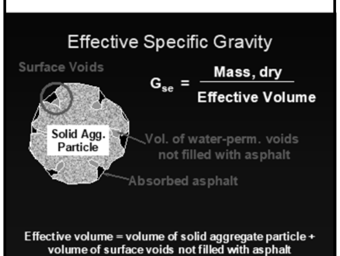

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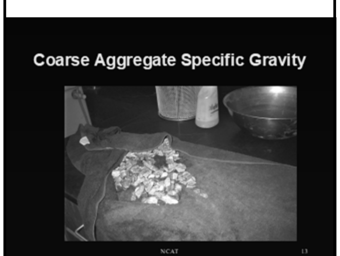
T 85
Coarse Aggregate



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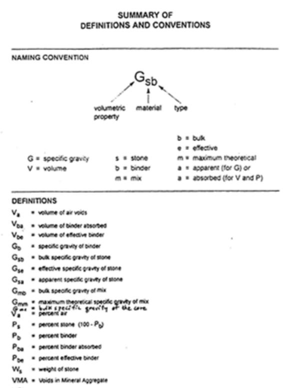
T 84
Fine Aggregate

70



SUMMARY OF
DEFINITIONS AND CONVENTIONS

NAMING CONVENTION

G_{sb} — volumetric property, material, type

G = specific gravity
V = volume

s = stone
b = binder
m = mix

b = bulk
e = effective
m = maximum theoretical
a = apparent (for G) or
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_{mb} = 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

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Blended Aggregate Specific Gravities

- Once the percentages of the stockpiles/bins have been established, the combined aggregate specific gravities can also be calculated

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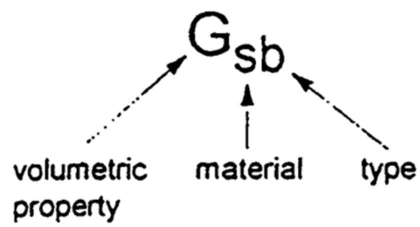
SUMMARY OF DEFINITIONS AND CONVENTIONS

NAMING CONVENTION



G = specific gravity
V = volume

s = stone
b = binder
m = mix

b = bulk
e = effective
m = maximum theoretical
a = apparent (for G) *or*
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
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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

Combined G_{sb}

$$Gsb, blend = \frac{P1 + P2 + P3}{\frac{P1}{Gsb1} + \frac{P2}{Gsb2} + \frac{P3}{Gsb3}}$$

- P= % of each aggregate
- G_{sb}= Bulk specific aggregate of each aggregate

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SUMMARY OF VOLUMETRIC EQUATIONS

Mix Design	Bulk Specific Gravity of Aggregate Blend $G_{sb} = G_{sb}\text{(combined)} = \frac{100}{\frac{P_{s1}}{G_{sb1}} + \frac{P_{s2}}{G_{sb2}} + \frac{P_{s3}}{G_{sb3}} + \ldots}$
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) $\frac{P_{0.075}}{P_{be}} = \frac{\%minus\#200}{P_{be}}$
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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G_{sb}, blend

- Calculate during mix design
- Re-calculate during production if fraction %'s change
- Example: Field Adjustment
- G_{sb} affects VMA and the porphyry: non-carbonate ratio

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SUMMARY OF VOLUMETRIC EQUATIONS

Mix Design	Bulk Specific Gravity of Aggregate Blend $$G_{sb} = G_{sb}\,(\text{combined}) = \frac{100}{\frac{P_{s1}}{G_{sb1}} + \frac{P_{s2}}{G_{sb2}} + \frac{P_{s3}}{G_{sb3}} + \ldots}$$
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 $$P_{be} = P_b - \left(\frac{P_{ba} \times P_s}{100}\right)$$
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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 $$VFA = \frac{VMA - V_a}{VMA} \times 100$$

OUTLINE

- Volumetrics
- Gradation
- Dust
- Particle shape
- Aggregate absorption
- Maintaining VMA
- Aggregate specific gravity
- ***Mix bulk specific gravity***
- Mix max. specific gravity
- Calculation of volumetrics

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AIR VOIDS

- $V_a = \frac{G_{mm} - \boldsymbol{G_{mb}}}{G_{mm}} \times 100$
- V_a = % air voids
- G_{mm}=maximum specific gravity of the voidless mix (Rice sp gravity)
- ***G_{mb}= sp. gravity of the compacted mix***

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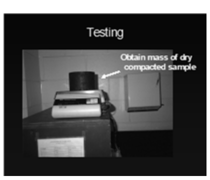
Bulk Sp. Gravity

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

  [AASHTO T 166]



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OUTLINE

- Volumetrics
- Gradation
- Dust
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- Mix bulk specific gravity
- ***Mix max. specific gravity***
- Calculation of volumetrics

79

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- $V_a = \dfrac{G_{mm} - G_{mb}}{G_{mm}} \times 100$

- V_a = % air voids
- ***G_{mm}=maximum specific gravity of the voidless mix (Rice sp gravity)***
- G_{mb}= sp. gravity of the compacted mix

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G_{mm} = "Rice" Sp. Gravity

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

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Determine Max. Sp. Gravity (Rice), G_{mm}

Maximum Specific Gravity

- Loose (uncompacted) mixture

$$G_{mm} = \frac{\text{Mass agg. and AC}}{\text{Vol. agg. and AC}}$$

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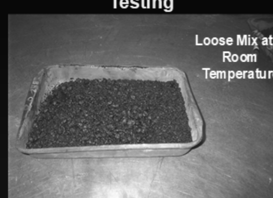
"RICE GRAVITY"

Testing



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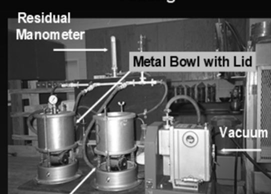
"RICE GRAVITY"

Testing



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"RICE GRAVITY"

Calculations

- G_{mm} = A / (A - C)

  Where:
  A = mass of dry sample
  C = mass of sample under water

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Why is *Aggregate Specific Gravity* Important?

- For a given asphalt mixture to obtain the proper mix properties, ***a certain amount (weight or volume) of asphalt binder is required***
- ***Aggregate specific gravity affects this amount*** and how it is calculated
- Can have dramatic effects on mix properties and performance

Why specific gravity changes

- Ledge to ledge changes:
  - Changes in absorption
  - Changes in mineralogy
- Different proportions of each ledge
- Subtle changes in crushing operation
- Increased proportions of low specific gravity aggregate (screenings, natural sand, etc)

Importance of Aggregate Specific Gravity, cont'd.

- If specific gravity of aggregate decreases, and aggregate weight is not changed, then aggregate bulk volume increases.
- Typically as specific gravity goes down, absorption increases
- Effective binder content will decrease due to absorption

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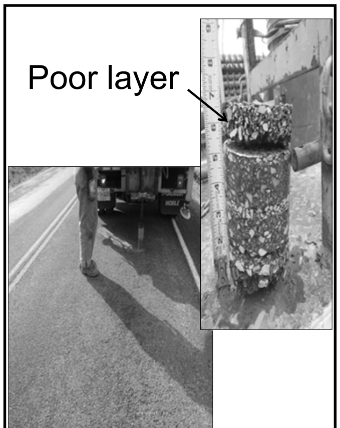
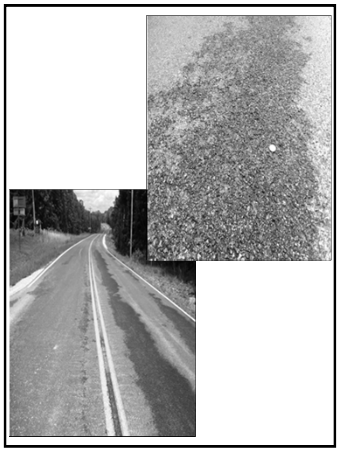
Effects on asphalt mixture

- Mix appears dry (absorption increases, %effective binder content decreases)
- Presence of "brown rock" or uncoated particles
- Difficult to work
- Surface appearance typically looks poor, dull, ragged, inconsistent





Compaction

- Mix is difficult to compact-get low density & high air voids
- Can be compounded by recycle content
- Asphalt cement acts as the lubrication agent between aggregate particles to allow for densification
- Under-asphalted mixtures have high amount of friction
- Increasing rolling intensity will typically fracture particles

Pavement Performance

- Can result in drastic decrease in pavement service life
- Rather than having a flexible homogenous surface, a brittle non-durable surface results
- Increased variability in final mat, i.e. more prone to segregation and associated distresses
- Service life of 7 years for thin overlay might be decreased to 3 years or less

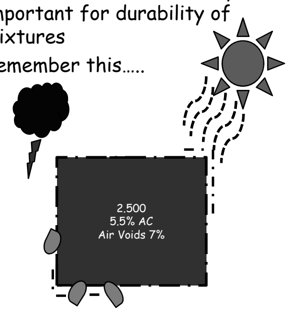
Compounding effects….

- Drastic decreases can be observed due to compounding effects
- Raveling and rapid oxidation from the surface
- Stripping and water damage from the bottom
- Sealing the surface only fixes part of the problem
- Revolves around film thickness

Film thickness

Film thickness is extremely important for durability of mixtures

Remember this…..



Film thickness purpose

- As stated previously film thickness or effective binder around particles, between particles, etc. serves as lubrication……think soil or aggregate base
- It "sticks" everything together
- It "protects" the mat from water and oxidation
- Essential to durability

Recycle

- Take a mix that has aggregate specific gravity off, i.e. gravity too high
- So you start with a mix that is already under asphalted or with low film thickness
- Mix is already harsh and difficult to compact
- Recycle pushed to the max could further compound the situation

Real world example…

- Assume a MoDOT 402 mixture
- Aggregate specific gravity and absorption are the only thing that changes
- Modest difference in gravity (0.050), modest difference in absorption (0.50%)
- Estimated required total AC increase of 0.4%
- Low volume road failure typically attributed to durability, not plastic rutting

Conclusions

- Performance properties can be affected when specific gravities are off, especially if low specific gravity materials (low quality) are substituted for high specific gravity materials
- Durability and film thickness are especially affected when specific gravities decrease
- Modest changes can have significant effects on required asphalt binder content

OUTLINE

- Volumetrics
- Gradation
- Dust
- Particle shape
- Aggregate absorption
- Maintaining VMA
- Aggregate specific gravity
- Mix bulk specific gravity
- Mix max. specific gravity
- ***Calculation of volumetrics***

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CALCULATION OF VOLUMETRICS

- ***Air Voids = V_a***
- VMA
- VFA

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AIR VOIDS

- $$V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$$
- V_a = % air voids
- G_{mm}=maximum specific gravity of the voidless mix (Rice sp gravity)
- G_{mb}= sp. gravity of the compacted mix

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CALCULATION OF VOLUMETRICS

- Air Voids = V_a
- ***VMA***
- VFA

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VMA

Voids in Mineral Aggregate

$$VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}$$

VMA is an indication of film thickness on the surface of the aggregate

$$G_{sb,\ blend} = \frac{P_1 + P_2 + P_3}{\frac{P_1}{G_{sb1}} + \frac{P_2}{G_{sb2}} + \frac{P_3}{G_{sb3}}}$$

P_s=% aggregate
P_s=100 - P_b
P_b=% binder
G_{sb}= bulk sp. gravity of the aggregate blend

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VMA

Example Calculations

- **Given that G_{mb} = 2.455, P_s = 95%, and G_{sb} = 2.703**

$$VMA = 100 - \frac{(2.455)(95)}{2.703} = 13.7$$

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CALCULATION OF VOLUMETRICS

- Air Voids = V_a
- VMA
- ***VFA***

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VFA

Voids Filled with Asphalt

$$VFA = 100 \times \frac{VMA - V_a}{VMA}$$

VFA is the percent of VMA that is filled with asphalt cement

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SUMMARY OF VOLUMETRIC EQUATIONS

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

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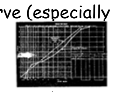
RUT RESISTANCE

- Gradation:
  - NMS – large
  - Avoid hump in curve (especially if natural sand)



  - Curve shape & position (gapping)
- Air voids (3-5%)
- VMA - above minimum
- VFA - 65-75, 65-78, or 70-80%
- Asphalt grade - hard enough/ high PG (M 320) temp number or greater M 323 traffic grade
- FA particle shape - angular
- Dust/binder ratio – 0.8-1.6

FATIGUE RESISTANCE

- Sufficient binder
- Low enough % air voids
- Binder viscosity:
  - Proper grade
  - Not overheated
  - Adjusted for RAP/RAS hardness

MODULE 2E

MIX DESIGN OVERVIEW:

Mix Design Phase 1

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

MODULE 2E

MIX DESIGN OVERVIEW:

Mix Design Phase 1

11-24-06 Revision
11-9-07 Revision
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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

AASHTO TEST METHODS & SPECIFICATIONS

- R35 Volumetric Design Practice
- M323 Volumetric Design Specs
- R30 Mix Conditioning
- T 312 Gyro operation
- T 166 Bulk Sp Gravity of gyro pucks
- T 209 Max Sp Gravity of Voidless Mix (Rice)

2

9 Steps to find Aggregate Structure

- 1. Choose 3 or more trial aggregate gradations based on experience.
- 2. Estimate the required "initial" binder content based on experience or standard procedure.
- 3. Mix aggregate and binder. Condition for 2 hours at the compaction temperature. This allows binder to be absorbed.
- 4. Compact duplicate mixture specimens of each trial gradation at the initial binder content using the gyratory compactor.
- During design, specimens are compacted using the gyratory compactor. The number of gyrations applied is a function of design traffic level.
- 5. Measure compacted puck specific gravity
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- 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. Compare to criteria. Choose blend that best meets criteria, economy, and chance of success.

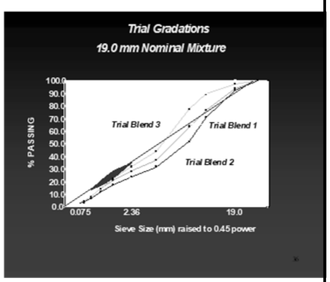
3

FINAL AGGREGATE STRUCTURE SELECTION

- ***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

1. Choose 3 or more trial aggregate gradations based on experience



5

FINAL AGGREGATE STRUCTURE SELECTION

- 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.

6

3. Mix aggregate and binder

7

3. Mix aggregate and binder

8

Condition for 2 hours ~~(4 for absorptive aggregates)~~ at the compaction temperature. This allows binder to be absorbed.

9

MIX CONDITIONING

- Hot mix ages at high temperatures: in plant, truck, and MTV. Called *short-term aging*.
- Aging means the binder gets more brittle due to oxidation and volatilization.
- Embrittlement leads to premature cracking and raveling.

10

MIX CONDITIONING, cont'd.

- 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.

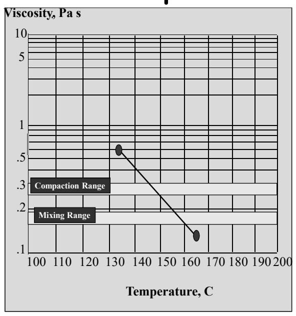
11

LAB CONDITIONING

- During mix design, must simulate the absorption and aging that occurs prior to compaction.
- Procedure:
  - Determine mixing and compaction temperatures
  - Mix the material at mixing temperature
  - Age the mix at the compaction temperature for 2hrs ± 5min. (stir at the 60 min interval)

12

Mixing/Compaction Temps



13

9 Steps to find Aggregate Structure

- 1. Choose 3 or more trial aggregate gradations based on experience.
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- 9. Compare to criteria. Choose blend that best meets criteria, economy, and chance of success.

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AGGREGATE STRUCTURE, cont'd.

- ***4. Compact duplicate mixture specimens of each trial gradation at the initial binder content*** using the gyratory compactor.
- During design, specimens are compacted using the gyratory compactor. The number of gyrations applied is a function of design traffic level.

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16

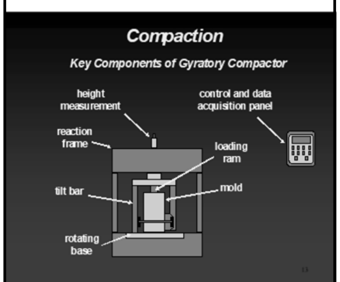
Place Mix in Mold

17

Place Mold in Compactor

18

19



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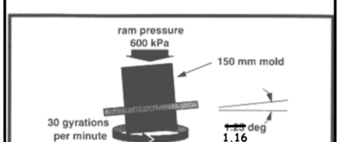


Figure 5.2 SGC Mold Configuration

21

Compaction

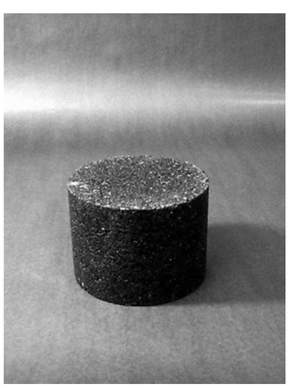
Once compaction is finished, extrude sample from mold.

22

Compaction

Remove the paper and label samples.

23



24

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AGGREGATE STRUCTURE, cont'd.

- ***5. Measure compacted puck specific gravity***
- 6. Run Rice maximum specific gravity (duplicates)
- 7. Calculate volumetrics (VMA, VFA, air voids) for each trial blend.

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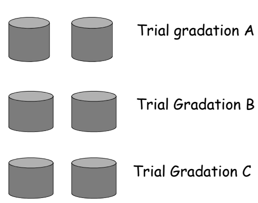
At this point, we have duplicate pucks at 3 trial gradations



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DETERMINE PUCK SPECIFIC GRAVITIES

- So we can calculate volumetrics (air voids, VMA, VFA)

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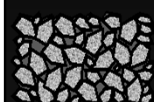
BSG of Compacted HMA

- AC mixed with agg. and compacted into sample

$$G_{mb} = \frac{\text{Mass agg. and AC}}{\text{Vol. agg., AC, air voids}}$$



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Testing

30

Testing

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Calculations

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

  Where:
  - A = mass of dry sample
  - B = mass of SSD sample
  - C = mass of sample under water

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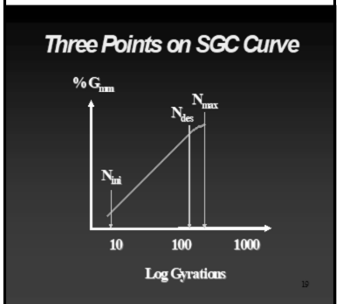
% G_{mm}

- G_{mb} = puck sp. gravity at any gyration level
- More compaction, G_{mb} increases
- % compaction = % G_{mm}
- % $G_{mm} = (G_{mb}/G_{mm}) * 100$ at any gyration level

33



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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:
  - N_{design}= 100
  - No N_{max} requirement

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AGGREGATE STRUCTURE, cont'd.

- 5. Measure compacted puck specific gravity
- ***6. Run Rice maximum specific gravity (duplicates)***
- 7. Calculate volumetrics (VMA, VFA, air voids) for each trial blend.

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6. Determine Max. Sp. Gravity (Rice), G_{mm}

Maximum Specific Gravity

- Loose (uncompacted) mixture

$$G_{mm} = \frac{\text{Mass agg. and AC}}{\text{Vol. agg. and AC}}$$

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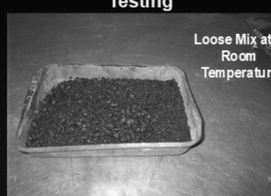
RICE GRAVITY

Testing



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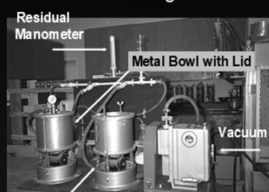
RICE GRAVITY

Testing



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RICE GRAVITY

Calculations

- $G_{mm} = A / (A - C)$

  Where:
  A = mass of dry sample
  C = mass of sample under water

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AGGREGATE STRUCTURE, cont'd.

- 5. Measure compacted puck specific gravity
- 6. Run Rice maximum specific gravity (duplicates)
- ***7. Calculate volumetrics (VMA, VFA, air voids) for each trial blend.***

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AIR VOIDS

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

42

VMA

Voids in Mineral Aggregate

$$VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}$$

VMA is an indication of film thickness on the surface of the aggregate

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VMA

Example Calculations

- Given that G_{mb} = 2.455, P_s = 95%, and G_{sb} = 2.703

$$VMA = 100 - \frac{(2.455)(95)}{2.703} = 13.7$$

44

VFA

Voids Filled with Asphalt

$$VFA = 100 \times \frac{VMA - V_a}{VMA}$$

VFA is the percent of VMA that is filled with asphalt cement

45

9 Steps to find Aggregate Structure

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- ***8. At N_{des} adjust (calculate) % binder to achieve V_a=4.0%. Calculate what VMA, VFA, and dust/effective asphalt would be.***
- ***9. Compare to criteria. Choose blend that best meets criteria, economy, and chance of success.***

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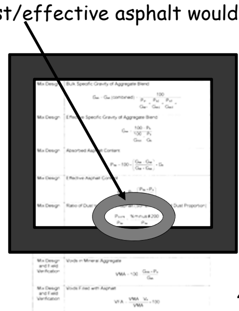
AGGREGATE STRUCTURE, cont'd.

- 8. At N_{des} adjust (calculate) % binder to achieve V_a= 4.0%. Calculate what VMA, VFA, and dust/effective asphalt would be.



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- 9. Compare to ***criteria***. Choose blend that best meets criteria, economy, and chance of success.

48

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

49

COMPACTION CRITERIA

Number of Gyrations	$\% G_{mm}$
$N_{initial}$	F: ≤ 91.5 E: ≤ 90.5 C: ≤ 89.0 B: ≤ 89.0
N_{design}	96.0
$N_{maximum}$	≤ 98.0

50

MODULE 2F

MIX DESIGN OVERVIEW:

Mix Design Phase II

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
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2-16-18 Revision
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MODULE 2F

MIX DESIGN
OVERVIEW:
Mix Design Phase II

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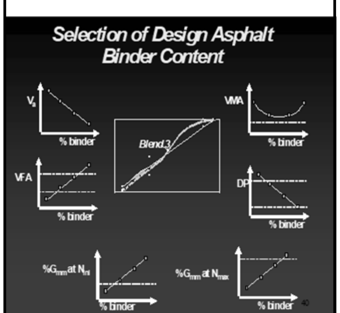
12-18-13 Revision
12-29-14 Revision
2-4-15 Revision
12-28-16 Revision
2-16-18 Revision
12-12-18 Revision
12-17-19 Revision

MIX DESIGN STEPS

- I. Material selection
- II. Aggregate structure selection
- ***III. Design binder content selection***
- IV. Evaluation of moisture sensitivity (stripping)

2



3

Binder Content Selection Steps

- 1. Using the winning blend, compact more specimens in duplicate to N_{des}, this time varying binder content. Use, say, 4 different %'s of binder: -0.5, +0.5, +1.0, 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.

4

Binder Content Selection Steps

- ***1. Using the winning blend, compact more specimens in duplicate to N_{des}, this time varying binder content. Use, say, 4 different %'s of binder: -0.5, +0.5, +1.0, and right on the initial %.***
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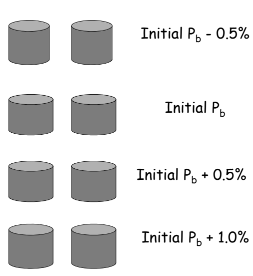
- 6. Compact more pucks at the design binder content to N_{max}; check criteria.

5

Compact 4 sets of pucks at varying asphalt contents using the gradation of choice

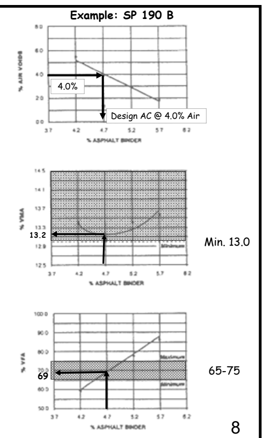


6

III. DESIGN BINDER CONTENT

- 1. Using the winning blend, compact more specimens in duplicate to N_{des}, this time varying binder content. Use, say, 4 different %'s of binder: -0.5, +0.5, +1.0, and right on the initial %.
- 2. Again calculate volumetrics. Plot % binder vs. % air voids. ***Choose the design % binder that produces 4% air voids.***

7



8

Factor	Criteria	Reason
Air voids, N_{des}	4.0%	Stability Durability
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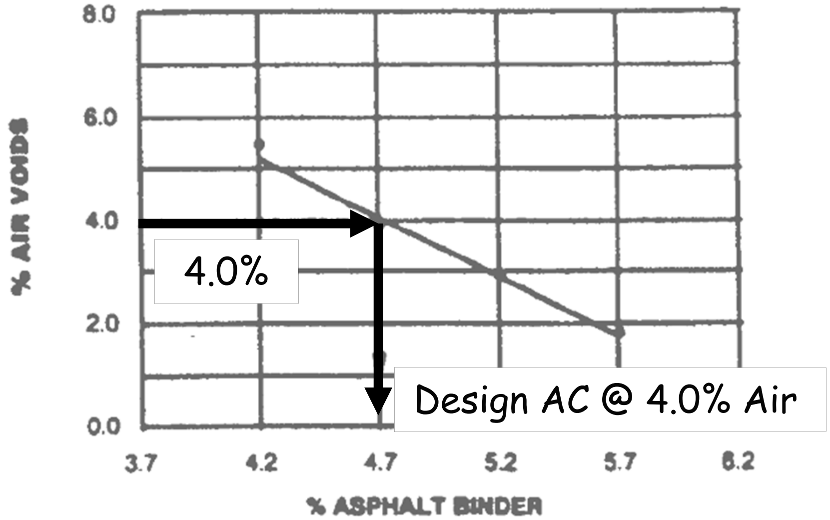
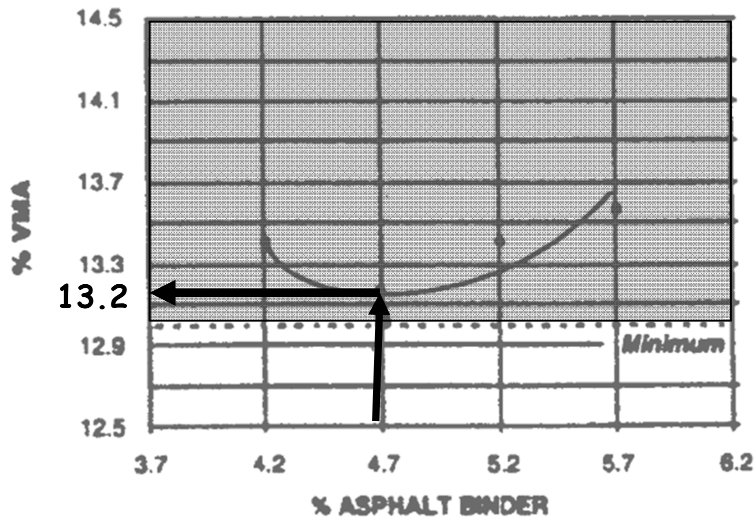
Dust/binder	0.8-1.6 0.9-2.0	Compaction Handling

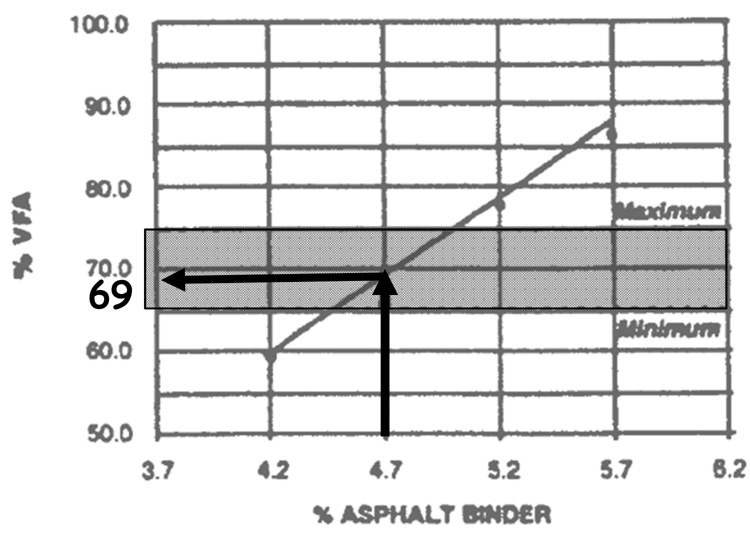
9

Example: SP 190 B





Min. 13.0



65-75

Binder Content Selection Steps

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- ***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.***

10

DESIGN BINDER CONTENT

- ***3. Check all other volumetric criteria.***
- 4. Check %G_{mm} @ N_{ini}
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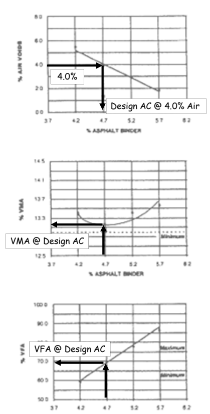
11



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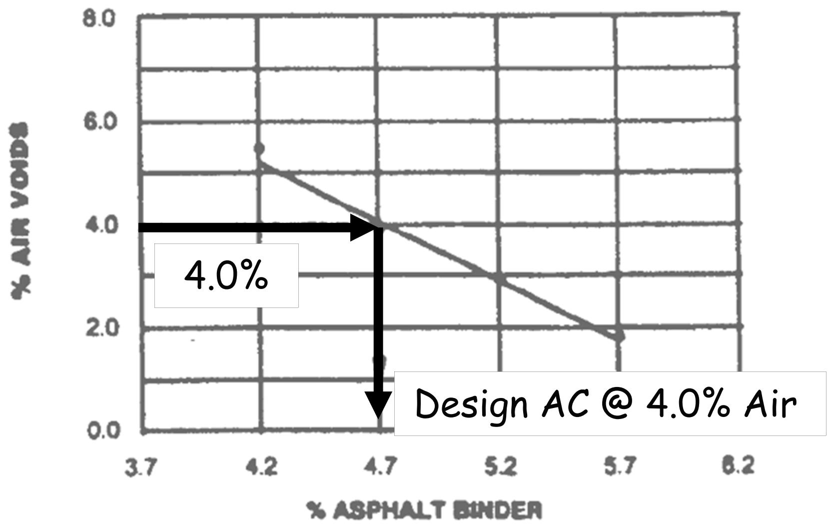
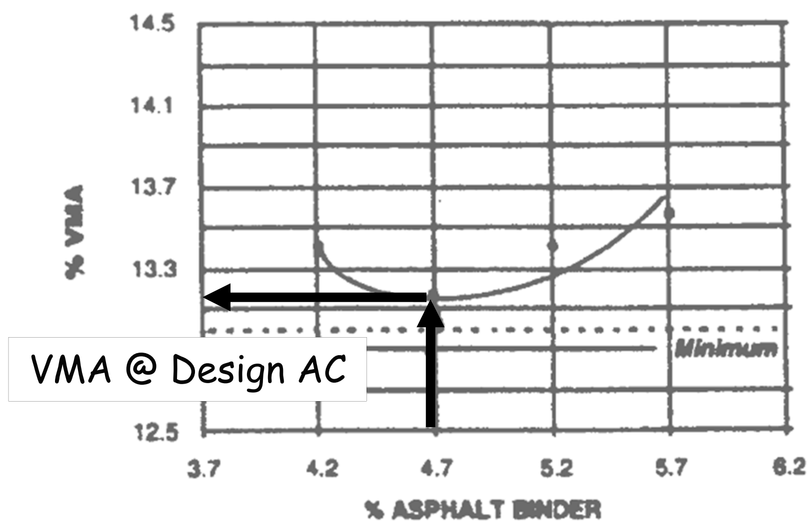
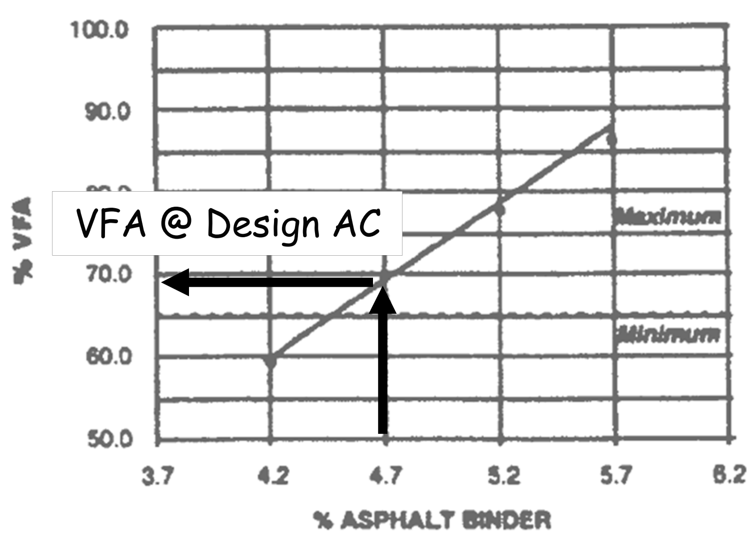


% AIR VOIDS
4.0%
Design AC @ 4.0% Air
% ASPHALT BINDER



% VMA
VMA @ Design AC
Minimum
% ASPHALT BINDER



% VFA
VFA @ Design AC
Maximum
Minimum
% ASPHALT BINDER

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13

DESIGN BINDER CONTENT

- 3. Check all other volumetric criteria.
- ***4. Check $\%G_{mm}$ @ N_{ini}***
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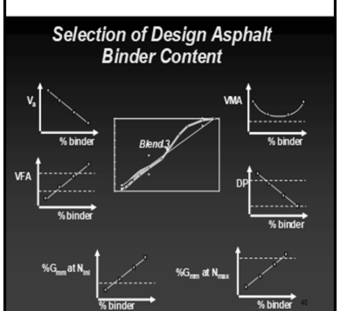
14



15

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DESIGN BINDER CONTENT

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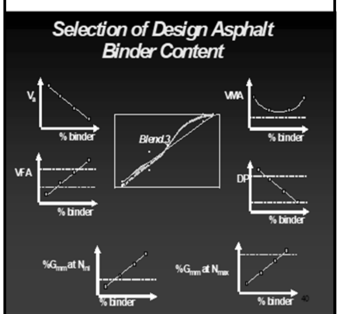
19



20

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$\%G_{mm}$ @ 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

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MODULE 2G

MIX DESIGN OVERVIEW:
TSR
JMF & Field Verification
Miscellaneous

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
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MODULE 2G

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2-16-18 Revision
12-12-18 Revision
12-17-19 Revision

Outline

- ***TSR***
- JMF and Field Verification
- Miscellaneous

2

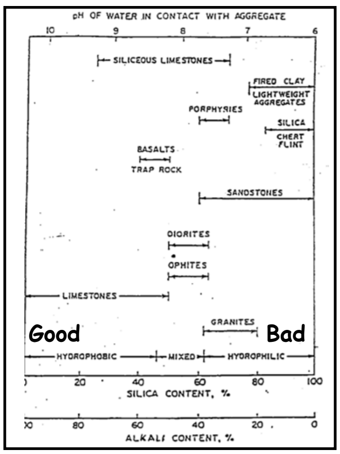
Loss of Strength in a Wet Condition

- Synonyms:
  - Moisture sensitivity
  - Moisture susceptibility
  - Stripping
- Main issue is the aggregate
- Loss of bond between aggregate surface and the binder

3

MATERIAL	PROPERTY	TEST/ CALCULATION
Aggregate	Cleanliness	Sand Equivalent; PI; minus#200; deletereous materials
Aggregate	Texture	Fract. Face Count; FA part. Shape
Aggregate	Absorption	Absorption
Aggregate	Affinity for AC	TSR
Mix	permeability	Air voids

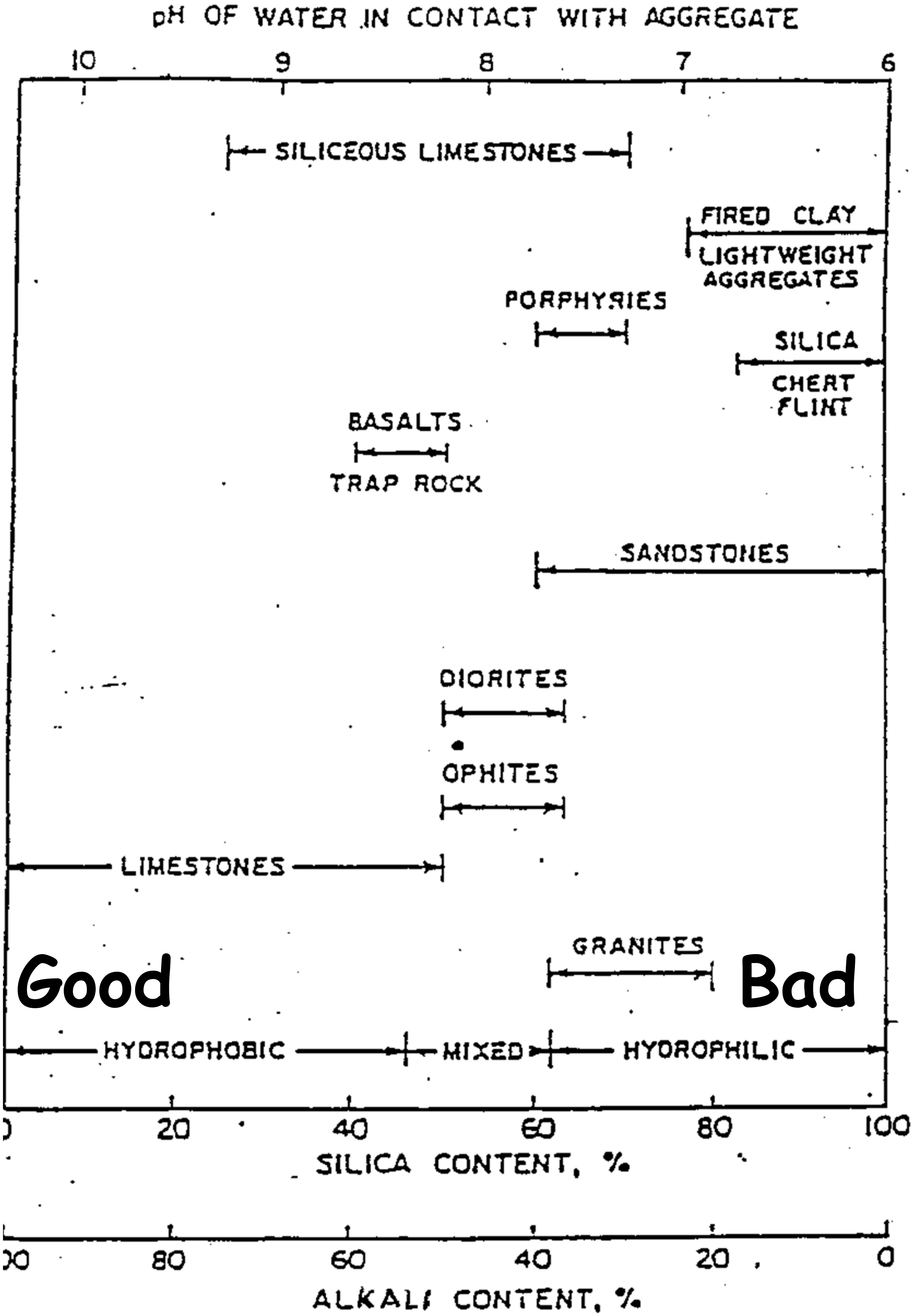
4



MOISTURE SENSITIVITY

- Run T 283, the Tensile Strength Ratio test using the final aggregate structure and at the design binder content.

6

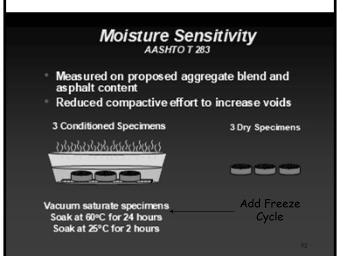


pH OF WATER IN CONTACT WITH AGGREGATE
10
9
8
7
6
SILICEOUS LIMESTONES
FIRED CLAY
LIGHTWEIGHT AGGREGATES
PORPHYRIES
SILICA
CHERT FLINT
BASALTS
TRAP ROCK
SANDSTONES
DIORITES
OPHITES
LIMESTONES
GRANITES
Good
Bad
HYDROPHOBIC
MIXED
HYDROPHILIC
20
40
60
80
100
SILICA CONTENT, %
80
60
40
20
0
ALKALI CONTENT, %

TSR Method

- Compact 6 specimens to 7.0 ± 0.5% (6.0 ± 0.5% for SMA) air voids.
- Saturate, freeze, and thaw 3 of the pucks.

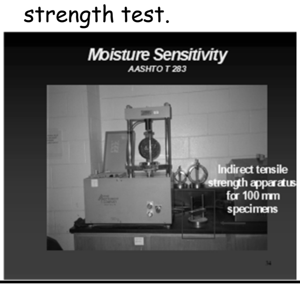

7



8

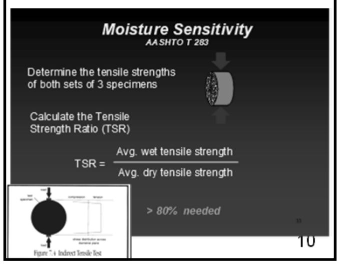
TSR METHOD

- Test the 3 unconditioned pucks and the 3 conditioned pucks using the indirect tensile strength test.



TSR Method

- Calculate the ratio of the average of the conditioned pucks tensile strength to the average of the control pucks tensile strength.



10

Outline

- TSR
- ***JMF and Field Verification***
- Miscellaneous

11

MoDOT VERIFICATION

- 1. When sampling aggregates for use in the mix design stage, contractor should obtain duplicate material and save for MoDOT.
- 2. Upon completion of the design, the duplicate aggregate and binder may need to be sent to MoDOT for mix verification.

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MIX DESIGN: FINAL PRODUCT

- The "Job Mix Formula" (JMF) is the final product of the mix design process

13

"Standardized" JMF Submittal Form

- Looks like a JMF-it isn't
- For submission of mix design data by contractor to MoDOT
- All-purpose—for many mix types: SP, SM, BP, PMBB, UBAWS

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BAGHOUSE FINES

Standardized Form

- ***Drum Plant:*** Baghouse fines are generated ***after*** the drum mix cold feed sample is taken (no return dust on cold feed as it goes into the drum), so the JMF target gradation for drum plants reflects this (doesn't have extra dust added into the total gradation to be checked against in the field)

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BAGHOUSE FINES
Standardized Form, cont'd.

- ***Batch Plant:*** Baghouse fines are generated ***before*** the hot bin samples are taken (dust is returned to hot elevator), so the JMF target gradation for batch plants reflects this (the target gradation should have dust included, usually placed in one fraction)

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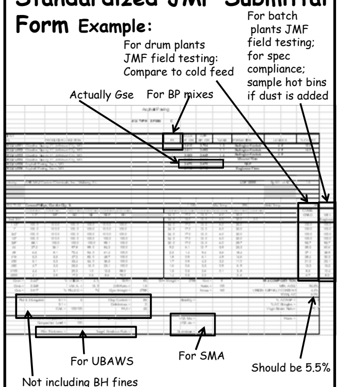
Standardized JMF Submittal Form **Example:**



JOB MIX FORMULA

- Upon final approval of the mix design, a final Job Mix Formula (JMF) is issued by MoDOT
- Used for setting up the plant process and controlling the process during production

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Standardized JMF Submittal Form Example:

For batch plants JMF field testing; for spec compliance; sample hot bins if dust is added

For drum plants JMF field testing: Compare to cold feed

Actually Gse

For BP mixes

Asphalt Paving

MIX TYPE SP095 C

IDENT NO.	PRODUCER-LOCATION	PI	BULK SP. GR.	APP. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
12CDJ1J001	Gibraltar Quarry #1, Jefferson City, MO		2.610	2.704	1.3	Burlington-Keokuk	4-8	10.0
12CDJ1J002	Gibraltar Quarry #1, Jefferson City, MO		2.611	2.692	1.1	Burlington-Keokuk	4-8	14.0
12CDJ1J003	Gibraltar Quarry #1, Jefferson City, MO	1	2.553	2.649	1.4	Burlington-Keokuk	4-8	
12CDJ1J004	Gibraltar Quarry #1, Jefferson City, MO		[illegible]	[illegible]	[illegible]	Missouri River		
12CDJ1J005	Asphalt Paving, Taos, MO		2.670	2.670		RAP		
12CDJ1J006	Asphalt Paving, Taos, MO		[illegible]	[illegible]		Baghouse Fines		

Antistrip	ARR MAZ Custom Chemicals, Inc., Mulberry, FL	LOF 12000	By Wt. of AC	1.5

PG 70-22	ConocoPhillips, Granite City, IL	1.030	Mix Temp.	295	Mold Temp.	28	

	12CDJ1J001	12CDJ1J002	12CDJ1J003	12CDJ1J004	12CDJ1J005	12CDJ1J006	12CDJ1J001	12CDJ1J002	12CDJ1J003	12CDJ1J004	12CDJ1J005	12CDJ1J006	COMB. GRAD	With Baghouse
	1/2"	3/8"	SG	NS	RAP	BH	34.0	17.0	13.0	6.0	30.0			
Incl. BH							34.0	15.0	13.0	6.0	30.0	2.0		
1 1/2"	100.0	100.0	100.0	100.0	100.0	100.0	34.0	17.0	13.0	6.0	30.0		100.0	100.0
1"	100.0	100.0	100.0	100.0	100.0	100.0	34.0	17.0	13.0	6.0	30.0		100.0	100.0
3/4"	100.0	100.0	100.0	100.0	100.0	100.0	34.0	17.0	13.0	6.0	30.0		100.0	100.0
1/2"	100.0	100.0	100.0	100.0	100.0	100.0	34.0	17.0	13.0	6.0	30.0		100.0	100.0
3/8"	88.1	100.0	100.0	100.0	99.1	100.0	30.0	17.0	13.0	6.0	29.7		95.7	95.7
#4	27.2	36.1	97.8	99.0	84.3	100.0	9.2	6.1	12.7	5.9	25.3		59.3	60.6
#8	6.5	8.1	72.4	94.0	61.4	100.0	2.2	1.4	9.4	5.6	18.4		37.1	38.9
#16	5.3	5.5	47.2	82.0	48.7	100.0	1.8	0.9	6.1	4.9	14.6		28.4	30.3
#30	5.1	5.3	33.4	54.0	36.5	100.0	1.7	0.9	4.3	3.2	11.0		21.2	23.1
#50	4.7	3.3	25.2	15.0	23.1	100.0	1.6	0.6	3.3	0.9	6.9		13.3	15.2
#100	4.4	3.1	20.2	1.0	12.5	98.0	1.5	0.5	2.6	0.1	3.8		8.5	10.4
#200	4.1	2.9	17.2	0.5	8.6	75.0	1.4	0.5	2.2		2.6		6.7	8.2

Gmm =	2.447	% VOIDS =	4.0	TSR =	83	TSR Weight =	3788	Nini =	8	**MIX COMPOSTITION**	
Gmb =	2.348	V.M.A. =	15.3	D/B Ratio =	1.5			Ndes =	100	MIN. AGG.	94.5%
Gsb =	2.617	% FILLED =	74	Gyro Weight =	4788			Nmax =	160	VIRGIN ASPHALT CONTENT	4.4%
[illegible]	[illegible]									TOTAL AC	6.0%
Flat & Elongated	5:1 =	5		Clay Content =	85	Stability =				% AC RAP =	[illegible]4.5
	3:1 =			Deleterious =	2					% AC Shingles =	
	CAA =	100/100		FAA =	45					Virgin Binder Ratio=	70.0
[illegible]		[illegible]		[illegible]		VCA Mix =				Fibers =	
Compaction Level =	100					VCA drc =					
Film Thickness =			Target Emulsion Rate =			Draindown =					

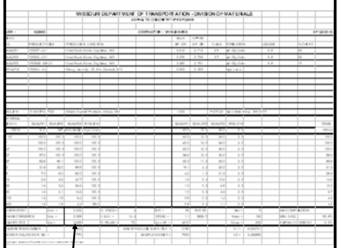
For SMA

For UBAWS

Should be 5.5%

Not including BH fines

JMF
EXAMPLE 1



G_{sb}= 2.497

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SUPERPAVE MIXTURE NAMES

- "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 = mixture design (millions of ESAL's)
  - F= <0.3
  - E= 0.3 to <3
  - C= 3 to <30
  - B= ≥30
- zz = special designations
  - LP= Limestone Porphyry
  - SM= Stone Mastic Asphalt
  - SMR= SM Rural
  - NC= Non Carbonate
  - LG= Low Gyration

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JMF
EXAMPLE 1

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"	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	1.0	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	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	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		9[illegible]004			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 M[illegible] Design

G_{sb}= 2.497

SUPERPAVE "NOMINAL MAXIMUM SIZE"

- 1. Look at the combined gradation of the hotmix. Identify the largest sieve that accumulatively retains 10% or more.
- 2. Move up one sieve larger--that is the "nominal maximum size" (NMS).
- 3. The "maximum size" is one size larger than the NMS.

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MIXTURE SUBSTUTUTION

- QC may substitute a smaller NMS mixture for a larger one.
- QC may substitute a higher traffic level mix for a lower one.

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INFO FROM THE JMF SHEET

- Aggregate "fractions" (materials) and sources
- For each material, lists:
  - producer, location
  - formation and ledge number
  - gradation
  - proportion in the mix
  - bulk & apparent specific gravities
  - absorption
  - % chert

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JMF INFO, cont'd.

- Binder: producer, source, & specific gravity
- Mixture:
  - target gradation
  - target binder content
  - Design VMA
  - target V_a
  - target voids filled (VFA)
  - Dust-to-binder ratio
  - TSR result
  - N_{des}=number of gyrations to use in field verification

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JMF INFO, cont'd.

- Gyro specimen weight
- nuclear binder content specimen weight
- gyro molding temperature
- aggregate blend combined bulk specific gravity (G_{sb})
- nuclear binder gage information
- TSR specimen weight

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INFO REQUIRED DAILY

- Gyro specimen required weight
- Gyro compaction temperature range
- Nuclear specimen required weight and other information
- Absorptions
- Target % asphalt
- Target % air voids

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DAILY INFO, cont'd.

- G_{sb} of blend
- TSR specimen required weight
- N_{des}

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Outline

- TSR
- JMF and Field Verification
- ***Miscellaneous***

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STONE MASTIC ASPHALT

- SMA mixtures fall under Superpave-QC/QA criteria
- There are numerous additional criteria for SMA mixes.

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DRAINDOWN

- One extra test: "Draindown" (AASHTO T 305).
- Draindown testing assures that the binder will not run out of the mix when hot
- A sample of loose mix is placed in a basket, heated for one hour at its mixing temperature, and the material that drains from the basket is weighed.

Draindown

- The allowable draindown is < 0.3% by weight of HMA

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ROUNDING

- EPG 106.20
- Based on ASTM E 29
- Is somewhat contradictory (eg., see gradation rounding in the EPG)
- Specifies "MoDOT rounding":
  - 0.35→0.4
  - 0.45 →0.4

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ROUNDING, cont'd.

- Usually, round to the same number of significant figures as the specification being compared to:
  - *Consensus, VFA, TSR*: nearest whole number
  - *Gradation*, passing or retained %: nearest 0.1%
  - *Binder content (compared to spec), Pay Factors, %compaction, D/B, VMA, V_a*: nearest 0.1%
  - *Binder content & moisture on data & some recording sheets*: nearest 0.01%
  - *Specific gravity*: 3 places to the right of the decimal

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SUMMARY OF VOLUMETRIC EQUATIONS

Mix Design	Bulk Specific Gravity of Aggregate Blend $G_{sb} = G_{sb}\text{ (combined)} = \frac{100}{\frac{P_{s1}}{G_{sb1}} + \frac{P_{s2}}{G_{sb2}} + \frac{P_{s3}}{G_{sb3}} + \ldots}$
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) $\frac{P_{0.075}}{P_{be}} = \frac{\%minus\#200}{P_{be}}$
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

- 1. Determine design traffic level (total ESAL's)
- 2. Select aggregate sources
- 3. Select binder grade
- 4. Try several trial gradations at a single % binder
- 5. Choose one blend that best meets V_a, VMA, VFA, $\%G_{mm,ini}$, economy, chance of success

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SUMMARY OF VOLUMETRIC EQUATIONS

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

SUMMARY

- 6. Using the single gradation, try several trial % binders
- 7. Determine the % binder that results in V_a = 4.0%
- 8. Check other parameters: VMA, VFA, $\%G_{mm,ini}$, $\%G_{mm,max}$, TSR
- 9. SP nomenclature: NMS, design traffic level, specialty info

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SUMMARY

- 10. NMS= One sieve size larger than the largest sieve to accumulate ≥10% retained
- 11. JMF info needed daily:
  - G_{sb},
  - target % binder
  - Absorptions
  - gyro specimen mass
  - gyro compaction temperature
  - nuclear specimen mass

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SUMMARY

- N_{des} for gyro
- Target % air voids
- (TSR specimen mass)

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Module 3

Plant Operations

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

Module 3

Plant Operations

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3-2-18 Revision
12-12-18 Revision
12-17-19 Revision

Types of Asphalt Plants

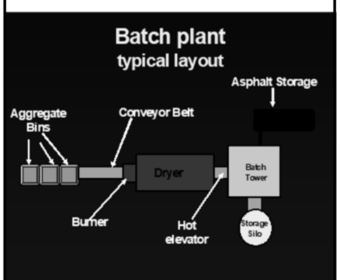
- ***Batch Plants***
- Drum Mix Plants

2

Batch Plant

3

4

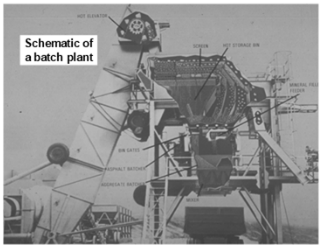


5

Batch Plant

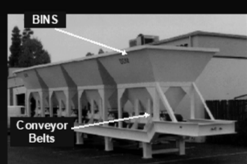
- Aggregate is heated. Reduces moisture related problems.
- Aggregate is rescreened.
- Aggregate is batched by weight.
- Batch plants provide a consistent mixture.

6



7

Cold Feed



NCAT 10

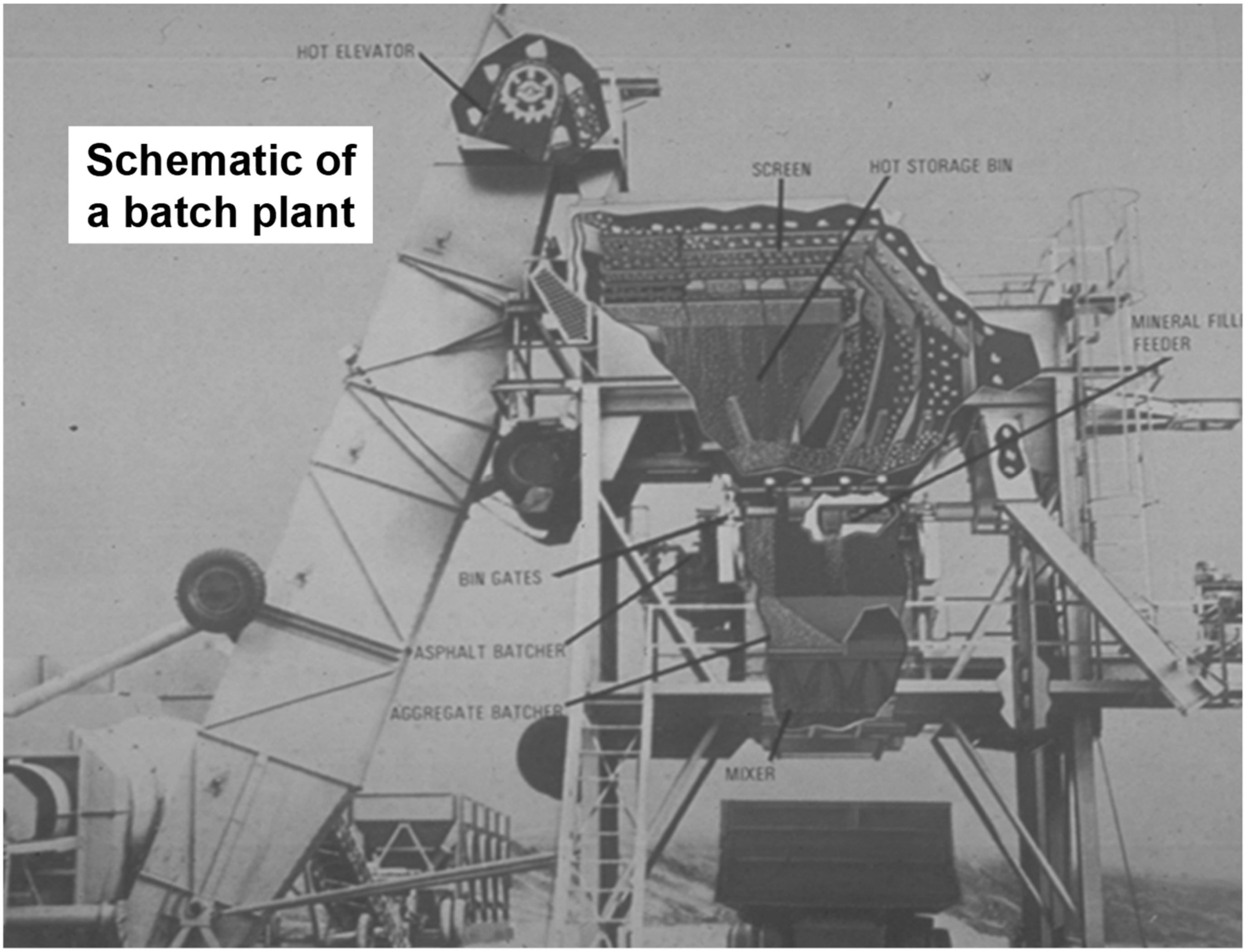
Depending on the plant, aggregate fraction JMF %'s are probably at cold bins

8

Burner - Batch Plant

NCAT

9

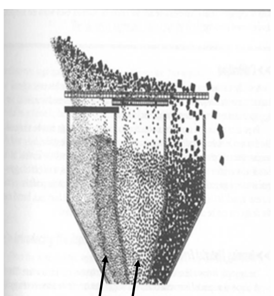

Schematic of a batch plant
HOT ELEVATOR
SCREEN
HOT STORAGE BIN
MINERAL FILL
FEEDER
BIN GATES
ASPHALT BATCHER
AGGREGATE BATCHER
MIXER

- 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

10

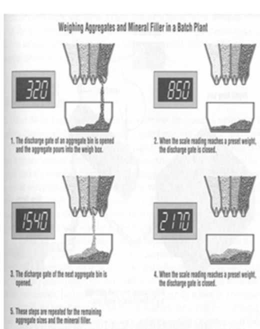
Screening Aggregate



Note segregation

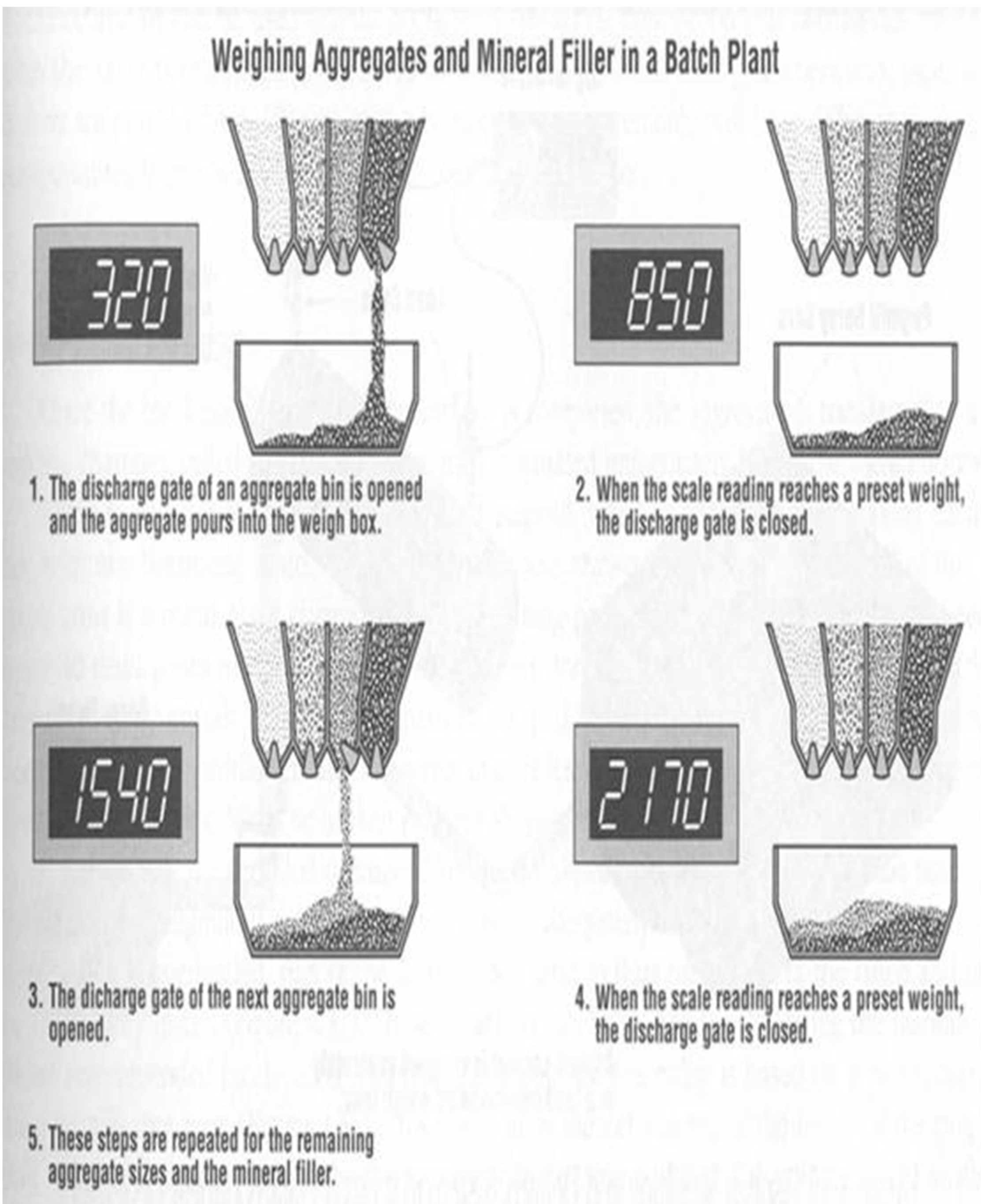
11

Batching Aggregates



12

Batching Aggregates



Pug Mill

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

Inspect paddle wear tolerance weekly, more if traprock

13

TRUCK BEING LOADED DIRECTLY FROM A BATCH PLANT

14

Types of Asphalt Plants

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

15

Drum Mix Plant

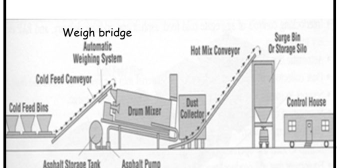
16

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 have a high production rate, but may not be able to use potential because of limiting roller rate.

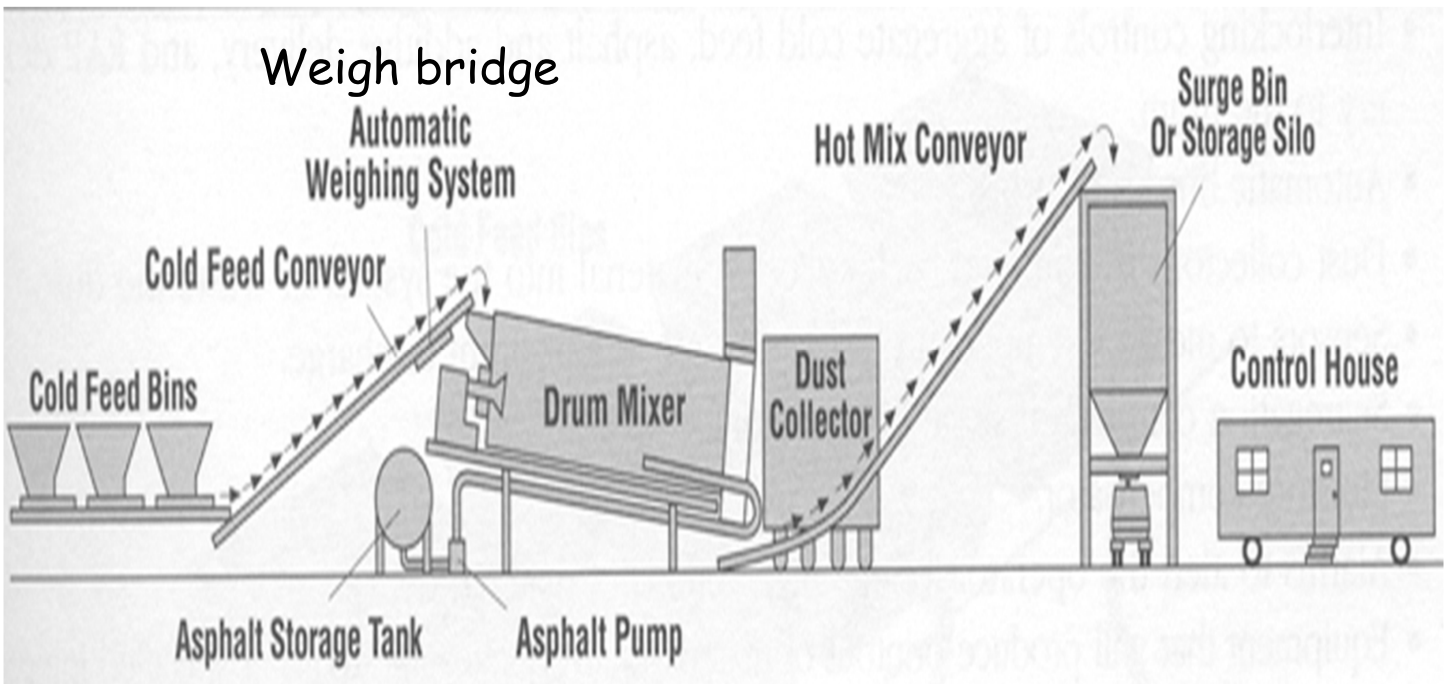
17

Drum Mix Plant

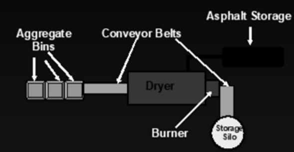


18

Drum Mix Plant

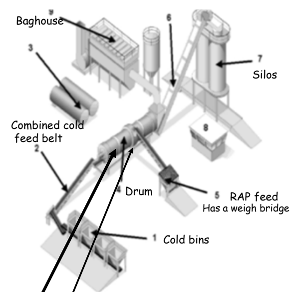


Drum Mixer Plant
typical layout



19

Drum Plant

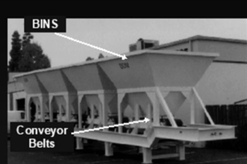


There is an optimum flight configuration for the % RAP to maintain the veil of aggregate that protects the RAP, binder, and baghouse

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

20

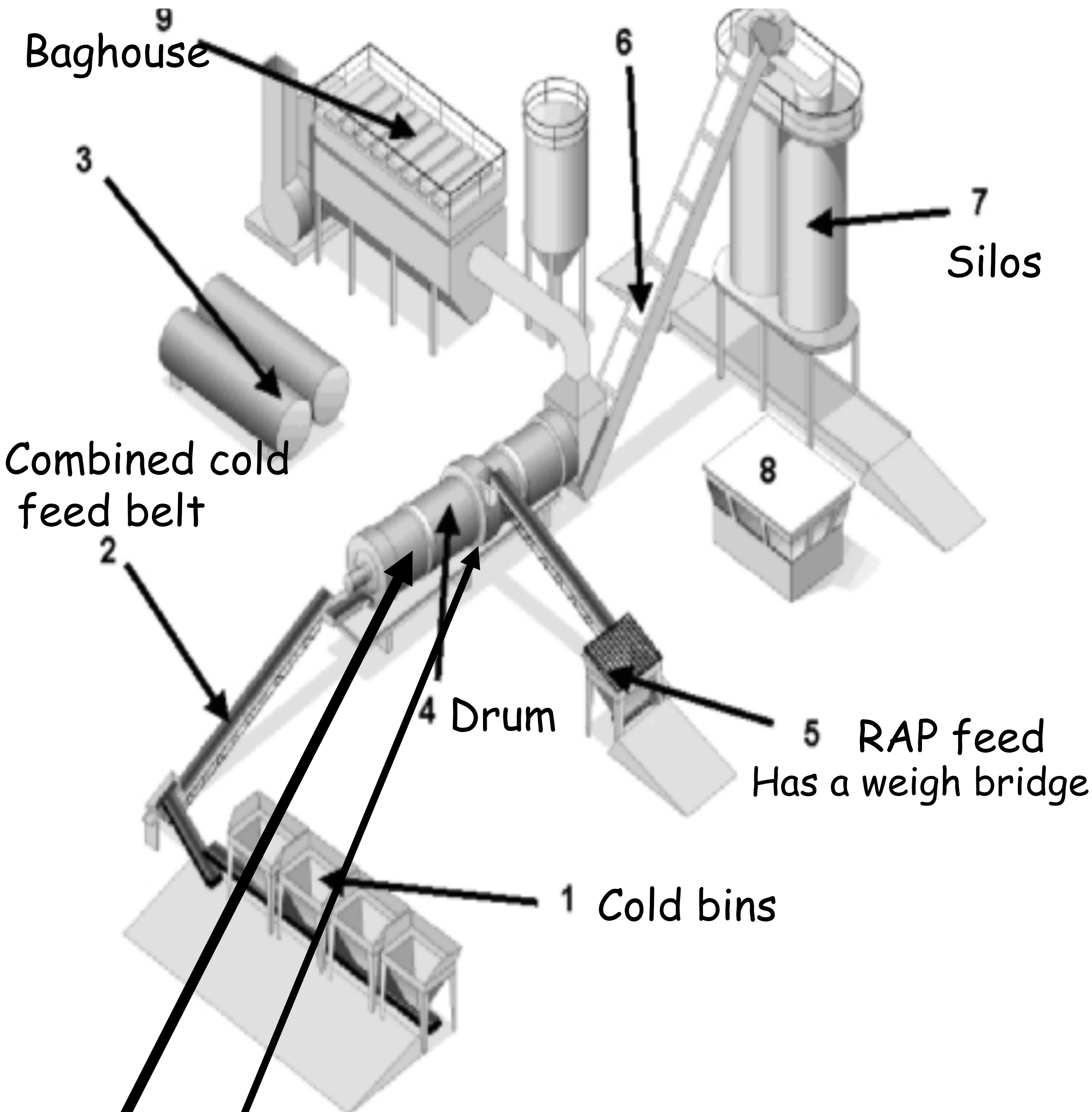
Cold Feed



NCAT

21

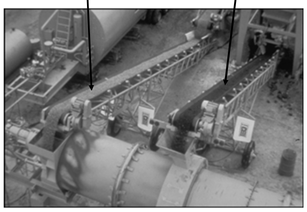
Drum Plant



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

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

Aggregate and RAP Feeds



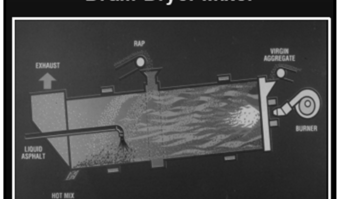
22

Dryer For Drum Dryer Mix Plant

End of day: shut off oil, run aggregate through to clean out mix to prevent chunks breaking loose

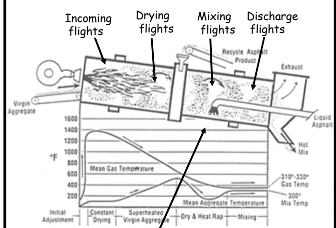
23

Drum Dryer Mixer



24

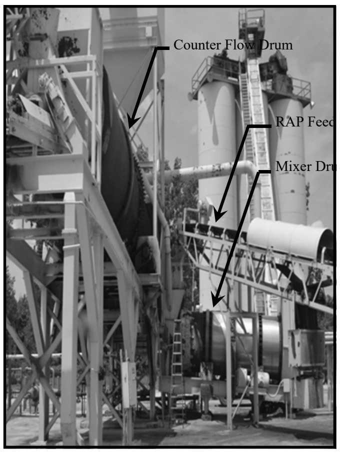
Temperature Profile in Drum Mixer

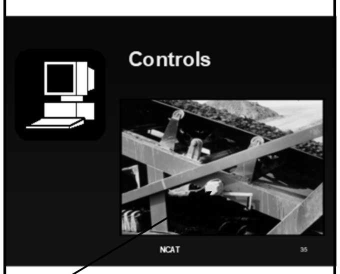


Superheated aggregate dries the RAP

Can be a problem with high RAP content

25

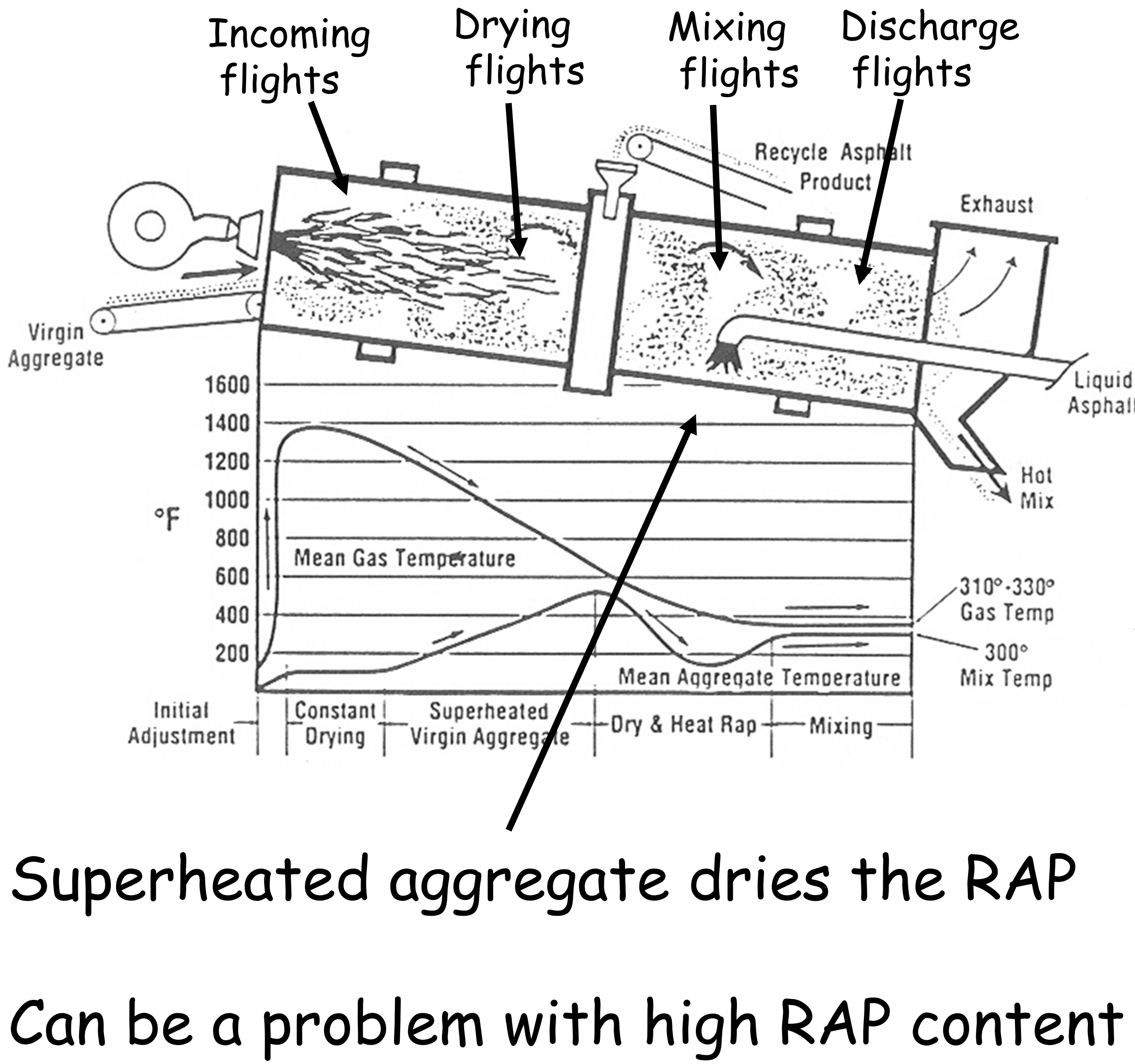




Weigh bridge: wind flops belt, "weight" of aggregate changes, so amount of binder changes, thus air voids change; 0.1% binder change results in ~0.3 %air voids

27

Temperature Profile in Drum Mixer



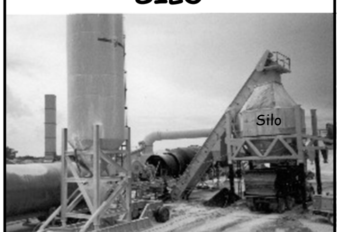
Superheated aggregate dries the RAP

Can be a problem with high RAP content

SURGE
SILO

28

SILO



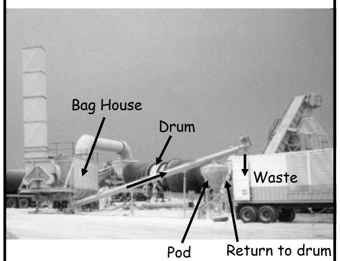
29

Hma Mixing Plants Create
Dust

NCAT 12

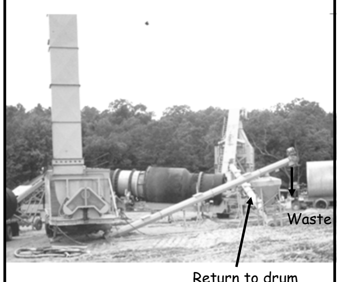
30

DUST HANDLING



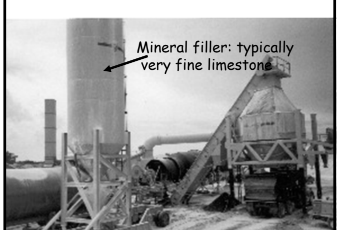
31

DUST HANDLING



32

Metering Dust



Weigh pod

33

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.

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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

35

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.

36

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.

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FIELD EXPERIENCES 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

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FIELD EXPERIENCES 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 $\frac{3}{8}$" products)
- Keep an eye on:
  - Gradation
  - Specific gravity for certain products
  - Flat & elongated (crusher wear)

FIELD EXPERIENCES
Receiving

- Contractor orders the wrong material (MoDOT and quarry may have different definitions of fractions)
- Contractor doesn't check material on a daily basis to ensure correct material is being delivered

40

FIELD EXPERIENCES
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

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FIELD EXPERIENCES
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

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FIELD EXPERIENCES: 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

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FIELD EXPERIENCES: 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

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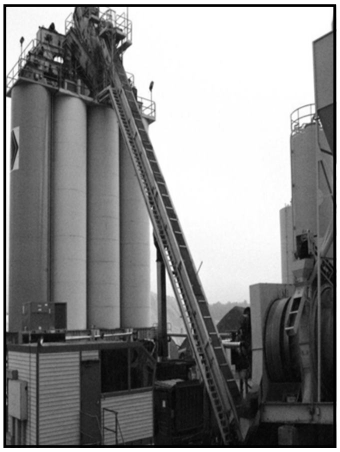
FIELD EXPERIENCES: Plant

- 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
- HMA silo-problems of carryover of wrong product when switching mixes



FIELD EXPERIENCES: 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

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FIELD EXPERIENCES: 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

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Hot Mix 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.

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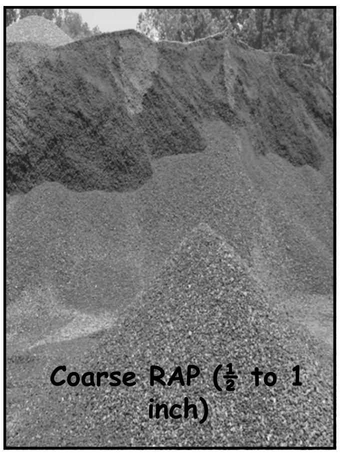
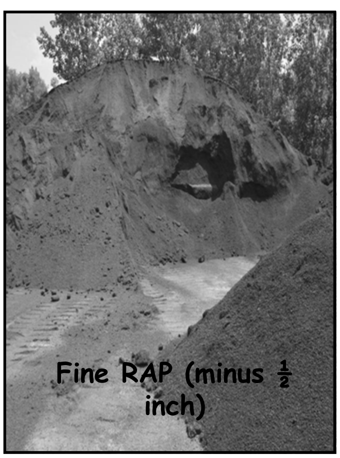


Coarse RAP (½ to 1 inch)



Fine RAP (minus ½ inch)

Shingles are usually covered
Sometimes RAP: Would take a huge cover for a 40% RAP mix

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2006 CHANGES

- Emphasis on end-result testing to allow quarries more flexibility during production
- Quarry QC plans no longer required

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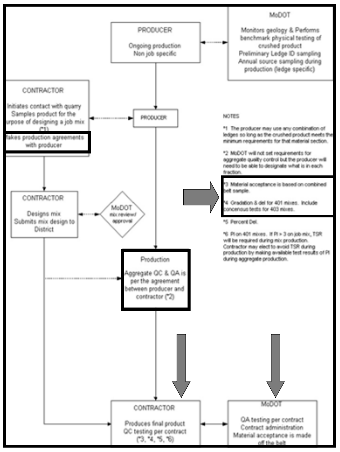
2006 CHANGES

- Aggregate acceptance is at the mixing facility
- Usage: MoDOT still sampling/testing ledges
- MoDOT still visits quarries to assure that proper ledges are being used

54



403 REQUIRED TESTING: Aggregate

- ***Gradation***
- ***Consensus tests***: FAA, SE, F&E, and CAA
- ***Deleterious Materials***
- ***RAP***

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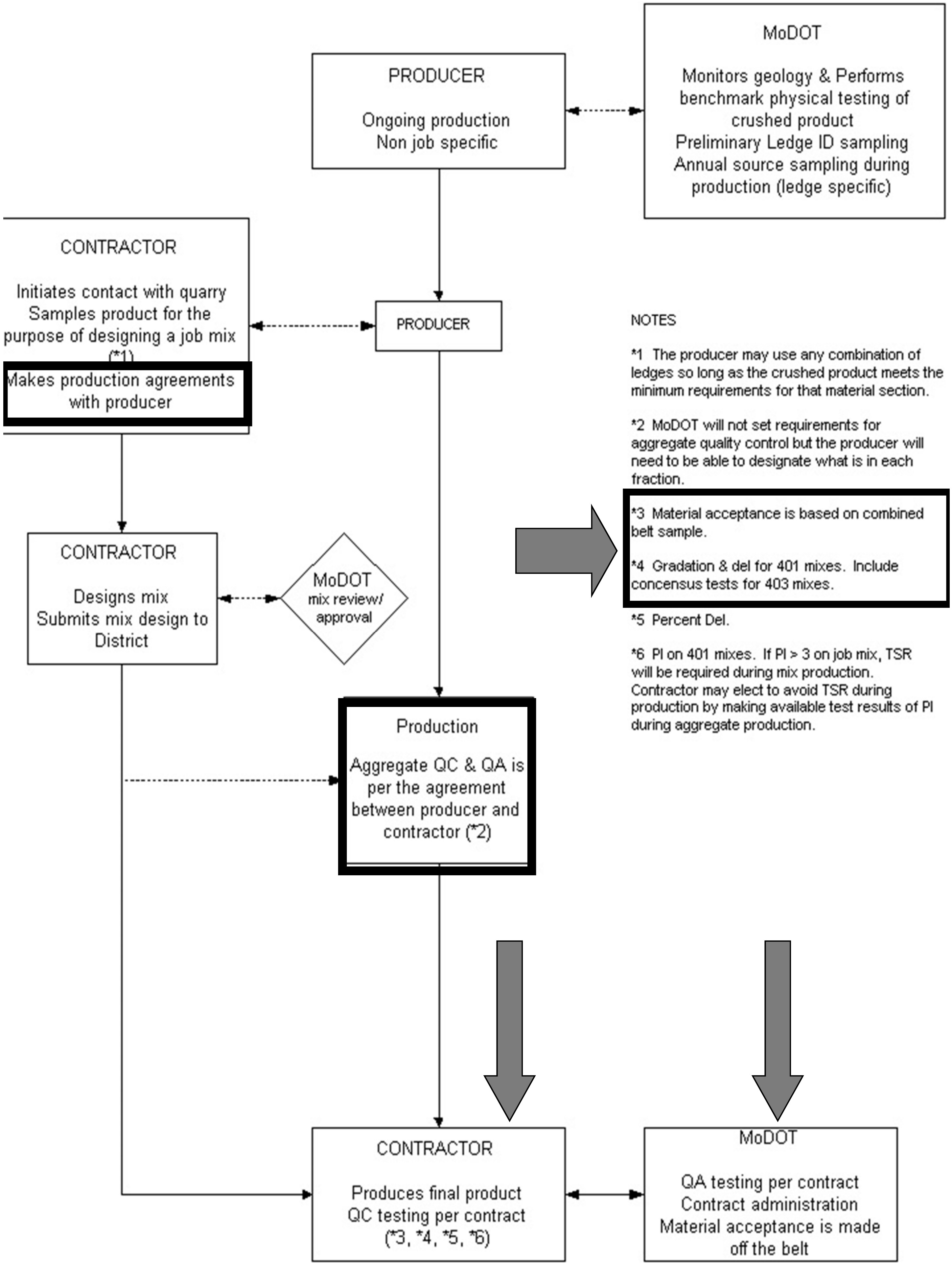
SAMPLING: Aggregate

- Gradation:
  - Drum—cold feed belt
  - Batch—hot bins
  - Can use HMA sample- T308 residue (can't for dolomite)
  - RAP- T308 residue; combine mathematically with virgin gradation (dolomite-have to extract)
- Deleterious:
  - All plants—cold feed belt
- Consensus:
  - All plants—cold feed belt

57


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: RAP

- RAP feed system
  - Gradation
  - Deleterious
  - RAP binder content
  - Micro-Deval*

*RAP from MoDOT roadways is exempt

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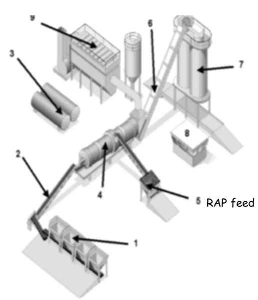

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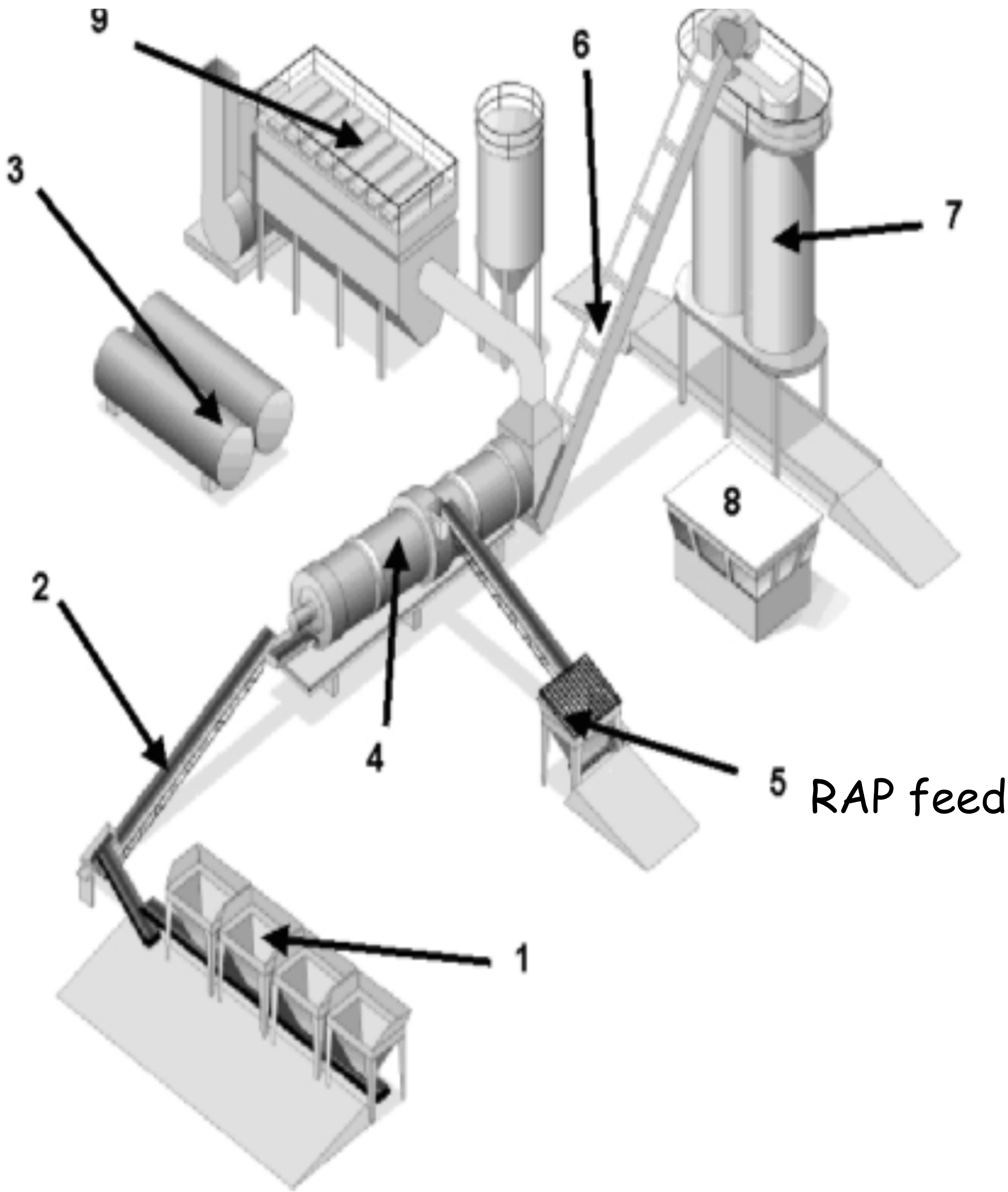
- QC retains half their sample (after final split) for QA.

60


9
6
3
7
8
2
4
5 RAP feed
1

COLD BINS

61

SAMPLING Drum Plant Methods

- Off the combined cold feed belt
- Diverter

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SAMPLING GRADATION

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SAMPLING
Cold Feed Belt

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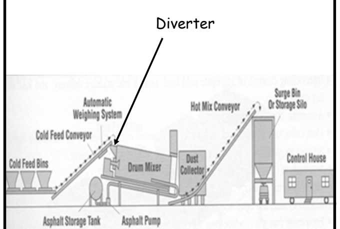
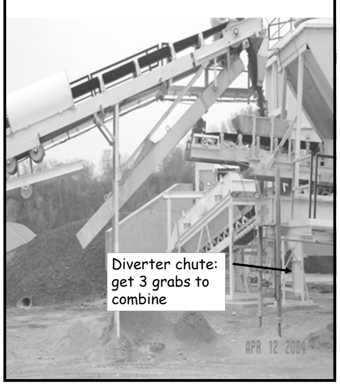
Drum Mix Plant



65

DIVERTER CHUTE



Splitting Down Diverter Sample

67

SAMPLING Batch Plant

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

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SAMPLING Hot Bins

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QC AGGREGATE SAMPLING/TESTING

Independent:

- ***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
- ***RAP:***
  - ***Gradation***-1 per day (T308)
  - ***Deleterious***-1 per 2 sublots
  - ***Binder content***- 1 per 4 sublots
  - ***Micro Deval***-1 per 1500 tons of RAP (RAP from MoDOT roadways is exempt)
- ***Shingles:*** gradation 1/10,000 tons (min. 1/project/mix type)
- Save a retained sample of each

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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
  - ***RAP binder content***- 1 per project
- QC retained split:
  - ***Gradation*** -1 per week minimum
  - ***Consensus***-1 per project minimum (no matter how many mixes)
  - ***Deleterious***-same as gradation
  - ***RAP***- none

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RAP & RAS Binder Content

- Per Spec 403.2.6, RAP & RAS binder contents must be determined (separately)
- 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
- If use commercial lab to do T164, may want to use your own oven for T 308 because ovens vary

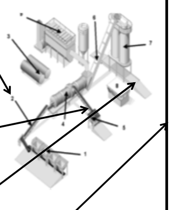
Sampling & Testing

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)
- Deleterious
- 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
- TSR-maybe



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AGGREGATE

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

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RAP

- ***Deleterious-*** Be within standard specs
- ***Micro Deval-*** be within Micro Deval of virgin aggregate + 5%
- May be difficult to find data on original virgin aggregate (try *MoDOT's "Quarry Sample Source Data"*)

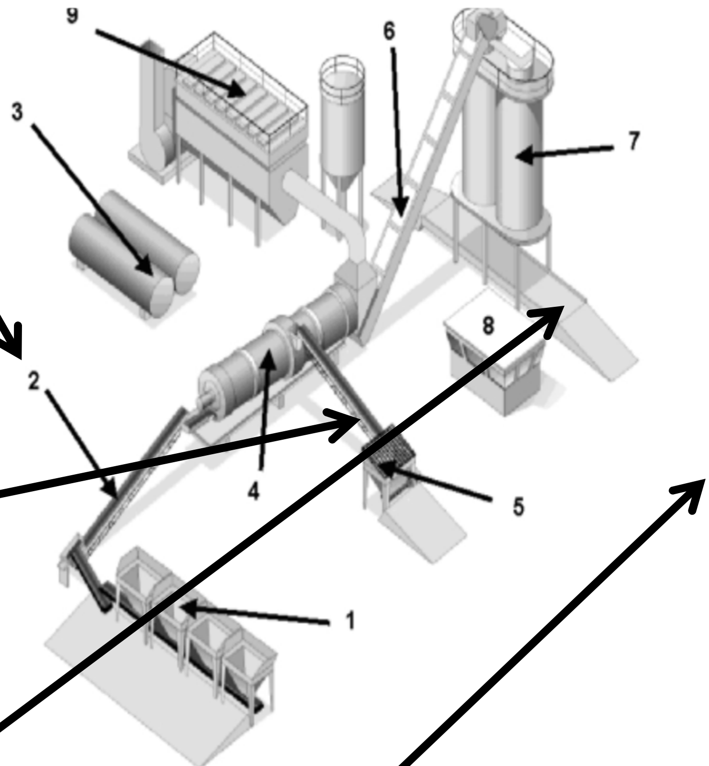
75

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)
- Deleterious
- 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
- TSR-maybe

RAP
Micro Deval
AASHTO TP 58

- Remove binder coating by extraction or ignition
- Test aggregate
- % loss no more than 5% more than virgin aggregate
- 1 per 1500 tons
- Waived if from MoDOT roadway


RAS

- Waste, manufacturer or new shingles must be essentially free of deleterious
- Post-consumer:
  - ≤ 1.5% wood
  - ≤ 3.0 total deleterious
  - Less than the maximum allowable asbestos defined by national or local standards

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UNFAVORABLE COMPARISON

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

GRADATION

- 403 master spec
- Field tolerances

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

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403 SPECIFIED GRADATIONS

Sieve	SP125xSM(R)	SP095xSM(R)
1.5	--	--
1	--	--
¾	100	--
½	90-100	100
3/8	50-80	70-95
#4	20-35	30-50
#8	16-24	20-30
#16	--	21 max
#30	--	18 max
#50	--	15 max
#100	--	---
#200	8.0-11.0	8.0-12.0

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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

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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

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SMA TOLERANCES

%'s off JMF Target Gradation

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

85

MINOR DEVIATIONS

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

1 sieve smaller than NMS:
2% above master spec

#8:
2% outside master spec

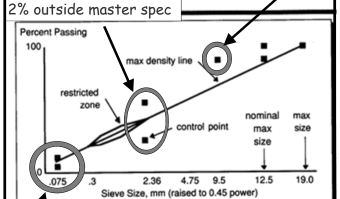

Figure 3.10 Superpave Gradation Limits

#200:
within master spec

87

1 sieve smaller than NMS:
2% above master spec

#8:
2% outside master spec

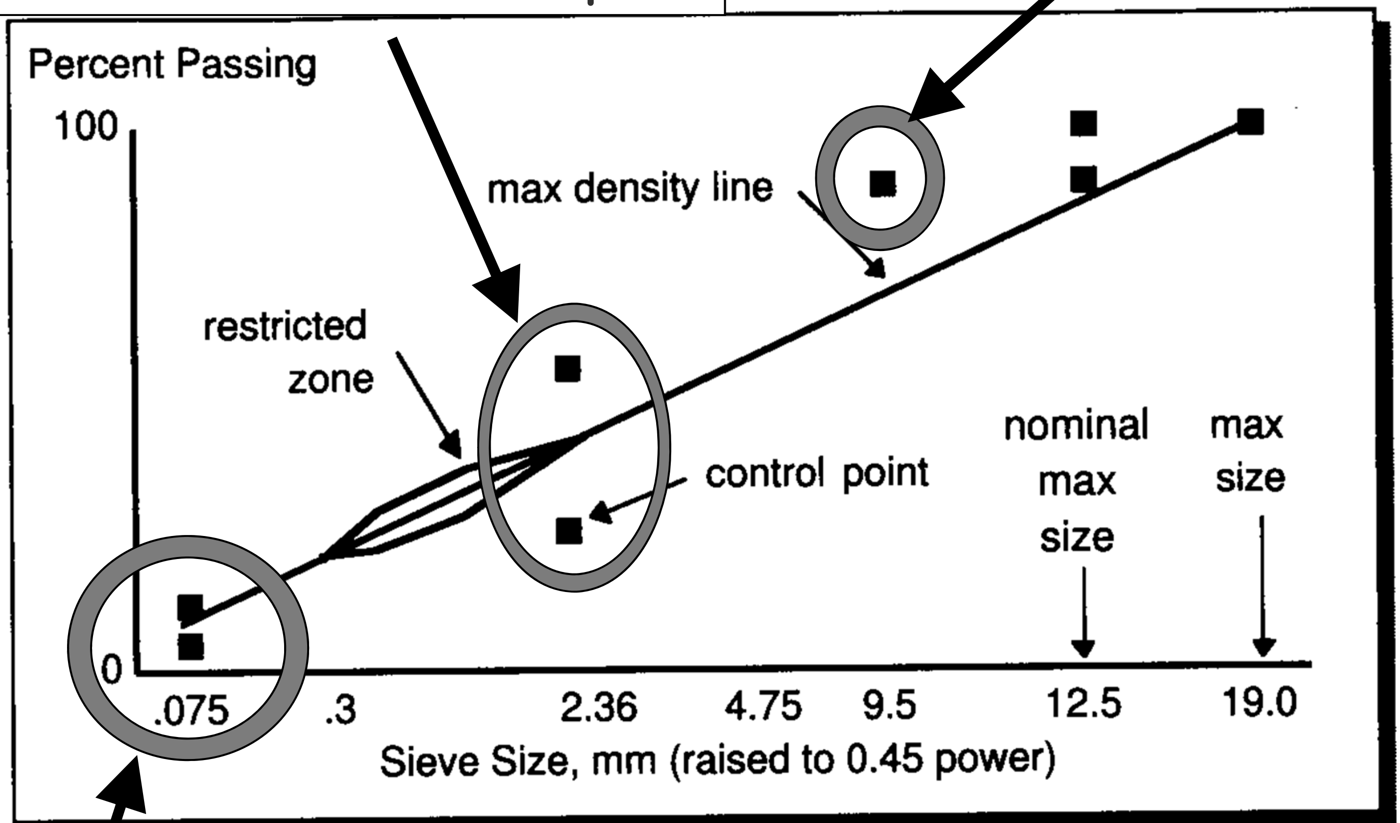

Figure 3.10 Superpave Gradation Limits

#200:
within master spec

COMPARISON TO SPECIFICATIONS

Consensus tests:

- FAA_{spec} -2%
- CAA_{spec} -5%
- SE_{spec} -5%
- $T\&E_{spec}$ +2%

88

Section 403 CONSENSUS REQUIREMENTS on blended aggregate

Traffic Level	CAA	FAA	SE	F&E*
F	55/none	--	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

*SMA ≤ 20% @ 3:1 and ≤ 5% @ 5:1
(Want a more cubical particle)

89

FIELD TOLERANCES Example: C mix

- FAA: 45-2= minimum of 43
- SE: 45-5= minimum of 40
- T&E: 10+2= maximum of 12
- CAA: 95-5= minimum of 90
  90-5= 85
  so….90/85

90

AGGREGATE

Acceptance:

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

91

COMPARING QA TO QC (QC Retained Sample)

- ***Consensus*** Tests:
  - CAA: QC ± 5%
  - FAA: QC ± 2%
  - SE: QC ± 8%
  - T& 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

92

EXAMPLE COMPARISON

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

93

UNFAVORABLE COMPARISON

- FAA most prone to "unfavorable comparison" because of incorrect specific gravity (eg-just using G_{sb} from JMF, which erroneously would include G_{sb} of coarse aggregate)

GRADATION

on QC retained sample so are running same type of sample

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

95

UNFAVORABLE COMPARISON

- If unfavorable comparison, initiate "dispute resolution"

96

Conclusion

- Everyone is at a different knowledge level about Superpave.
- Work together, not against each other.
- Early on: Watch each other pull samples and run tests
- Big differences in results come from QA and QC using different sampling and splitting procedures

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Module 4

QC/QA OVERVIEW and HOT MIX ASPHALT QUALITY CONTROL PLAN

12-28-06 Revision
4-22-09 Revision
12-29-09 Revision
1-19-11 Revision
2-26-13 Revision
12-18-13 Revision
3-2-16 Revision
3-2-18 Revision
12-12-18 Revision
12-17-19 Revision

Module 4

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3-2-18 Revision
12-12-18 Revision
12-17-19 Revision

Who's Who?

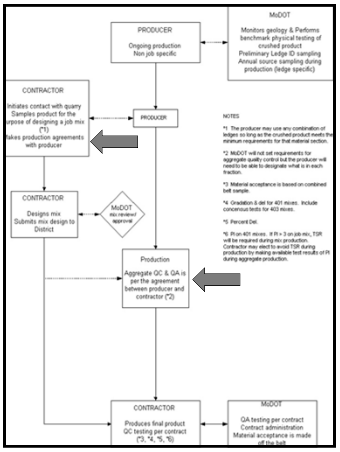
- Quality Control (QC) is the hot mix asphalt contractor.
- Quality Assurance (QA) is the specifying agency. MoDOT.
- QC can also refer to the aggregate producer.

2

PROJECT FLOWCHART

- 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. Samples aggregate for mix design (often, this is done earlier)

3



Important

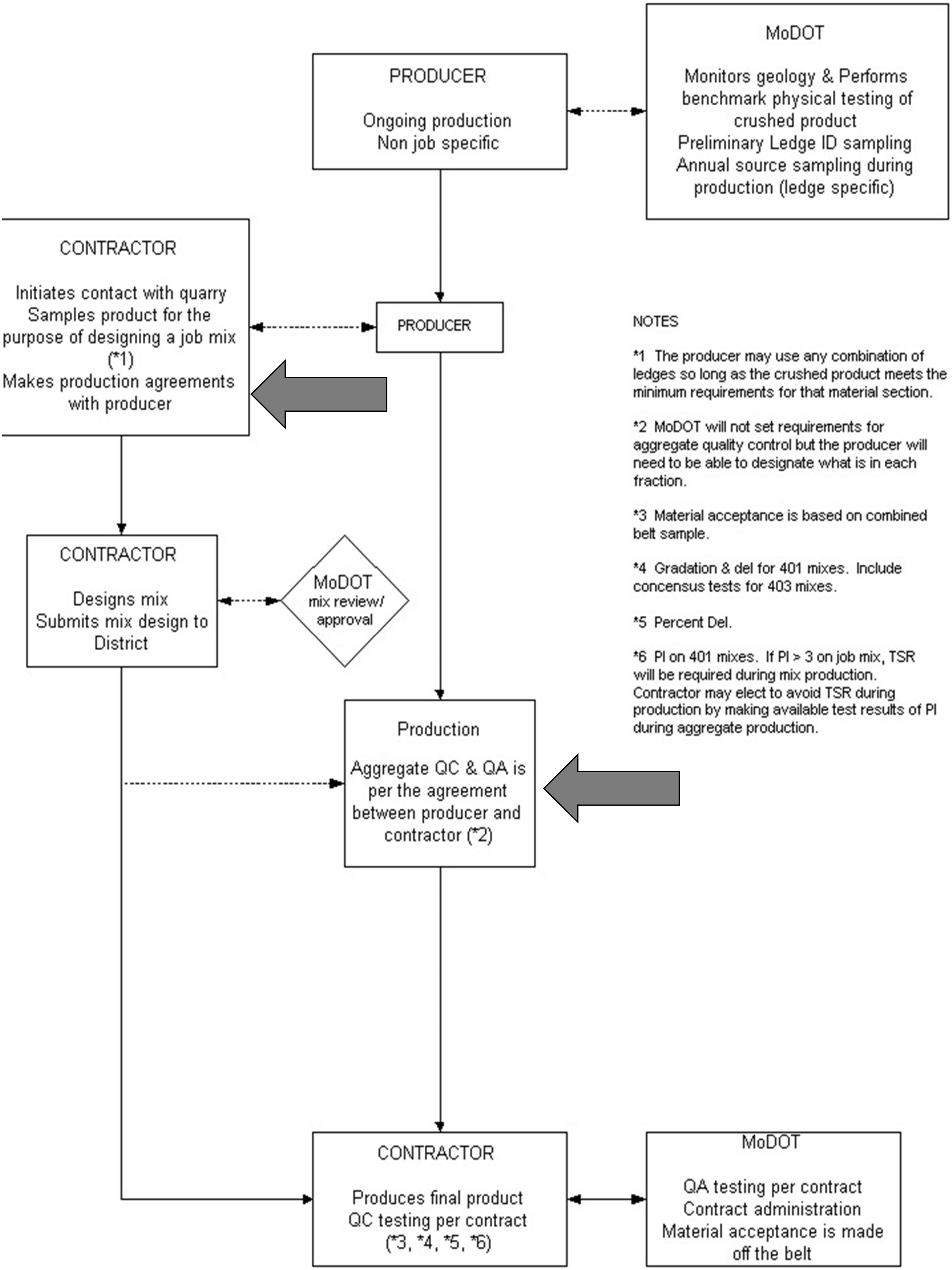
- Agreement between Paving Contractor and the Quarry as to gradation tolerances

5

FLOWCHART, cont'd.

- 4. Paving contractor submits mix design info (Job Mix Formula=JMF) to MoDOT through the district.
- 5. MoDOT Central Lab will verify the mix if QC lab does not have an AMRL round-robin rating of 3-5 and be within 2 standard deviations on each test. JMF approval granted (still have to sample aggregate if running nuclear gage so MoDOT can calibrate; or building a database)
- 6. Aggregate production begins (actually, Superpave rock is more common now)
- 7. Hot mix production begins. See "Hotmix Production."

6



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.

AGGREGATE INSPECTION

- QC and QA perform tests at the mixing facility, compare results to each other and:
  - Job Special Provisions
  - Standard specifications (the version in effect on day of bid letting)
  - Engineering Policy Guide (EPG) guidelines

7

HOTMIX 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, now)

8

Quality Control

- QC is the contractor's responsibility to do the necessary testing during the production of the hot mix 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

9

Quality Control

- The contractor provides control of all steps of the process: aggregate, binder, additives, mix design, HMA 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.

10

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.

11

Quality Control Plan

- The Quality Control Plan is a means for the producer to describe how control of the operation will be accomplished to ensure the materials produced meet specifications.
- The Quality Control Plan should not try to bypass any Standard Specifications or Special Provisions.

12

HMA Quality Control Plans

- Prior to the approval of the trial mix design the HMA contractor will submit a QC Plan to the District which adds traffic and the sends to MoDOT Construction & Materials in Jefferson City

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QC PLAN

- "Short Form"
- "On file"

14

QC PLAN Short Form

- Contract name
- Contract #
- Job #
- Route
- Contractor rep in charge of QC plus contact info
- Project level rep plus contact info
- ***Lot & sublot sizes and how they will be designated***
- ***Binder content test method***
- ***Number of cores cut per sample*** (more cores may be an advantage; up to 3 cores per "sample", traveled way and unconfined longitudinal joint)
- ***Whether gradations will be on T308 residue***
- Name, address, and phone number of the third party testing lab that will be used for dispute resolution.

15

Items to be included in the HMA QC Plan- On File

- Location and phone number of the asphalt plant.
- List of material suppliers (not aggregate).
- List of personnel that will be performing QC testing, their responsibilities, and their Superpave QC/QA certification number.

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Notes

- Lot sizes can be different for the same project (eg. 3000tons first lot, 10,000 thereafter)
- Third party cannot be the the one that performed the mix design

17

Items to be included in the HMA QC Plan

- Stockpile procedures at the asphalt plant.
  - Minimum stockpile size.
  - How will material be loaded into asphalt bins.
  - Steps should minimize degradation, segregation, and contamination.
- Method for transporting samples from roadway to testing laboratory.
- Sampling/Testing procedures and their corresponding AASHTO/ASTM/MoDOT specification number.

18

Items to be included in the HMA QC Plan

- Discuss how segregation is to be minimized and what will be done if segregation is encountered.
- Describe how and when cores will be taken from the roadway.

19

Items to be included in the HMA QC Plan

- Describe how retained samples and cores will be maintained.
- Describe how retained samples and cores will be designated and labeled.
- Describe steps to be followed if the loose mix sample location falls on a roadway obstruction or at the beginning of the day before the plant has leveled out.

20

Items to be included in the HMA QC Plan

- State the course of action for out-of-specification mix.
- Discuss how a re-sample will be collected if a sample is contaminated.

21

Items to be included in the HMA QC Plan

- Describe how the rolling pattern will be determined.
- State what will happen if equipment failure occurs.
- Describe how the plant is to be calibrated.
- State if control charts will be used.
- Attach copies of unique data sheets.

22

Items to be included in the HMA QC Plan

- Provide a detailed description of your mix design process.
  - Explain how aggregates were combined.
  - Explain mixing technique. (duration, type of mixer etc.)
  - Explain how Specific Gravities of the aggregate were determined. (plus #4?, plus # 8?, or combined?.)
  - Include any information that will eliminate testing variations.

23

PRE-PAVING MEETING

- Go over QC/QA Project Checklist
- Include course of action for out-of-specification mix
- Will substantially reduce conflict

24

Checklist Items

- Review QC Plan
- Random Number Method (and who: roadway? Plant?)
- Sample Identification (what, how, who)
- Location of QC Lab
- Rice Dryback
- Dispute Resolution
- Paperwork Sharing & Storage

25

Checklist Items, cont'd.

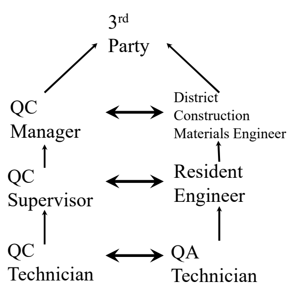
- Pay Factor Spreadsheet Version –the one in effect on the contract date (current version is posted on MoDOT website)
- Test Method Options
- Job Mix Approval
- Specifications to Review (use spec version in force at time of bidding)
- Anything else important to the Project

26

I have a disagreement with QC that we can't resolve. What do I do now?

27

Conflict Resolution
Example



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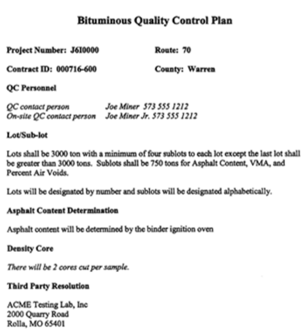
Example QC Plan



Bituminous Quality Control Plan

Project Number: J6I0000 **Route: 70**

Contract ID: 000716-600 **County: Warren**

QC Personnel

QC contact person *Joe Miner 573 555 1212*
On-site QC contact person *Joe Miner Jr. 573 555 1212*

Lot/Sub-lot

Lots shall be 3000 ton with a minimum of four sublots to each lot except the last lot shall be greater than 3000 tons. Sublots shall be 750 tons for Asphalt Content, VMA, and Percent Air Voids.

Lots will be designated by number and sublots will be designated alphabetically.

Asphalt Content Determination

Asphalt content will be determined by the binder ignition oven

Density Core

There will be 2 cores cut per sample.

Third Party Resolution

ACME Testing Lab, Inc
2000 Quarry Road
Rolla, MO 65401

29

Example QC Plan

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MODULE 5

SAMPLING LOOSE MIX AND CORES

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3-2-16 Revision
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12-17-19 Revision

MODULE 5

SAMPLING LOOSE MIX AND CORES

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12-12-18 Revision
2-8-19 Revision
3-15-19 Revision
12-17-19 Revision

1

SAMPLING LOOSE MIX AND CORES

- I. Loose mix

- II. Cores

2

Resources

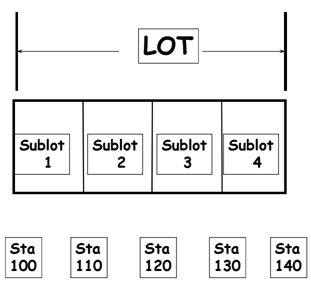
- 403 specification
- General provisions & Supplemental Specifications
- AASHTO Test Methods:
  - R 97 Sampling Asphalt Mixtures
  - R 47 Reducing Sample Size
- EPG
- FAQ
- Short Course Notebook

3

LOTS and SUBLOTS

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

4



Construction 5 QC QA Sampling

LOTS and SUBLOTS, cont'd.

- Definition of a "Lot":
  No specified limitation

  Typically 3000 or 4000 tons

  Sometimes much larger

6

LOTS AND SUBLOTS, cont'd.

- Sublot:
  - must have at least 4 sublots per lot
  - Maximum sublot size= 1000 tons
  - number of lots: Contractor's choice--put in QC plan
  - more sublots means more lab work, but may increase pay factor somewhat
  - If lot=3000 tons, a sublot= 750 tons

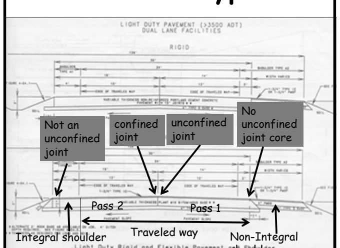
7

LOT ROUTINES 403 Mixes

- Traveled way + integral shoulders
- Non-integral shoulders (if Superpave)
- If not Superpave (eg, BP-1), random numbers not required- see "non-traveled area" notes

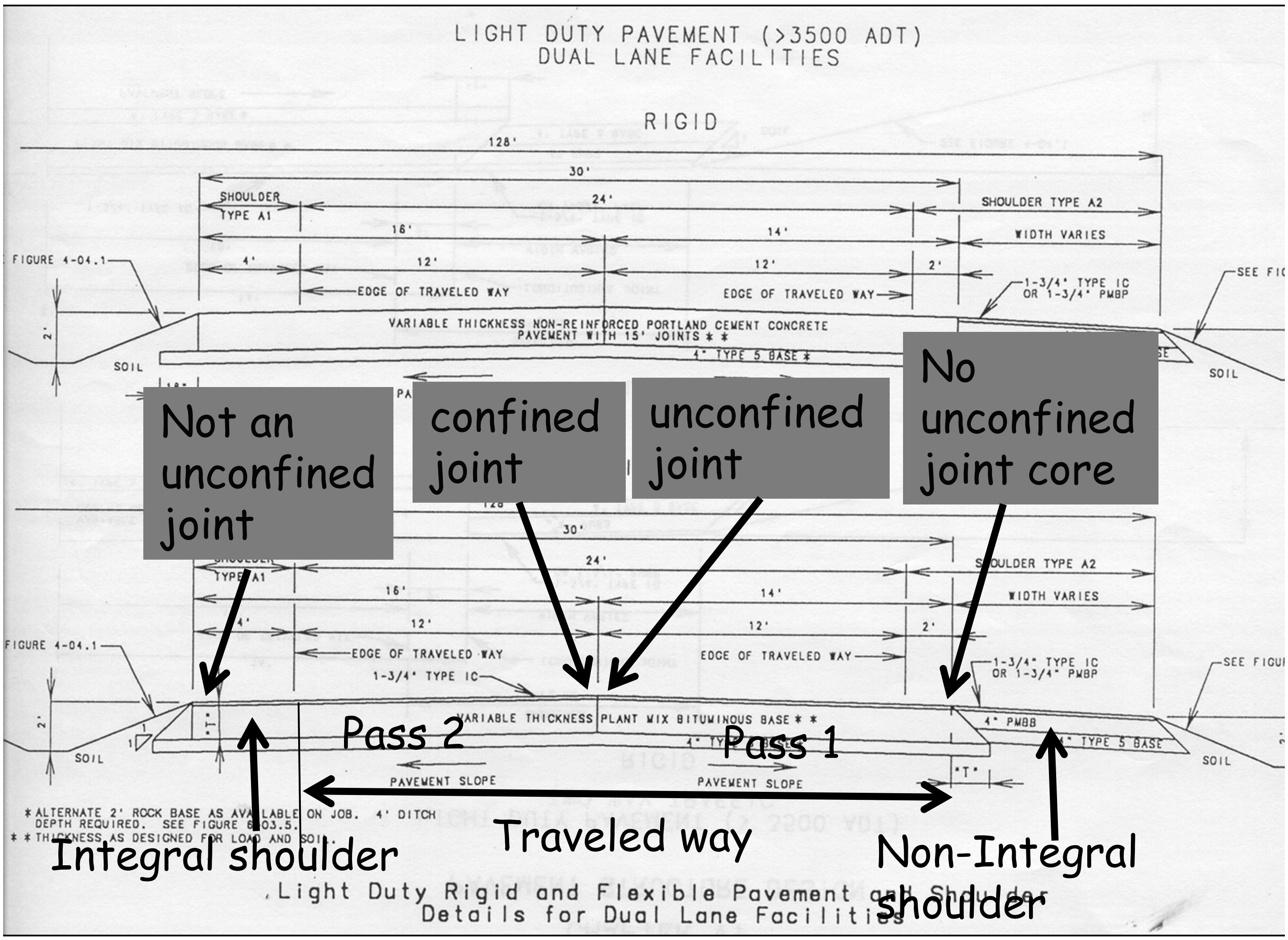
8

Traveled Way and Shoulder Types



9

Traveled Way and Shoulder Types



SAMPLE TYPES

- QUALITY LEVEL ANAYSIS (QLA)
  - 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
- Samples should be clearly marked as to what they are

10

EXTRA or CHECK SAMPLES

Extra sampling done by MoDOT or contractor to:

- 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, mat
- Not random-cannot be used for QLA

11

EXTRA or CHECK SAMPLES

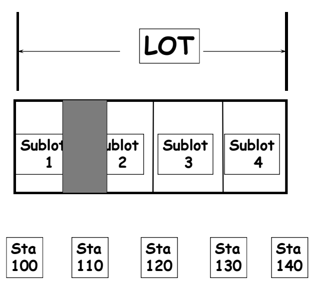
- Can be used to define removal limits, but must be "well-documented"

12

Circumstances Warranting Relocation

- May need to move sampling spot to avoid interfering obstacles:
  - Areas of hand-work
  - QA sample in close proximity to a QC sample in same production period
  - Manholes
  - Approaches to overpasses
  - Etc.

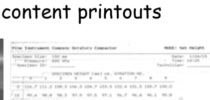
13



Construction 14 QC QA Sampling

"WELL-DOCUMENTED" The Following are Available:

- Gyro pucks
- Gyration/height printouts
- Binder content printouts

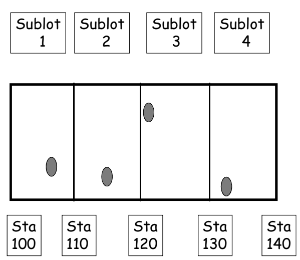
15

LOOSE MIX
Volumetric/%Binder Sample
Roadway
QC

- Sampling Frequency:
  - QC: one per ***sublot***

16

Stratified Random Sampling



Construction 17

LOOSE MIX
Volumetric/%Binder Sample
Roadway Only
QA

- QA: one per ***4 sublots***- "independent sample" *(spec 403.19.3)*
- QA: once per ***day*** test QC "retained sample". This may be omitted on days when independent QA sample is taken, if confident and "favorable comparison" exists between QA's QC split and QC *(403.1.18 EPG & FAQ #14)*

18

Retained Samples

403.17.2.3 – Retained samples should be clearly labeled and not discarded 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. If the contractor wishes to keep ADDITIONAL mix for internal use they may of course do so

19

FAVORABLE COMPARISON QC:QA

- G_{mm}: within 0.005
- G_{mb}: within 0.010
- P_b: within 0.1%

20

LOOSE MIX QLA Volumetric/%Binder Sample, cont'd.

- Random locations
  - QC= required
  - QA= required

(Might become part of the dataset from which Pay Factors are computed)

21

LOOSE MIX: TSR Sample

- 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)*

22

LOOSE MIX SAMPLING LOCATION

- Volumetrics/binder content sample- ***ROADWAY***
- *(use of spray paver or trackless tack may contaminate sample-consider an alternate sample type)*
- TSR–
  - ***ROADWAY****
  - ***PLANT DISCHARGE****
  - ***TRUCK***

  **** Preferred***

QA should get sample same place as QC, but not at same time

23

SAMPLING: QC Volumetrics/Binder

- QC gets their own ***volumetrics & %binder*** sample plus a "retained" sample for QA ***behind the paver***
- Size: about 50 lbs each
- Additional 75-125 lbs for ***TSR*** (plus another 125 lb sample retained for QA) ***behind the paver, at the plant, or a truck sample***
- Depth: full depth of the course

24

QC SAMPLING, Volumetrics/Binder cont'd.

- Preferred: ~100 lbs, mixed, quartered, from 2 opposite quarters 50 lbs retained for QA

25

QA SAMPLING

- QA gets their own "independent" sample plus their retained sample
- Samples that are used for comparison to QC (QLA) should be randomly located

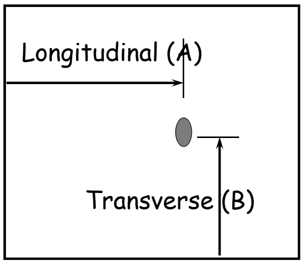
26

LOOSE MIX SAMPLE LOCATION

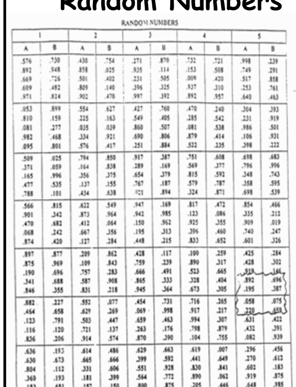
- ***Longitudinal*** position in terms of tons of mix from the start of the lot
- ***Transverse*** position in terms of distance from edge of mat

27

Sublot 1- Sample Location



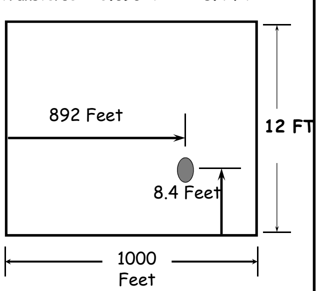
Random Numbers



RANDOM NUMBERS

1		2		3		4		5	
A	B	A	B	A	B	A	B	A	B
.576	.730	.430	.754	.271	.870	.732	.721	.998	.239
.892	.948	.858	.025	.935	.114	.153	.508	.749	.291
.669	.726	.501	.402	.231	.505	.009	.420	.517	.858
.609	.482	.809	.140	.396	.325	.937	.310	.253	.761
.971	.824	.902	.470	.997	.392	.892	.957	.640	.463
.053	.899	.554	.627	.427	.760	.470	.240	.304	.393
.810	.159	.225	.163	.549	.405	.285	.542	.231	.919
.081	.277	.035	.039	.860	.507	.081	.538	.986	.501
.982	.468	.334	.921	.690	.806	.879	.414	.106	.931
.095	.801	.576	.417	.251	.884	.522	.235	.398	.222
.509	.025	.794	.850	.917	.387	.751	.608	.698	.683
.371	.059	.164	.838	.289	.169	.569	.377	.796	.996
.165	.996	.356	.375	.654	.379	.815	.592	.348	.743
.477	.535	.137	.155	.767	.187	.579	.787	.358	.595
.788	.101	.434	.638	.921	.894	.324	.871	.698	.539
.566	.815	.622	.549	.947	.169	.817	.472	.854	.466
.901	.342	.873	.964	.942	.985	.123	.086	.335	.212
.470	.682	.412	.064	.150	.962	.925	.355	.909	.019
.068	.242	.667	.356	.195	.313	.396	.460	.740	.247
.874	.420	.127	.284	.448	.215	.833	.652	.601	.326
.897	.877	.209	.862	.428	.117	.100	.259	.425	.284
.875	.969	.109	.843	.759	.239	.890	.317	.428	.302
.190	.696	.757	.283	.666	.491	.523	.665	.919	.146
.341	.688	.587	.908	.865	.333	.328	.404	.892	.696
.846	.355	.831	.218	.945	.364	.673	.305	.195	.387
.882	.227	.552	.077	.454	.731	.716	.265	.058	.075
.464	.658	.629	.269	.069	.998	.917	.217	.220	.659
.123	.791	.503	.447	.659	.463	.994	.307	.631	.422
.116	.120	.721	.137	.263	.176	.798	.879	.432	.391
.836	.206	.914	.574	.870	.390	.104	.755	.082	.939
.636	.195	.614	.486	.629	.663	.619	.007	.296	.456
.630	.673	.665	.666	.399	.592	.441	.649	.270	.612
.804	.112	.331	.606	.551	.928	.830	.841	.602	.183
.360	.193	.181	.399	.564	.772	.890	.062	.919	.875
.183	.651	.157	.150	.800	.875	.205	.446	.648	.985

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



Random Numbers

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.971	.824	.902	.470	.997	.392	.892	.957	.640	.463
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.810	.159	.225	.163	.549	.405	.285	.542	.231	.919
.081	.277	.035	.039	.860	.507	.081	.538	.986	.501
.982	.468	.334	.921	.690	.806	.879	.414	.106	.931
.095	.801	.576	.417	.251	.884	.522	.235	.398	.222
.509	.025	.794	.850	.917	.387	.751	.608	.698	.683
.371	.059	.164	.838	.289	.169	.569	.377	.796	.996
.165	.996	.356	.375	.654	.379	.815	.592	.348	.743
.477	.535	.137	.155	.767	.187	.579	.787	.358	.595
.788	.101	.434	.638	.021	.894	.324	.871	.698	.539
.566	.815	.622	.549	.947	.169	.817	.472	.854	.466
.901	.342	.873	.964	.942	.985	.123	.086	.335	.212
.470	.682	.412	.064	.150	.962	.925	.355	.909	.019
.068	.242	.667	.356	.195	.313	.396	.460	.740	.247
.874	.420	.127	.284	.448	.215	.833	.652	.601	.326
.897	.877	.209	.862	.428	.117	.100	.259	.425	.284
.875	.969	.109	.843	.759	.239	.890	.317	.428	.302
.190	.696	.757	.283	.666	.491	.523	.665	.919	.146
.341	.688	.587	.908	.865	.333	.328	.404	.892	.696
.846	.355	.831	.218	.945	.364	.673	.305	.195	.387
.882	.227	.552	.077	.454	.731	.716	.265	.058	.075
.464	.658	.629	.269	.069	.998	.917	.217	.220	.659
.123	.791	.503	.447	.659	.463	.994	.307	.631	.422
.116	.120	.721	.137	.263	.176	.798	.879	.432	.391
.836	.206	.914	.574	.870	.390	.104	.755	.082	.939
.636	.193	.614	.486	.629	.663	.619	.007	.296	.456
.630	.673	.665	.666	.399	.592	.441	.649	.270	.612
.804	.112	.331	.606	.551	.928	.830	.841	.602	.183
.360	.193	.181	.399	.564	.772	.890	.062	.919	.875
.183	.651	.157	.150	.800	.875	.205	.446	.648	.985

RANDOM NUMBERS

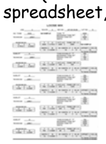
- Position of each loose mix sample and core: a transverse distance and a longitudinal distance
- Distances are determined by random numbers-one for longitudinal (A), one for transverse (B)
- The pair of random numbers are different for each sample location (core or loose mix) QC, or QA.

31

RANDOM NUMBERS

- RN's are generated by QA
- Methods of generating RN's:
  - use of RN tables

  - by computer (routines, websites, MoDOT spreadsheet, etc)



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Random Numbers

- Object: to produce unbiased samples-sample bias occurs either during construction or during sampling
- QC should provide contingencies in QC Plan to handle RN's in weird locations (does not apply to early tonnage e.g first 50 tons)

33

RANDOM NUMBERS

1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B	5 A	5 B
.576	.730	.430	.754	.271	.870	.732	.721	.998	.239
.892	.948	.858	.025	.935	.114	.153	.508	.749	.291
.669	.726	.501	.402	.231	.505	.009	.420	.517	.858
.609	.482	.809	.140	.396	.325	.937	.310	.253	.761
.971	.824	.902	.470	.997	.392	.892	.957	.640	.463
.053	.899	.554	.627	.427	.760	.470	.240	.304	.393
.810	.159	.225	.163	.549	.405	.285	.542	.231	.919
.081	.277	.035	.039	.860	.507	.081	.538	.986	.501
.982	.468	.334	.921	.690	.806	.879	.414	.106	.931
.095	.801	.576	.417	.251	.884	.522	.235	.398	.222
.509	.025	.794	.850	.917	.387	.751	.608	.698	.683
.371	.059	.164	.838	.289	.169	.569	.377	.796	.996
.165	.996	.356	.375	.654	.379	.815	.592	.348	.743
.477	.535	.137	.155	.767	.187	.579	.787	.358	.595
.788	.101	.434	.638	.921	.894	.324	.871	.698	.539
.566	.815	.622	.549	.947	.169	.817	.472	.854	.466
.901	.342	.873	.964	.942	.985	.123	.086	.335	.212
.470	.682	.412	.064	.150	.962	.925	.355	.909	.019
.068	.242	.667	.356	.195	.313	.396	.460	.740	.247
.874	.420	.127	.284	.448	.215	.833	.652	.601	.326
.897	.877	.209	.862	.428	.117	.100	.259	.425	.284
.875	.969	.109	.843	.759	.239	.890	.317	.428	.302
.190	.696	.757	.283	.666	.491	.523	.665	.919	.146
.341	.688	.587	.908	.865	.333	.328	.404	.892	.696
.846	.355	.831	.218	.945	.364	.673	.305	.195	.387
.882	.227	.552	.077	.454	[illegible]	.716	.265	.058	.075
.464	.658	.629	.269	.069	.998	.917	.217	.220	.659
.123	.791	.503	.447	.659	[illegible]	.994	.307	.631	.422
.116	.120	.721	.137	.263	.176	.798	.879	.432	.391
.836	.206	.914	.574	.870	.390	.104	[illegible]	.082	.939
.636	.193	.614	.486	.629	.663	.619	.007	.296	.456
.630	.673	.665	.666	.399	.592	.441	[illegible]	.270	.612
.804	.112	.331	.606	.551	.928	.830	.841	.602	.183
.360	.193	.181	.399	.564	.772	.890	.062	.919	.875
.183	.651	.157	.150	.800	.875	.205	.446	.648	.985

RN TABLES

- Pick pairs row by row or column by column
- Don't jump around

35

RANDOM NUMBER GENERATION

- MoDOT spreadsheet is the preferred method
- Use the "Asphalt Random Location spreadsheet" (FAQ #5)
- MoDOT internal site:

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

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RANDOM NUMBERS

1		2		3		4		5	
A	B	A	B	A	B	A	B	A	B
.576	.730	.430	.754	.271	.870	.732	.721	.998	.239
.892	.948	.858	.025	.935	.114	.153	.508	.749	.291
.669	.726	.501	.402	.231	.505	.009	.420	.517	.858
.609	.482	.809	.140	.396	.325	.937	.310	.253	.761
.971	.824	.902	.470	.997	.392	.892	.957	.640	.463
.053	.899	.554	.627	.427	.760	.470	.240	.304	.393
.810	.159	.225	.163	.549	.405	.285	.542	.231	.919
.081	.277	.035	.039	.860	.507	.081	.538	.986	.501
.982	.468	.334	.921	.690	.806	.879	.414	.106	.931
.095	.801	.576	.417	.251	.884	.522	.235	.398	.222
.509	.025	.794	.850	.917	.387	.751	.608	.698	.683
.371	.059	.164	.838	.289	.169	.569	.377	.796	.996
.165	.996	.356	.375	.654	.379	.815	.592	.348	.743
.477	.535	.137	.155	.767	.187	.579	.787	.358	.595
.788	.101	.434	.638	.021	.894	.324	.871	.698	.539
.566	.815	.622	.549	.947	.169	.817	.472	.854	.466
.901	.342	.873	.964	.942	.985	.123	.086	.335	.212
.470	.682	.412	.064	.150	.962	.925	.355	.909	.019
.068	.242	.667	.356	.195	.313	.396	.460	.740	.247
.874	.420	.127	.284	.448	.215	.833	.652	.601	.326
.897	.877	.209	.862	.428	.117	.100	.259	.425	.284
.875	.969	.109	.843	.759	.239	.890	.317	.428	.302
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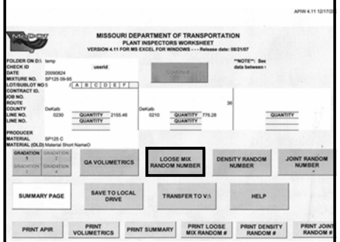
.341	.688	.587	.908	.865	.333	.328	.404	.892	.696
.846	.355	.831	.218	.945	.364	.673	.305	.195	.387
.882	.227	.552	.077	.454	.731	.716	.265	.058	.075
.464	.658	.629	.269	.069	.998	.917	.217	.220	.659
.123	.791	.503	.447	.659	.463	.994	.307	.631	.422
.116	.120	.721	.137	.263	.176	.798	.879	.432	.391
.836	.206	.914	.574	.870	.390	.104	.755	.082	.939
.636	.193	.614	.486	.629	.663	.619	.007	.296	.456
.630	.673	.665	.666	.399	.592	.441	.649	.270	.612
.804	.112	.331	.606	.551	.928	.830	.841	.602	.183
.360	.193	.181	.399	.564	.772	.890	.062	.919	.875
.183	.651	.157	.150	.800	.875	.205	.446	.648	.985

MoDOT SPREADSHEET



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LOOSE MIX

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

NO. TONS 3000 QA SAMPLE

TECHNICIAN philc1

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 philc1

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 philc1

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 philc1

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 philc1

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

RANDOM NO.

A	B
0.0596	0.0308

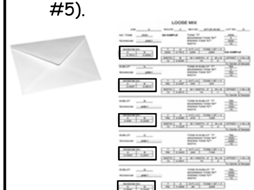
T	A	X=T x A	TONS = BT + X
750	0.0596	45	2295

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

To Center of Sample

LOOSE MIX SAMPLING STEPS- Typical Scenario (EPG)

1. QA generates pairs of RN's 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 (FAQ #5).



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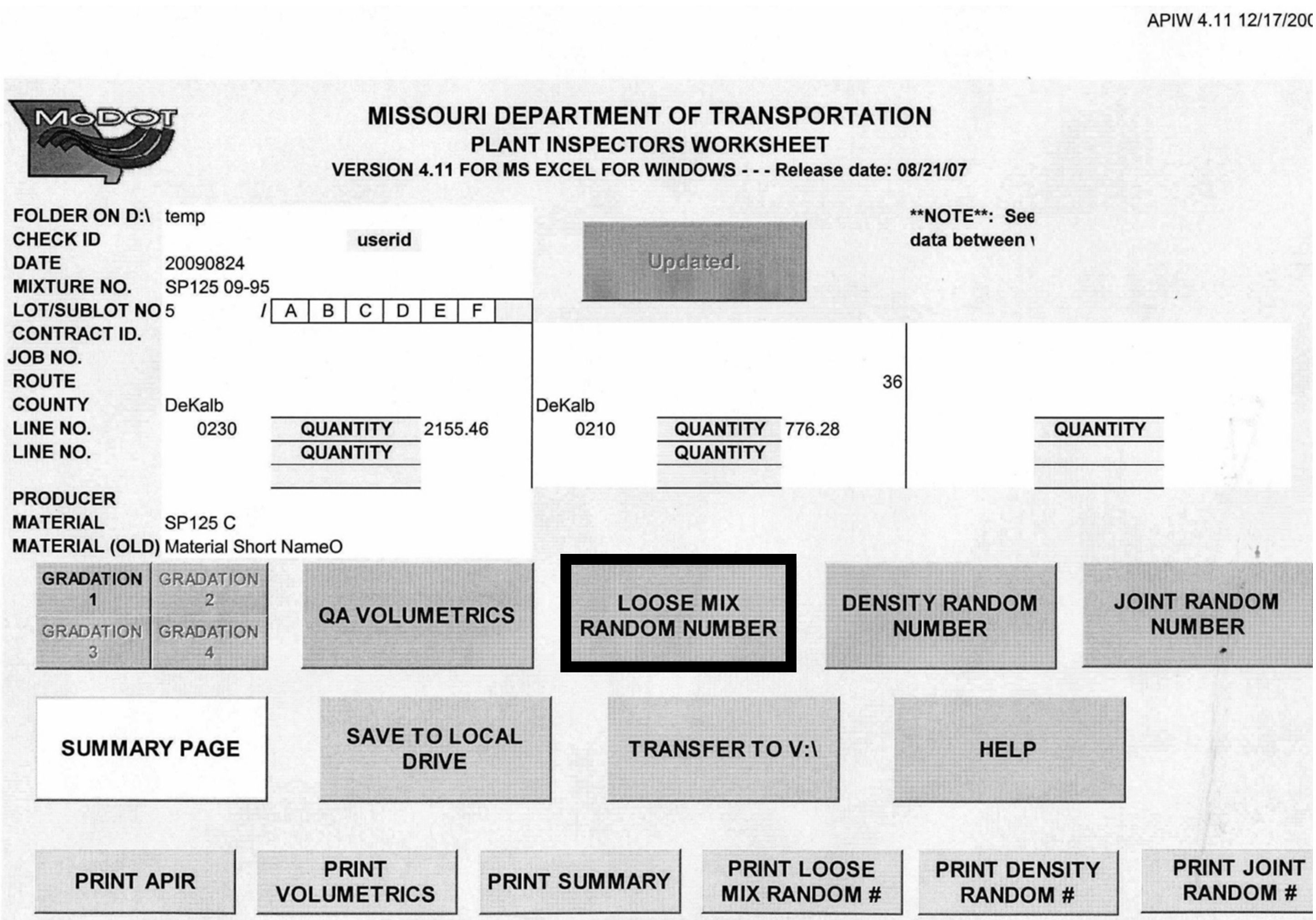
MoDOT SPREADSHEET



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

Typical Scenario (EPG)

QA uses RN's to calculate the longitudinal measurement to sample (ton or distance) and the transverse measurement (distance).

2. QA gives info to QC 100-150 tons in advance of the test (FAQ #6).

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SAMPLING STEPS, cont'd.

3. QC gives info to plant operator.

4. Plant operator marks ticket of the load that the RN ton fell in.

5. QC follows truck to site.

6. Roadway inspector notes the location (station) where the load went down. This will be arbitrary.

7. Samples should not be taken in areas of handwork; move 10 ft ahead of affected area (FAQ #6)

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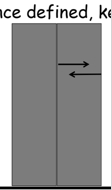
SAMPLING STEPS, cont'd.

- 8. QC measures transversely from edge of mat to the sampling location.
- "Edge of mat":
  - Which edge is not specified
  - Typically: away from traffic for safety
  - Once defined, keep consistent



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SAMPLING STEPS,
cont'd.

9. Loose mix is removed from roadway, sometimes with aid of a template.

10. QC places sample in insulated container and transports it to mobile lab.

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SAMPLING STEPS,
cont'd.

11. Sample is split down and tests are begun.

12. When testing completed, envelopes are opened to verify non-manipulation (FAQ #6).

Procedure for QA sample is similar.

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LOOSE MIX SAMPLING EXAMPLE

- See example

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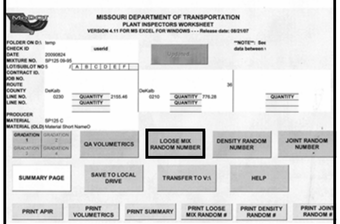
MoDOT SPREADSHEET



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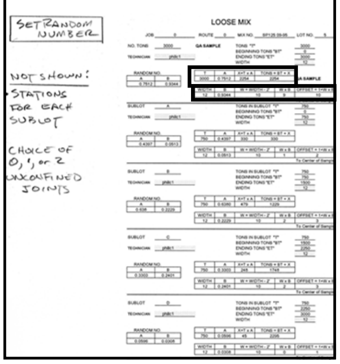
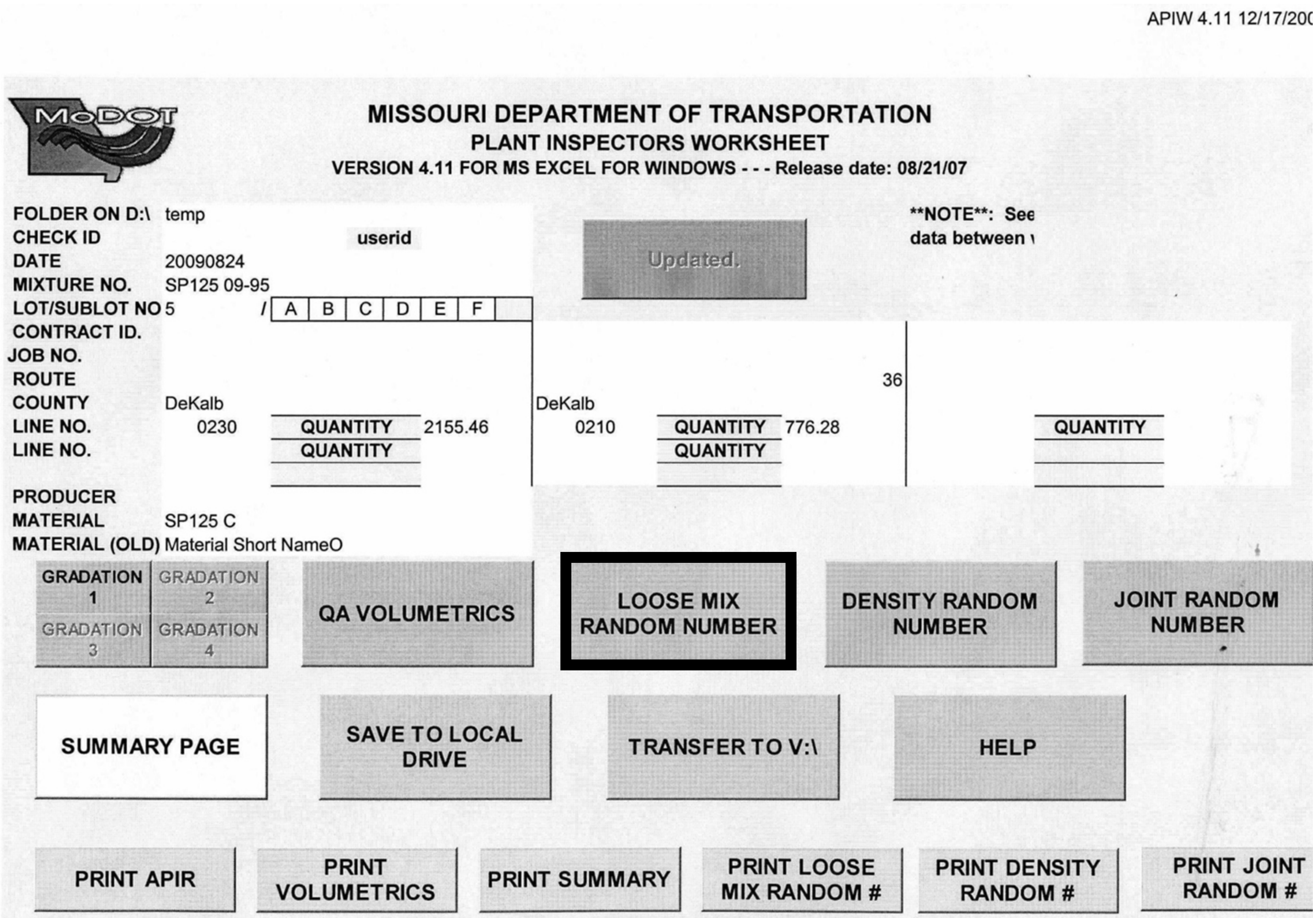
LOOSE MIX



RANDOM NUMBERS

1		2		3		4		5	
A	B	A	B	A	B	A	B	A	B
.576	.730	.430	.754	.271	.870	.732	.721	.998	.239
.892	.948	.858	.025	.935	.114	.153	.508	.749	.291
.669	.726	.501	.402	.231	.505	.009	.420	.517	.858
.609	.482	.809	.140	.396	.325	.937	.310	.253	.761
.971	.824	.902	.470	.997	.392	.892	.957	.640	.463
.053	.899	.554	.627	.427	.760	.470	.240	.304	.393
.810	.159	.225	.163	.549	.405	.285	.542	.231	.919
.081	.277	.035	.039	.860	.507	.081	.538	.986	.501
.982	.468	.334	.921	.690	.806	.879	.414	.106	.931
.095	.801	.576	.417	.251	.884	.522	.235	.398	.222
.509	.025	.794	.850	.917	.387	.751	.608	.698	.683
.371	.059	.164	.838	.289	.169	.569	.377	.796	.996
.165	.996	.356	.375	.654	.379	.815	.592	.348	.743
.477	.535	.137	.155	.767	.187	.579	.787	.358	.595
.788	.101	.434	.638	.921	.894	.324	.871	.698	.539
.566	.815	.622	.549	.947	.169	.817	.472	.854	.466
.901	.342	.873	.964	.942	.985	.123	.086	.335	.212
.470	.682	.412	.064	.150	.962	.925	.355	.909	.019
.068	.242	.667	.356	.195	.313	.396	.460	.740	.247
.874	.420	.127	.284	.448	.215	.833	.652	.601	.326
.897	.877	.209	.862	.428	.117	.100	.259	.425	.284
.875	.969	.109	.843	.759	.239	.890	.317	.428	.302
.190	.696	.757	.283	.666	.491	.523	.665	.919	.146
.341	.688	.587	.908	.865	.333	.328	.404	.892	.696
.846	.355	.831	.218	.945	.364	.673	.305	.195	.387
.882	.227	.552	.077	.454	[illegible]	.716	.265	.058	.075
.464	.658	.629	.269	.069	.998	.917	.217	.220	.659
.123	.791	.503	.447	.659	[illegible]	.994	.307	.631	.422
.116	.120	.721	.137	.263	.176	.798	.879	.432	.391
.836	.206	.914	.574	.870	.390	.104	[illegible]	.082	.939
.636	.195	.614	.486	.629	.663	.619	.007	.296	.456
.630	.673	.665	.666	.399	.592	.441	[illegible]	.270	.612
.804	.112	.331	.606	.551	.928	.830	.841	.602	.183
.360	.193	.181	.399	.564	.772	.890	.062	.919	.875
.183	.651	.157	.150	.800	.875	.205	.446	.648	.985

MoDOT SPREADSHEET



LOOSE MIX

SET RANDOM NUMBER

NOT SHOWN:

- STATIONS FOR EACH SUBLOT
- CHOICE OF 0, 1, or 2 UNCONFINED JOINTS

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

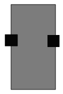
To Center of Sample

RANDOM NUMBERS

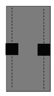
1		2		3		4		5	
A	B	A	B	A	B	A	B	A	B
.576	.730	.430	.754	.271	.870	.732	.721	.998	.239
.892	.948	.858	.025	.935	.114	.153	.508	.749	.291
.669	.726	.501	.402	.231	.505	.009	.420	.517	.858
.609	.482	.809	.140	.396	.325	.937	.310	.253	.761
.971	.824	.902	.470	.997	.392	.892	.957	.640	.463
.053	.899	.554	.627	.427	.760	.470	.240	.304	.393
.810	.159	.225	.163	.549	.405	.285	.542	.231	.919
.081	.277	.035	.039	.860	.507	.081	.538	.986	.501
.982	.468	.334	.921	.690	.806	.879	.414	.106	.931
.095	.801	.576	.417	.251	.884	.522	.235	.398	.222
.509	.025	.794	.850	.917	.387	.751	.608	.698	.683
.371	.059	.164	.838	.289	.169	.569	.377	.796	.996
.165	.996	.356	.375	.654	.379	.815	.592	.348	.743
.477	.535	.137	.155	.767	.187	.579	.787	.358	.595
.788	.101	.434	.638	.021	.894	.324	.871	.698	.539
.566	.815	.622	.549	.947	.169	.817	.472	.854	.466
.901	.342	.873	.964	.942	.985	.123	.086	.335	.212
.470	.682	.412	.064	.150	.962	.925	.355	.909	.019
.068	.242	.667	.356	.195	.313	.396	.460	.740	.247
.874	.420	.127	.284	.448	.215	.833	.652	.601	.326
.897	.877	.209	.862	.428	.117	.100	.259	.425	.284
.875	.969	.109	.843	.759	.239	.890	.317	.428	.302
.190	.696	.757	.283	.666	.491	.523	.665	.919	.146
.341	.688	.587	.908	.865	.333	.328	.404	.892	.696
.846	.355	.831	.218	.945	.364	.673	.305	.195	.387
.882	.227	.552	.077	.454	.731	.716	.265	.058	.075
.464	.658	.629	.269	.069	.998	.917	.217	.220	.659
.123	.791	.503	.447	.659	.463	.994	.307	.631	.422
.116	.120	.721	.137	.263	.176	.798	.879	.432	.391
.836	.206	.914	.574	.870	.390	.104	.755	.082	.939
.636	.193	.614	.486	.629	.663	.619	.007	.296	.456
.630	.673	.665	.666	.399	.592	.441	.649	.270	.612
.804	.112	.331	.606	.551	.928	.830	.841	.602	.183
.360	.193	.181	.399	.564	.772	.890	.062	.919	.875
.183	.651	.157	.150	.800	.875	.205	.446	.648	.985

SAMPLE LOCATION

- The random number location is the center of the sample
- If the RN is ~0.000 or ~1.000, the sample center could land on the mat edge, and half the sample would be missing



- Hence, the 1 ft offset line
- Keeps the sample in the mat of interest



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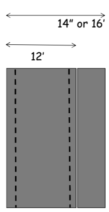
SAMPLE LOCATION

If the paving mat width is 14 or 16 ft, still run calculations based on 12 ft, with omission of 1 ft on each "side" of the 12 ft width

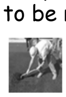
The intent is to sample the "traveled way"



50

ROADWAY SAMPLING

- Using a square-nosed shovel and possibly a template, mark the area to be removed



- Remove ***all*** mixture within the area
- Do not contaminate the sample with underlying material
- Avoid segregation of the material

51

SAMPLING

- Place in insulated container
- Carry back to mobile lab
- Split 100 lb. sample at lab for gyro pucks, Rice gravity, asphalt & moisture contents, and retained sample



- Split 75-125 lb. sample down for TSR pucks and a Rice (could use Rice from volumetric sample if in same sublot)
- Samples must have a unique identification, even extra samples used for identification of removal limits

52

Mix Sampling

- Suitable Sample Container
  - Clean, heat resistant
  - Transport in insulated container

Mobile Superpave Lab

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LAB LOCATION

- No longer required to be at the plant
- To be located at a site appropriate to the work

55

CONFLICT AVOIDANCE

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

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

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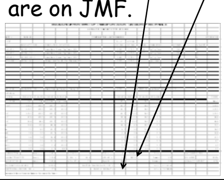
QUARTERING and TESTING

- See insert for method.

- Specimen size for gyro & MoDOT nuclear samples are on JMF.



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QUARTERING and TESTING

- Specimen size for Rice & ignition oven samples are in the test procedures.
  - Back of Module 7 cookbook
  - Back of Module 8 cookbook

58

AASHTO R47

- Quartering templates

- Quartering

- "Quartermaster"

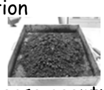
- Riffle splitters

- Incremental (loaf)

59

100 lbs

- Mix, avoid segregation
- Split/quarter



- Use appropriate release agent: no solvents or petroleum-based products

- Combine & retain opposite quarters = 50 lbs
- Combine other 2 opposite quarters = 50 lbs---continue quartering as follows

60

Splitting loose mix sample

Splitting the loose mix sample taken from the road - four samples

Quartering with Mechanical Splitter "A"

62

Quartering

63

Segregated Samples from the Same Mix

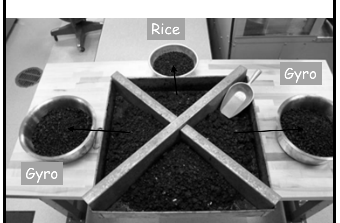
Coarse Portion
3.79% Asphalt Binder

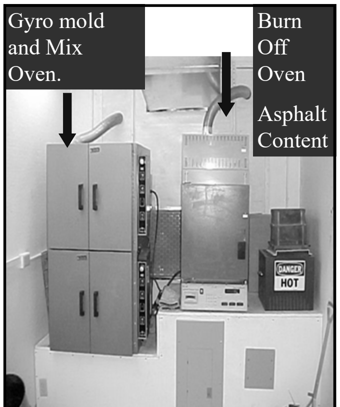
Fine Portion
5.21% Asphalt Binder

VOLUMETRICS-%AC SAMPLE

- 50 lb. sample –get portions for:
  - 2 volumetric gyro pucks
  - Rice specific gravity
  - Asphalt content (ignition oven or nuclear)
  - Moisture content

SAMPLE SPLIT





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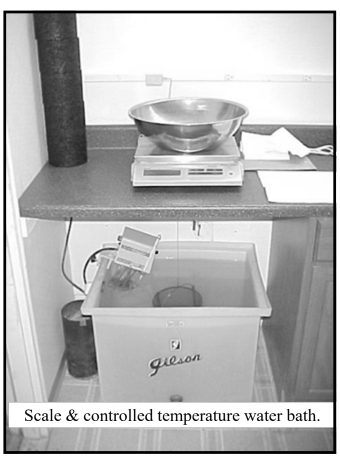
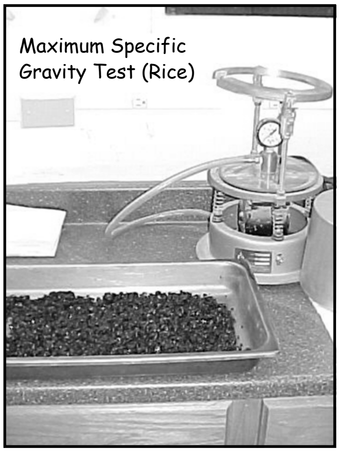
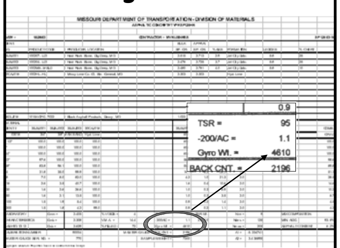
Gyro Pucks - G_{mb}



Scale & controlled temperature water bath.



Location of Gyro Weight on JMF



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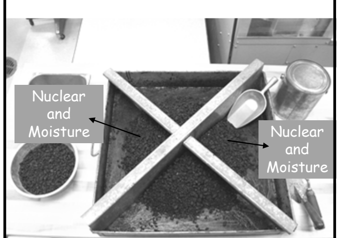
REMIX, SPLIT AGAIN Nuclear & Moisture



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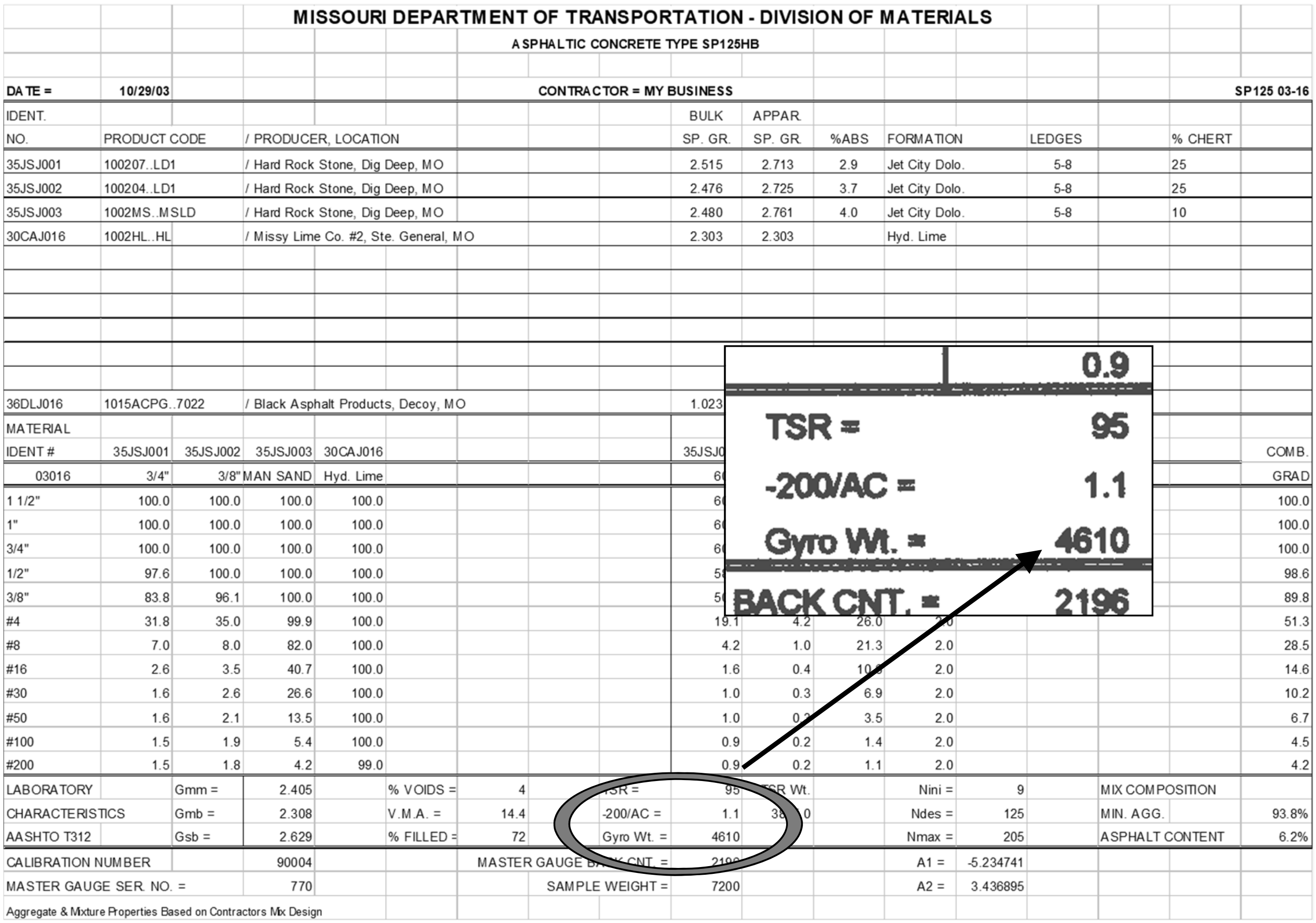
Location of Gyro Weight on JMF



MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP125HB

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

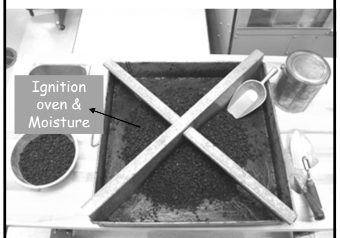
IDENT. NO.	PRODUCT CODE	/ PRODUCER, LOCATION	BULK SP. GR.	APPAR. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
35JSJ001	100207..LD1	/ Hard Rock Stone, Dig Deep, MO	2.515	2.713	2.9	Jet City Dolo.	5-8	25
35JSJ002	100204..LD1	/ Hard Rock Stone, Dig Deep, MO	2.476	2.725	3.7	Jet City Dolo.	5-8	25
35JSJ003	1002MS..MSLD	/ Hard Rock Stone, Dig Deep, MO	2.480	2.761	4.0	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	[illegible]	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. =	219[illegible]		A1 =	-5.234741	
MASTER GAUGE SER. NO. =		770			SAMPLE WEIGHT =	7200		A2 =	3.436895	

Aggregate & Mixture Properties Based on Contractors Mix Design

REMIX, SPLIT AGAIN Ignition Oven & Moisture



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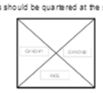
Asphalt Content - Ignition

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.

76

**2008 PROCESS REVIEW TEAM*

- ***Poor quartering procedures (QC & QA)***
- ***Poor split sample retention***

77

TSR SAMPLING

- Roadway
- Plant discharge
- Truck

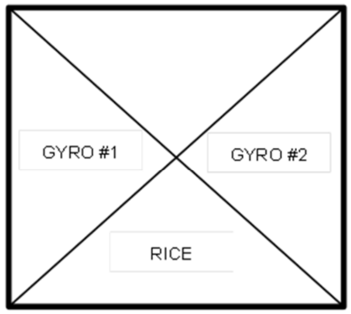
- QA samples should be taken from the same point as the QC, although ***not at the same time***

78

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.



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

TSR Sampling-Roadway

79

CAUTION

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

80

PLANT DISCHARGE (Chop Gate-Diverter Chute)

81

PLANT DISCHARGE (Chop Gate-Diverter Chute)

- Divert entire production stream from drum to a loader bucket

- Sample all across the loader bucket, one shovel per box , all boxes
- Repeat until boxes are full
- Cool (beware of dust)
- Close boxes

82

PLANT DISCHARGE (Chop Gate-Diverter Chute)

- Re-heat material
- Mix all boxes
- Quarter with templates
- Remove quarters to 4 buckets
- Quarter each bucket
- Pull one puck from each quarter

83

Truck Sampling

84

Truck Sampling

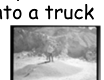
CAUTION

- Sampling methods limits the position of sampling
- Don't leave sample boxes uncovered at this location—may get contaminated with dust and overspray of release agent

86

Truck "Mini-stockpile"

- About 2 tons sampled from silo discharge into a truck
- Dumped
- Back dragged

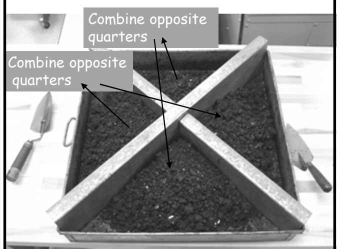


- Sampled into, say, 4 buckets or boxes…
- Back at lab, material is combined, mixed, and quartered , combined into 2 piles
- 4 pucks sampled from each pile

87

TSR SAMPLE

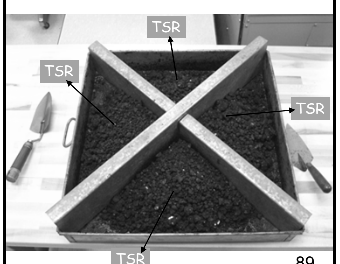
- Sample for six TSR pucks (and possibly a Rice)



88

TSR SAMPLE

- Quarter one combined portion to obtain four TSR puck amounts



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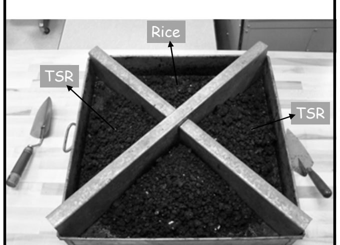
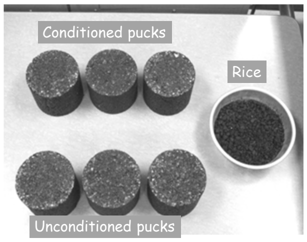
TSR SAMPLE

- Quarter second combined portion to obtain two TSR puck amounts and a Rice

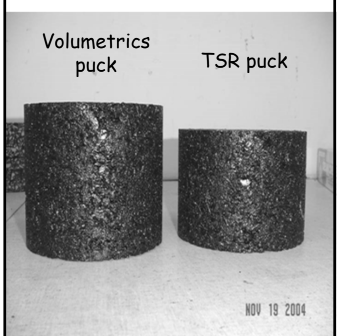


90

TSR



91



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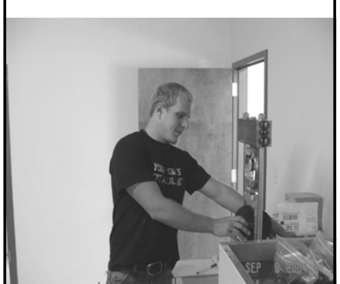
TSR Testing



93

QA TSR Sample

- QA inspector will box up 125 lbs. of loose mix sample and ship to Central Lab for testing, retaining another 125 lbs

94

QA TSR Sample

- Central Lab will determine from testing the received material the TSR puck weight to be used

95

TSR BOX INFO

- Site Manager ID number
- Mix number
- G_{mm} from sublot taken (QC or QA)
- Specimen weight QC is using

96

LOOSE MIX TESTING

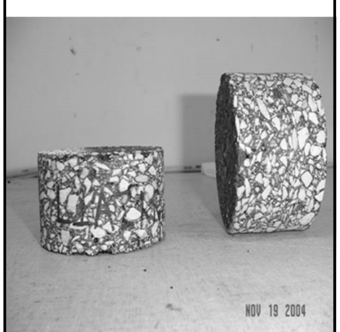
- Label samples!
- Re-heat mix to molding temperature (use a temperature probe in mix to facilitate temperature verification)
- Recommended to put gyro material into oven immediately to minimize additional binder absorption and aging
- Begin cooling Rice sample

97

II. CORING Mat Density

98

Density Cores - G_{mc}



USE of CORE

- Primarily to compute % Density:
- % Density = $(G_{mc} / G_{mm}) \times 100$
- G_{mm} from same sublot as core
- QA: use QC's G_{mm} if necessary

(403.23.7.2.1 and FAQ #16)

100

TYPES OF CORES

- QLA cores----QLA Pay Factor
- Longitudinal unconfined joint density cores----Pay Adjustment Factor
- Non-integral shoulder cores---Pay Adjustment Factor

101

Types of Cores

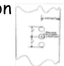
- ***QLA***
- Non-integral shoulders
- Unconfined joints

102

QC/QA CORING FREQUENCY & LOCATION

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

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
- QA 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

103

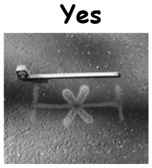
QA Core

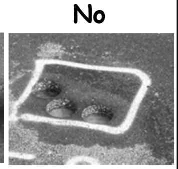
- Independent
- Can be randomly located as a location independent from QC’s core, OR
- Typically, same “location” as QC core sample:
  - Same transverse offset from mat edge as QC sample
  - Within 6 in. longitudinally from QA core

104

Core Positions

Yes **No**





105

Coring

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

106

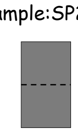
EXTRA QC CORES

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

107

Thick Lifts

- 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

108

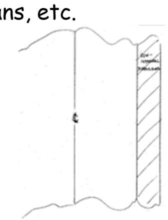
Types of Cores

- QLA
- ***Non-integral shoulders***
- Unconfined joints

109

NON-TRAFFIC AREAS- (403 mixes)

- Non-integral shoulders, medians, etc.



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

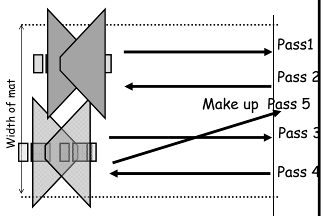
110

NON-TRAFFIC AREAS- (403 mixes), cont'd.

- When rolling pattern demonstrates successful achievement of density, RE may allow the pattern in lieu of density tests
- On re-surfacing projects where shoulders cannot withstand the compactive effort, RE can relax the density requirements

111

Pass & Coverage Defined



This is a 5 pass pattern that provides 2 complete coverages.

DENSITY PAY ADJUSTMENT FACTOR

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

Types of Cores

- QLA
- Non-integral shoulders
- ***Unconfined joints***

LONGITUDINAL JOINT

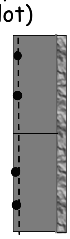
Coring Frequencies

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

116

LONGITUDINAL UNCONFINED JOINT DENSITY

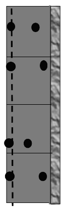
- Area within 6" of joint on traveled way side
- Average of 4 cores, each randomly located (1 sample per sublot)



117

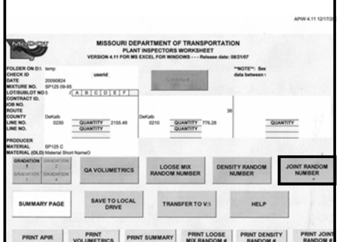
LONGITUDINAL UNCONFINED JOINT DENSITY

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



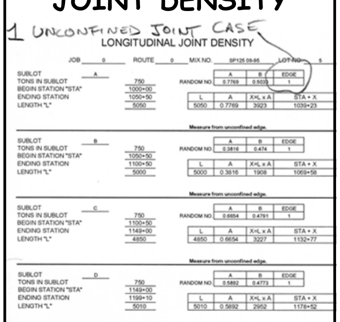
118

MoDOT SPREADSHEET



119

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	0.5039	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

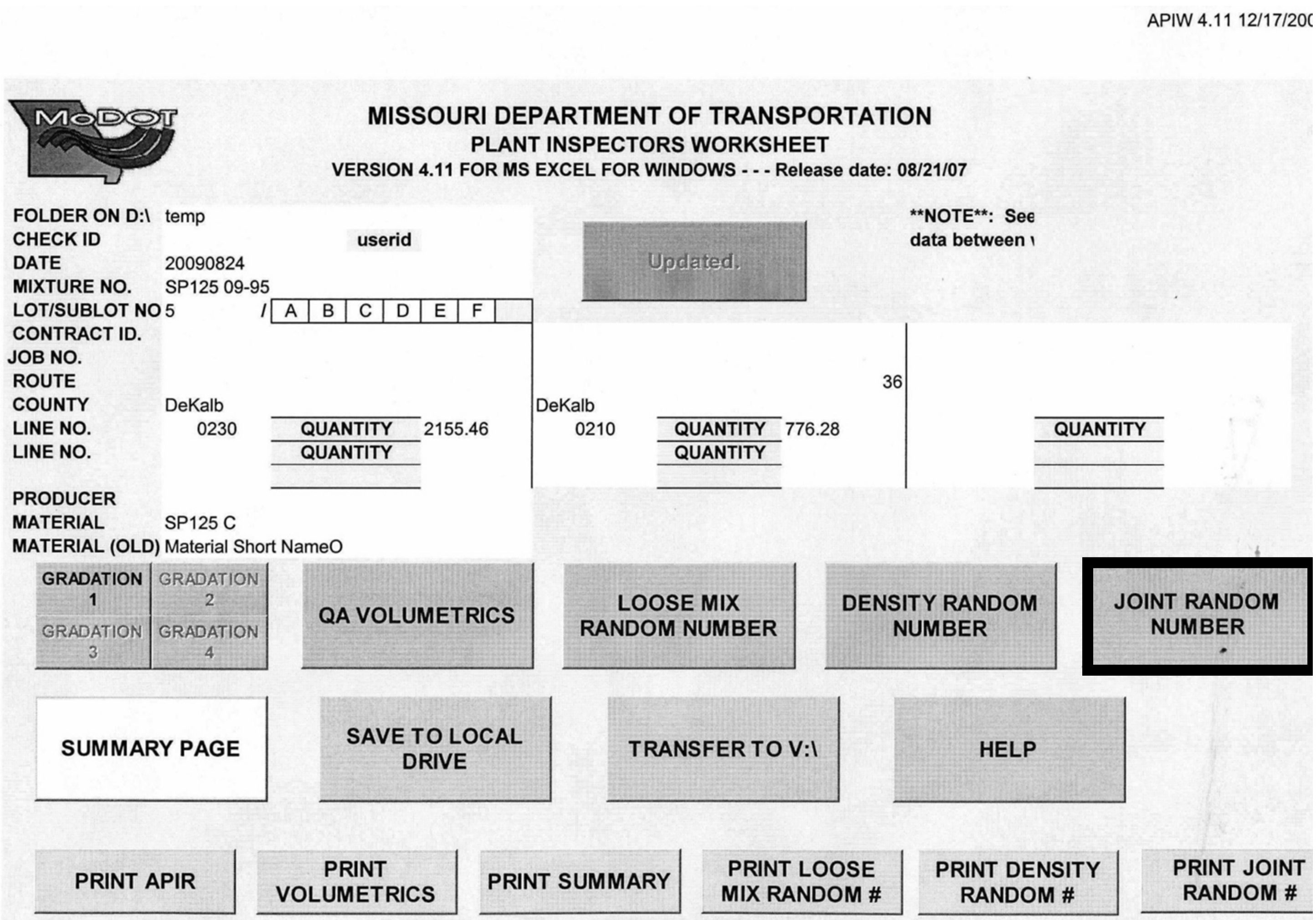
	A	B	EDGE
RANDOM NO.	0.5892	0.4773	1

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

Measure from unconfined edge.

120

MoDOT SPREADSHEET



LONGITUDINAL JOINT DENSITY

1 UNCONFINED JOINT CASE

LONGITUDINAL JOINT DENSITY

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

SUBLOT	A			A	B	EDGE
TONS IN SUBLOT		750	RANDOM NO.	0.7769	0.5033	1
BEGIN STATION "STA"		1000+00				
ENDING STATION		1050+50	L	A	X=L x A	STA + X
LENGTH "L"		5050	5050	0.7769	3923	1039+23

Measure from unconfined edge.

SUBLOT	B			A	B	EDGE
TONS IN SUBLOT		750	RANDOM NO.	0.3816	0.474	1
BEGIN STATION "STA"		1050+50				
ENDING STATION		1100+50	L	A	X=L x A	STA + X
LENGTH "L"		5000	5000	0.3816	1908	1069+58

Measure from unconfined edge.

SUBLOT	C			A	B	EDGE
TONS IN SUBLOT		750	RANDOM NO.	0.6654	0.4791	1
BEGIN STATION "STA"		1100+50				
ENDING STATION		1149+00	L	A	X=L x A	STA + X
LENGTH "L"		4850	4850	0.6654	3227	1132+77

Measure from unconfined edge.

SUBLOT	D			A	B	EDGE
TONS IN SUBLOT		750	RANDOM NO.	0.5892	0.4773	1
BEGIN STATION "STA"		1149+00				
ENDING STATION		1199+10	L	A	X=L x A	STA + X
LENGTH "L"		5010	5010	0.5892	2952	1178+52

Measure from unconfined edge.

- Must alternate sides if have 2 unconfined joints

121

LONGITUDINAL UNCONFINED JOINT DENSITY, cont'd.

- Required density:
  - Unconfined: no less than 2.0% below specified density (lower specified side = 92.0%)
    - SP = 90.0 %
    - SMA = 92.0 %
  - Confined: included in evaluation of remainder of mat (thus, 94.5 ± 2.5% for non-SMA)

122

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

123

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 PF's for binder content, air voids, VMA, and density)

124

UNCONFINED JOINT DEDUCTIONS, cont'd.

- See Module 10a for application
- 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

125

CONFINED JOINTS

- 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

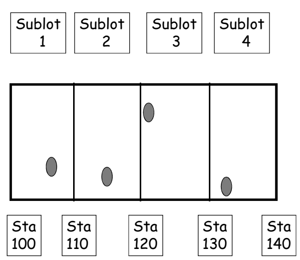
126

QLA CORING
Typical Scenario

- Roadway inspector marks where each sublot starts.
- 1. QA generates and records RN's for freshly laid sublot.
- 2. QA calculates the longitudinal and transverse distances for the core.

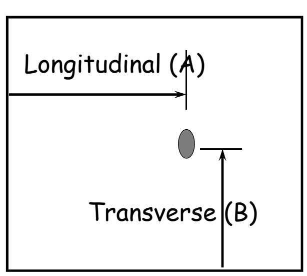
127

Stratified Random Sampling



Construction 128

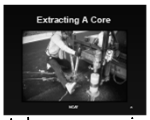
Sublot 1- Sample Location



Construction 129 QC QA Sampling

CORING, cont'd.

- 3. QA gives RN's to QC when rolling is complete.
- 4. QC cuts the core no later than the day following placement.



- 5. QA takes possession of the cores, if possible. ***Cores are marked as soon as cool enough. No un-marked cores allowed in lab.***

130

CORING, cont'd.

- 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

131

CORING, cont'd.

- 6. At the mobile trailer, core density (G_{mc}) is determined.
- 7. Density = ($G_{mc} \div G_{mm}$) x 100
- G_{mm} is from the loose mix Rice test sampled from the same sublot

132

STATIONS

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

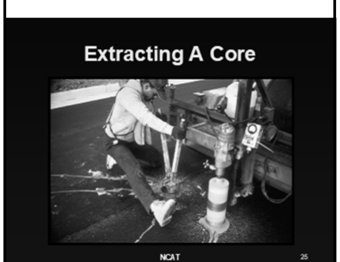
133

STATIONING Example

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

```
 1200+00
   52+38
 1252+38
```

134



135

PROCEDURE

- Avoid distorting or cracking of the cores during and after removal from pavement.
- Cores should be free from seal coats, soil, paper, paint, any other foreign materials.
- Cores may be separated from other pavement lifts by sawing or other appropriate methods.
- Cores should be allowed to air dry overnight (12 hr minimum) to a constant weight (checking at 2 hr intervals) as per T 166.
- Some contractors report less variability with 6" diameter cores

136

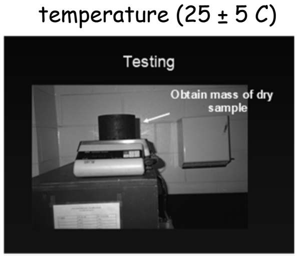
LABELING CORES

- Mark type of core, job number, mix ID
- Use a Sharpie or paint pen, not a felt-tip or a crayon

137

TESTING G_{mc}

- Core should be at room temperature (25 ± 5 C)



138

COMMON ERRORS: TESTING 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
- Cores should initially be dry

139

COMMON ERRORS: TESTING CORES

- After submersion, core should be at SSD condition:
  - Don't shake the specimen
  - Don't blot with a dry towel-use a damp one
- Make sure basket doesn't touch bottom or sides of tank. Make sure hook isn't touching hole in table
- Check for excessive water absorption (>2.0%) –use Corelok (T331) or Parafilm (D 1188) [not paraffin-coating]. Can cut top off for these methods
- See Module 6 for more details

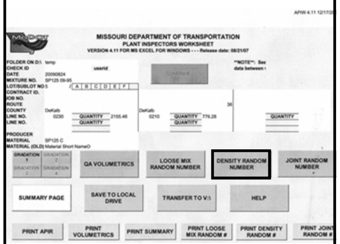
140

CORING EXAMPLES

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

141

MoDOT SPREADSHEET



142

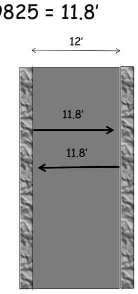
COMPACTED MAT DENSITY
No Unconfined Joint Case

- Sample full width (12 ft)

143

No Unconfined Joints

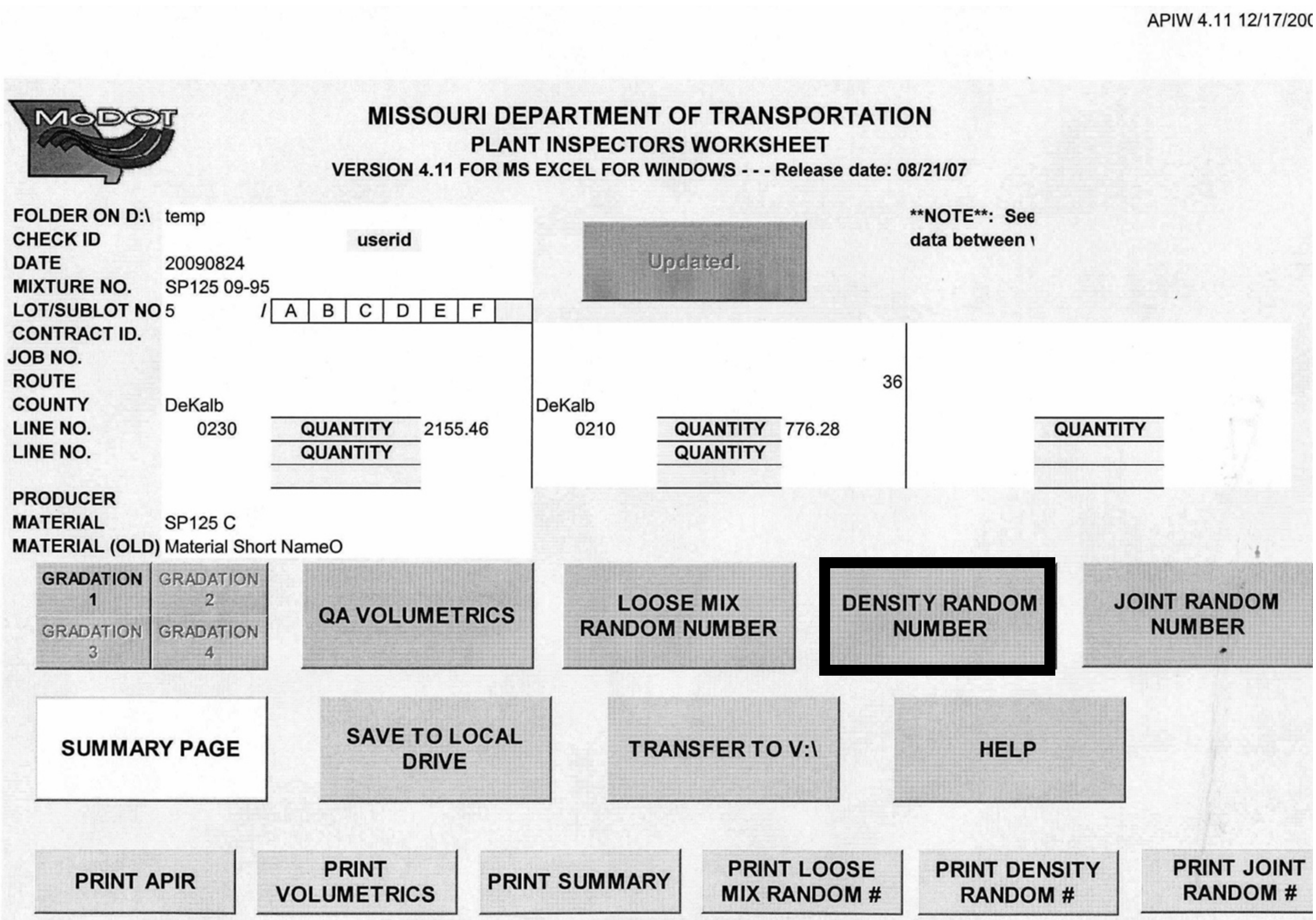
12' x 0.9825 = 11.8'



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

144

MoDOT SPREADSHEET



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	

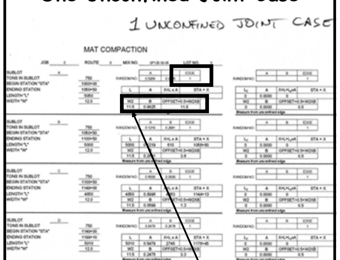
- Sample full width (12 ft)

CORING EXAMPLES

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

145

COMPACTED MAT DENSITY
One Unconfined Joint Case

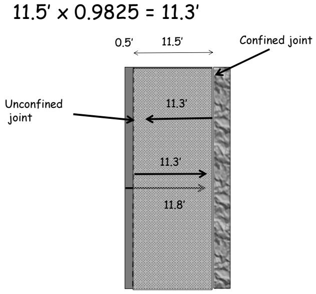


- Leave out the 6" strip by the unconfined joint in the calculations (sample 11.5 ft)

146

One unconfined joint

11.5' x 0.9825 = 11.3'



147

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)

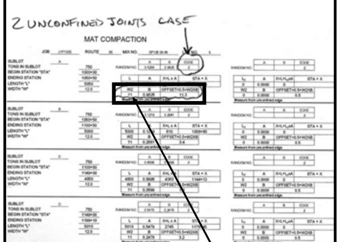
CORING EXAMPLES

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

148

COMPACTED MAT DENSITY

Two Unconfined Joints Case

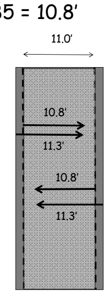


- Leave out both 6" strips at mat edges (sample 11.0 ft)

149

Two unconfined joints

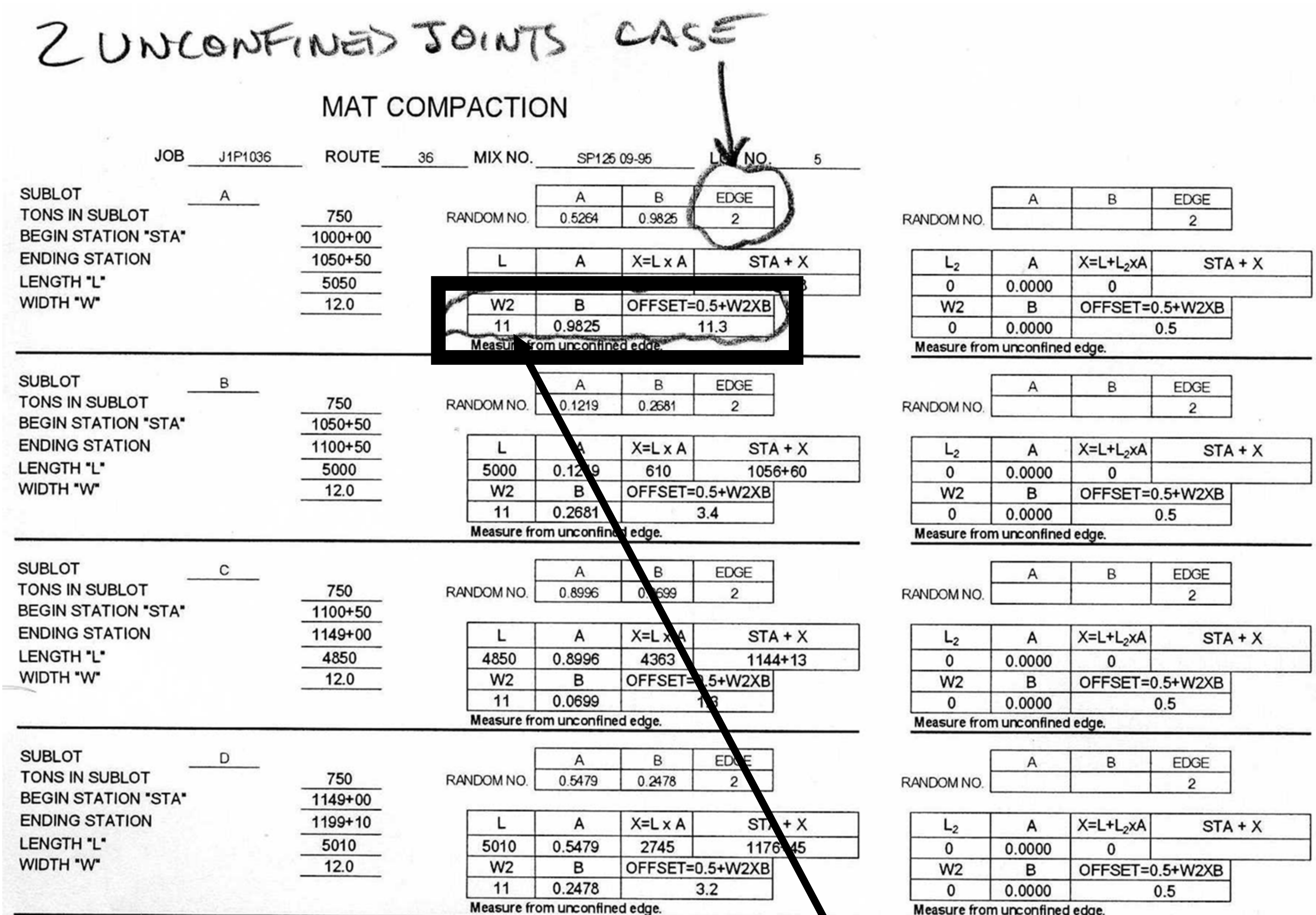
11.0 x 0.985 = 10.8'



150

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	[illegible]	

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	

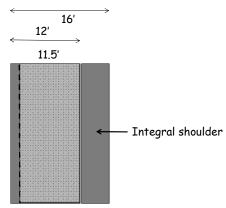
Measure from unconfined edge.

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

SAMPLE LOCATION

If the paving mat width is 16 ft, still run calculations based on 11.5' (one unconfined) or 12' (both confined)

The intent is to sample the "traveled way"



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Where's That Ton?

- If laying out by tons instead of stations:
- RN x sublot size:
- (0.5264)(750 tons)= 395th ton
- Density = (Gmb)(62.4 lb/cf)
- Ex: Density = (2.404)(62.4) = 150 lb/cf
- M/density
- L = ------------
- TW

T = thickness, ft
W= width, ft

(395tn)(2000lb/tn)/ 150 lb/cf
- L= --------------------------------
- (1.75"/12)(12')
- L = 3010'

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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 Density Pay Adjustment Factor
- Smoothness Pay Adjustment Factor

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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)

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SUMMARY

- 1. Lots - unlimited size.
- 2. Each lot must be subdivided into 4 or more sublots.
- 3. Maximum sublot size= 1000 tons
- 4. QC & QA get their own independent loose mix samples. Both are to be located by random number.

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SUMMARY

- 5. Loose mix volumetrics-%binder samples taken behind the paver:
  - QC: 1 sample per sublot:
    50 lbs. for QC
    50 lbs. for QA-retained

  -QA: 1 independent sample per 4 sublots
    50 lbs.
    50 lbs. retained
  -QA: 1 QC retained split per day

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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)

SUMMARY

- 6. Loose mix TSR samples taken behind the paver or plant:
  - QC: 1 per 10,000 tons:
    - 75-125 lbs for QC
    - 125 lbs for QA-retained
  - QA: 1 independent sample per 50,000 tons
    - 125 lbs sent to Central Lab, 125 lbs retained

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SUMMARY

- 7. Location by random numbers:
  - longitudinally by tonnage or feet
  - transversely by feet
- 8. Sample is quartered:
  - 2 gyro pucks
  - 1 Rice
  - 1 binder content (nuclear or ignition oven)
  - 1 moisture content
- 9. TSR sample split: 6+ pucks and a Rice

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SUMMARY

- 10. Coring:
  - QC: 1 QLA sample per sublot
  - QA: 1 QLA sample per 4 sublots
- 11. Location by random numbers:
  - longitudinally by station or tonnage
  - transversely by feet
- 12. Extra samples may be taken by the contractor or MoDOT, but are not allowable as QLA samples.

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SUMMARY

- 13. Acceptance is from QA independent samples, not retained QC splits.
- 14. Retained samples are good for checking procedures, etc.

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Questions - ?

NCAT 28

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MODULE 6

GYRATORY COMPACTOR OPERATIONS

T 312

11-24-06 Revision
11-9-07 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
1-19-11 Revision
3-2-12 Revision
2-5-15 Revision
12-28-16 Revision
12-12-18 Revision
1-11-19 Revision
1-14-19 Revision
2-8-19 Revision
2-25-19 Revision
12-17-19 Revision

MODULE 6

GYRATORY COMPACTOR OPERATIONS
T 312

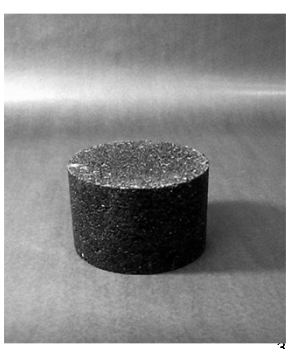
11-24-06 Revision
11-9-07 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
1-19-11 Revision
3-2-12 Revision
2-5-15 Revision
12-28-16 Revision
12-12-18 Revision
1-11-19 Revision
1-14-19 Revision
2-8-19 Revision
2-25-19 Revision
12-17-19 Revision

OUTLINE

- ***Introduction***
- Compaction method
- Bulk specific gravity of gyro pucks
- Calculations
- Verification & Calibration

2

Gyratory Puck



3

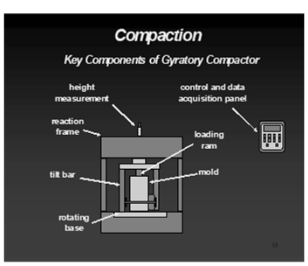
4

GYRATORY COMPACTOR

- Uses a gyratory motion which compacts by shearing action
- Simulates compacting action achieved under a roller
- The resulting specimen's density, particle orientation and structural characteristics are similar to a pavement

5

"GYRO"



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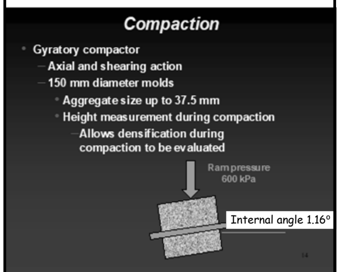

7

USES of the GYRO

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

8

USES, cont'd.

- To evaluate:
  - volumetric properties e.g. ***air voids*** and ***VMA***
  - densification properties e.g. ***tenderness potential***
  - moisture sensitivity (***TSR***)

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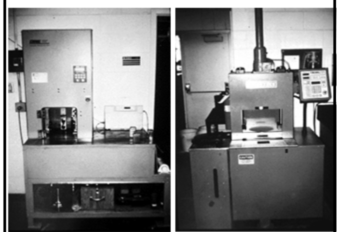
GYRATORY COMPACTOR



10

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GYROS In Missouri

In descending order of usage:

- Big Pine
- Baby Pine
- Troxler 4141
- Troxler 4140
- Brovold

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OUTLINE

- Introduction
- ***Compaction method***
- Bulk specific gravity of gyro pucks
- Calculations
- Verification & Calibration

13

AASHTO TEST METHODS & SPECIFICATIONS

- R35 Volumetric Design Practice
- M323 Volumetric Design Specs
- R30 Mix Conditioning
- ***T 312 Gyro operation***
- ***T 166 Bulk Sp Gravity of gyro pucks***
- T 209 Max Sp Gravity of Voidless Mix (Rice)
- T 283 Moisture Sensitivity

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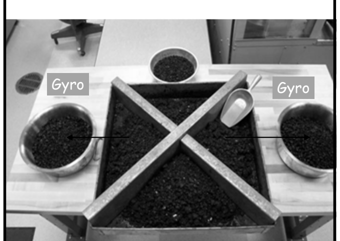
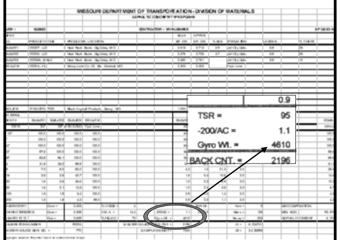
Volumetrics/Binder Content Sample

- 50 lb. sample –get 2 portions for the 2 volumetric pucks



Location of Gyro Puck Weight on JMF



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OPERATIONAL MODES

- 1. Normally, compact to a ***fixed number of gyrations***; resulting height must be =115 ± 5 mm
- 2. For TSR, compact to a ***fixed height*** = 95 ± 5 mm

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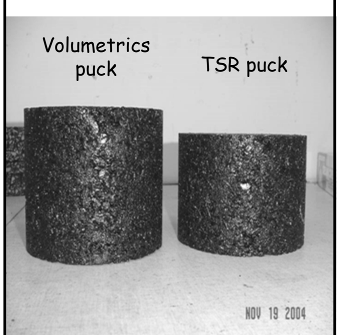

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Location of Gyro Puck Weight on JMF

MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP125HB

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

IDENT. 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					

MATERIAL IDENT #	35JSJ001	35JSJ002	35JSJ003	30CAJ016	35JSJ0[illegible]	[illegible]	[illegible]	[illegible]	COMB.
03016	3/4"	3/8"	MAN SAND	Hyd. Lime	6[illegible]	[illegible]	[illegible]	[illegible]	GRAD
1 1/2"	100.0	100.0	100.0	100.0	6[illegible]	[illegible]	[illegible]	[illegible]	100.0
1"	100.0	100.0	100.0	100.0	6[illegible]	[illegible]	[illegible]	[illegible]	100.0
3/4"	100.0	100.0	100.0	100.0	6[illegible]	[illegible]	[illegible]	[illegible]	100.0
1/2"	97.6	100.0	100.0	100.0	5[illegible]	[illegible]	[illegible]	[illegible]	98.6
3/8"	83.8	96.1	100.0	100.0	5[illegible]	[illegible]	[illegible]	[illegible]	89.8
#4	31.8	35.0	99.9	100.0	19.1	4.2	26.0	[illegible]	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. =	219[illegible]		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

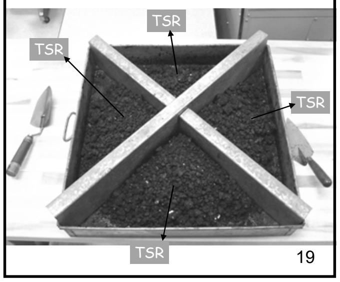
-200/AC = 1.1

Gyro Wt. = 4610

BACK CNT. = 2196

TSR SAMPLE

- 60-75 lb. sample for six TSR pucks



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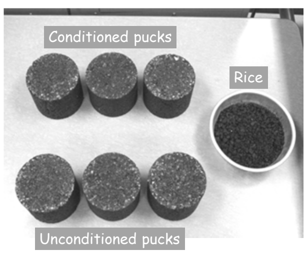
TSR



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SAMPLE PREP

- Mix design ***lab-produced sample***: prior to compaction, condition sample in oven for 2 hours at compaction temperature.
- Absorption is occurring during this step.
- ***Field verification sample***: no special conditioning step; conditioning occurs in silo, truck, and MTV.
- Recommended that reheating of field sample should not exceed 30 min.

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TIME AT HIGH TEMPERATURE

- Continued absorption of asphalt
- Age-hardening of asphalt

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TIME AT HIGH TEMPERATURE

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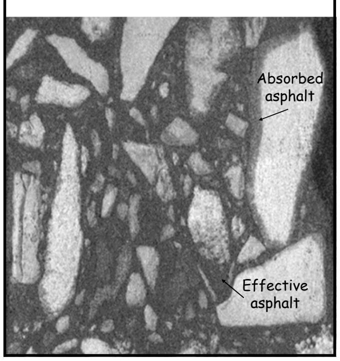
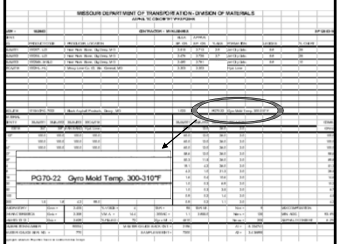
ABSORPTIVENESS OF AGGREGATE



Location of Gyro Molding Temperature on JMF



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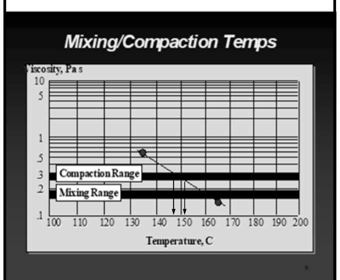
MIXTURE MOLDING TEMPERATURE



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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"					58.6	12.0	26.0	2.0	98.6
3/8"					50.3	11.5	26.0	2.0	89.8
#4					19.1	4.2	26.0	2.0	51.3
#8					4.2	1.0	21.3	2.0	28.5
#16					1.6	0.4	10.6	2.0	14.6
#30					1.0	0.3	6.9	2.0	10.2
#50					1.0	0.3	3.5	2.0	6.7
#100					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

Place Mix in Mold

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Place Mold in Gyro Compactor

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GYRO SETTINGS

- Pressure= 600 ± 18 kPa
- Number of gyrations is a function of design traffic

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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:
  - N_{design}= 100
  - No N_{max} requirement

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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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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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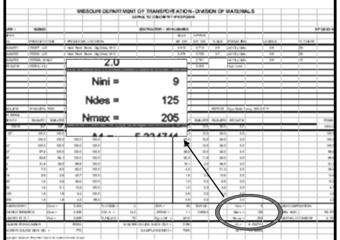
Location of Gyration Info on JMF



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Compaction

Once compaction is finished, extrude sample from mold.

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Compaction

Remove the paper and label samples.

- Label on sides

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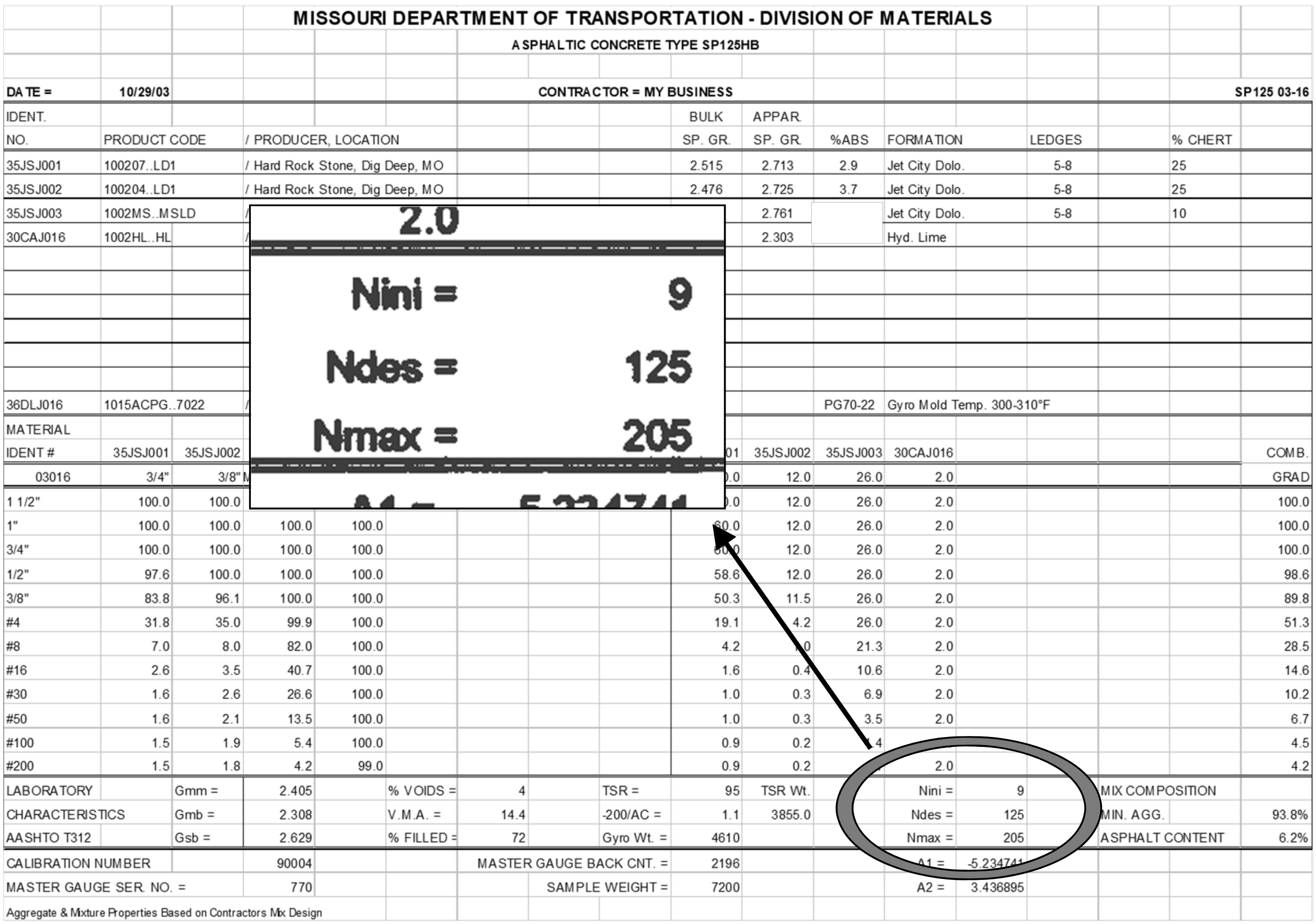
Location of Gyration Info on JMF



MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

ASPHALTIC CONCRETE TYPE SP125HB

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

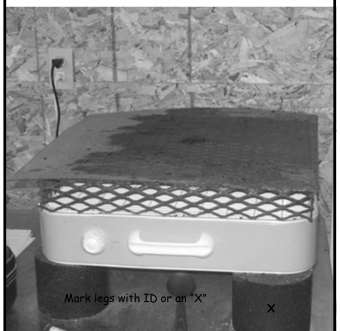
IDENT. NO.	PRODUCT CODE	/ PRODUCER, LOCATION	BULK SP. GR.	APPAR. SP. GR.	%ABS	FORMATION	LEDGES	% CHERT
35JSJ001	100207..LD1	/ Hard Rock Stone, Dig Deep, MO	2.515	2.713	2.9	Jet City Dolo.	5-8	25
35JSJ002	100204..LD1	/ Hard Rock Stone, Dig Deep, MO	2.476	2.725	3.7	Jet City Dolo.	5-8	25
35JSJ003	1002MS..MSLD	/		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.
03016	3/4"	3/8"			.0	12.0	26.0	2.0	GRAD
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	60.0	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	.0	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		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 =	-5.23474		
MASTER GAUGE SER. NO. =		770		SAMPLE WEIGHT =		7200		A2 =	3.436895		

Aggregate & Mixture Properties Based on Contractors Mix Design

COOLING



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NOTES

- 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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RECORD KEEPING

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

COMMON GYRO 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

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COMMON GYRO ERRORS, cont'd.

- 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

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OUTLINE

- Introduction
- Compaction method
- ***Bulk specific gravity of gyro pucks***
- Calculations
- Verification & Calibration

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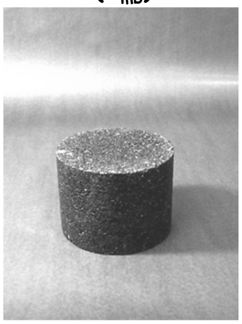
MIXTURE BULK SPECIFIC GRAVITY (G_{mb})



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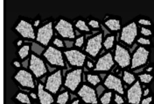
BSG of Compacted HMA

- AC mixed with agg. and compacted into sample

$$G_{mb} = \frac{\text{Mass agg. and AC}}{\text{Vol. agg., AC, air voids}}$$



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TESTING G_{mb}

- Puck should be at room temperature (25±5 C)

Testing

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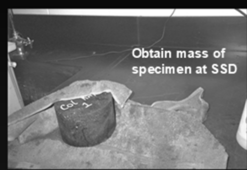
Testing



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COMMON G_{mb} TESTING ERRORS

- Submerged specimens touch side of water container
- Water temperature not 25 ± 1 C (77 ± 1.8 F)
- Specimen temperature not 25 ± 5 C (77 ± 9 F)
- Dirty water in water container
- Air bubbles clinging to the basket
- Blotting with a dry towel
- Blotting more than 15 seconds
- Water level not maintained

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Consequences of Mistakes Examples

$$G_{mb} = \frac{W_{dry}}{(W_{ssd} - W_{submerged})}$$

$$V_a = \frac{G_{mm} - \mathbf{G_{mb}}}{G_{mm}} \times 100$$

Low W_{dry} → Low G_{mb} → High V_a
High W_{ssd} → Low G_{mb} → High V_a
Low W_{ssd} → High G_{mb} → Low V_a

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OUTLINE

- Introduction
- Compaction method
- Bulk specific gravity of gyro pucks
- ***Calculations***
- Verification & Calibration

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Calculations

- G_{mb} = A / (B - C)

  Where:

  A = mass of dry sample

  B = mass of SSD sample

  C = mass of sample under water

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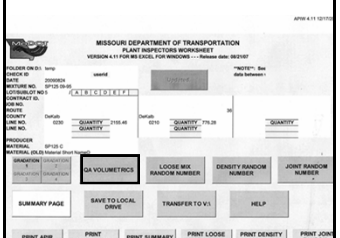
MoDOT SPREADSHEET



SUPERPAVE MIXTURE PROPERTIES

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

SUBLOT	A	B	C	D	E	F	
DATE		08/24/09					
AASHTO T 209	A2 required when T85 absorption >2.0% on any aggregate fraction.						
TECHNICIAN		phillc1					
A = Wt. of sample:		2076.6					
A2=Wt. of sample (dry-back):							
D = Wt. of flask filled with water:		1392.3					
X = A + D (A2 used in lieu of A for dry-back)	0.0	3468.9	0.0	0.0	0.0	0.0	0.0
E = Wt. of flask filled with water and sample:		2628.1					
Y = X - E	0.0	840.8	0.0	0.0	0.0	0.0	0.0
Gmm = MAX. SPECIFIC GRAVITY = A / Y	0.000	2.470	2.470	2.470	2.470	2.470	2.470
AASHTO T 166							
TECHNICIAN		phillc1					
MOLDING TEMPERATURE		152					
A = Weight of sample in air:		4748.0					
B = Weight of sample in water: SPEC. 1		2758.3					
C = Weight of surface dry sample:		4752.2					
Gmb = BULK SP. G. = A / (C-B)	0.000	2.381	0.000	0.000	0.000	0.000	0.000
A = Weight of sample in air:		4748.0					
B = Weight of sample in water: SPEC. 2		2758.8					
C = Weight of surface dry sample:		4753.2					
Gmb = BULK SP. G. = A / (C-B)	0.000	2.381	0.000	0.000	0.000	0.000	0.000
AVG. Gmb	0.000	2.381	0.000	0.000	0.000	0.000	0.000
TECHNICIAN		phillc1					
MoDOT TM54 (NUCLEAR)							
SAMPLE WEIGHT							
BACKGROUND							
COUNTS							
GAUGE % AC							
AASHTO T 308 (IGNITION)							
GAUGE %AC		5.71					
NUCLEAR OR IGNITION							
% MOISTURE		0.12					
% AC BY IGNITION OR NUCLEAR		5.6					
AASHTO R 35							
A = Gmm (FIELD)	0.000	2.470	2.470	2.470	2.470	2.470	2.470
B = Gmb (FIELD) (Avg.)	0.000	2.381	0.000	0.000	0.000	0.000	0.000
C = Gsb (Job Mix)		2.642	0.000	0.000	0.000	0.000	0.000
D = Ps = Percent Agg. in mix	100.0	94.4	100.0	100.0	100.0	100.0	100.0
VMA = 100 - (B X D / C)	0.0	14.9	0.0	0.0	0.0	0.0	0.0
Va = 100 X ((A - B) / A)	0.0	3.6	100.0	100.0	100.0	100.0	100.0
VFA = (VMA-Va) / VMA	0	76	0	0	0	0	0

Weight of sample in air:							
Weight in water:							
Weight of surface dry sample:							
= CORE SPECIFIC GRAVITY = A / (C - B)	0.000	0.000	0.000	0.000	0.000	0.000	0
= MAX. SPECIFIC GRAVITY (T209)	0.000	2.470	2.470	2.470	2.470	2.470	2
OMPACTION OF CORE = 100 x (Gmc / Gmm)	0.0	0.0	0.0	0.0	0.0	0.0	
KNESS							
LOT	A	B	C	D	E	F	
Weight of sample in air:							
Weight in water:							
Weight of surface dry sample:							
= CORE SPECIFIC GRAVITY = A / (C - B)	0.000	0.000	0.000	0.000	0.000	0.000	0
= MAX. SPECIFIC GRAVITY (T209)	0.000	2.470	2.470	2.470	2.470	2.470	2

See Updated worksheet

Puck Bulk Specific Gravity Portion

AASHTO T 166							
TECHNICIAN		phillc1					
MOLDING TEMPERATURE		152					
A = Weight of sample in air:		4748.0					
B = Weight of sample in water: SPEC. 1		2758.3					
C = Weight of surface dry sample:		4752.2					
Gmb = BULK SP. G. = A / (C-B)	0.000	2.381	0.000	0.000	0.000	0.000	0.000
A = Weight of sample in air:		4748.0					
B = Weight of sample in water: SPEC. 2		2758.8					
C = Weight of surface dry sample:		4753.2					
Gmb = BULK SP. G. = A / (C-B)	0.000	2.381	0.000	0.000	0.000	0.000	0.000
AVG. Gmb	0.000	2.381	0.000	0.000	0.000	0.000	0.000

Excessive Water Absorption

- MoDOT now enforcing the water absorption check: at the end of the test, water absorption is calculated:
- Abs= [(B – A) / (B – C)] x 100
- A= mass dry specimen in air
- B = mass SSD specimen in air
- C = mass specimen in water
- If greater than 2%, must re-run using CoreLok (T331) or paraffin coated (wrapped) ["Parafilm"] specimen (D1188)

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SUPERPAVE MIXTURE PROPERTIES

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

SUBLOT	A	B	C	D	E	F	
DATE		08/24/09					

AASHTO T 209 — A2 required when T85 absorption >2.0% on any aggregate fraction.

TECHNICIAN		phillc1					
A = Wt. of sample:		2076.6					
A2=Wt. of sample (dry-back):							
D = Wt. of flask filled with water:		1392.3					
X = A + D (A2 used in lieu of A for dry-back)	0.0	3468.9	0.0	0.0	0.0	0.0	0.0
E = Wt. of flask filled with water and sample:		2628.1					
Y = X - E	0.0	840.8	0.0	0.0	0.0	0.0	0.0
Gmm = MAX. SPECIFIC GRAVITY = A / Y	0.000	2.470	2.470	2.470	2.470	2.470	2.470

AASHTO T 166

TECHNICIAN			phillc1					
MOLDING TEMPERATURE			152					
A = Weight of sample in air:	SPEC. 1		4748.0					
B = Weight of sample in water:	SPEC. 1		2758.3					
C = Weight of surface dry sample:	SPEC. 1		4752.2					
Gmb = BULK SP. G. = A / (C-B)		0.000	2.381	0.000	0.000	0.000	0.000	0.000
A = Weight of sample in air:	SPEC. 2		4748.0					
B = Weight of sample in water:	SPEC. 2		2758.8					
C = Weight of surface dry sample:	SPEC. 2		4753.2					
Gmb = BULK SP. G. = A / (C-B)		0.000	2.381	0.000	0.000	0.000	0.000	0.000
AVG. Gmb		0.000	2.381	0.000	0.000	0.000	0.000	0.000

TECHNICIAN		phillc1					
MoDOT TM54 (NUCLEAR)							
SAMPLE WEIGHT							
BACKGROUND							
COUNTS							
GAUGE % AC							
AASHTO T 308 (IGNITION)							
GAUGE %AC		5.71					
NUCLEAR OR IGNITION							
% MOISTURE		0.12					
% AC BY IGNITION OR NUCLEAR		5.6					

AASHTO R 35

A = Gmm (FIELD)	0.000	2.470	2.470	2.470	2.470	2.470	2.470
B = Gmb (FIELD) (Avg.)	0.000	2.381	0.000	0.000	0.000	0.000	0.000
C = Gsb (Job Mix)		2.642	0.000	0.000	0.000	0.000	0.000
D = Ps = Percent Agg. in mix	100.0	94.4	100.0	100.0	100.0	100.0	100.0
VMA = 100 - (B X D / C)	0.0	14.9	0.0	0.0	0.0	0.0	0.0
Va = 100 X ((A - B) / A)	0.0	3.6	100.0	100.0	100.0	100.0	100.0
VFA = (VMA-Va) / VMA	0	76	0	0	0	0	0

Veight of sample in air:							
Veight in water:							
Veight of surface dry sample:							
= CORE SPECIFIC GRAVITY = A / (C - B)	0.000	0.000	0.000	0.000	0.000	0.000	0
= MAX. SPECIFIC GRAVITY (T209)	0.000	2.470	2.470	2.470	2.470	2.470	2
OMPACTION OF CORE = 100 x (Gmc / Gmm)	0.0	0.0	0.0	0.0	0.0	0.0	
KNESS							
LOT	A	B	C	D	E	F	

2ND CORE SUBLOT WHEN DENOTED IN QC PLAN

See Updated worksheet

NICIAN							
Veight of sample in air:							
Veight in water:							
Veight of surface dry sample:							
= CORE SPECIFIC GRAVITY = A / (C - B)	0.000	0.000	0.000	0.000	0.000	0.000	0
= MAX. SPECIFIC GRAVITY (T209)	0.000	2.470	2.470	2.470	2.470	2.470	2
OMPACTION OF CORE = 100 x (Gmc / Gmm)							

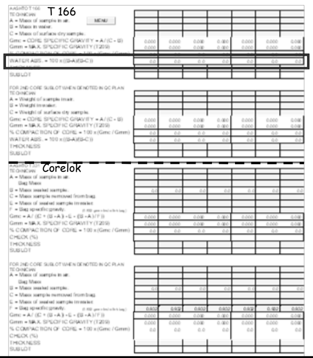
Puck Bulk Specific Gravity Portion

AASHTO T 166

TECHNICIAN			phillc1					
MOLDING TEMPERATURE			152					
A = Weight of sample in air:			4748.0					
B = Weight of sample in water:	SPEC. 1		2758.3					
C = Weight of surface dry sample:			4752.2					
Gmb = BULK SP. G. = A / (C-B)		0.000	2.381	0.000	0.000	0.000	0.000	0.000
A = Weight of sample in air:			4748.0					
B = Weight of sample in water:	SPEC. 2		2758.8					
C = Weight of surface dry sample:			4753.2					
Gmb = BULK SP. G. = A / (C-B)		0.000	2.381	0.000	0.000	0.000	0.000	0.000
AVG. Gmb		0.000	2.381	0.000	0.000	0.000	0.000	0.000

Check for Excessive Water Absorption

Up to 2 Cores at Same Location



VOLUMETRICS

- Air Voids
- VMA
- VFA

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AIR VOIDS

- $V_a = \dfrac{G_{mm} - \mathbf{G_{mb}}}{G_{mm}} \times 100$

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Check for Excessive Water Absorption

Up to 2 Cores at Same Location

AASHTO T 166 — T 166

MENU

TECHNICIAN							
A = Mass of sample in air:							
B = Mass in water:							
C = Mass 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)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WATER ABS. = 100 x ((B-A)/(B-C))	0.0	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)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WATER ABS. = 100 x ((B-A)/(B-C))	0.0	0.0	0.0	0.0	0.0	0.0	0.0
THICKNESS							
SUBLOT							

AASHTO T 331 — Corelok

TECHNICIAN							
A = Mass of sample in air:							
Bag Mass							
B = Mass sealed sample:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C = Mass sample removed from bag:							
E = Mass of sealed sample in water:							
F = Bag specific gravity: (0.932 green InstroTek bag)							
Gmc = A / ((C + (B - A)) - E - ((B - A) / F))	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gmm = MAX. SPECIFIC GRAVITY (T209)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHECK (%)							
THICKNESS							
SUBLOT							

FOR 2ND CORE SUBLOT WHEN DENOTED IN QC PLAN

TECHNICIAN							
A = Mass of sample in air:							
Bag Mass							
B = Mass sealed sample:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C = Mass sample removed from bag:							
E = Mass of sealed sample in water:							
F = Bag specific gravity: (0.932 green InstroTek bag)	0.932	0.932	0.932	0.932	0.932	0.932	0.932
Gmc = A / ((C + (B - A)) - E - ((B - A) / F))	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gmm = MAX. SPECIFIC GRAVITY (T209)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% COMPACTION OF CORE = 100 x (Gmc / Gmm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHECK (%)							
THICKNESS							
SUBLOT							

VMA

Voids in Mineral Aggregate

$$VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}$$

VMA is an indication of film thickness on the surface of the aggregate

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VFA

- $VFA = \frac{VMA - V_a}{VMA} \times 100$

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OUTLINE

- Introduction
- Compaction method
- Bulk specific gravity of gyro pucks
- Calculations
- ***Verification & Calibration***

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VERIFICATION & CALIBRATION

- ***Gyratory compactor***
- Molds

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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)

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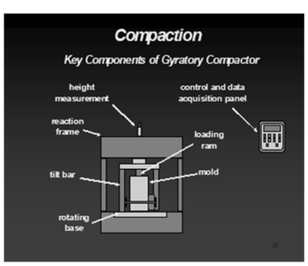
"GYRO"



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Actions

- Calibration:
  - Measure
  - Adjust
  - Re-measure
- Verification:
  - Measurement

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CALIBRATION

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CALIBRATION FREQUENCY

- Calibration should be performed:
  - At least once per year
  - When verification fails

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Calibration Actions

- Rate of gyration (speed)
- Roller clearance & zero position
- Ram force:
  - 18 loads
  - 1500 to 18,000 N
- Specimen Height
  - 8 positions (blocks)
  - 3 to 10 in.
- Angle of gyration (***internal*** angle)

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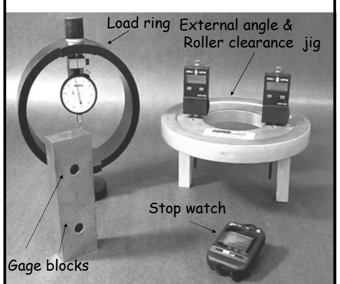
CALIBRATION & VERIFICATION INSTRUMENTS



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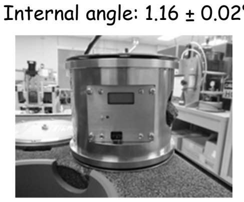
CALIBRATION

- Internal angle: 1.16 ± 0.02°



CALIBRATION

- Rate of gyration (rotational speed): 30.0 ± 0.5 rotations per minute (10 rotations in 20 ± 0.33 sec)
- Ram Force: Target ± 1%
- Ram Position (height):±0.002"
- Internal angle: 1.16 ± 0.02°
- Roller clearances and zero position - done on some machines

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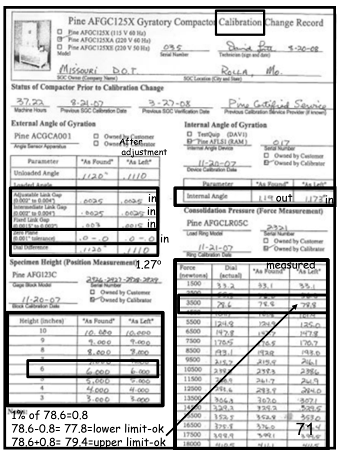

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PROVING RING SERIAL NUMBER: 1440 CALIBRATION DATE: 8/1/2006

Different than previous example

GYRATORY COMPACTOR CALIBRATION DATA POINTS

This sheet is specific to a certain proving ring

Newtons	lbf	Dial (actual)	Dial - 1%	Dial + 1%	Dial - 3%	Dial + 3%
0	0.0	0.0	0.0	0.0	0.0	0.0
500	112.4	11.0	10.9	11.1	10.7	11.3
1000	224.8	22.0	21.8	22.2	21.3	22.7
1500	337.2	33.0	32.7	33.3	32.0	34.0
2000	449.6	44.4	43.9	44.8	43.1	45.7
2500	562.0	55.8	55.2	56.3	54.1	57.5
3000	674.4	67.2	66.5	67.8	65.2	69.2
3500	786.8	78.9	78.1	79.6	76.5	81.2
4000	899.2	90.6	[illegible]	[illegible]	87.8	93.3
4500	1011.6	102.2	101.2	103.3	99.2	105.3
5000	1124.1	113.9	112.8	115.1	110.5	117.4
5500	1236.5	125.1	123.8	126.3	121.3	128.8
6000	1348.9	136.2	134.8	137.5	132.1	140.3
6500	1461.3	147.7	146.2	149.2	143.3	152.1
7000	1573.7	159.3	157.7	160.8	154.5	164.0
7500	1686.1	170.8	169.1	172.5	165.7	175.9
8000	1798.5	182.5	180.7	184.3	177.0	188.0
8500	1910.9	194.2	192.2	196.1	188.3	200.0
9000	2023.3	205.8	203.8	207.9	199.7	212.0
9500	2135.7	217.2	215.0	219.3	210.7	223.7
10000	2248.1	228.5	226.2	230.8	221.7	235.4
10500	2360.5	239.9	237.5	242.3	232.7	247.1
11000	2472.9	251.3	248.8	253.8	243.7	258.8
11500	2585.3	262.7	260.1	265.3	254.8	270.6
12000	2697.7	274.1	271.4	276.8	265.9	282.3
12500	2810.1	286.0	283.2	288.9	277.5	294.6
13000	2922.5	298.0	295.0	301.0	289.0	306.9
13500	3034.9	309.9	306.8	313.0	300.6	319.2
14000	3147.3	320.9	317.7	324.1	311.3	330.6
14500	3259.7	331.9	328.6	335.3	322.0	341.9
15000	3372.2	343.5	340.0	346.9	333.2	353.8
15500	3484.6	355.0	351.5	358.6	344.4	365.7
16000	3597.0	366.6	362.9	370.2	355.6	377.6
16500	3709.4	378.1	374.4	381.9	366.8	389.5
17000	3821.8	389.7	385.8	393.6	378.1	401.4
17500	3934.2	401.4	397.3	405.4	389.3	413.4
18000	4046.6	413.0	408.8	417.1	400.6	425.4

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Pine AFGC125X Gyratory Compactor Calibration Change Record

- ☐ Pine AFGC125X (115 V 60 Hz)
- ☒ Pine AFGC125XA (220 V 60 Hz)
- ☐ Pine AFGC125XE (220 V 50 Hz)

Model

Serial Number: 035

Technician (sign and date): David Lott 3-20-08

SGC Owner (Company Name): Missouri D.O.T.

SGC Location (City and State): Rolla, Mo.

Status of Compactor Prior to Calibration Change

Machine Hours	Previous SGC Calibration Date	Previous SGC Verification Date	Previous Calibration Service Provider (if known)
37.22	8-21-07	3-27-08	Pine Certified Service

External Angle of Gyration

Angle Sensor Apparatus: Pine ACGCA001

- ☐ Owned by Customer
- ☐ Owned by Calibrator

After adjustment

Parameter	"As Found"	"As Left"	
Unloaded Angle	.1120"	.1110	
Loaded Angle			
Adjustable Link Gap (0.002" to 0.004")	.0025	.0025	in
Intermediate Link Gap (0.002" to 0.004")	.0025	.0025	in
Fixed Link Gap (0.0015" to 0.002")	.003	.0015	in
Zero Plane (0.001" tolerance)	.0 - .0	.0 - .0	in
Dial Difference	.1120"	.1110	

1.27°

Internal Angle of Gyration

Internal Angle Device:

- ☐ TestQuip (DAV1)
- ☒ Pine AFLS1 (RAM)

Serial Number: 017

- ☐ Owned by Customer
- ☒ Owned by Calibrator

Device Calibration Date: 11-20-07

Parameter	"As Found"	"As Left"
Internal Angle	1.19 out	1.173° in

Consolidation Pressure (Force Measurement)

Load Ring Model: Pine AFGCLR05C

Serial Number: 2321

- ☐ Owned by Customer
- ☒ Owned by Calibrator

Ring Calibration Date: 11-21-07

measured

Force (newtons)	Dial (actual)	"As Found"	"As Left"
1500	33.2	33.1	33.1
2500	[illegible]	[illegible]	[illegible]
3500	78.6	78.8	78.8
4500	[illegible]	[illegible]	[illegible]
5500	124.8	124.9	125.0
6500	147.8	147.7	147.8
7500	170.5	170.5	170.7
8500	193.1	192.8	193.0
9500	215.7	215.9	216.1
10500	238.3	238.3	238.6
11500	260.9	261.7	261.9
12500	283.6	283.9	284.0
13500	306.3	307.0	307.1
14500	329.2	329.2	329.5
15500	352.5	352.8	353.0
16500	375.8	376.0	71
17500	398.9	399.1	399.5
18000	410.5	411.1	411.5

Specimen Height (Position Measurement)

Gage Block Model: Pine AFG123C

Serial Number: 2926-2927-2928-2929

- ☐ Owned by Customer
- ☒ Owned by Calibrator

Block Calibration Date: 11-20-07

Height (inches)	"As Found"	"As Left"
10	10.000	10.000
9	9.000	9.000
8	8.000	8.000
7	7.000	7.000
6	6.000	6.000
5	5.000	5.000
4	4.000	4.000
3	3.000	3.000

Notes:

1% of 78.6=0.8

78.6-0.8= 77.8=lower limit-ok

78.6+0.8= 79.4=upper limit-ok

PROVING RING SERIAL NUMBER: 1440 **CALIBRATION DATE: 8/1/2006**

Different than previous example

GYRATORY COMPACTOR CALIBRATION DATA POINTS

This sheet is specific to a certain proving ring

Newtons	lbf	Dial (actual)	Dial - 1%	Dial + 1%	Dial - 3%	Dial + 3%
0	0.0	0.0	0.0	0.0	0.0	0.0
500	112.4	11.0	10.9	11.1	10.7	11.3
1000	224.8	22.0	21.8	22.2	21.3	22.7
1500	337.2	33.0	32.7	33.3	32.0	34.0
2000	449.6	44.4	43.9	44.8	43.1	45.7
2500	562.0	55.8	55.2	56.3	54.1	57.5
3000	674.4	67.2	66.5	67.8	65.2	69.2
3500	786.8	78.9	78.1	79.6	76.5	81.2
4000	899.2	90.6	89.6	91.5	87.8	93.3
4500	1011.6	102.2	101.2	103.3	99.2	105.3
5000	1124.1	113.9	112.8	115.1	110.5	117.4
5500	1236.5	125.1	123.8	126.3	121.3	128.8
6000	1348.9	136.2	134.8	137.5	132.1	140.3
6500	1461.3	147.7	146.2	149.2	143.3	152.1
7000	1573.7	159.3	157.7	160.8	154.5	164.0
7500	1686.1	170.8	169.1	172.5	165.7	175.9
8000	1798.5	182.5	180.7	184.3	177.0	188.0
8500	1910.9	194.2	192.2	196.1	188.3	200.0
9000	2023.3	205.8	203.8	207.9	199.7	212.0
9500	2135.7	217.2	215.0	219.3	210.7	223.7
10000	2248.1	228.5	226.2	230.8	221.7	235.4
10500	2360.5	239.9	237.5	242.3	232.7	247.1
11000	2472.9	251.3	248.8	253.8	243.7	258.8
11500	2585.3	262.7	260.1	265.3	254.8	270.6
12000	2697.7	274.1	271.4	276.8	265.9	282.3
12500	2810.1	286.0	283.2	288.9	277.5	294.6
13000	2922.5	298.0	295.0	301.0	289.0	306.9
13500	3034.9	309.9	306.8	313.0	300.6	319.2
14000	3147.3	320.9	317.7	324.1	311.3	330.6
14500	3259.7	331.9	328.6	335.3	322.0	341.9
15000	3372.2	343.5	340.0	346.9	333.2	353.8
15500	3484.6	355.0	351.5	358.6	344.4	365.7
16000	3597.0	366.6	362.9	370.2	355.6	377.6
16500	3709.4	378.1	374.4	381.9	366.8	389.5
17000	3821.8	389.7	385.8	393.6	378.1	401.4
17500	3934.2	401.4	397.3	405.4	389.3	413.4
18000	4046.6	413.0	408.8	417.1	400.6	425.4

Roller Clearance & Zero Position

- Make sure external angle jig and rollers are clean
- Make sure dial gages are in snug and gage tips are tightened
- Want some play in rollers:
  - 0.0015 to 0.0020 (fixed post)
  - 0.0020 to 0.0040 (other 2 posts)
- Zero Degree Position Check: at 180° rotation dial readings remain within ± 0.0010"

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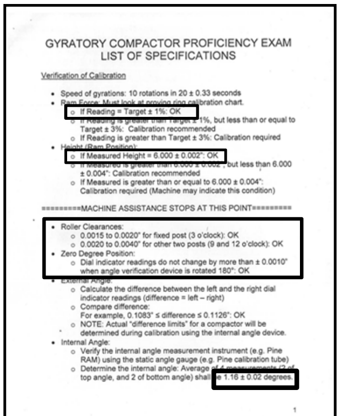

GYRATORY COMPACTOR PROFICIENCY EXAM
LIST OF SPECIFICATIONS

Verification of Calibration

- Speed of gyrations: 10 rotations in 20 ± 0.33 seconds
- Ram Force: Must look at proving ring calibration chart.
  - If Reading = Target ± 1%: OK
  - If Reading is greater than Target ± 1%, but less than or equal to Target ± 3%: Calibration recommended
  - If Reading is greater than Target ± 3%: Calibration required
- Height (Ram Position):
  - If Measured Height = 6.000 ± 0.002": OK
  - If Measured is greater than 6.000 ± 0.002", but less than 6.000 ± 0.004": Calibration recommended
  - If Measured is greater than or equal to 6.000 ± 0.004": Calibration required (Machine may indicate this condition)

=========MACHINE ASSISTANCE STOPS AT THIS POINT=========

- Roller Clearances:
  - 0.0015 to 0.0020" for fixed post (3 o'clock): OK
  - 0.0020 to 0.0040" for other two posts (9 and 12 o'clock): OK
- Zero Degree Position:
  - Dial indicator readings do not change by more than ± 0.0010" when angle verification device is rotated 180°: OK
- External Angle:
  - Calculate the difference between the left and the right dial indicator readings (difference = left – right)
  - Compare difference: For example, 0.1083" ≤ difference ≤ 0.1126": OK
  - NOTE: Actual "difference limits" for a compactor will be determined during calibration using the internal angle device.
- Internal Angle:
  - Verify the internal angle measurement instrument (e.g. Pine RAM) using the static angle gauge (e.g. Pine calibration tube)
  - Determine the internal angle: Average of 4 measurements (2 of top angle, and 2 of bottom angle) shall be 1.16 ± 0.02 degrees.

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VERIFICATION

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GYRATORY COMPACTOR PROFICIENCY EXAM
LIST OF SPECIFICATIONS

<u>Verification of Calibration</u>

- Speed of gyrations: 10 rotations in 20 ± 0.33 seconds
- Ram Force: Must look at proving ring calibration chart.
  - If Reading = Target ± 1%: OK
  - If Reading is greater than Target ± 1%, but less than or equal to Target ± 3%: Calibration recommended
  - If Reading is greater than Target ± 3%: Calibration required
- Height (Ram Position):
  - If Measured Height = 6.000 ± 0.002": OK
  - If Measured is greater than 6.000 ± 0.002", but less than 6.000 ± 0.004": Calibration recommended
  - If Measured is greater than or equal to 6.000 ± 0.004": Calibration required (Machine may indicate this condition)

=========MACHINE ASSISTANCE STOPS AT THIS POINT=========

- Roller Clearances:
  - 0.0015 to 0.0020" for fixed post (3 o'clock): OK
  - 0.0020 to 0.0040" for other two posts (9 and 12 o'clock): OK
- Zero Degree Position:
  - Dial indicator readings do not change by more than ± 0.0010" when angle verification device is rotated 180°: OK
- External Angle:
  - Calculate the difference between the left and the right dial indicator readings (difference = left – right)
  - Compare difference:
    For example, 0.1083" ≤ difference ≤ 0.1126": OK
  - NOTE: Actual "difference limits" for a compactor will be determined during calibration using the internal angle device.
- Internal Angle:
  - Verify the internal angle measurement instrument (e.g. Pine RAM) using the static angle gauge (e.g. Pine calibration tube)
  - Determine the internal angle: Average of 4 measurements (2 of top angle, and 2 of bottom angle) shall be 1.16 ± 0.02 degrees.

Verification Actions

- Rate of gyration (speed)
- Roller clearance & zero position
- Ram force:
  - 2 loads
  - 3500; 14,500 N
- Specimen Height
  - 1 position (blocks)
  - 6 in.
- Angle of gyration (***external*** angle)

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VERIFICATION FREQUENCY

- ***Verification*** is a shortened version of ***calibration***
- Frequency of verification:
  - ***Monthly***
  - ***When moved***
  - ***After any maintenance or adjustments***
  - ***After questionable results***
- Condition:
  - *Clean, cold machine*
  - "Cold" = warmed up to operating temperature, but mix has *not* been run through the machine

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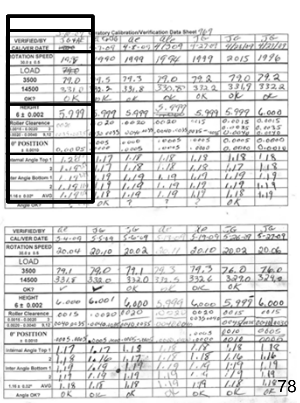
Ex.: Verification Work Sheet Using Internal Instead of External Angle



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Ex.: Verification Work Sheet Using Internal Instead of External Angle

ratory Calibration/Verification Data Sheet 969

VERIFIED/BY	5-10-09 JG+AE	AE+JG	ae	ae	JG	JG	JG
CAL/VER DATE	~~[illegible]~~	-7-09	4-8-09	4/13/09	4-27-09	4/28/09	4/29/09
ROTATION SPEED 30.0 ± 0.5	19.98	1990	1999	1994	1999	2015	1996
LOAD	~~79.0~~						
3500	79.0	9.5	79.3	79.0	79.2	79.0	79.2
14500	331.0	32.2	331.8	330.8	332.2	331.9	332.2
OK?	OK	oK	ok	OK	OK	ok	ok
HEIGHT 6 ± 0.002	5.999	5.999	5.999	5.999 ~~6.000~~	5.999	5.999	6.000
Roller Clearence 0.0015 - 0.0020 3	.0020	.0020	.0020	.0020	.0015	0.0015	0.0015
0.0020 - 0.0040 9,12	.0035 .0035	030 .0035	.0040 .0035	.0040 .0035	.0035 - .0035	0.0035 0.0040	0.0035 0.0040
0° POSITION ± 0.0010	0.0005	005 .0000	.0000 .0005	.0005 .0005	.0005 .0000	0.0005 0.0000	0.0000 0.0010
nternal Angle Top 1	1.20	1.17	1.18	1.18	1.18	1.18	1.18
2	1.19	1.17	1.18	1.18	1.18	1.17	1.18
nter Angle Bottom 1	1.19	1.19	1.19	1.19	1.19	1.19	1.19
2	1.19	1.19	1.19	1.19	1.19	1.19	1.19
1.16 ± 0.02° AVG	1.19	1.18	1.19	1.19	1.19	1.18	1.19
Angle OK?		OK	?	?	?	OK	

VERIFIED/BY	ae	JG	JG	ae	ae	JG	JG
CAL/VER DATE	5-4-09	5-5-09	5-6-09	5-13-09	5-19-09	5-26-09	5-27-09
ROTATION SPEED 30.0 ± 0.5	20.04	20.10	20.02	20.11	20.10	20.02	20.06
LOAD							
3500	79.1	79.0	79.1	79.3	79.3	76.0	76.0
14500	331.8	332.0	332.0	332.5	332.6	329.0	324.0
OK?	✓	✓	OK	ok	OK	OK	
HEIGHT 6 ± 0.002	6.000	6.001	6.000	5.999	6.000	5.999	6.000
Roller Clearence 0.0015 - 0.0020 3	.0015	.0020	.0020	.0020	.0020	.0015	.0015
0.0020 - 0.0040 9,12	.0040 .0035	.0040 .0035	.0040 .0035	.0040 .0040	.0035 .0040	.0045/.0035	.0040/.0030
0° POSITION ± 0.0010	.0005 .0005	.0005 .0000	.0005 - .0005	.0000 .0000	.0005 .0000	.0010 .0010	.0005 .0005
Internal Angle Top 1	1.17	1.17	1.18	1.18	1.18	1.18	1.18
2	1.18	1.16	1.17	1.18	1.18	1.16	1.16
Inter Angle Bottom 1	1.19	1.19	1.19	1.19	1.19	1.19	1.19
2	1.19	1.19	1.19	1.19	1.19	1.19	1.19
1.16 ± 0.02° AVG	1.18	1.18	1.18	1.19	1.19	1.18	1.18
Angle OK?	OK	OK	OK	OK	OK	OK	OK

Standard Specification

- **403.17.3.1 (standard spec) – The gyratory compactor should be calibrated yearly using internal angle. It may be <u>verified</u> using external angle. It should be verified ~~daily~~ monthly during production and after each move.**

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VERIFICATION:

- ***External angle verification can be substituted for internal angle verification***; The external angle must correspond to be within the proper internal angle range as established during ***calibration,*** e.g, during calibration of the internal angle, the corresponding external angle will be noted. This can be used for external angle verification

VERIFICATION

- Rate of gyration (rotational speed): 30.0 ± 0.5 rotations per minute (10 rotations in 20 ± 0.33 sec)
- Ram Force: Target ± 1%
- Ram Position (height):±0.002"
- External angle: Whatever corresponds to internal angle as set during calibration: 1.16 ± 0.02°
- Roller clearances and zero position - done on some machines

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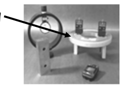
External Angle Methods

- Depending on the gyro make/model:
  - External angle jig



  - Internal check provided by the gyro (not "internal angle")

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Example

- During calibration, the internal angle was set to 1.173 ° which met 1.16 ± 0.02°
- At the same time, the external angle difference was 0.1110 in. which, using trigonometry, corresponds to 1.27 ° (tan Θ = Difference/ L) where L = 5.000 in.

- For the next year, during monthly verification, the external angle must be 1.27 ± 0.02°

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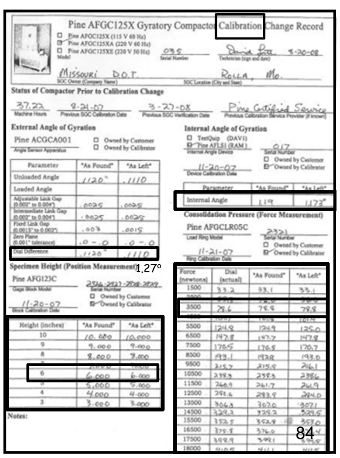

Pine AFGC125X Gyratory Compactor Calibration Change Record

☐ Pine AFGC125X (115 V 60 Hz)
☑ Pine AFGC125XA (220 V 60 Hz)
☐ Pine AFGC125XE (220 V 50 Hz)
Model

035 — Serial Number
Technician (sign and date) 5-20-08

Missouri D.O.T. — SGC Owner (Company Name)
Rolla, Mo. — SGC Location (City and State)

Status of Compactor Prior to Calibration Change

37.22 — Machine Hours
8-21-07 — Previous SGC Calibration Date
3-27-08 — Previous SGC Verification Date
Pine Certified Service — Previous Calibration Service Provider (if known)

External Angle of Gyration

Pine ACGCA001 — Angle Sensor Apparatus
☐ Owned by Customer
☐ Owned by Calibrator

Parameter	"As Found"	"As Left"
Unloaded Angle	.1120"	.1110
Loaded Angle		
Adjustable Link Gap (0.002" to 0.004")	.0025	.0025
Intermediate Link Gap (0.002" to 0.004")	.0025	.0025
Fixed Link Gap (0.0015" to 0.002")	.003	.0015
Zero Plane (0.001" tolerance)	.0 - .0	.0 - .0
Dial Difference	.1120"	.1110

1.27°

Internal Angle of Gyration

☐ TestQuip (DAV1)
☑ Pine AFLS1 (RAM) — Internal Angle Device
017 — Serial Number
☐ Owned by Customer
☑ Owned by Calibrator
11-20-07 — Device Calibration Date

Parameter	"As Found"	"As Left"
Internal Angle	1.19	1.173°

Consolidation Pressure (Force Measurement)

Pine AFGCLR05C — Load Ring Model
2321 — Serial Number
☐ Owned by Customer
☑ Owned by Calibrator
11-21-07 — Ring Calibration Date

Force (newtons)	Dial (actual)	"As Found"	"As Left"
1500	33.2	33.1	33.1
2500	[illegible]	[illegible]	[illegible]
3500	78.6	78.8	78.8
4500	[illegible]	[illegible]	[illegible]
5500	124.8	124.9	125.0
6500	147.8	147.7	147.8
7500	170.5	170.5	170.7
8500	193.1	192.8	193.0
9500	215.7	215.9	216.1
10500	238.3	238.3	238.6
11500	260.9	261.7	261.9
12500	283.6	283.9	284.0
13500	306.3	307.0	307.1
14500	329.2	329.2	329.5
15500	352.5	352.8	353.0
16500	375.8	376.0	[illegible]
17500	398.9	399.1	[illegible]
18000	[illegible]	[illegible]	[illegible]

Specimen Height (Position Measurement)

Pine AFG123C — Gage Block Model
2926-2927-2928-2929 — Serial Number
☐ Owned by Customer
☑ Owned by Calibrator
11-20-07 — Block Calibration Date

Height (inches)	"As Found"	"As Left"
10	10.000	10.000
9	9.000	9.000
8	8.000	8.000
7	[illegible]	[illegible]
6	6.000	6.000
5	5.000	5.000
4	4.000	4.000
3	3.000	3.000

Notes:

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Pine AFGC125X Gyratory Compactor Calibration Change Record

- ☐ Pine AFGC125X (115 V 60 Hz)
- ☒ Pine AFGC125XA (220 V 60 Hz)
- ☐ Pine AFGC125XE (220 V 50 Hz)

Model

035 — Serial Number

David Lott 3-20-08 — Technician (sign and date)

MISSOURI D.O.T. — SGC Owner (Company Name)

ROLLA, MO. — SGC Location (City and State)

Status of Compactor Prior to Calibration Change

Machine Hours	Previous SGC Calibration Date	Previous SGC Verification Date	Previous Calibration Service Provider (if known)
37.22	8-21-07	3-27-08	Pine Certified Service

External Angle of Gyration

Pine ACGCA001 — Angle Sensor Apparatus

- ☐ Owned by Customer
- ☐ Owned by Calibrator

Parameter	"As Found"	"As Left"
Unloaded Angle	.1120"	.1110
Loaded Angle		
Adjustable Link Gap (0.002" to 0.004")	.0025	.0025
Intermediate Link Gap (0.002" to 0.004")	.0025	.0025
Fixed Link Gap (0.0015" to 0.002")	.003	.0015
Zero Plane (0.001" tolerance)	.0 - .0	.0 - .0
Dial Difference	.1120"	.1110

1.27°

Internal Angle of Gyration

- ☐ TestQuip (DAV1)
- ☒ Pine AFLS1 (RAM)

Internal Angle Device

017 — Serial Number

- ☐ Owned by Customer
- ☒ Owned by Calibrator

11-20-07 — Device Calibration Date

Parameter	"As Found"	"As Left"
Internal Angle	1.19	1.173°

Consolidation Pressure (Force Measurement)

Pine AFGCLR05C — Load Ring Model

2321 — Serial Number

- ☐ Owned by Customer
- ☒ Owned by Calibrator

11-21-07 — Ring Calibration Date

Force (newtons)	Dial (actual)	"As Found"	"As Left"
1500	33.2	33.1	33.1
2500	55.5	56.0	56.0
3500	78.6	78.8	78.8
4500	101.7	101.9	101.9
5500	124.8	124.9	125.0
6500	147.8	147.7	147.8
7500	170.5	170.5	170.7
8500	193.1	192.8	193.0
9500	215.7	215.9	216.1
10500	238.3	238.3	238.6
11500	260.9	261.7	261.9
12500	283.6	283.9	284.0
13500	306.3	307.0	307.1
14500	329.2	329.2	329.5
15500	352.5	352.8	353.0
16500	375.8	376.0	[illegible]
17500	398.9	399.1	399.5
18000	410.5	411.1	411.5

Specimen Height (Position Measurement)

Pine AFG123C — Gage Block Model

2926-2927-2928-2929 — Serial Number

- ☐ Owned by Customer
- ☒ Owned by Calibrator

11-20-07 — Block Calibration Date

Height (inches)	"As Found"	"As Left"
10	10.000	10.000
9	9.000	9.000
8	8.000	8.000
7	7.000	7.000
6	6.000	6.000
5	5.000	5.000
4	4.000	4.000
3	3.000	3.000

Notes:

VERIFICATION & CALIBRATION

- Gyratory compactor
- ***Molds***

85

GYRO MOLD EVALUATION

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

86

Internal Diameter

- Methods:
  - ***Three-point internal bore gauge***
  - Coordinate Measuring Machine (CMM)

87

Mold Diameter
3-Point Bore Gauge

- Set the zero with a "master ring"

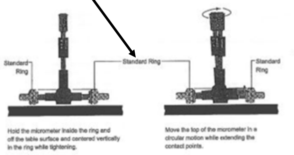


Figure A4.1—Techniques for Using the Three-Point Bore Gauge with the Calibrated Master Ring

88

Mold Diameter
3-Point Bore Gauge

- Measure mold internal diameter at 3 elevations, with 3 different measurements (nearest 0.001 mm preferred) at each elevation: total of 9 measurements

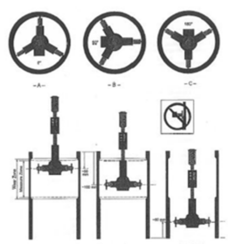


Figure A4.2—Bore Gauge Measurement Positions within the Mold Bore

89

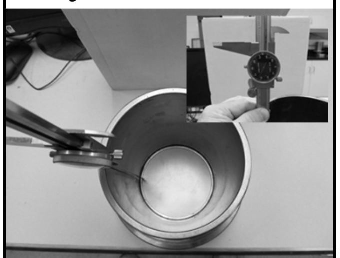
Mold Diameter
3-Point Bore Gauge

- For in-service molds, each diameter bore measurement recommended to be 149.9-150.0 mm.
- Maximum clearance should be ≤ 150.2 mm
- If any diameter fails maximum, mold should not be used (too much play, compaction tends to decrease, which would affect volumetrics)

90

Mold Length

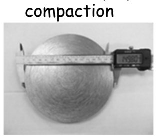
- Caliper or micrometer
- Measure to nearest 0.025 mm
- Length should be at least 250 mm

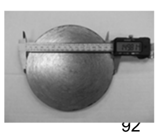


91

End Plate Diameter

- Measure with a caliper or micrometer
- Find maximum plate diameter (A) by measuring several points
- Measure a "B" diameter at a point 90° from A
- Diameters at each point should be 149.50 to 149.75 mm
- If end plate has excessive clearance, it should not be used: too much play, decrease in compaction





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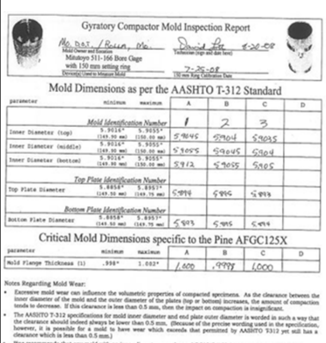
Calibration Data Sheet- Mold



Gyratory Compactor Mold Inspection Report

Mo. DOT. / Rolla, Mo. — Mold Owner and Location
David Lee 8-20-08 — Technician (sign and date here)
Mitutoyo 511-166 Bore Gage with 150 mm setting ring — Device(s) Used to Measure Mold
7-25-08 — 150 mm Ring Calibration Date

Mold Dimensions as per the AASHTO T-312 Standard

parameter	minimum	maximum	A	B	C	D
Mold Identification Number			1	2	3	
Inner Diameter (top)	5.9016" (149.90 mm)	5.9055" (150.00 mm)	5.9045	5.904	5.9035	
Inner Diameter (middle)	5.9016" (149.90 mm)	5.9055" (150.00 mm)	5.9055	5.9045	5.904	
Inner Diameter (bottom)	5.9016" (149.90 mm)	5.9055" (150.00 mm)	5.912	5.9055	5.905	
Top Plate Identification Number						
Top Plate Diameter	5.8858" (149.50 mm)	5.8957" (149.75 mm)	5.894	5.895	5.893	
Bottom Plate Identification Number						
Bottom Plate Diameter	5.8858" (149.50 mm)	5.8957" (149.75 mm)	5.893	5.895	5.894	

Critical Mold Dimensions specific to the Pine AFGC125X

parameter	minimum	maximum	A	B	C	D
Mold Flange Thickness (1)	.998"	1.002"	1.000	.9998	1.000	

Notes Regarding Mold Wear:

- Excessive mold wear can influence the volumetric properties of compacted specimens. As the clearance between the inner diameter of the mold and the outer diameter of the plates (top or bottom) increases, the amount of compaction tends to decrease. If this clearance is less than 0.5 mm, then the impact on compaction is insignificant.
- The AASHTO T-312 specifications for mold inner diameter and end plate outer diameter is worded in such a way that the clearance should indeed always be lower than 0.5 mm. (Because of the precise wording used in the specification, however, it is possible for a mold to have wear which exceeds that permitted by AASHTO T312 yet still has a clearance which is less than 0.5 mm.)
- Pine recommends that any mold with an inner diameter worn beyond 5.9134" (150.20 mm) should be replaced.

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Calibration Data Sheet- Mold

Gyratory Compactor Mold Inspection Report

Mo. D.O.T. / Rolla, Mo.	David Lott 8-20-08
Mold Owner and Location	Technician (sign and date here)
Mitutoyo 511-166 Bore Gage with 150 mm setting ring	7-25-08
Device(s) Used to Measure Mold	150 mm Ring Calibration Date

Mold Dimensions as per the AASHTO T-312 Standard

parameter	minimum	maximum	A	B	C	D
Mold Identification Number			1	2	3	
Inner Diameter (top)	5.9016" (149.90 mm)	5.9055" (150.00 mm)	5.9045	5.904	5.9035	
Inner Diameter (middle)	5.9016" (149.90 mm)	5.9055" (150.00 mm)	5.9055	5.9045	5.904	
Inner Diameter (bottom)	5.9016" (149.90 mm)	5.9055" (150.00 mm)	5.912	5.9055	5.905	
Top Plate Identification Number						
Top Plate Diameter	5.8858" (149.50 mm)	5.8957" (149.75 mm)	5.894	5.895	5.893	
Bottom Plate Identification Number						
Bottom Plate Diameter	5.8858" (149.50 mm)	5.8957" (149.75 mm)	5.893	5.895	5.894	

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- The AASHTO T-312 specifications for mold inner diameter and end plate outer diameter is worded in such a way that the clearance should indeed always be lower than 0.5 mm. (Because of the precise wording used in the specification, however, it is possible for a mold to have wear which exceeds that permitted by AASHTO T-312 yet still has a clearance which is less than 0.5 mm.)
- Pine recommends that any mold with an inner diameter worn beyond 5.9134" (150.20 mm) should be replaced.

VISUAL INSPECTION

- Free of residue and deep gouges
- Identify visible wear areas
- End plates should be free of raised burrs

94

PROFICIENCY EXAMS

- Make pucks
- Verification of the gyro

95

MODULE 7

MAXIMUM SPECIFIC GRAVITY OF VOIDLESS LOOSE MIX (RICE)

G_{mm}

11-24-06 Revision
11-9-07 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
12-29-14 Revision
12-9-15 Revision
3-2-16 Revision
12-12-18 Revision
2-8-19 Revision
12-17-19 Revision

MODULE 7

MAXIMUM SPECIFIC GRAVITY OF VOIDLESS LOOSE MIX (RICE)

G_{mm}

11-24-06 Revision
11-9-07 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
12-29-14 Revision
12-9-15 Revision
3-2-16 Revision
12-12-18 Revision
2-8-19 Revision
12-17-19 Revision

AASHTO TEST METHODS & SPECIFICATIONS

- R35 Volumetric Design Practice
- M323 Volumetric Design Specs
- R30 Mix Conditioning
- T 312 Gyro operation
- T 166 Bulk Sp Gravity of gyro pucks
- ***T 209 Max Sp Gravity of Voidless Mix (Rice)***
- T 283 Moisture Sensitivity

2

"RICE" GRAVITY

Maximum Specific Gravity

- **Loose (uncompacted) mixture**

$$G_{mm} = \frac{\text{Mass agg. and AC}}{\text{Vol. agg. and AC}}$$

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
- "Rice" test
- "G_{mm}":
  - G=specific gravity
  - m=mix
  - m=maximum

4

SAMPLE LOCATION

- Volumetric sample: behind the paver
- TSR sample:
  - Behind paver
  - Truck
  - Plant discharge

5

USES

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

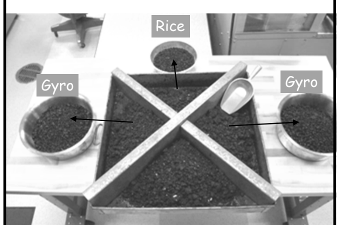
6

CALIBRATION

- Pycnometer: daily
- Vacuum: every 12 months

7

SAMPLE SPLIT



8

ALTERNATE METHODS

- ***Weigh-in-Air***
- Weigh-in-Water

9

SUMMARY OF STEPS: Weigh-in-Air Method

- 1. Dry specimen to constant weight at 105 ± 5 ºC (mass repeats within 0.1%) -*see cookbook on "mass repeats"*

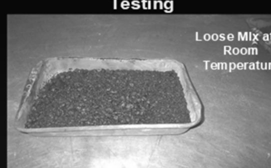
Or

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

10

- 2. Separate loose mix into small pieces. Be sure not to over-manipulate the sample and cause aggregate to be broken into pieces smaller than original size. Bring specimen to room temperature.

Testing



3. Weigh the dry specimen Total- tare = "A"

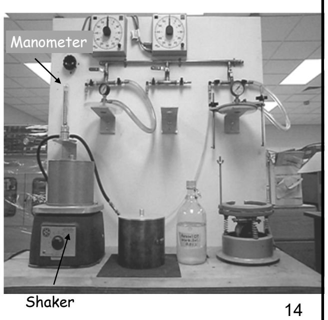
12

Weigh-in-Air Method

- 4. Add sufficient water to the pycnometer containing the specimen to cover it (~25 °C)

13

5. De-air the specimen (shake under vacuum). The vacuum is required to be 27.5 ± 2.5 mm Hg absolute vacuum. A manometer is to be connected to the system during testing.



14

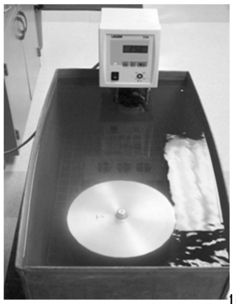
AGITATION

- Mechanical
- Manual

- Manual method has come and gone and come again in the specs as an allowable method

15

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



16

7. Determine weight of [specimen + pycnometer + water] = "E"

Weigh-in-Air Method: Pycnometer Standardization

- 8. Determine weight of pycnometer full of water to determine its volume. The water is required to be at 25 ± 0.5 °C
  "D"

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

"D" will be too low with high temperature

18

CALCULATION

- Results of steps 3,4, 8 determine the volume of specimen.
- 9. Knowing mass of specimen and mass of water displaced (volume of specimen), calculate G_{mm}

$$G_{mm} = \frac{A}{A + D - E}$$

19

DRY-BACK STEP

- 10. If absorption of ***any*** coarse aggregate fraction is greater than 2.0%, dry back the specimen to a surface dry condition and weigh. Use this weight ***"A2" in the denominator in place of "A"***.
- Absorption data is on the JMF.

20

DRY-BACK

- Purpose- to see if water has penetrated the binder coating
- So--dry the sample back to a surface-dry condition --don't oven dry all the way to ~ zero moisture

21

When to Implement Dry-Back

- If coarse aggregate absorptions are excessive, perform on first lot (all sublots)
- If initial G_{mm} and the dry-back G_{mm} 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 *(FAQ)*.

22

CALCULATION (Dry-Back Procedure)

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

$$G_{mm} = \frac{A}{A2 + D - E}$$

23

ALTERNATE METHODS

- Weigh-in-Air
- ***Weigh-in-Water***

24

SUMMARY OF STEPS: Weigh-in-Water Method

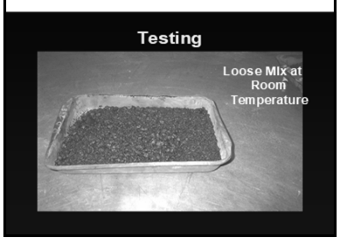
- 1. Dry specimen to constant weight at 105 ± 5 ºC (mass repeats within 0.1%)-*see cookbook on "mass repeats"*

Or

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

25

- 2. Separate loose mix into small pieces. Be sure not to over-manipulate the sample and cause aggregate to be broken into pieces smaller than original size. Bring specimen to room temperature.



3. Weigh the dry specimen
Total-tare = "A"

27

4. De-air the specimen (shake under vacuum). The vacuum is required to be 27.5 ± 2.5 mm Hg absolute vacuum. A manometer is to be connected to the system during testing.

28

ALTERNATE METHOD: Weigh-in-Water

- 5. Instead of weighing on top of the scale (in air), suspend the pycnometer below the scale in water (25 ± 1°C) without lid:

[pycnometer +specimen] under water= ***C***

29

Weigh in Water

- 6. Remove specimen from pycnometer. Immediately determine weight under water of pycnometer.
- [pycnometer] under water= **B**
- 7. Calculate G_{mm}:

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

30

DRY-BACK STEP

- 8. If absorption of ***any*** coarse aggregate fraction is greater than 2.0%, dry back the specimen to a surface dry condition and weigh. Use this weight "A2" in the denominator.
- Absorption data is on the JMF.

31

CALCULATION (Dry-Back Procedure)

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

$$G_{mm} = \frac{A}{A2 + B - C}$$

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

32

RICE GRAVITY Methods in Missouri

- Weigh-in-air: slight majority
- Weigh-in-water

33

RICE GRAVITY Methods in Missouri

- Mechanical agitation- vast majority
- Manual – very few
- Combination - a few

- A few tailor the method to the circumstance

34

CALCULATIONS OF VOLUMETRICS

AIR VOIDS

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

36

AIR VOIDS

- $V_a = \dfrac{2.557 - 2.455}{2.557} \times 100$

V_a = 4.0%

37

VMA

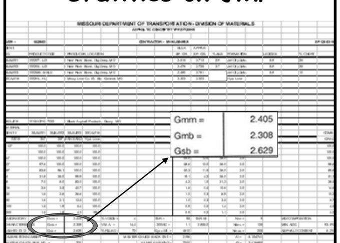
Voids in Mineral Aggregate

$$VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}$$

VMA is an indication of film thickness on the surface of the aggregate

38

Location of Specific Gravities on JMF



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Location of Specific Gravities 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						

MATERIAL IDENT #	35JSJ001	35JSJ002	35JSJ003	30CAJ016					COMB.
03016	3/4"	3/8"	MAN SAND	Hyd. Lime					GRAD
1 1/2"	100.0	100.0	100.0	100.0					100.0
1"	100.0	100.0	100.0	100.0					100.0
3/4"	100.0	100.0	100.0	100.0	60.0	12.0	26.0	2.0	100.0
1/2"	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	1.0	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	1.4	2.0	4.5
#200	1.5	[illegible]	4.2	[illegible]	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	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

Gmm =	2.405
Gmb =	2.308
Gsb =	2.629

VMA

Example Calculations

- Given that G_{mb} = 2.455, P_s = 95%, and G_{sb} = 2.703

$$VMA = 100 - \frac{(2.455)(95)}{2.703} = 13.7$$

40

G_{sb} CHANGES

- If the blend has changed say, due to a Field Adjustment of fraction %'s, then Gsb should be re-calculated.

41

VFA

Voids Filled with Asphalt

$$VFA = 100 \times \frac{VMA - V_a}{VMA}$$

VFA is the percent of VMA that is filled with asphalt cement

42

VFA

- $VFA = \frac{13.7 - 4.0}{13.7} \times 100$

VFA= 71%

43

CALCULATIONS

- QC calculates air voids, VMA, and VFA 1 per ***sublot***
- QA calculates air voids, VMA, and VFA 1 per ***4 sublots***
- ***Only air voids and VMA are pay factors***

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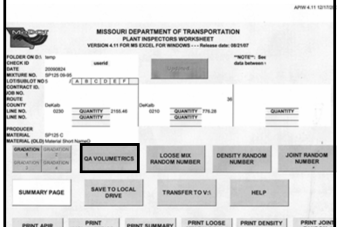
MoDOT SPREADSHEET



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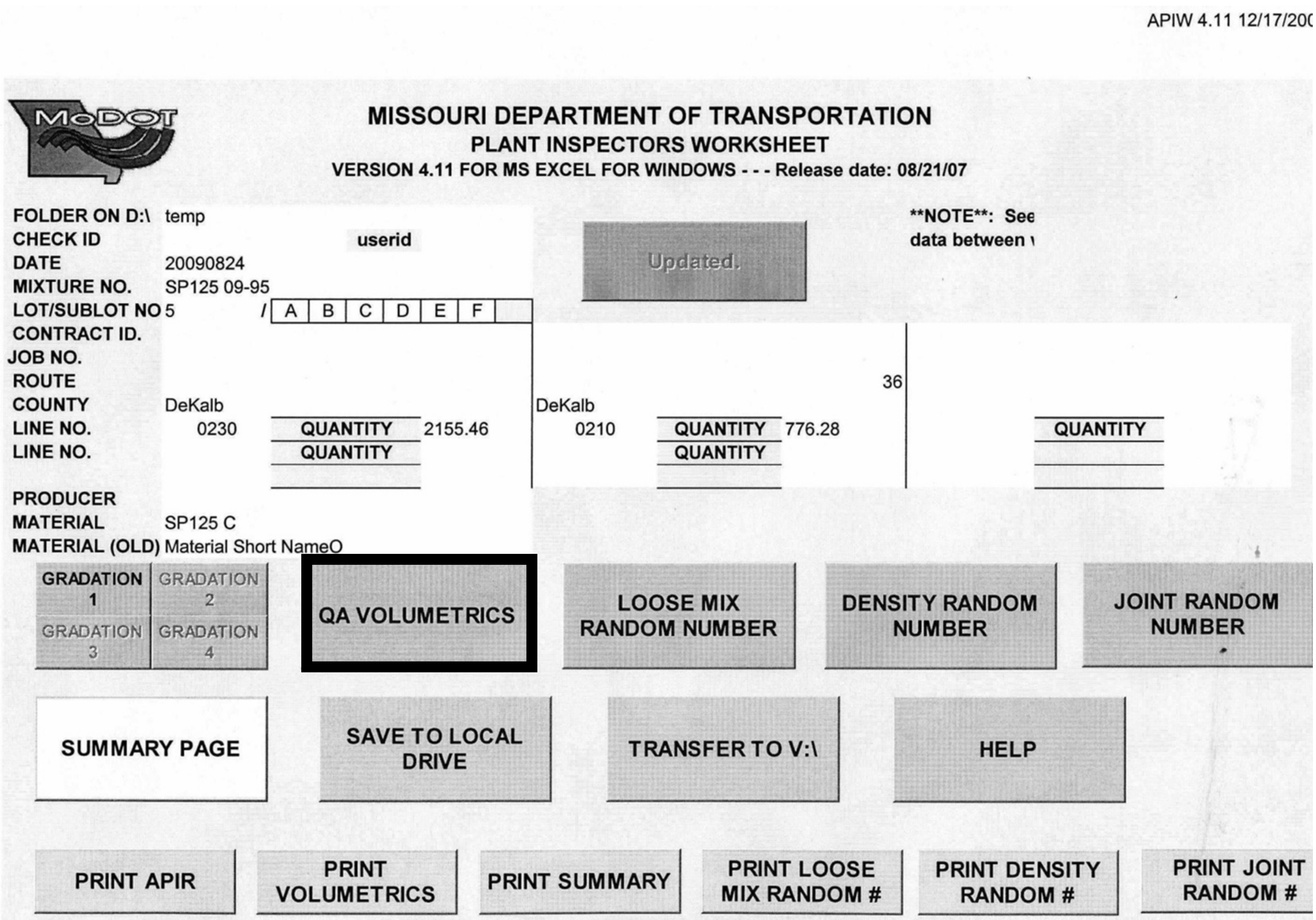
MoDOT SPREADSHEET



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
[illegible]							
TECHNICIAN							
MOLDING TEMPERATURE							
A = Weight of sample in air: (SPEC. 1)	4667.6						
B = Weight of sample in water: (SPEC. 1)	2601.9						
C = Weight of surface dry sample: (SPEC. 1)	4680.4						
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: (SPEC. 2)	2814.5						
C = Weight of surface dry sample: (SPEC. 2)	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
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						
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] X 100	59	0	0	0	0	0	0
AASHTO T 166							
TECHNICIAN							
A = Weight of sample in air:	1265						
B = Weight in water:	710						
C = Weight of surface dry sample:	1269						
Gmc = CORE SPECIFIC GRAVITY = A / (C - B)	2.262	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							

G_{mm} Portion

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

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DRY-BACK

- If dry-back procedure is done, substitute "A_2" for "A" in the ***denominator***

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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:	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		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	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] X 100	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							

G_{mm} Portion

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

DRY-BACK

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

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USE of G_{mm}

- Calculate Air Voids
- Calculate Core Density

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SUPERPAVE MIXTURE PROPERTIES

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

Rice Gmm

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: (SPEC. 1)	4867.8						
B = Weight of sample in water: (SPEC. 1)	2801.9						
C = Weight of surface dry sample: (SPEC. 1)	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: (SPEC. 2)	2814.5						
C = Weight of surface dry sample: (SPEC. 2)	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

Gmb

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						

Pb

A = Gmm (FIELD)	2.472	2.472	2.472	2.472	2.472	2.472	2.472
B = Gmb (FIELD) (Avg.)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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:	1265						
B = Weight in water:	710						
C = Weight of surface dry sample:	1260						
Gmc = CORE SPECIFIC GRAVITY = A / (C - B)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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							

cores

DRY-BACK

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

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 — Gmb

TECHNICIAN							
MOLDING TEMPERATURE							
SPEC. 1: A = Weight of sample in air:	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
SPEC. 2: A = Weight of sample in air:	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	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 (Pb)							
% MOISTURE	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
B = Gmb (FIELD) (Avg.)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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 — cores

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)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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							

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

- Time interval at high temperature
- Absorptiveness of aggregate

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TIME AT HIGH TEMPERATURE

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SPREADSHEET CALCULATIONS

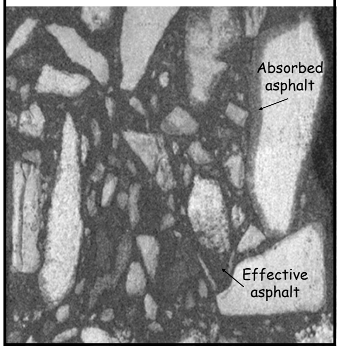
AASHTO R 35

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							

ABSORPTIVENESS OF AGGREGATE



COMMON TESTING ERRORS

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

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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.

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COMMON TESTING ERRORS, cont'd.

- 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

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COMMON TESTING ERRORS, cont'd.

- Use of a dry towel may wick water out of the pycnometer hole.
- Not using approximately the same size specimen each time.
- Not changing vacuum level at proper rates

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Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA): AASHTO T 209-19

This test method shall be used to determine the maximum specific gravity (G_{mm}) of uncompacted asphalt mixtures.

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 209-19, 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 209-19, 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)

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):	____________
1st Drying Interval (DI)	
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 (%):	____________
2nd Drying Interval (DI)	
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 (%):	____________
3rd Drying Interval (DI)	
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 (%):	____________
4th Drying Interval (DI)	
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 (%):	____________
5th Drying Interval (DI)	
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 ____________

MODULE 8

ASPHALT CONTENT IGNITION OVEN METHOD T 308

12-28-06 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
2-26-10 Revision
2-16-11 Revision
3-2-12 Revision
2-26-13 Revision
12-18-13 Revision
12-29-14 Revision
2-5-15 Revision
12-9-15 Revision
3-2-16 Revision
12-28-16 Revision
1-18-18 Revision
12-12-18 Revision
2-8-19 Revision
3-15-19 Revision
12-17-19 Revision

MODULE 8

ASPHALT CONTENT IGNITION OVEN METHOD T 308

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12-29-14 Revision
2-5-15 Revision
12-9-15 Revision
3-2-16 Revision
12-28-16 Revision
1-18-18 Revision
12-12-18 Revision
2-8-19 Revision
3-15-19 Revision
12-17-19 Revision

AASHTO T308

Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Oven Method

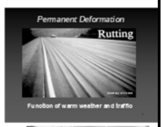
SCOPE

- ***Background***
- Binder Content Role in QC/QA
- Sampling
- Test procedure
- Field verification
- Oven verification

3

BINDER CONTENT-WHY TEST?

- Excessive binder can cause instability e.g. rutting, shoving, corrugations, bleeding



- Binder content is an important part of the dust-to-binder ratio which affects compactibility and cohesion

4

BINDER CONTENT-WHY TEST?

- Insufficient binder can lead to lack of adhesion, raveling, stripping, and cracking

5

AASHTO TEST METHODS & SPECIFICATIONS

- R 97 Sampling Hot Mix
- R 47 HMA Sample Splitting
- T 329 Moisture Content of Hot Mix
- ***T 308 Binder Content Ignition Oven***
- ***T30 Sieve Analysis of Residue***
- ***R 96 Installation, Operation, and Maintenance of Ignition Furnaces***

6

Equipment

- Ignition Furnace
- Basket assembly
- Oven (110 ± 5 C)
- Balance
- Safety Equipment: face shield, gloves, long-sleeved jacket, protective basket cage

7

BINDER CONTENT TEST METHODS

- Solvent extraction T 164
- Nuclear gage: T 287, TM 54
  - Low radiation
  - Regular radiation
- Ignition oven: T 308
  - Method A
    - Convection oven
    - Infrared oven
  - Method B
- Method A: internal scale
- Method B: no internal scale

8

SOLVENT EXTRACTION T 164

- Solvent health issues
- Solvent disposal issues
- Thus, expensive



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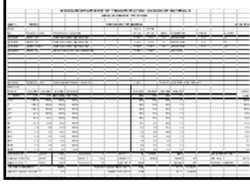
NUCLEAR GAGE
T 287, TM 54

- Health issues
- Interferences
- Calibration issues



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IGNITION OVEN
T 308

Method A:

- more convenient, higher lab production rates

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METHOD "A"

- Convection oven (NCAT)
- Infrared oven:
  - First generation
  - Second generation (NTO)

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HEAT TRANSFER

- ***Convection:*** heat warms the air, which warms the sample
- ***Infrared:*** electromagnetic energy waves directly heat the sample

3

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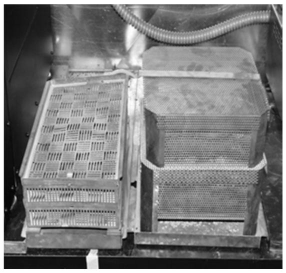
BASKETS



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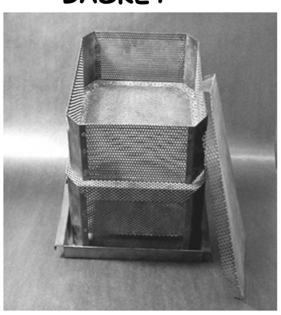
CONVECTION OVEN BASKET



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INFRARED OVEN

Default - Normal

Option 1 - Less

Option 2 - More

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SECOND GENERATION INFRARED

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IGNITION OVEN

Method B: no internal scale

- lower oven cost; less operational problems

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METHOD "B"

- Note the special heat resistant shirt

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TYPES OF METHODS In Missouri

- NCAT oven - vast majority
- Nuclear – a few
- Low radiation nuclear - 1
- First generation infrared ignition oven – 1
- Second generation infrared ignition oven – 1

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MATCHING AGGREGATE TYPE TO BINDER TEST METHOD

- Dolomite:
  - Nuclear
  - Low radiation nuclear
- All other: convection or infrared ignition ovens

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SCOPE

- Background
- ***Binder Content Role in QC/QA***
- Sampling
- Test procedure
- Field verification
- Oven verification

24

Binder Content Role

- ***Mix design & acceptance***
- Field Verification of mix

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Mix Design & Mix Acceptance

- Contractor designs mix & submits target binder content to MoDOT
- MoDOT approves and sets JMF target binder %

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Binder Content Role

- Mix design & acceptance
- ***Field verification of mix***

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CONTENT

- ***Binder content of mix***
- Binder content of RAP
- Aggregate gradation

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% BINDER

- Design (target) binder content is determined during mix design and verified/approved by MoDOT
- May have to be adjusted in the field resulting in a new target binder content:
  - Different aggregate sources
  - Significant change in % of aggregate sources
  - Different oven

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Binder Role

- Binder content is a pay factor in 403 projects

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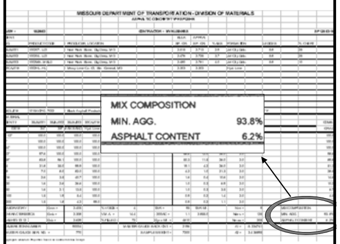
Location of Target Binder Content on JMF



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SCOPE

- Background
- Binder Content Role in QC/QA
- ***Sampling***
- Test procedure
- Field verification
- Oven verification

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Binder Content Samples

- 401: plant
- 403: roadway

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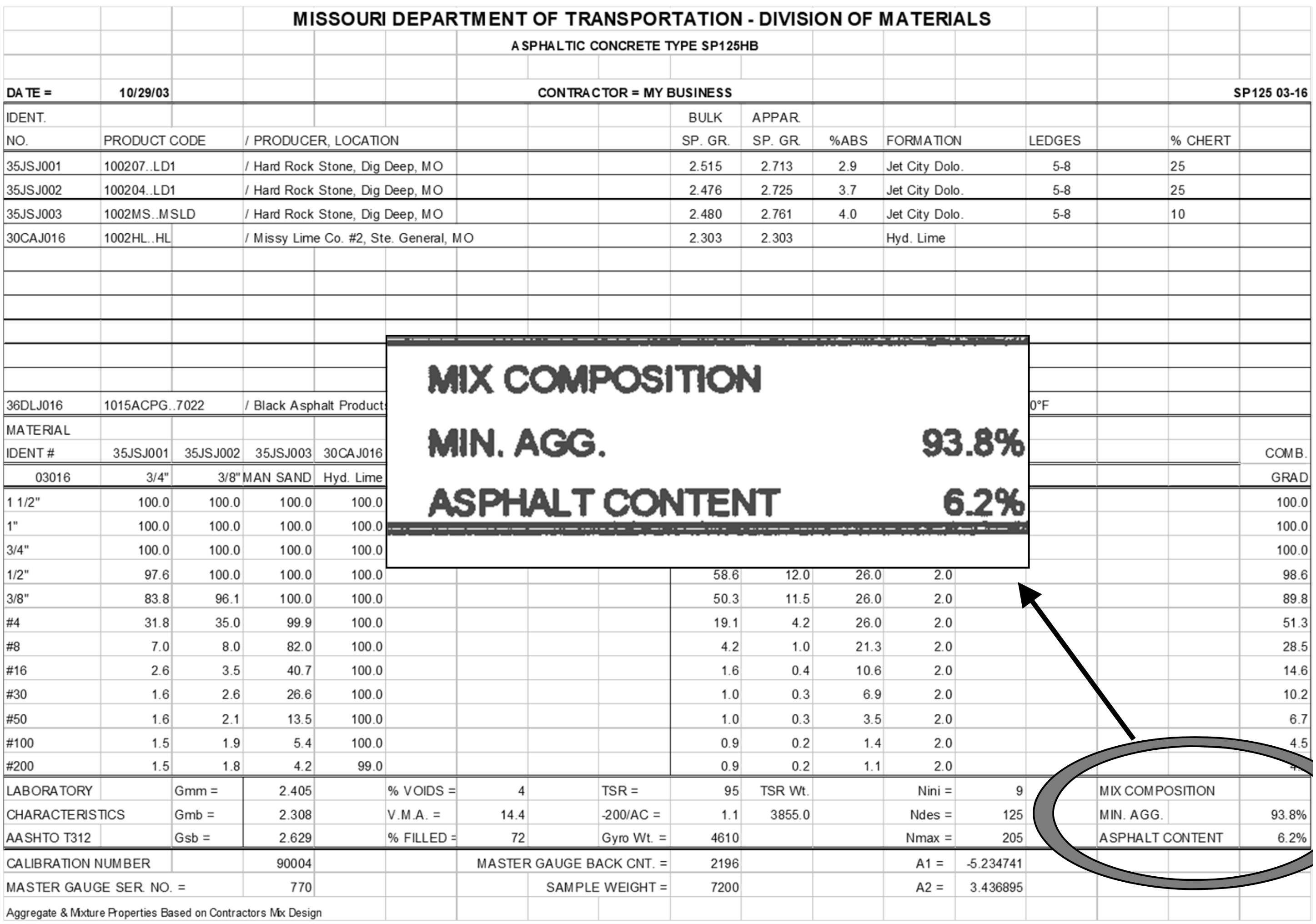
Location of Target Binder Content on JMF



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	4.0	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 Product[s]				0°F		

MATERIAL IDENT #	35JSJ001	35JSJ002	35JSJ003	30CAJ016					COMB.
03016	3/4"	3/8"	MAN SAND	Hyd. Lime					GRAD
1 1/2"	100.0	100.0	100.0	100.0					100.0
1"	100.0	100.0	100.0	100.0					100.0
3/4"	100.0	100.0	100.0	100.0					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	1.0	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	1.4	2.0	4.5
#200	1.5	1.8	4.2	99.0	0.9	0.2	1.1	2.0	

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

Binder Content Field Verification

- 401: JMF - 0.3 to + 0.5%
- 403: JMF ± 0.3%

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LOOSE MIX: 403

Volumetric/%Binder Sample

- Sampling Frequency:
  - QC: one per ***sublot***
  - QA: one per ***4 sublots***- "independent sample"
  - QA: once per ***day*** test QC "retained sample". This may be omitted on days when independent QA sample is taken, if confident and "favorable comparison" exists between QA's QC split and QC (within 0.1%)

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Loose Mix: 401

- QC: binder content-every 1000 tons. If less than 1000 tons per day, test at least once; RE may waive testing if less than 200 tons per day
- QA: one independent sample every 4 QC tests
- QA: Retained QC sample split: once per 5 days

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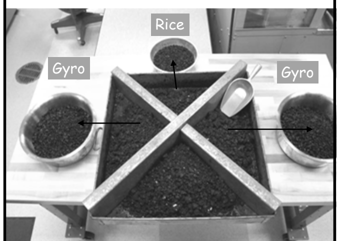
403: SAMPLE

- 50 lb. sample –get 2 portions for the 2 volumetric pucks plus Rice



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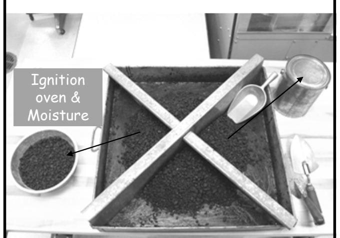
403
REMIX, QUARTER AGAIN
Ignition Oven & Moisture



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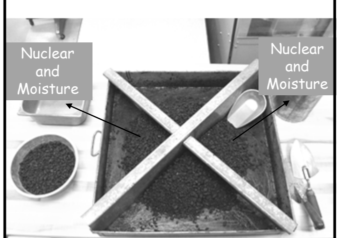
Or
REMIX, QUARTER AGAIN
Nuclear & Moisture



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IGNITION OVEN SPECIMEN SIZE

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
SP 250	1	3000-3500

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IGNITION OVEN SPECIMEN SIZE

- Large specimens of fine mixes tend to result in incomplete ignition

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SCOPE

- Background
- Binder Content Role in QC/QA
- Sampling
- ***Test procedure***
- Field verification
- Oven verification

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TEST PROCEDURE

- Corrections
- Binder content test procedure

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IGNITION OVEN BASICS

- % Binder: loss in mass of specimen
- Problem: other materials also burn off
  - moisture
  - aggregate

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TEST PROCEDURE

- ***Corrections***
- Binder content test procedure

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BINDER CONTENT CORRECTIONS

- ***Moisture***
- Aggregate burn loss
- Temperature effects on weighing

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MOISTURE CORRECTION

- Moisture in mix will burn off, too.
- This will count as binder unless corrected
- Correction:
  - Dry mix to a constant mass at 110 ± 5 C prior to testing
  - "Aging"—must still verify that constant mass has been achieved

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

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AASHTO T 329-15

- Temperature now:
  - Within the JMF mixing temperature range
  - If unavailable, use 325 ±25 F
- Initial drying time is 90 ± 5 minutes
- Moisture is now calculated based on *dry* weight of HMA

$$MC = \left[\frac{M_{i(wet)} - M_{i(dry)}}{M_{i(dry)}} \right] X100$$

MC = % moisture
$M_{i(wet)}$ = initial mass of mix, wet
$M_{f(dry)}$ = final mass of mix, dry

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Rounding

- When calculating, round to nearest 0.01% for moisture content, binder content, and C_f
- When comparing to specification, round to nearest binder content 0.1%

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MOISTURE DATA SHEET

MOISTURE CONTENT OF HOT MIX ASPHALT (HMA) by OVEN METHOD
AASHTO T 329-15
(for ignition oven correction purposes)

Project No.	Job No.	Route	County
Technician	Date	Sublot No.	Mix No.
Oven Temp.	Time in	Time out	Interval
		Sample:	Sample:
Pan wt. (g)		340	
Mix + pan wt., moist (g) = (W_{wet})		1840	
Mix + pan wt., dry (g) [Trial 1]		1839	
Mix + pan wt., dry (g) [Trial 2]		1838	
Mix + pan wt., dry (g) [Trial 3] = (W_{dry})		1838	
$\%Moisture = \frac{W_{wet} - W_{dry}}{W_{dry} - pan} \times 100$			

NOTE: All weights to nearest 0.1 gram and % moisture to nearest 0.01%

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MOISTURE TESTING FREQUENCY: Several per Day

- 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

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MOISTURE DATA SHEET

MOISTURE CONTENT OF HOT MIX ASPHALT (HMA) by OVEN METHOD AASHTO T 329-15 (for ignition oven correction purposes)			
Project No.	Job No.	Route	County
Technician	Date	Sublot No.	Mix No.
Oven Temp.	Time in	Time out	Interval
		Sample:	Sample:
Pan wt. (g)		340	
Mix + pan wt., moist (g) = (W_{wet})		1840	
Mix + pan wt., dry (g) [Trial 1]		1839	
Mix + pan wt., dry (g) [Trial 2]		1838	
Mix + pan wt., dry (g) [Trial 3] = (W_{dry})		1838	
$\%Moisture = \frac{W_{wet} - W_{dry}}{W_{dry} - pan} \times 100$			

NOTE: All weights to nearest 0.1 gram and % moisture to nearest 0.01%

MOISTURE TESTING FREQUENCY: Less Often

- Dry weather
- Same stockpiles
- No moisture when tested

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BINDER CONTENT CORRECTIONS

- **Moisture**
- ***Aggregate burn loss***
- Temperature effects on weighing

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Asphalt Binder Correction Factor
(Aggregate Correction Factor)

- To correct for loss of mass during the mix ignition due to aggregate burn-off
- Determined during mix design and then verified by mix designer (usually QC)
- Re-determined if mix design changes (e.g. >5% change in stockpiled aggregate proportions)

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Asphalt Binder Correction Factor (Aggregate Correction Factor), cont'd.

- 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

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Definitions

- M = mass (g)
- $M_{i(dry)}$ = mass of mix before burning, dry already
- M_f = final mass of mix after burning (binder and some aggregate burned off)
- ($M_{i(dry)}$ – M_f) = binder & aggregate burned off
- M_{agg} = initial unburned mass of just the aggregate, dry
- ($M_{i(dry)}$ – $M_{i(agg)}$)= mix mass minus aggregate mass is the mass of binder, initially

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Asphalt Binder Correction Factor (Aggregate Correction Factor), cont'd.

- Lab-produced sample (dry)

$$C_f = Measured - Actual$$

- Math:

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

- 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 temperature

57

CONVECTION OVEN TEMPERATURES

- AASHTO:
  - Normal: 538 *C*
  - High C_F's (>1.0%): 482 *C*
- MoDOT:
  - Normal: 538 *C*
  - High C_F's: if >1.0% try 482 *C*
  - Very high C_F's: if >1.0% at 482 *C*, use 427 *C*

58

Use of C_f

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

C_f=Measured content–Actual content

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

Actual = Measured content - C_f

59

Number of Replicate Specimens

- Use two.
- If the difference in measured asphalt contents is > 0.15%, test 2 more replicates.
- For the four replicates, discard the high and low results.

60

Asphalt Binder Correction Factor (Aggregate Correction Factor) Data Sheet

ASPHALT CONTENT IGNITION METHOD
(AASHTO T 308-10)
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	3000		
Total Dry Mass (g)	5000	5005		
Initial Dry Specimen Mass (g)	2000	2005		
Loss in Weight (g)	125	126		
%AC, measured = M	6.25	6.28		
%AC, actual = A	6.00	6.01		
$\%AC_{diff}$ ($M_1 - M_2$)	0.03	> 0.15%? If so, 2 more replicates		
$C_F = M - A$	0.25	0.27		
C_F, average	0.26			

INFRARED BURN PROFILES

- "Default"- most mixes
- "Option 1" (Less)- for C_f > 1.0% eg. RAP containing dolomite
- "Option 2" (More) – hard to burn mixes

62

Asphalt Binder (Aggregate) Correction Factors

- Anecdotal: Infrared runs ~0.05% higher than convection oven
- AMRL Proficiency samples are comparable

63

Asphalt Binder Correction Factor (Aggregate Correction Factor) Data Sheet

ASPHALT CONTENT IGNITION METHOD
(AASHTO T 308-10)
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	3000		
Total Dry Mass (g)	5000	5005		
Initial Dry Specimen Mass (g)	2000	2005		
Loss in Weight (g)	125	126		
%AC, measured = M	6.25	6.28		
%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	0.25	0.27		
C_F, average	0.26			

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 C_f from the virgin materials test is used as the C_f for the whole mix

64

BINDER CONTENT CORRECTIONS

- Moisture
- Aggregate burn loss
- ***Temperature effects on weighing***

65

CONVECTION OVEN: TEMPERATURE COMPENSATION FACTOR

- 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 weight due to heating***

66

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

67

Second Generation Infrared oven

- No Temperature Correction Factor
- Scale is better insulated from the chamber

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TEST PROCEDURE

- Corrections
- ***Binder content test procedure***

69

REHEATING

EPG 403.1.5

- If a retained sample must be reheated:
  - Warm the sample until workable
  - Spread it in a large pan and reheat—this will minimize the damage caused by reheating

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CONVECTION OVEN TEST PROCEDURE: *Method A*

- 1. Dry specimen at 110 ± 5 °C or determine moisture content (T 329-15). Cool to room temperature.
- 2. Enter the ***chamber set point*** (desired oven temperature).
- 3. Enter the ***asphalt correction factor (C_F)***

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CONVECTION OVEN TEST PROCEDURE: *Method A*

- 4. Weigh the test specimen.

- 5. Enter the ***specimen weight***.
- 6. Place the sample in the oven and compare the weight indicated by the oven scale to that of the external scale the sample was first weighed on (this helps detect if basket is contacting the furnace wall)

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CONVECTION OVEN
TEST PROCEDURE:
Method A

- 7. Burn
- 8. Oven will stop when burn is complete and 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.
- 9. ***You*** must then correct (subtract) for ***moisture*** if started with a wet sample

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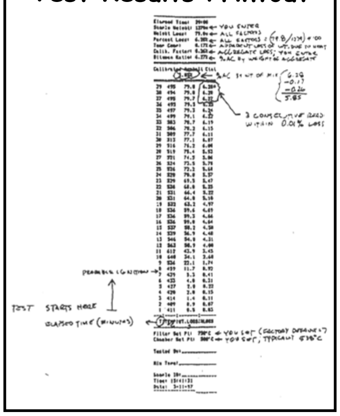
Test Results Printout



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
Basket Assembly + Wet (or dry) Sample Weight (g), [T_i]	4270
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), [$P_b = P_{bcal} - MC$]*	

Test Results Printout

Elapsed Time: 39:00
Sample Weight: 1279g ← YOU ENTER
Weight Loss: 79.8g ← ALL FACTORS
Percent Loss: 6.28% ← ALL FACTORS = (79.8/1279) * 100
Temp Comp: 0.17% ← APPARENT LOSS OF WT. DUE TO HEAT
Calib. Factor: 0.26% ← AGGREGATE LOSS; YOU ENTER
Bitumen Ratio: 6.27% ← %AC by WEIGHT OF AGGREGATE

Calibrated Asphalt Cont
5.85% ← %AC BY WT. OF MIX

6.28
−0.17
−0.26
5.85

T	TEMP	WT.LOSS	%LOSS
39	495	79.8	6.28%
38	494	79.8	6.28
37	495	79.7	6.27
36	495	79.5	6.25
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

3 CONSECUTIVE READ[INGS] WITHIN 0.01% LOSS (readings 39, 38, 37)

PROBABLE IGNITION → (8)

TEST STARTS HERE (1)

ELAPSED TIME (MINUTES) ← T

Filter Set Pt: 750°C ← YOU SET (FACTORY DEFAULT = 7
Chamber Set Pt: 500°C ← YOU SET; TYPICALLY 538°C

Tested By: ____________

Mix Type: ____________

Sample ID: ____________
Time: 15:41:31
Date: 3-11-97

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
Basket Assembly + Wet (or dry) Sample Weight (g), [T_i]			4270
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 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 mass of mix, wet or dry

M_f = final mass of mix

MC = % moisture

C_f = Asphalt Binder Correction Factor (old Aggregate Correction Factor)

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Example Manual Method

- Moisture = 0.05%
- C_f = 0.22%
- Initial wet mass = 5400 g
- Final burned mass (after cooling to room temperature) = 5256 g

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ASPHALT CONTENT IGNITION METHOD (AASHTO T 308-10) METHOD A Manual Weighing Method

Project No.	Job No.	Route	County
Technician	Date	Sublot No.	Mix No.
Empty Basket Assembly Weight (g), $[T_e]$			3000
Initial Basket Assembly + Wet (or dry) Sample Weight (g), $[T_i]$			5400
Initial Wet (or dry) Sample Weight (g), $[W_i = (T_i - T_e)]$			2400
Final Basket Assembly + Burned Sample Weight (g), $[T_f]$			5256
Loss in Weight (g), $[L = T_i - T_f]$			144
% Loss, $[P_L = (L / W_i) \times 100]$			6.00
Aggregate Correction (Calibration) Factor (%), $[C_f]$			-0.22
Calibrated %AC, $[P_{bcal} = P_L - C_f]$			5.78
% Moisture Content, [MC]*			-0.05
% AC, corrected (by weight of mix), $[P_b = P_{bcal} - MC]$*			5.73

- *If non-dried specimen was used (w_i = wet)

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ASPHALT CONTENT IGNITION METHOD (AASHTO T 308-10) METHOD A Manual Weighing Method

Project No.	Job No.	Route	County
Technician	Date	Sublot No.	Mix No.
Empty Basket Assembly Weight (g), [T_e]			3000
Initial Basket Assembly + Wet (or dry) Sample Weight (g), [T_i]			5400
Initial Wet (or dry) Sample Weight (g), [$W_i = (T_i - T_e)$]			2400
Final Basket Assembly + Burned Sample Weight (g), [T_f]			5256
Loss in Weight (g), [$L= T_i - T_f$]			144
% Loss, [$P_L= (L / W_i)$ x100]			6.00
Aggregate Correction (Calibration) Factor (%), [C_f]			-0.22
Calibrated %AC, [$P_{bcal} = P_L – C_f$]			5.78
% Moisture Content, [MC]*			-0.05
% AC, corrected (by weight of mix), [$P_b = P_{bcal} – MC$]*			5.73

- *If non-dried specimen was used (w_i = wet)

TEST PROCEDURE Method B

- 1. Weigh out specimen.
- 2. Burn for about 45 minutes.
- 3. Remove, cool, weigh.
- 4. Burn for another 15 minutes.
- 5. Remove, cool, weigh.
- 6. Keep repeating until 2 consecutive mass weighings do not change by > 0.05%.
- 7. Subtract moisture %.

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Common Testing Errors/Source 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
- Using vent pipe less than 4 in, diameter (NTO clogs more quickly)

80

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

- 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)

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

- 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

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

- 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

83

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

- Wrong chamber set point
- Wrong burn profile
- Weighing on bench balance when specimen is hot

84

OPERATIONAL 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)

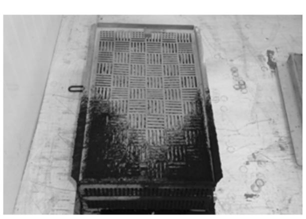
85

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)

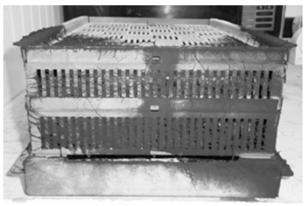
86

NTO Incomplete Burn Pattern: Shingle Mix



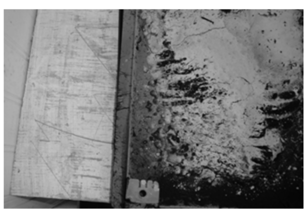
87

Soot



88

Coke



89

SCOPE

- Background
- Binder Content Role in QC/QA
- Sampling
- Test procedure
- ***Field verification***
- Oven verification

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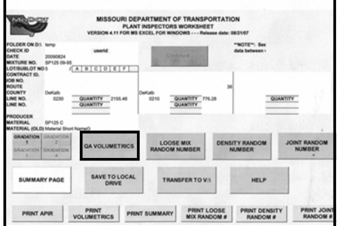
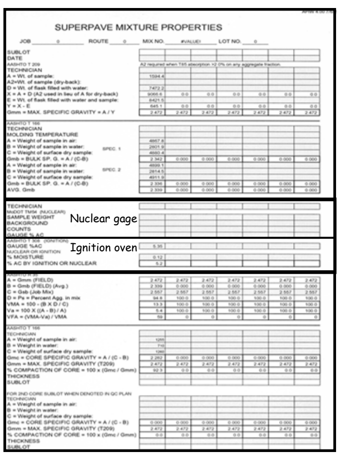
MoDOT SPREADSHEET



91



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						

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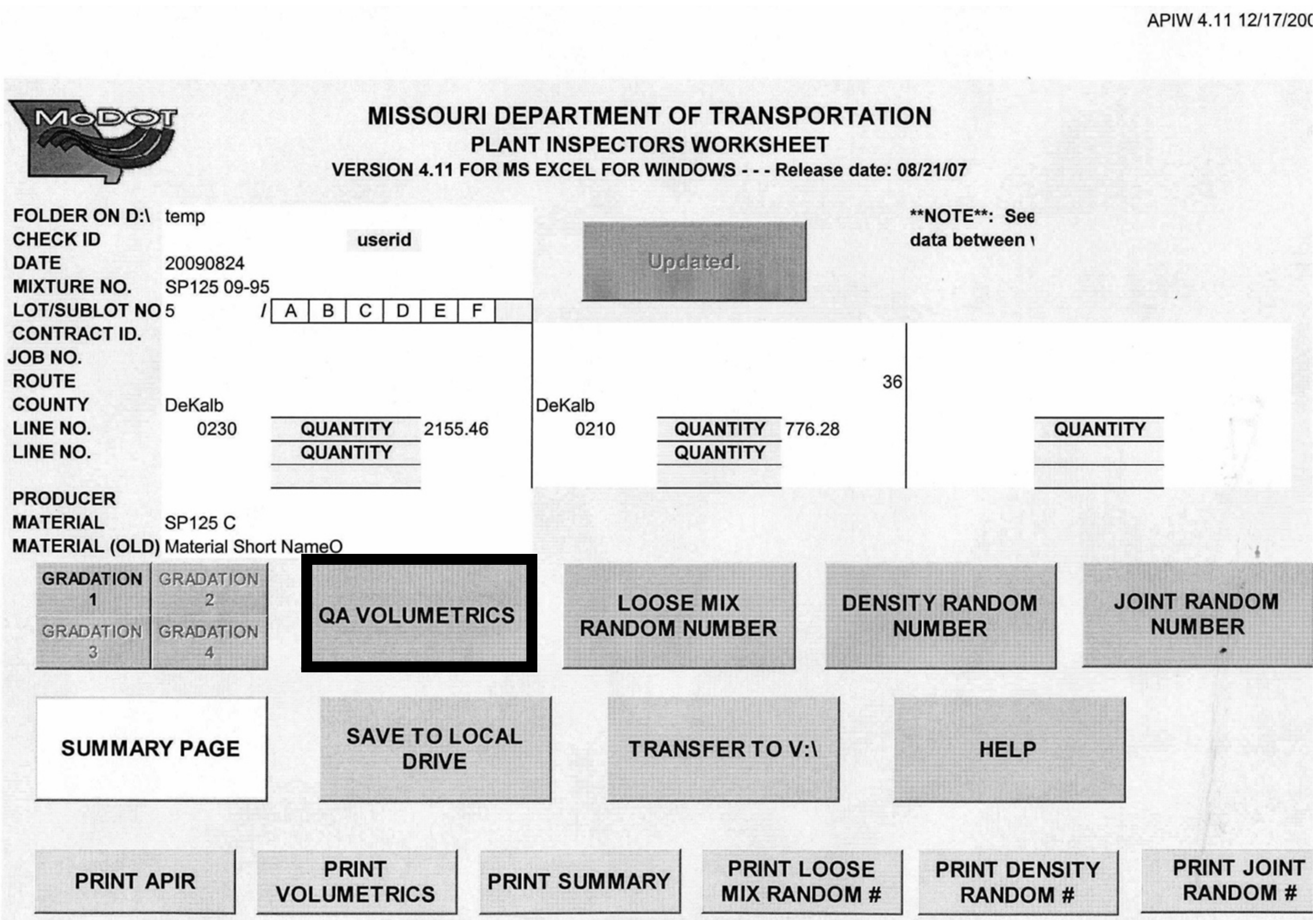
MoDOT SPREADSHEET



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

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

Nuclear gage

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

Ignition oven

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							

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						

MODULE CONTENT

- Binder content of mix
- ***Binder content of RAP***
- Aggregate gradation

94

RAP Binder Content

- Per Spec 403.2.6, 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)

95

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

96

MODULE CONTENT

- Binder content of mix
- Binder content of RAP
- ***Aggregate gradation***

97

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

98

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

99

RAS Gradation

- Ground to minus 3/8 in.
- 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

100

GRADATION SAMPLES

- When determining the ***aggregate (gradation) correction factor*** (AGCF), prepare a aggregate blank (no binder) specimen.
- Do a washed gradation analysis (T 30) of the blank
- Do a washed gradation analysis of the burned HMA specimen (T 30)

101

GRADATION SAMPLES Plus #200 Portion

- Determine a difference for each sieve, each replicate:

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

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

- Calculate the average difference for that sieve (#4) = AGCF for #4
- If the difference on ***any*** sieve exceeds the allowable (see below), then each sieve must have its AGCF applied to each sieve result.
- Allowable differences:
  - ≥ #8: ± 5.0%
  - ≥ #200 to < #8: ± 3.0%
  - ≤#200 ± 0.5%

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GRADATION SAMPLES
Passing the #200 Portion

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

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Example

Sieve	Rep# 1	Rep# 2	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 = 0.1

Compare to ±5.0 OK

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SCOPE

- Background
- Binder Content Role in QC/QA
- Sampling
- Test procedure
- Field verification
- ***Oven verification***

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Example

Sieve	Rep# 1	Rep# 2	Blank	Rep# 1 Diff	Rep# 2 Diff	Avg Diff= AGCF	Allow able
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 = 0.1

Compare to ±5.0 OK

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

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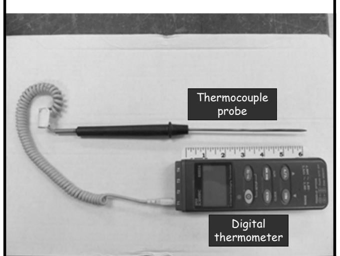
IN-HOUSE VERIFICATION: Temperature

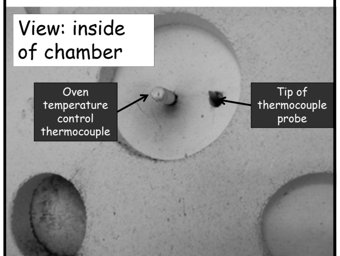
- Equipment



IN-HOUSE VERIFICATION: Temperature

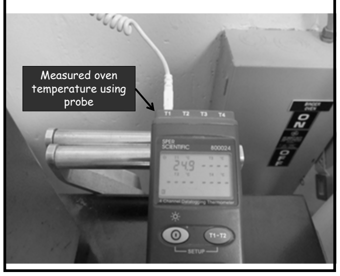
- Insert temperature probe into furnace back; probe is attached to the digital thermometer

IN-HOUSE VERIFICATION:
Temperature



IN-HOUSE VERIFICATION:
Temperature

- Raise temperature to 538C
- Compare digital thermometer reading to Actual Chamber Temperature on oven display
- May wish to calibrate



Calibration

- Follow Owner's Manual
- In "calibration" mode, enter the digital thermometer reading

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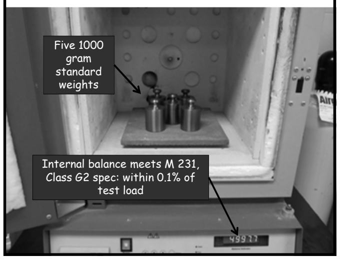
IN-HOUSE VERIFICATION: Internal Balance

- Balance should be checked at ≥ 5 points throughout the range of use
- Example: try nominal 5000g (these masses are Class 5, have a 0.050g tolerance)
- Balance requirement: 0.1% of 5000 is 5g
- 5000-4997.7 = 2.3 < 5 g OK



Balance Calibration

- Refer to operator's manual
- For ***calibration***, get into "calibration" mode, use an 8000g weight on the ceramic plate

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Conventional vs. Infrared

Conventional (NCAT)	Infrared (NTO)
Chamber temperature	Burn profile
240 v	120 or 240 v
Ceramic filter or afterburner	none
Reports burn time to the nearest minute	Reports burn time to the nearest second (thus is not an indication of operator interference)
Asterisk at end of machine stop	No asterisk

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Conventional vs. Infrared

Conventional (NCAT)	Infrared (NTO)
Fan starts when "Start" is pressed	Fan does not start when "Start" is pressed: good for RAP/RAS- won't suck out fines; Bad: odors
	Reduced emissions, but still requires venting
	Requires cleaning more often
	No Temperature Compensation Factor

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SUMMARY

- 1. Sample loose mix every sublot (QC) or every 4 sublots (QA).
- 2. Obtain specimen from quartered sample.
- 3. Specimen size is tied to NMS of gradation.
- 4. Burn
- 5. Loss of mass is the total of burned off binder, water, & aggregate.
- 6. Subtract the loss of aggregate & moisture.
- 7. Remains of the HMA burned specimen may be used for checking gradation.
- RAP binder content required

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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)

MODULE 9
Tensile Strength Ratio (TSR)

Resistance to Compacted Asphalt Mixtures to Moisture Induced Damage

AASHTO T 283

9-21-06
1-29-07
11-9-07
4-24-08
5-13-09
5-14-09
11-18-09
11-17-10
1-19-11
1-23-15
2-26-13
4-23-15
3-6-18
2-19-19

MODULE 9
Tensile Strength Ratio
(TSR)

Resistance to Compacted Asphalt Mixtures to Moisture Induced Damage
AASHTO T 283

9-21-06
1-29-07
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5-14-09
11-18-09
11-17-10
1-19-11
1-23-15
2-26-13
4-23-15
3-6-18
2-19-19

AASHTO T283 Tensile Strength Ratio (TSR)

Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

SCOPE

- ***Background***
- TSR Role in QC/QA
- Sampling
- Test procedure
- Field verification

3

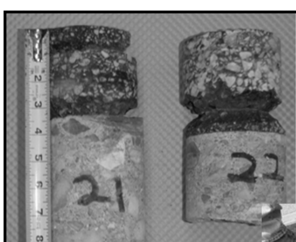
Why are we concerned with Moisture Sensitivity?

- Stripping will result if the bond is broken between the asphalt cement and aggregate.
  - Resulting in pavement:
    - Rutting
    - Shoving
    - Raveling
    - Cracking

4

MOISTURE DAMAGE (STRIPPING)

5



AASHTO TEST METHODS & SPECIFICATIONS

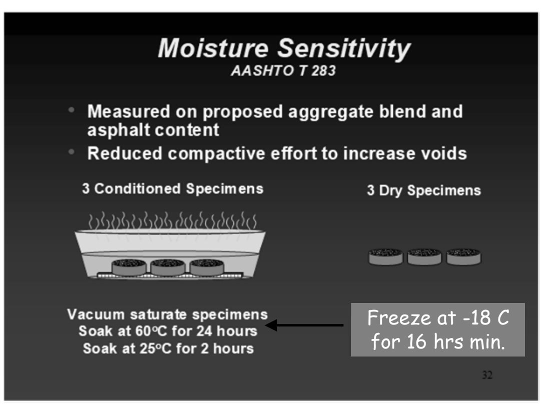
- R35 Volumetric Design Practice
- M323 Volumetric Design Specs
- R30 Mix Conditioning
- T 312 Gyro operation
- T 166 Bulk Sp Gravity of gyro pucks
- T 209 Max Sp Gravity of Voidless Mix (Rice)
- ***T 283 Moisture Sensitivity***
- ***R 47 HMA Sample Splitting***
- ***D 3549 Thickness of Specimens***

7

What is Tensile Strength Ratio?

- Moisture Sensitivity of Asphalt Mixtures
- Affects the structural integrity of a mixture.
- Based on the ratio of the tensile strength of a set of conditioned to a set of unconditioned specimens expressed as a %.

8



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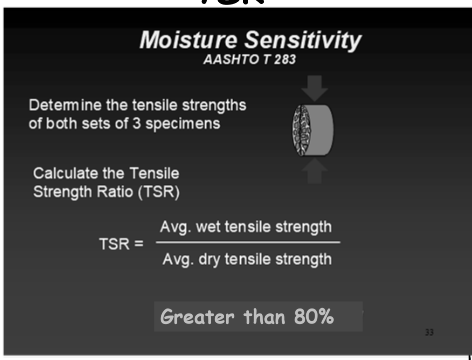
TSR



10

TYPICAL TEST RESULTS

- Range in initial mix design: 40-95+ %

11

SCOPE

- Background
- ***TSR Role in QC/QA***
- Sampling
- Test procedure
- Field verification

12

TSR Role

- ***Mix design/acceptance***
- Field Verification of mix

13

Non-Moisture Sensitive

- The intent is for Superpave and Plant mix be ***non-moisture-sensitive***
  - Superpave- ***must*** be proven through TSR testing
  - Plant mix- ***may*** be required to be proven through TSR testing

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Section 401: BB and BP Mixes

- 401.2.1 (Standard Spec): During mix design, TSR required when PI exceeds 3 for any individual aggregate fraction with 10% or more passing the #30 sieve
- 401.9 (Standard Spec): During production QA checks PI once per project: if for an individual aggregate fraction the PI > 2 points above mix design value, TSR is required

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Section 401: BB and BP Mixes, cont'd.

- Engineering Policy Guide 401.2.3: Additional TSR testing is warranted if: in the field, if the PI of the fine aggregate fractions has significantly increased or the overall quality of the aggregate has changed
- If a source has a history of stripping, MoDOT may require TSR testing during design and/or production

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MIX DESIGN ACCEPTANCE

- TSR ≥ 70% for ***BB and BP*** mixes
- TSR > 80% for ***Superpave*** mixes

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TSR Role

- Mix design/acceptance
- ***Field Verification of mix***

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SUPERPAVE TSR PAY ADJUSTMENT

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

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SCOPE

- Background
- TSR Role in QC/QA
- ***Sampling***
- Test procedure
- Field verification

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Sampling Field TSR QC/QA

- During production, loose mix samples will be taken and quartered as described in EPG Section 403.1.5
- QC has the option of taking loose mix samples from any point in the production process.
- QA samples should be taken from the same point as the QC, although not at the same time

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LOOSE MIX: TSR Sample

- QC: 1 per 10,000 tons
- QA: 1 per 50,000 tons or one per mix (combination of projects)

[contract with several projects with same mix, totaling < 50,000 tons)

- Random locations by spec (not enforced)

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SAMPLING: QC

- QC gets their own TSR sample plus a retained sample for QA
- Depth: full depth of the course (if roadway sample)

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SAMPLING: QA

- QA gets their own “independent” ~250 lb sample, retain 125 lbs

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LOOSE MIX SAMPLING LOCATION

- *ROADWAY**
- *PLANT DISCHARGE**
- *TRUCK*

** Preferred*

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TSR Sampling-Roadway

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CAUTION

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

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TSR SAMPLING
Roadway

- Profiler issues
- Big hole to fill

28

LOOSE MIX SAMPLING LOCATION



- ***ROADWAY****
- ***PLANT DISCHARGE****
- ***TRUCK***

**** Preferred***

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PLANT DISCHARGE

30

PLANT DISCHARGE (Chop Gate-Diverter Chute)

- Divert entire production stream from drum to a loader bucket

- Sample all across the loader bucket, one shovel per box , all boxes
- Repeat until boxes are full
- Cool (beware of dust)
- Close boxes

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PLANT DISCHARGE (Chop Gate-Diverter Chute), cont'd.

- Re-heat material
- Mix all boxes
- Quarter with templates
- Remove quarters to 4 buckets
- Quarter each bucket
- Pull one puck from each quarter

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TSR SAMPLING
DIVERTER CHUTE

- Contamination issues from diesel used to clean the area

33

LOOSE MIX SAMPLING LOCATION

- ***ROADWAY****
- ***PLANT DISCHARGE****
- ***TRUCK***

**** Preferred***



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"Mini-stockpile"

- About 2 tons sampled from silo discharge into a truck
- Dumped
- Back dragged
- Sampled into, say, 4 buckets or boxes
- Back at lab, material is combined, mixed, and quartered , combined into 2 piles
- 4 pucks sampled from each pile


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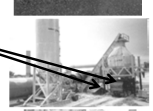
LOOSE MIX SAMPLING LOCATION

- ***ROADWAY****
- ***PLANT DISCHARGE****
- ***TRUCK***

**** Preferred***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Truck Sampling

37

Truck Sampling

CAUTION

- Possible segregation in truck bed
- Sampling methods (eg. length of arms) limit the position of sampling in the truck bed→ non-representative sample
- Safety issues
- Don't leave sample boxes uncovered at this location—may get contaminated with dust and overspray of release agent

39

QUARTERING THE SAMPLE

40

AASHTO R47

- Quartering templates

- Quartering

- "Quartermaster"

- Riffle splitters

- Incremental (loaf)


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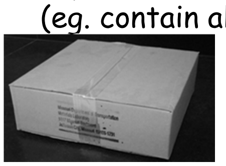
QUARTERMASTER

42

43

QA TSR Sample

- QA inspector will box up 125 lbs loose mix sample and ship to the Central Lab for testing
- Each box should contain as representative a sample as possible (eg. contain all fines, etc)



44

QA TSR Sample, cont'd.

- Central Lab will determine the TSR puck weight to be used from testing one of the boxes
- Central Lab will combine the remaining samples and go through the splitting procedure
- So, field tech needs to know how "Central Lab" will handle (combine) the boxes

45

QA TSR Sample

- Field QA should also retain a 125 lbssample ***(Do not send to Central Lab unless asked for. Discard only after issues of favorable comparison between QC and QA have been determined)***

46

TSR BOX INFO

- Site Manager ID number
- Mix number
- G_{mm} from sublot taken (QC or QA)
- Specimen weight QC is using

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SCOPE

- Background
- TSR Role in QC/QA
- Sampling
- ***Test procedure***
- Field verification

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TSR TEST PROCEDURE

- Determine TSR puck weights
- Compact pucks, run specific gravity
- Run Rice specific gravity
- Calculate air voids
- Break dry pucks
- Condition wet pucks
- Break wet pucks
- Calculate TSR
- Inspect conditioned pucks

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DURING MIX DESIGN
In Addition to Field Verification Steps
(One extra day for lab mix at front end)

- Mixture prepared in lab
- After mixing, place mixture in a pan (one specimen per pan) and cool at room temperature for 2.0 ± 0.5 hrs
- Place in oven on perforated shelf (or on spacers) at 60±3° C for 16 ± 1 hrs

50

PROCEDURE

- The following slides relate to TSR testing of ***field*** samples and to l***ab-mixed*** samples after the first day

51

DAILY PROCEDURE-Outline

- Day 1:
  - Sample, quarter, heat to compaction temperature ± 3°C ***[for lab-mixed, heating time is 2 hr ± 10 min.]***
  - Compact pucks, store at room temperature 24±3hr
    - Run Rice gravity
- Day 2:
  - Determine G_{mb} of pucks
  - Calculate air voids
  - Group into two sets of 3
  - Saturate the Wet set
  - Put Wet set into freezer
  - Start air drying of Dry set (24±3hr)

52

DAILY PROCEDURE Outline, cont'd.

- Day 3:
  - Test Dry set
  - Start high temperature conditioning of Wet set
- Day 4:
  - Test Wet set
  - Calculate TSR

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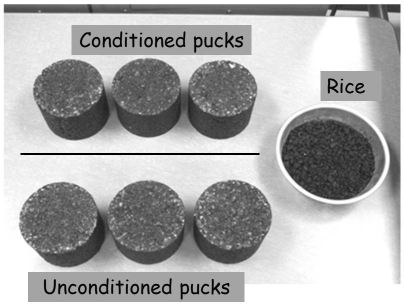
Tender Pucks

TSR



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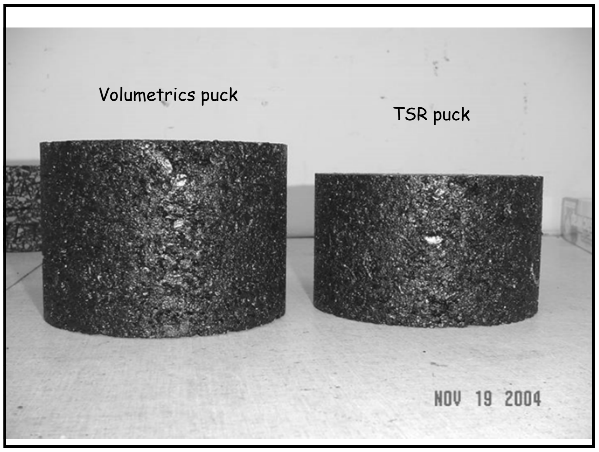

Puck Characteristics

- 95 ± 5 mm tall
- 7.0 ± 0.5% air voids (6.0% SMA)
- Difficult to determine amount of material to place in mold to achieve both requirements
- ***Is trial & error, so need plenty of material, make more than 6 pucks***

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VACUUM SATURATION
Wet Pucks

- Permissible range: 70-80%
- Pre-calculate partially saturated puck weights at 70 and 80%
- By iteration, progressively vacuum & weigh at intervals until puck weight is in the permissible weight range

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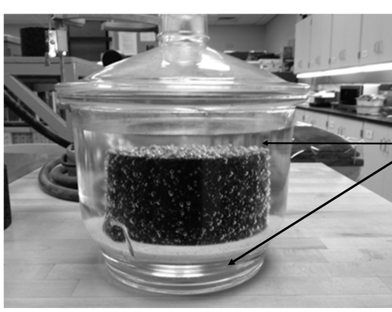
Day 2: Wet Pucks

- Determine the surface dry weight.

59

Apply Vacuum



60

% SATURATION, Cont.

- If the saturation is less than 70%, re-vacuum at 26" mercury vacuum for 1 minute. Slowly remove vacuum. Let puck set in water for 5-10 minutes (if this is omitted, QA & QC may not compare)
- Check saturation
- Repeat as necessary

- ***If the saturation is greater than 80%, puck is considered destroyed and must be discarded.***

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REPORTING

- Report TSR to the nearest whole %

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COMPARISON: QC TO QA

TSR -favorable comparison is when QA and QC results 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

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Need for Extra Material

- One or more pucks not at proper (desired) air voids
- Exceeded 80% saturation & puck discarded
- Tender puck disintegrated during handling (low number of gyrations)
- Sample lost in delivery
- Sample contaminated & discarded

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Need for Extra Material

- QC/QA didn't compare and need to run again
  - Sample/specimens not marked
  - Sample prematurely discarded
  - Initial sample used up, need retained sample

65

MODULE 10A

QUALITY LEVEL ANALYSIS

PAY FACTORS

11-24-06 Revision
11-9-07 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
1-19-11 Revision
3-2-12 Revision
12-18-13 Revision
12-29-14 Revision
2-5-15 Revision
12-9-15 Revision
3-2-16 Revision
12-28-16 Revision
3-6-18 Revision
12-12-18 Revision
3-15-19 Revision
12-17-19 Revision

MODULE 10A

QUALITY LEVEL ANALYSIS

PAY FACTORS

11-24-06 Revision
11-9-07 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
1-19-11 Revision
3-2-12 Revision
12-18-13 Revision
12-29-14 Revision
2-5-15 Revision
12-9-15 Revision
3-2-16 Revision
12-28-16 Revision
3-6-18 Revision
12-12-18 Revision
3-15-19 Revision
12-17-19 Revision

PAY FACTORS

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

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 %

3

PAY FACTORS

- Pay factors (PF's) are numbers that you multiply times the contract unit price to adjust for quality.
- PF's are either *incentives* or *disincentives.*

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

5

PAY FACTORS, cont'd.

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

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

6

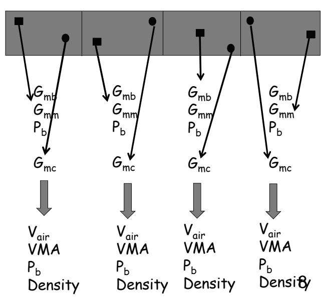
QLA PAY FACTORS

- QLA=Quality Level Analysis
- QLA PF's are calculated for each lot, say 3000 tons of mix.
- Next lot, new PF's.

7

Pay Factors

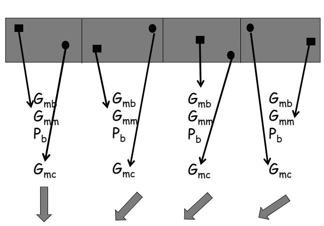
- Lot:



8

Pay Factors

- Lot:



4 V_{air} → $\bar{x}_{air}$, S_{air} → Q_{air} → PWL_{air} → PF_{air}
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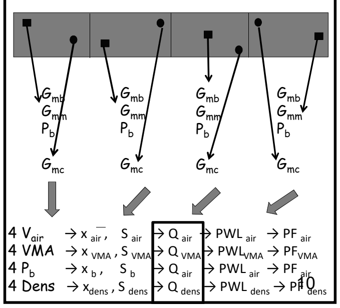
4 P_b → x_b, S_b → Q_{air} → PWL_{air} → PF_{air}
4 Dens → x_{dens}, S_{dens} → Q_{dens} → PWL_{dens} → PF_{dens}

9

Pay Factors

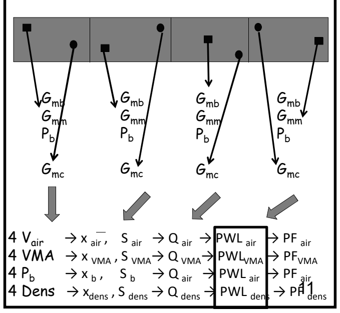
- Lot:



10

Pay Factors

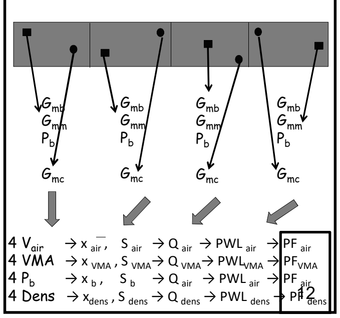
- Lot:



11

Pay Factors

- Lot:



12

QLA PAY FACTORS

- The overall PF_T for the lot is the average of (usually) 4 PF's:
  - $PF_{air\ voids\ (Va)}$
  - PF_{VMA}
  - $PF_{binder\ content\ (Pb)}$
  - $PF_{mat\ density}$

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

13

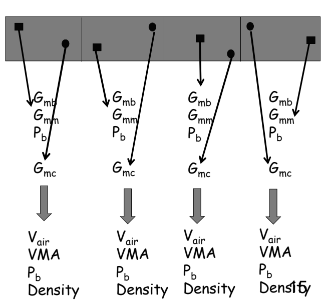
QLA PAY FACTORS

- Each sublot is sampled (50 lbs 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.

14

Tests & Parameters

- Lot:



15

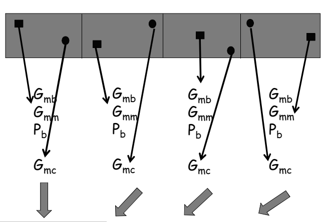
QLA PAY FACTORS

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

16

Means (Averages)

- Lot:



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4 P_b → x_b, S_b → Q_{air} → PWL_{air} → PF_{air}
4 Dens → x_{dens}, S_{dens} → Q_{dens} → PWL_{dens} → PF_{dens}

17

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).***

18

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)

19

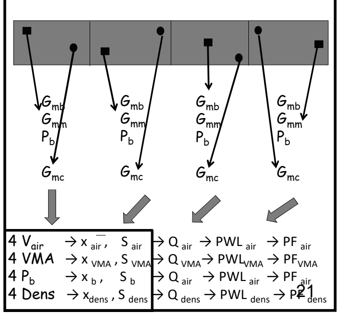
QLA PAY FACTORS

- 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}

20

Standard Deviations

- Lot:



21

QLA PAY FACTORS

- PF's 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!***

22

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

23

QLA PAY FACTORS

- QLA PF's 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.

24

QLA PAY FACTORS

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

25

QLA PAY FACTORS

- The PWL for each test parameter (e.g. air voids) is calculated for each lot:
  - PWL_{air}
  - PWL_{VMA}
  - PWL_{AC}
  - PWL_{dens}
- PWL's are based on the average and standard deviation of each lot's data (say, the 4 sublots).

26

Quality Index (Q)

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

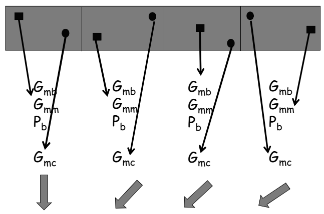
OR

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

27

Quality Index

- Lot:



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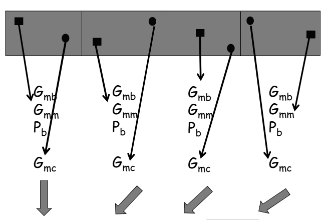
4 P_b → x_b, S_b → Q_{air} → PWL_{air} → PF_{air}
4 Dens → x_{dens}, S_{dens} → Q_{dens} → PWL_{dens} → PF_{dens}

28

Percent Within Limits

- Lot:



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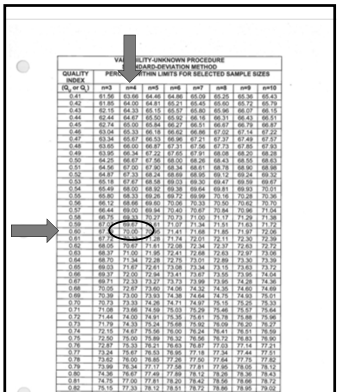
4 VMA → x_{VMA}, S_{VMA} → Q_{VMA} → PWL_{VMA} → PF_{VMA}
4 P_b → x_b, S_b → Q_{air} → PWL_{air} → PF_{air}
4 Dens → x_{dens}, S_{dens} → Q_{dens} → PWL_{dens} → PF_{dens}

29



VARIABILITY-UNKNOWN PROCEDURE
STANDARD-DEVIATION METHOD

QUALITY INDEX (Q_U or Q_L)	PERCENT WITHIN LIMITS FOR SELECTED SAMPLE SIZES							
	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	[illegible]	69.67	[illegible]	71.07	71.34	71.51	71.63	71.72
0.60	[illegible]	70.00	[illegible]	71.41	71.68	71.85	71.97	72.06
0.61	67.72	[illegible]	[illegible]	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

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
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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

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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EXAMPLE

- Let's say we sample 30 batches of concrete, all supposedly the same mix design, and we check air content.
- Attached are the results.

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Frequency Table for Air Content

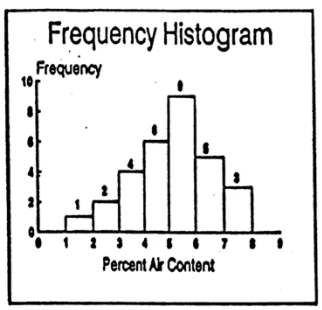
Class Limits	Class Midpoint	Tally	Frequency	Relative Frequency
1.0 - 2.0	1.5	/	1	0.033
2.0 - 3.0	2.5	//	2	0.067
3.0 - 4.0	3.5	////	4	0.133
4.0 - 5.0	4.5	//////	6	0.2
5.0 - 6.0	5.5	/////////	9	0.3
6.0 - 7.0	6.5	/////	5	0.167
7.0 - 8.0	7.5	///	3	0.1
8.0 - 9.0	8.5		0	0

33

EXAMPLE

- *As we can see, there is a higher frequency of test values tending to cluster around 5.5%*
- The % air content vs. frequency of certain test results can be plotted on a histogram.

34

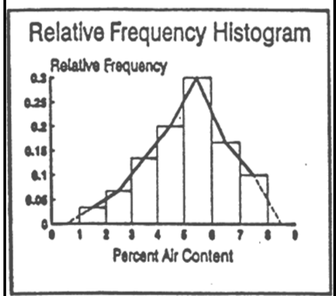


35

EXAMPLE

- The "relative frequency" of each air content interval can be computed; *e.g.* 9 is 30% of all 30 data values.
- We can connect the tops of the histogram bars to form a rough curve.

36

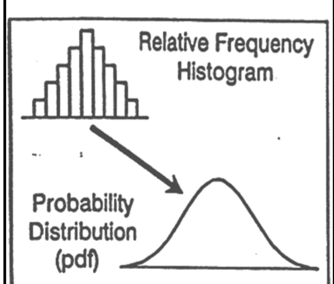


37

PROBABILITY

- Relative frequency histogram data can also be expressed by "probability distributions".
- "Probability" is defined as a measure of chance.
- The sum of all probabilities of all of the possible outcomes is 100%
- The sum of all relative frequencies is 100%.

38

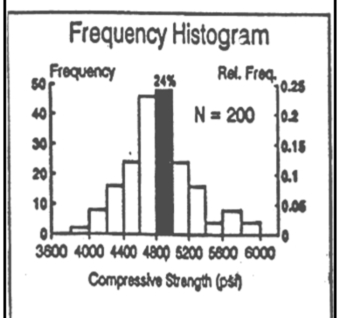


39

PROBABILITY

- *A second example involves a set of data that includes 200 concrete strength tests.*

40



41

PROBABILITY

- As shown, 24% of the tests were between 4800 and 5000 psi.
- If we set the total area under the histogram to be equal to 100%, then 24% of the *area under the curve* would represent test values between 4800 and 5000 psi.
- The *area under the curve* represents *probability.*

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PROBABILITY

- Another way of saying it is if a single test result is randomly selected, there is a 24% *probability* that it is between 4800 and 5000 psi.

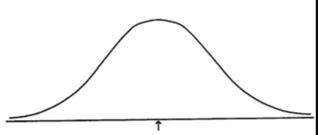
43

PROBABILITY

- The most common probability curve that has a peak in the center and is symmetrical is called a “Normal Distribution”.
- Usually, highway materials test results tend to be normally distributed.

44

The Normal Distribution is the most important for highway materials

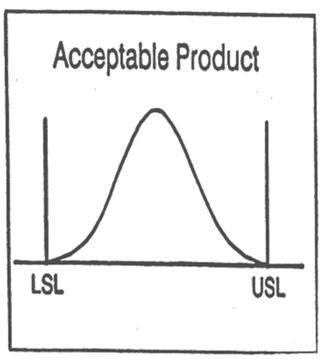


45

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%

46

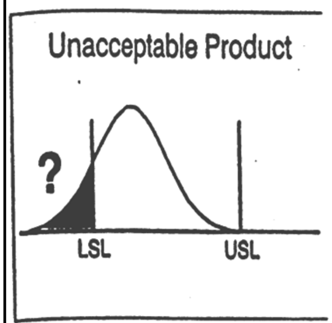


47

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.

48



49

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)"***

50

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.

51

PERCENT WITHIN LIMITS

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

52

Quality Index (Q)

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

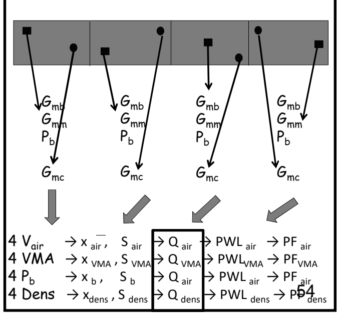
OR

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

53

Pay Factors

- Lot:

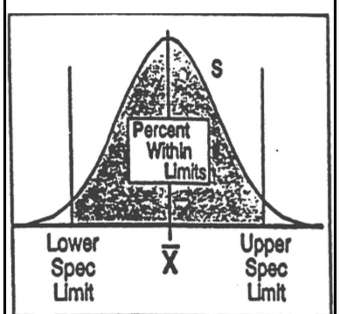


54

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.***

55



56

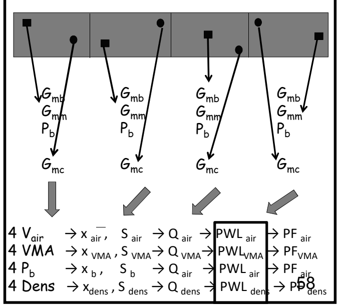
PERCENT WITHIN LIMITS

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

57

Pay Factors

- Lot:

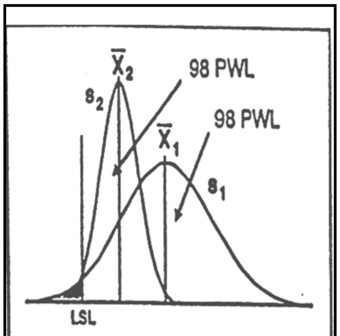


58

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 lot2. The area (probability) in the left-hand tail is equal under both curves.

59



60

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, more slender curve).
- The smaller the standard deviation, the more slender the curve.
- This illustrates that consistency of results is very important.

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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.

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QLA PAY FACTORS

- If $PWL_T < 70\%$:

  $PF = 2(PWL_T)-50$

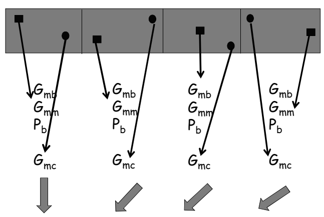
- If $PWL_T \geq 70\%$:

  $PF = 0.50(PWL_T)+55$

63

Pay Factors

- Lot:



4 V_{air} → $\bar{x}_{air}$, S_{air} → Q_{air} → PWL_{air} → PF_{air}
4 VMA → x_{VMA}, S_{VMA} → Q_{VMA} → PWL_{VMA} → PF_{VMA}
4 P_b → x_b, S_b → Q_{air} → PWL_{air} → PF_{air}
4 Dens → x_{dens}, S_{dens} → Q_{dens} → PWL_{dens} → PF_{dens}

64

QLA PAY FACTORS

- The PF's for each test parameter are then averaged to obtain the total PF_T :

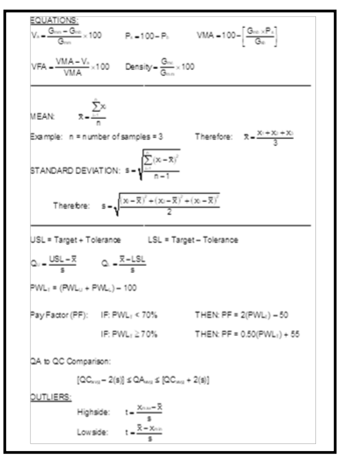
For the traveled way:

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

For non-integral shoulders:

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

65



EQUATIONS:

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

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

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

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

USL = Target + Tolerance 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: $t = \frac{\bar{x} - x_{min}}{s}$

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

QLA PAY FACTORS

- So, back to our original example, if the average of the 4 test parameter PF's 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%.

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EXAMPLE

- See handout of MoDOT spreadsheet
- The Q table is in Section 403, Standard Specifications
- Note: density is now 94.5 ± 2.5%

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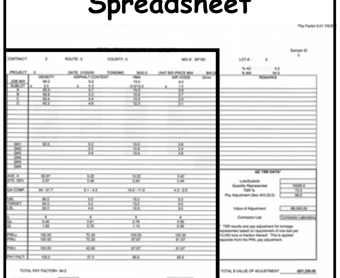
MoDOT Pay Factor Spreadsheet



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MoDOT Pay Factor Spreadsheet

Pay Factor 5.01 7/6/200

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 $45.0

	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

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	13.6	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

$PWL_T = (PWL_U + PWL_L) - 100$

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

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Q_L & PWL_L

VARIABILITY-UNKNOWN PROCEDURE
STANDARD-DEVIATION METHOD

QUALITY INDEX (Q_U or Q_L)	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

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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

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	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

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

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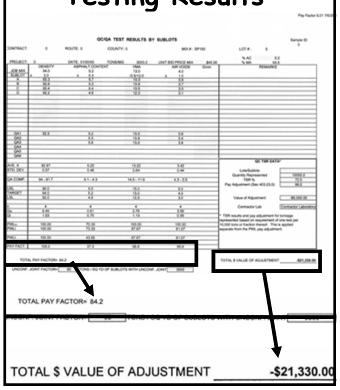
Traveled Way Lot Testing Results



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 PF's for binder content, air voids, VMA, and density)

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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

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
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	

REMARKS

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, cont'd.

- See Module 10a for application
- 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

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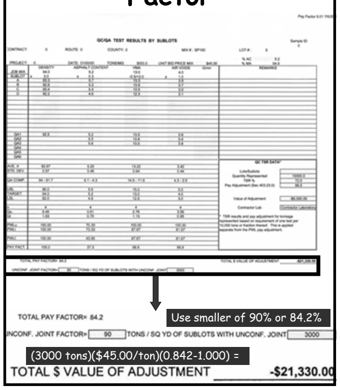
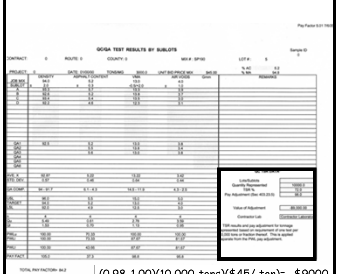
Unconfined Joint Factor



TSR Results



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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

% 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

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

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

TSR Results

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 Laborator

* 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.

(0.02)(10,000 tons)($45/ ton) = -$9000

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New Spreadsheets 2016

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"Asphalt QA" / Analysis / QC

MoDOT Asphalt QA

Main | Quantity | Analysis | Send/Sync | Reports | Help

QC | QC/QA | | Mix Control

QC Imported 2/4/2016 6:28 by Glen Cary

QC Lot #	Sublot	%AC	VMA (Volumetrics)	Va (Volumetrics)	Mat (Density)	Joint (Density)	QC Info Only	Use in Payfactor?
2	QCA	5.1	14.2	3.2	92.2		No	Yes
	QCB	5.1	14.8	3.9	94.5		No	Yes
Sample Records Imported:	QCC	4.8	13.6	3.1	92.2		No	Yes
	QCD	5	14.1	3.2	94.6		No	Yes
15QMAPA6519	QCE	5	13.8	3.2	93.5		No	Yes

	%AC	VMA	Va	Mat
Average	5.0	14.1	3.3	93.4
Std Deviation	0.12	0.45	0.32	1.17

- N = 5 (all QC)

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TSR Results

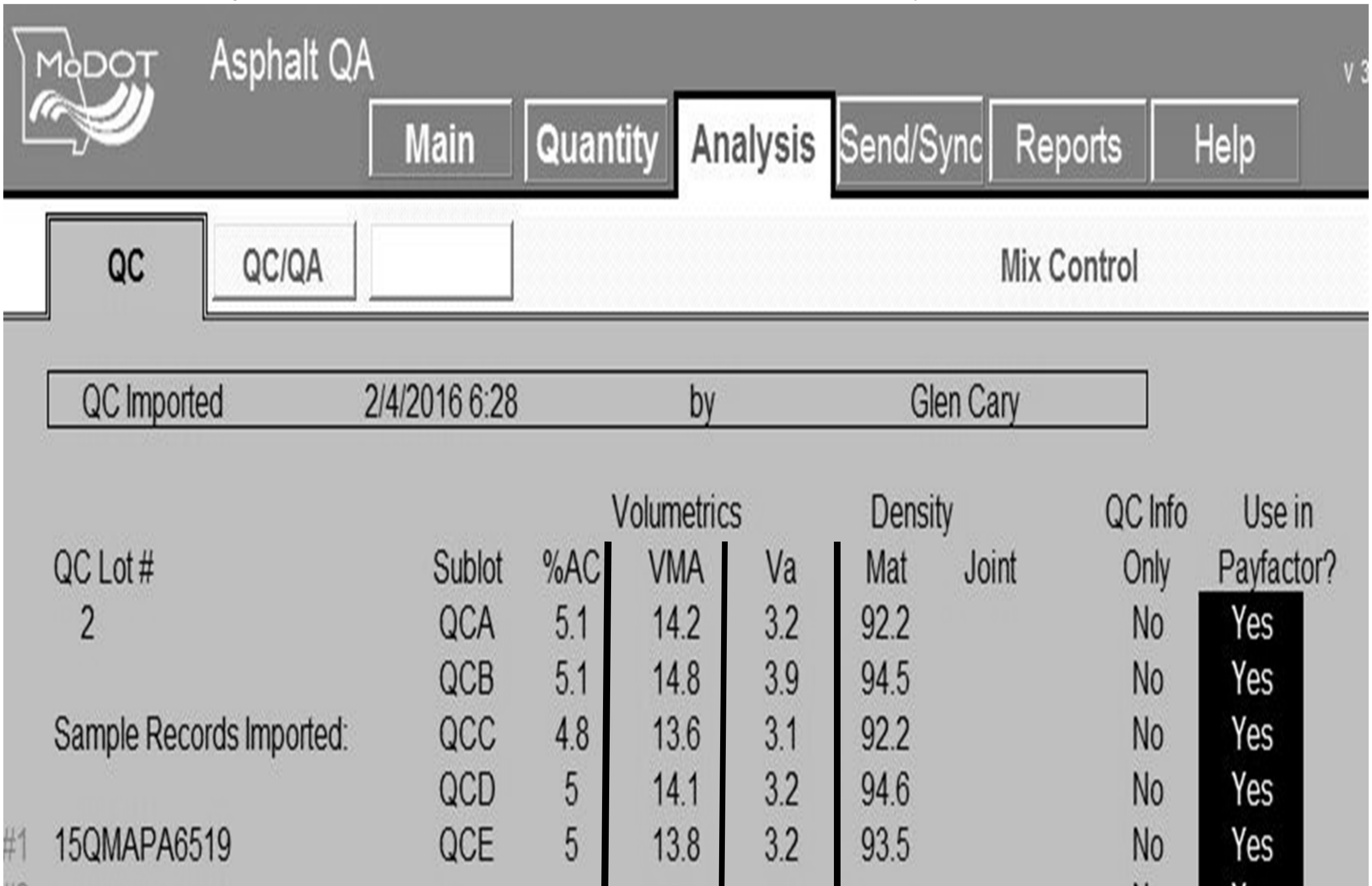
QC TSR DATA*

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.

(0.02)(10,000 tons)($45/ ton) = -$9000

"Asphalt QA" / Analysis / QC

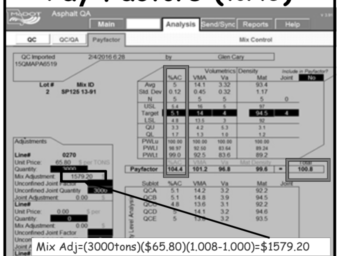


QC Lot #	Sublot	%AC	Volumetrics VMA	Va	Density Mat	Joint	QC Info Only	Use in Payfactor?
2	QCA	5.1	14.2	3.2	92.2		No	Yes
	QCB	5.1	14.8	3.9	94.5		No	Yes
Sample Records Imported:	QCC	4.8	13.6	3.1	92.2		No	Yes
	QCD	5	14.1	3.2	94.6		No	Yes
#1 15QMAPA6519	QCE	5	13.8	3.2	93.5		No	Yes

	%AC	VMA	Va	Mat
▪ *Average*	5.0	14.1	3.3	93.4
▪ Std Deviation	0.12	0.45	0.32	1.17

- N = 5 (all QC)

Pay Factors (%AC)



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

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

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

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

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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

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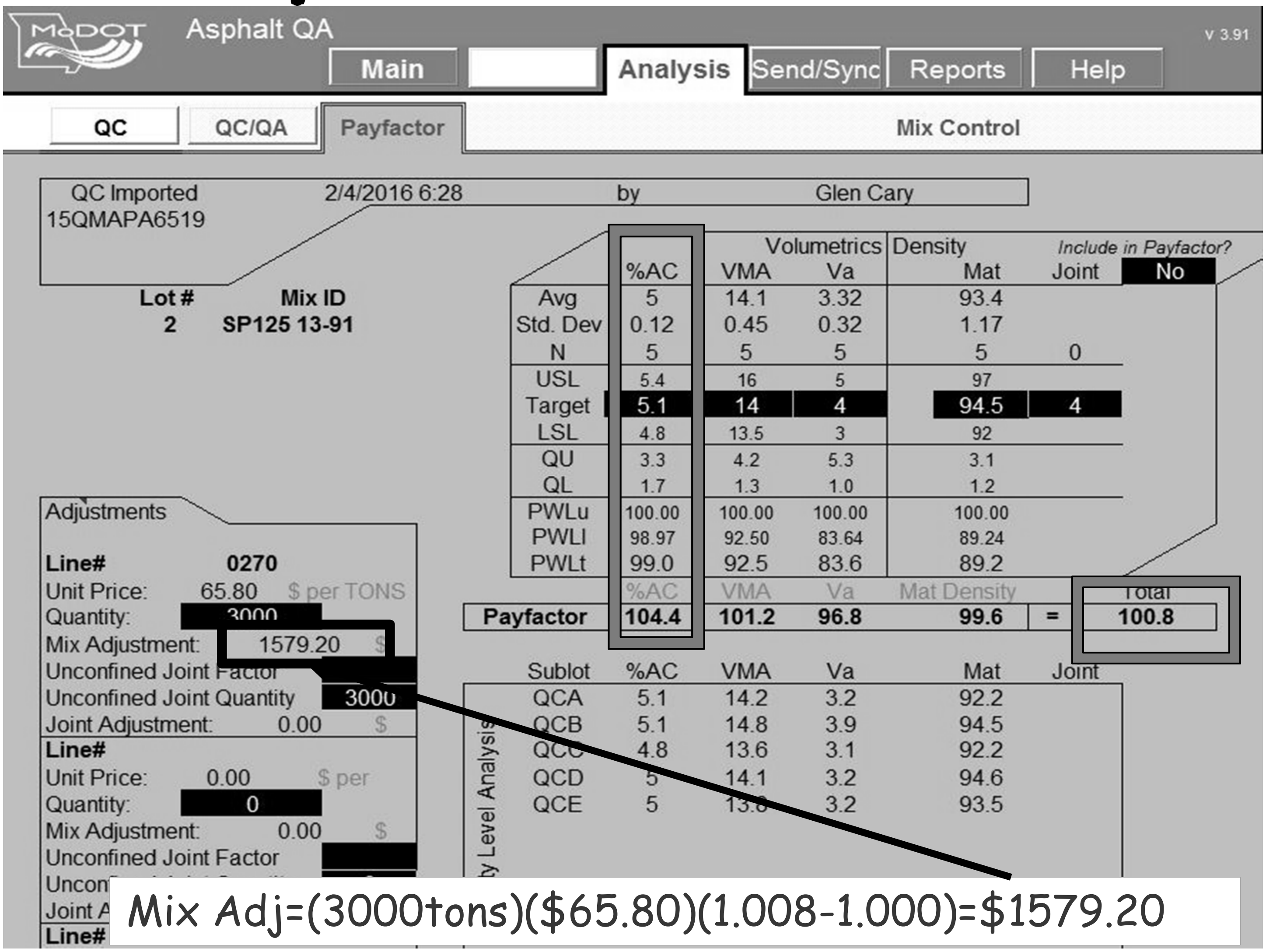
Pay Factors (%AC)



- 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***

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

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

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 PF's for binder content, air voids, and VMA.***

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11.0 PWL Determination Table.

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
0.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
0.01	50.28	50.33	50.36	50.37	50.37	50.38	50.38	50.38
0.02	50.55	50.67	50.71	50.74	50.75	50.76	50.76	50.77
0.03	50.83	51.00	51.07	51.10	51.12	51.13	51.15	51.15
0.04	51.10	51.34	51.42	51.47	51.50	51.51	51.53	51.54
0.05	51.38	51.67	51.78	51.84	51.87	51.89	51.91	51.92
0.06	51.66	52.00	52.14	52.21	52.24	52.27	52.29	52.30
0.07	51.93	52.33	52.49	52.57	52.62	52.65	52.67	52.69
0.08	52.21	52.67	52.85	52.94	52.99	53.02	53.06	53.07
0.09	52.48	53.00	53.20	53.30	53.37	53.40	53.44	53.46
0.10	52.76	53.33	53.56	53.67	53.74	53.78	53.82	53.84
0.11	53.04	53.66	53.91	54.04	54.11	54.16	54.20	54.22
0.12	53.32	54.00	54.27	54.40	54.48	54.54	54.58	54.60
0.13	53.59	54.33	54.62	54.77	54.86	54.91	54.95	54.99
0.14	53.87	54.67	54.98	55.13	55.23	55.29	55.33	55.37
0.15	54.15	55.00	55.33	55.50	55.60	55.67	55.71	55.75
0.16	54.43	55.33	55.68	55.86	55.97	56.04	56.09	56.13
0.17	54.71	55.67	56.04	56.23	56.34	56.42	56.47	56.51
0.18	54.98	56.00	56.39	56.59	56.72	56.79	56.84	56.89
0.19	55.26	56.34	56.75	56.96	57.09	57.17	57.22	57.27
0.20	55.54	56.67	57.10	57.32	57.46	57.54	57.60	57.65
0.21	55.82	57.00	57.45	57.68	57.83	57.91	57.98	58.03
0.22	56.10	57.33	57.81	58.05	58.20	58.29	58.35	58.40
0.23	56.39	57.67	58.16	58.41	58.56	58.66	58.73	58.78
0.24	56.67	58.00	58.52	58.78	58.93	59.04	59.10	59.15
0.25	56.95	58.33	58.87	59.14	59.30	59.41	59.48	59.53
0.26	57.23	58.66	59.22	59.50	59.67	59.78	59.85	59.90
0.27	57.52	59.00	59.57	59.86	60.03	60.15	60.22	60.28
0.28	57.80	59.33	59.93	60.22	60.40	60.51	60.60	60.65
0.29	58.09	59.67	60.28	60.58	60.76	60.88	60.97	61.03
0.30	58.37	60.00	60.63	60.94	61.13	61.25	61.34	61.40
0.31	58.66	60.33	60.98	61.30	61.49	61.62	61.71	61.77
0.32	58.94	60.67	61.33	61.66	61.85	61.98	62.08	62.14
0.33	59.23	61.00	61.68	62.01	62.22	62.35	62.44	62.51
0.34	59.51	61.34	62.03	62.37	62.58	62.71	62.81	62.88
0.35	59.80	61.67	62.38	62.73	62.94	63.08	63.18	63.25
0.36	60.09	62.00	62.73	63.09	63.30	63.44	63.54	63.61
0.37	60.38	62.33	63.08	63.44	63.66	63.80	63.91	63.98
0.38	60.68	62.67	63.42	63.80	64.02	64.17	64.27	64.34
0.39	60.97	63.00	63.77	64.15	64.38	64.53	64.64	64.71
0.40	61.26	63.33	64.12	64.51	64.74	64.89	65.00	65.07

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

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
0.84	75.94	78.00	78.75	79.12	79.33	79.46	79.54	79.61
0.85	76.33	78.33	79.07	79.43	79.63	79.76	79.84	79.90
0.86	76.75	78.66	79.38	79.73	79.92	80.05	80.13	80.19
0.87	77.18	79.00	79.69	80.03	80.22	80.34	80.42	80.47
0.88	77.60	79.33	80.00	80.33	80.51	80.63	80.70	80.76
0.89	78.03	79.67	80.31	80.63	80.81	80.92	80.99	81.04
0.90	78.45	80.00	80.62	80.93	81.10	81.21	81.28	81.33
0.91	78.91	80.33	80.92	81.22	81.38	81.49	81.56	81.61
0.92	79.37	80.67	81.23	81.51	81.67	81.77	81.84	81.88
0.93	79.83	81.00	81.53	81.81	81.95	82.05	82.11	82.16
0.94	80.29	81.34	81.84	82.10	82.24	82.33	82.39	82.43
0.95	80.75	81.67	82.14	82.39	82.52	82.61	82.67	82.71
0.96	81.27	82.00	82.44	82.67	82.80	82.88	82.94	82.97
0.97	81.78	82.33	82.74	82.95	83.07	83.15	83.20	83.24
0.98	82.30	82.67	83.04	83.24	83.35	83.42	83.47	83.50
0.99	82.81	83.00	83.34	83.52	83.62	83.69	83.73	83.77
1.00	83.33	83.33	83.64	83.80	83.90	83.96	84.00	84.03
1.01	83.93	83.66	83.93	84.08	84.17	84.22	84.26	84.28
1.02	84.53	84.00	84.22	84.35	84.43	84.48	84.51	84.53
1.03	85.14	84.33	84.51	84.63	84.70	84.74	84.77	84.79
1.04	85.74	84.67	84.80	84.90	84.96	85.00	85.02	85.04
1.05	86.34	85.00	85.09	85.18	85.23	85.26	85.28	85.29
1.06	87.10	85.33	85.38	85.44	85.49	85.51	85.53	85.53
1.07	87.87	85.67	85.66	85.71	85.74	85.76	85.77	85.77
1.08	88.63	86.00	85.95	85.97	86.00	86.01	86.02	86.02
1.09	89.40	86.34	86.23	86.24	86.25	86.26	86.26	86.26
1.10	90.16	86.67	86.52	86.50	86.51	86.51	86.51	86.50
1.11	91.55	87.00	86.80	86.76	86.75	86.75	86.74	86.73
1.12	92.95	87.33	87.07	87.01	87.00	86.99	86.98	86.96
1.13	94.34	87.67	87.35	87.27	87.24	87.22	87.21	87.20
1.14	95.74	88.00	87.62	87.52	87.49	87.46	87.45	87.43
1.15	97.13	88.33	87.90	87.78	87.73	87.70	87.68	87.66
1.16	100.00	88.66	88.17	88.03	87.96	87.93	87.90	87.88
1.17	100.00	89.00	88.44	88.27	88.20	88.15	88.12	88.10
1.18	100.00	89.33	88.70	88.52	88.43	88.38	88.35	88.32
1.19	100.00	89.67	88.97	88.76	88.67	88.60	88.57	88.54
1.20	100.00	90.00	89.24	89.01	88.90	88.83	88.79	88.76
1.21	100.00	90.33	89.50	89.25	89.12	89.05	89.00	88.97
1.22	100.00	90.67	89.76	89.48	89.35	89.26	89.21	89.17
1.23	100.00	91.00	90.02	89.72	89.57	89.48	89.43	89.38
1.24	100.00	91.34	90.28	89.95	89.80	89.69	89.64	89.58
1.25	100.00	91.67	90.54	90.19	90.02	89.91	89.85	89.79
1.26	100.00	92.00	90.79	90.41	90.23	90.12	90.05	89.99

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	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

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
1.70	100.00	100.00	99.34	98.02	97.38	97.01	96.76	96.59
1.71	100.00	100.00	99.43	98.13	97.48	97.11	96.86	96.69
1.72	100.00	100.00	99.53	98.23	97.58	97.21	96.96	96.78
1.73	100.00	100.00	99.62	98.34	97.69	97.31	97.05	96.88
1.74	100.00	100.00	99.72	98.44	97.79	97.41	97.15	96.97
1.75	100.00	100.00	99.81	98.55	97.89	97.51	97.25	97.07
1.76	100.00	100.00	99.86	98.64	97.98	97.60	97.34	97.16
1.77	100.00	100.00	99.91	98.73	98.07	97.69	97.43	97.25
1.78	100.00	100.00	99.95	98.81	98.17	97.78	97.52	97.33
1.79	100.00	100.00	100.00	98.90	98.26	97.87	97.61	97.42
1.80	100.00	100.00	100.00	98.99	98.35	97.96	97.70	97.51
1.81	100.00	100.00	100.00	99.06	98.43	98.04	97.78	97.59
1.82	100.00	100.00	100.00	99.14	98.51	98.12	97.86	97.67
1.83	100.00	100.00	100.00	99.21	98.58	98.19	97.93	97.75
1.84	100.00	100.00	100.00	99.29	98.66	98.27	98.01	97.83
1.85	100.00	100.00	100.00	99.36	98.74	98.35	98.09	97.91
1.86	100.00	100.00	100.00	99.42	98.81	98.42	98.16	97.98
1.87	100.00	100.00	100.00	99.48	98.87	98.49	98.23	98.05
1.88	100.00	100.00	100.00	99.53	98.94	98.55	98.30	98.11
1.89	100.00	100.00	100.00	99.59	99.00	98.62	98.37	98.18
1.90	100.00	100.00	100.00	99.65	99.07	98.69	98.44	98.25
1.91	100.00	100.00	100.00	99.69	99.13	98.75	98.50	98.31
1.92	100.00	100.00	100.00	99.73	99.18	98.81	98.56	98.37
1.93	100.00	100.00	100.00	99.77	99.24	98.87	98.62	98.44
1.94	100.00	100.00	100.00	99.81	99.29	98.93	98.68	98.50
1.95	100.00	100.00	100.00	99.85	99.35	98.99	98.74	98.56
1.96	100.00	100.00	100.00	99.87	99.39	99.04	98.79	98.61
1.97	100.00	100.00	100.00	99.90	99.44	99.09	98.84	98.67
1.98	100.00	100.00	100.00	99.92	99.48	99.14	98.90	98.72
1.99	100.00	100.00	100.00	99.95	99.53	99.19	98.95	98.78
2.00	100.00	100.00	100.00	99.97	99.57	99.24	99.00	98.83
2.01	100.00	100.00	100.00	99.98	99.60	99.28	99.05	98.88
2.02	100.00	100.00	100.00	99.98	99.64	99.32	99.09	98.92
2.03	100.00	100.00	100.00	99.99	99.67	99.37	99.14	98.97
2.04	100.00	100.00	100.00	99.99	99.71	99.41	99.18	99.01
2.05	100.00	100.00	100.00	100.00	99.74	99.45	99.23	99.06
2.06	100.00	100.00	100.00	100.00	99.76	99.48	99.27	99.10
2.07	100.00	100.00	100.00	100.00	99.79	99.51	99.30	99.14
2.08	100.00	100.00	100.00	100.00	99.81	99.55	99.34	99.18
2.09	100.00	100.00	100.00	100.00	99.84	99.58	99.37	99.22
2.10	100.00	100.00	100.00	100.00	99.86	99.61	99.41	99.26
2.11	100.00	100.00	100.00	100.00	99.88	99.64	99.44	99.29
2.12	100.00	100.00	100.00	100.00	99.89	99.66	99.47	99.32

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**
2.13	100.00	100.00	100.00	100.00	99.91	99.69	99.51	99.36
2.14	100.00	100.00	100.00	100.00	99.92	99.71	99.54	99.39
2.15	100.00	100.00	100.00	100.00	99.94	99.74	99.57	99.42
2.16	100.00	100.00	100.00	100.00	99.95	99.76	99.59	99.45
2.17	100.00	100.00	100.00	100.00	99.96	99.78	99.62	99.48
2.18	100.00	100.00	100.00	100.00	99.97	99.80	99.64	99.50
2.19	100.00	100.00	100.00	100.00	99.98	99.82	99.67	99.53
2.20	100.00	100.00	100.00	100.00	99.99	99.84	99.69	99.56
2.21	100.00	100.00	100.00	100.00	99.99	99.85	99.71	99.58
2.22	100.00	100.00	100.00	100.00	99.99	99.87	99.73	99.61
2.23	100.00	100.00	100.00	100.00	100.00	99.88	99.75	99.63
2.24	100.00	100.00	100.00	100.00	100.00	99.90	99.77	99.66
2.25	100.00	100.00	100.00	100.00	100.00	99.91	99.79	99.68
2.26	100.00	100.00	100.00	100.00	100.00	99.92	99.80	99.70
2.27	100.00	100.00	100.00	100.00	100.00	99.93	99.82	99.72
2.28	100.00	100.00	100.00	100.00	100.00	99.94	99.83	99.73
2.29	100.00	100.00	100.00	100.00	100.00	99.95	99.85	99.75
2.30	100.00	100.00	100.00	100.00	100.00	99.96	99.86	99.77
2.31	100.00	100.00	100.00	100.00	100.00	99.96	99.87	99.78
2.32	100.00	100.00	100.00	100.00	100.00	99.97	99.88	99.80
2.33	100.00	100.00	100.00	100.00	100.00	99.97	99.90	99.81
2.34	100.00	100.00	100.00	100.00	100.00	99.98	99.91	99.83
2.35	100.00	100.00	100.00	100.00	100.00	99.98	99.92	99.84
2.36	100.00	100.00	100.00	100.00	100.00	99.98	99.93	99.85
2.37	100.00	100.00	100.00	100.00	100.00	99.99	99.93	99.86
2.38	100.00	100.00	100.00	100.00	100.00	99.99	99.94	99.87
2.39	100.00	100.00	100.00	100.00	100.00	100.00	99.94	99.88
2.40	100.00	100.00	100.00	100.00	100.00	100.00	99.95	99.89
2.41	100.00	100.00	100.00	100.00	100.00	100.00	99.96	99.90
2.42	100.00	100.00	100.00	100.00	100.00	100.00	99.96	99.91
2.43	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.91
2.44	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.92
2.45	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.93
2.46	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.94
2.47	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.94
2.48	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.95
2.49	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.95
2.50	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96
2.51	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96
2.52	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97
2.53	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97
2.54	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98
2.55	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98

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

Numbers in the body of this table are estimates of percent within limits (PWL) corresponding to specific values of Q, the QUALITY INDEX. For Q values less than zero, subtract the table value from 100.

MODULE 10B

QUALITY LEVEL ANALYSIS

FAVORABLE AND UNFAVORABLE COMPARISON

11-24-06 Revision
11-9-07 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
1-19-11 Revision
3-2-12 Revision
12-18-13 Revision
12-29-14 Revision
2-5-15 Revision
12-9-15 Revision
3-2-16 Revision
12-28-16 Revision
3-6-18 Revision
12-12-18 Revision
3-15-19 Revision
12-17-19 Revision

MODULE 10B

QUALITY LEVEL ANALYSIS

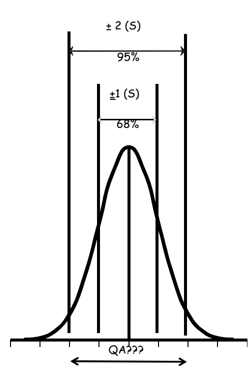
FAVORABLE AND UNFAVORABLE COMPARISON

11-24-06 Revision
11-9-07 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
1-19-11 Revision
3-2-12 Revision
12-18-13 Revision
12-29-14 Revision
2-5-15 Revision
12-9-15 Revision
3-2-16 Revision
12-28-16 Revision
3-6-18 Revision
12-12-18 Revision
3-15-19 Revision
12-17-19 Revision

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 in with QC's)
  - If not, add QA's result to QC's to include it in the population

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:

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

  Or within ½ of the specification tolerance.

Whichever is greater

This applies to air voids, VMA, %AC, and mat density

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Comparison QA to QC-*Example*

- 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?

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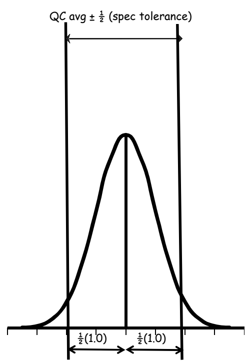
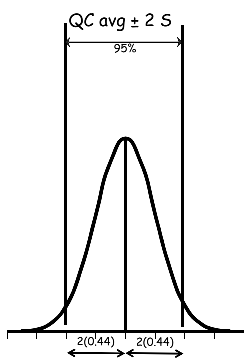
Comparison QA to QC-Example, cont'd.

First, should you use 2 (S) or ½ the spec tolerance?

- 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***

6

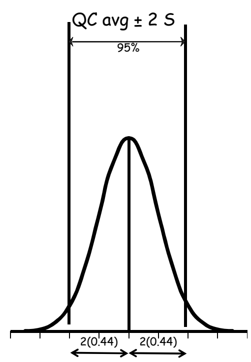




Comparison QA to QC-Example, cont'd.

- 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 this calculation had turned out to be less than 0.5%, the 0.5% would be used.

9



Comparison QA to QC-Example, 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

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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

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HALF SPEC RANGE:

EPG 403.1.21

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

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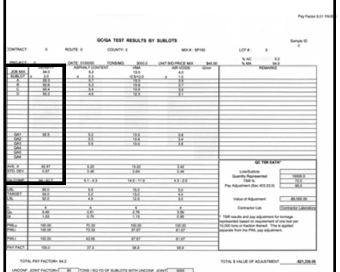
QC: QA Comparison



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		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

91.7 < 92.87 < 94.0
ok

15

QC: QA Comparison

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

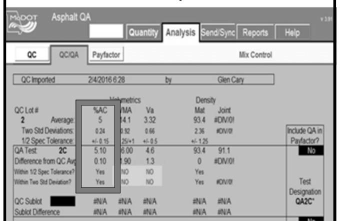
TOTAL $ VALUE OF ADJUSTMENT **-$21,330.00**

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

	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

91.7 < 92.87 < 94.0
ok

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**

16

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 extened periods

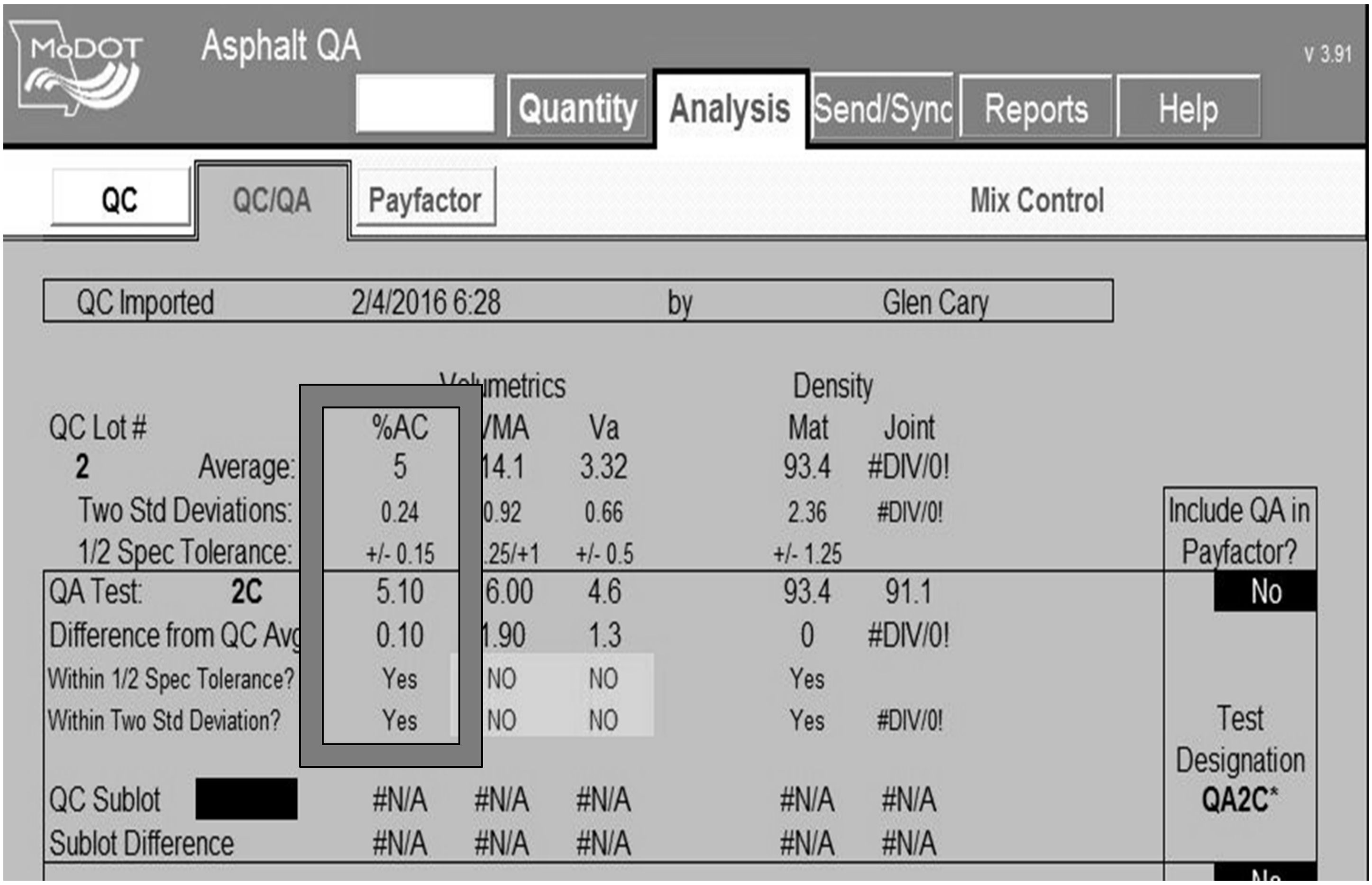
17

QLA

- WHAT IF QA FALLS OUTSIDE OF THE QC RANGE???
- "***UNFAVORABLE COMPARISON***"
- See FAQ (also in EPG)

18

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**

Example: QA Pb is Suspect
First Comparison

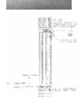
Example 1- QA Pb.xls				Initial QA results:	
				Pb	4.1
				Gmm	2.472
Initial Comparison:				Gmb	2.381
Target Pb=		5.2		Gsb	2.634
QC		5.7		Va	3.7
"		5.2		VMA	13.3
"		5.4			
"		5.2			
QC avg		5.38			
QC S		0.24			
Range,lower		4.90			
Range,upper		5.85			
QA		4.1			
Fit?		no			
		unfavorable			

19

UNFAVORABLE COMPARISON:
Case: QA Binder Content

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






20

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] (mean & S are now different)

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

↓

New PWL

↓

New PF

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			
Range,upper		5.85			
QA		4.1			
Fit?		no			
		unfavorable			

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:

22

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)

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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

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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:

UNFAVORABLE COMPARISON Loose Mix cont'd.

- Favorable comparisons between loose mix splits (original vs. retained) is defined as:
  - G_{mm}: within 0.005
  - G_{mb}: within 0.010
  - P_b: within 0.1%
- If this step verifies that all 3 ***original test results are valid***, keep using the original results.

Step 3a:	QA		
	Retained	Original:	Close?
Pb	4.1	4.1	yes
Gmm	2.475	2.472	yes
Gmb	2.388	2.381	yes

UNFAVORABLE COMPARISON
Loose Mix cont'd.

- Add QA's independent results to the 3 data sets (Pb, VMA, Va), now n = (4 + 1) = 5
- Re-run all 3 PWL analyses (this is shown in Step 2, previous slide 22)

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

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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).

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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	

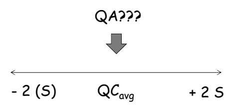
27

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	

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)

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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

29

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

30

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

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

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

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

31

Unfavorable Core Comparison

32

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
	unfavorabl	

33

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
	unfavorabl	

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.

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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

35

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

36

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

37

CORES. Cont'd.

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

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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

39

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

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

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

40

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)

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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

MODULE 10C

QUALITY LEVEL ANALYSIS

MISCELLANEOUS

11-24-06 Revision
11-9-07 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
1-19-11 Revision
3-2-12 Revision
12-18-13 Revision
12-29-14 Revision
2-5-15 Revision
12-9-15 Revision
3-2-16 Revision
12-28-16 Revision
3-6-18 Revision
12-12-18 Revision
2-8-19 Revision
12-17-19 Revision

MODULE 10C

QUALITY LEVEL ANALYSIS

MISCELLANEOUS

11-24-06 Revision
11-9-07 Revision
1-2-09 Revision
4-22-09 Revision
11-18-09 Revision
11-17-10 Revision
1-19-11 Revision
3-2-12 Revision
12-18-13 Revision
12-29-14 Revision
2-5-15 Revision
12-9-15 Revision
3-2-16 Revision
12-28-16 Revision
3-6-18 Revision
12-12-18 Revision
2-8-19 Revision
12-17-19 Revision

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

2

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 example

3

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)

4

ASTM E-178 Dealing with Outlying Observations

Example

G_{mm} – 2.474, 2.478, 2.484, 2.522

$\bar{x} = 2.490$

$s = 0.022$

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

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

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.

5

DISPUTE ESCALATION

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

6

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.

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

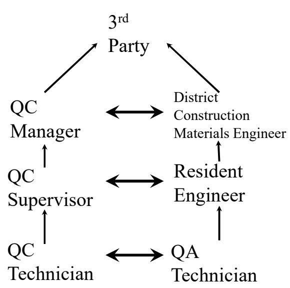
$$T_1 = \frac{(\bar{x} - x_1)}{s} = \frac{(2.490 - 2.474)}{0.022} = 0.727 \quad < 1.463$$

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.

Conflict Resolution
Example



7

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

8

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)

9

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)

TSR PAY ADJUSTMENT

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

10

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

11

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

12

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

13

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%).

14

SMOOTHNESS PAY ADJUSTMENT

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

15

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

16

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

17

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

18

REMOVE & REPLACE

- Replacement mix will be sampled & tested to calculate PWL

19

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.

20

SUMMARY

- 4. The PF_T is the average of the PF's for V_a, VMA, P_b, density (traveled way).
- 5. Standard deviation is a measure of variability.
- 6. More variability, bigger standard deviation, wider and flatter curve, more chance of material being above or below the LSL or USL.

21

SUMMARY

- 7. PF's are based on PWL's-probability that a certain amount of material is within the LSL and USL.
- 8. PWL's are found in Q tables. Q's are calculated from the lot's mean and standard deviation.

22

SUMMARY

- 9. QA results must be within 2 standard deviations (or 1/2 of the specification tolerance, ***whichever is greater***) of the QC results in order for QC results to be used to calculate PWL's.
- 10. Pay adjustment factor types include QLA, TSR, Density, and Smoothness.

23

MODULE 10D

QUALITY LEVEL ANALYSIS

PERFORMANCE TESTING

12-12-18 Version
12-17-19 Revision

MODULE 10D

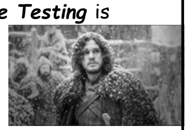
QUALITY LEVEL ANALYSIS

PERFORMANCE TESTING

12-12-18 Version
12-17-19 Revision

GAME OF SPECS

- ***Performance Testing*** is coming



- May 2018

2

CRACKING & RUTTING

- ***Fatigue cracking-*** "Flexibility Index (FI)" OR "Ideal CT"

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

3

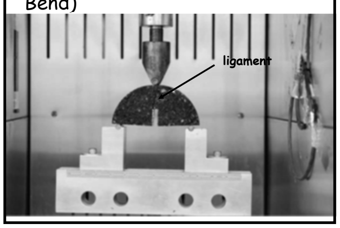
PERFORMANCE TESTING

- ***Fatigue Cracking***
- Rutting

4

FLEXIBILITY INDEX

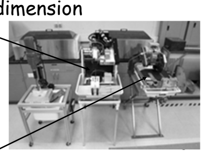
- Capacity to resist cracking
- Intermediate temperatures (***fatigue cracking***)
- SCB specimen (Semi Circular Bend)



Flexibility Index
Specimen Preparation

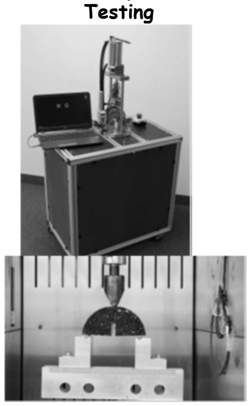
- Gyro-compacted

- Sawn to dimension



- Notched

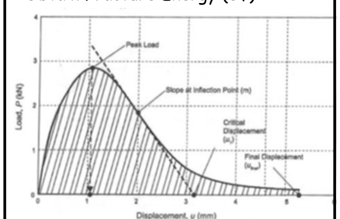
Flexibility Index
Testing



7

FLEXIBILITY INDEX

- Illinois Test Procedure 495 (IFIT)
- Run at intermediate temperature (25 ± 0.5° C)
- Apply load, measure displacement
- Obtain Fracture Energy (Gf)



$$Gf = \frac{Wf x 10^6}{Area_{ligament}}$$

$$FI = \frac{0.01 x Gf}{m}$$

8

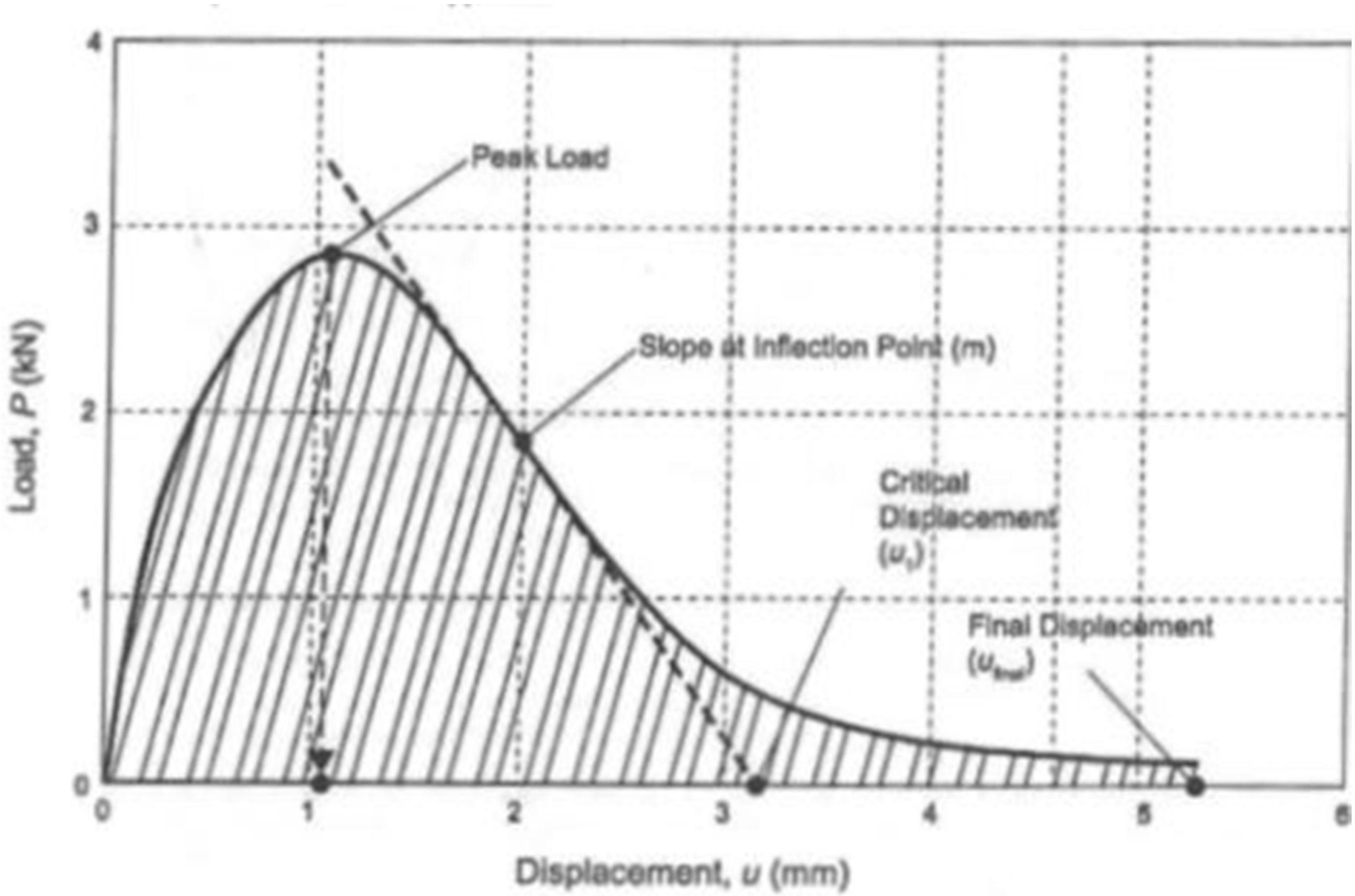
QC/QA
2018 Season

- QC: 1 per 10,000 tons
- QA: 1 per 10,000 tons
- 2% incentive if both tests are in
- 1% incentive if one test is in and the other is not deficient
- 0% incentive if either is deficient
- No disincentives
- Favorable comparison: QA and QC are within 30%

9

FLEXIBILITY INDEX

- Illinois Test Procedure 495 (IFIT)
- Run at intermediate temperature (25 ± 0.5° C)
- Apply load, measure displacement
- Obtain Fracture Energy (Gf)



$$Gf = \frac{Wfx10^6}{Area_{ligament}}$$

$$FI = \frac{0.01xGf}{m}$$

Flexibility Index
Job Special Provision
2018 Season

401 BP Only	402	403 SMA	403 Non-SMA, NMAS <190 mm	% Pay
>5	>5	>20	>5	101
<2	<2	<6	<2	Deficient

10

Alternate Cracking Test: "IDEAL-CT"
CT = Cracking Test

Test temperature: 25 °C
Loading rate: 50mm/min.
Specimen: cylindrical specimen without cutting, gluing, instrumentation, drilling, and notching.

- Much Simpler specimen prep
- ASTM D8225

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IDEAL-CT

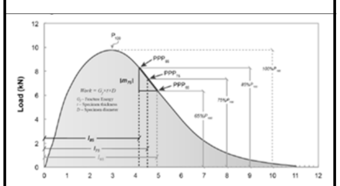


Figure 2. *Illustration of the PPP_{75} Point and Its Slope $|m_{75}|$*

Gf=Area under curve/tD

For non-62 mm thick specimens: $CT_{Index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$

12

IDEAL-CT

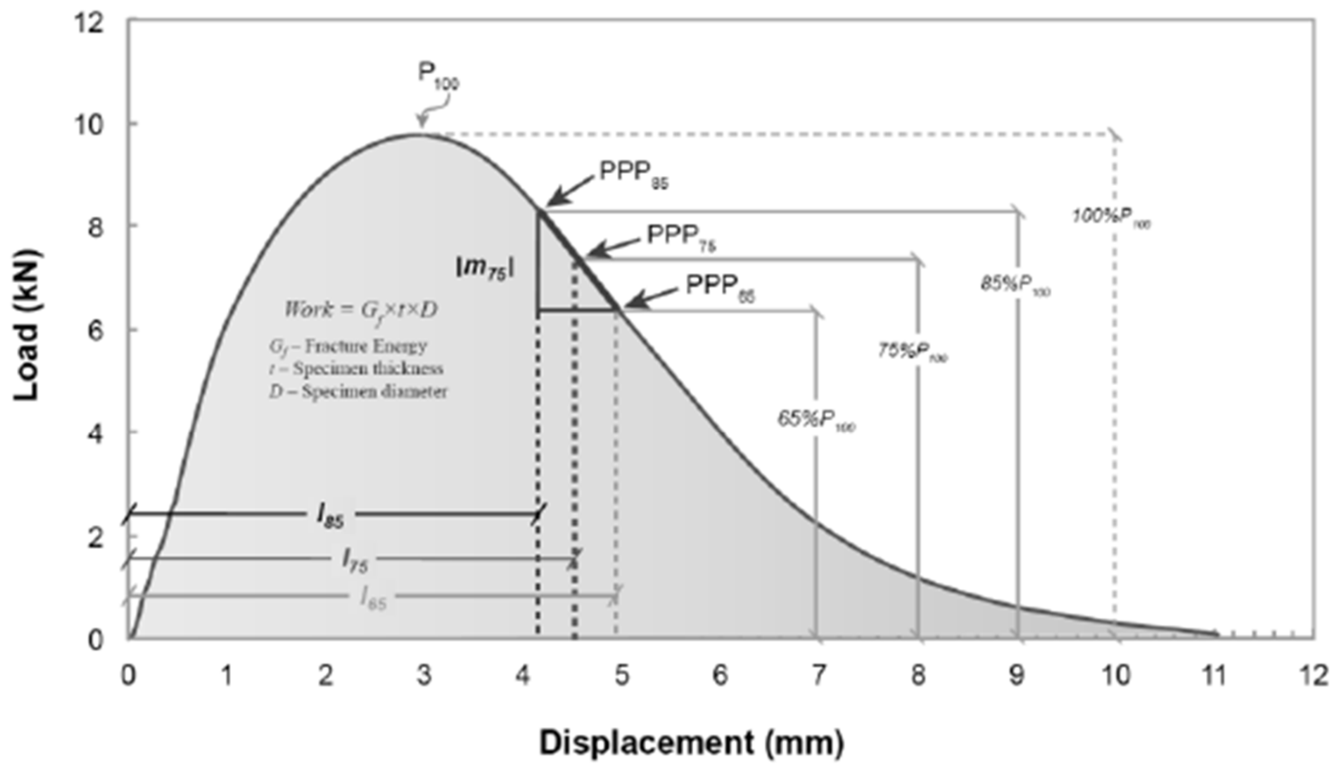


Figure 2. *Illustration of the PPP₇₅ Point and Its Slope* $|m_{75}|$

Gf=Area under curve/tD

For non-62 mm thick specimens: $CT_{Index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$

PERFORMANCE TESTING

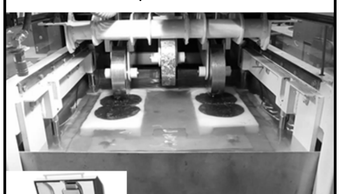
- Fatigue Cracking
- ***Rutting***

13

Hamburg Wheel Tracker

AASHTO T 324

- Capacity to resist rutting (and stripping)
- Warm temperatures



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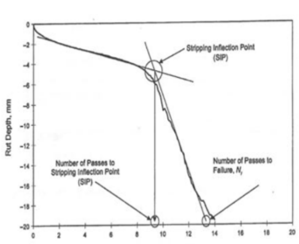
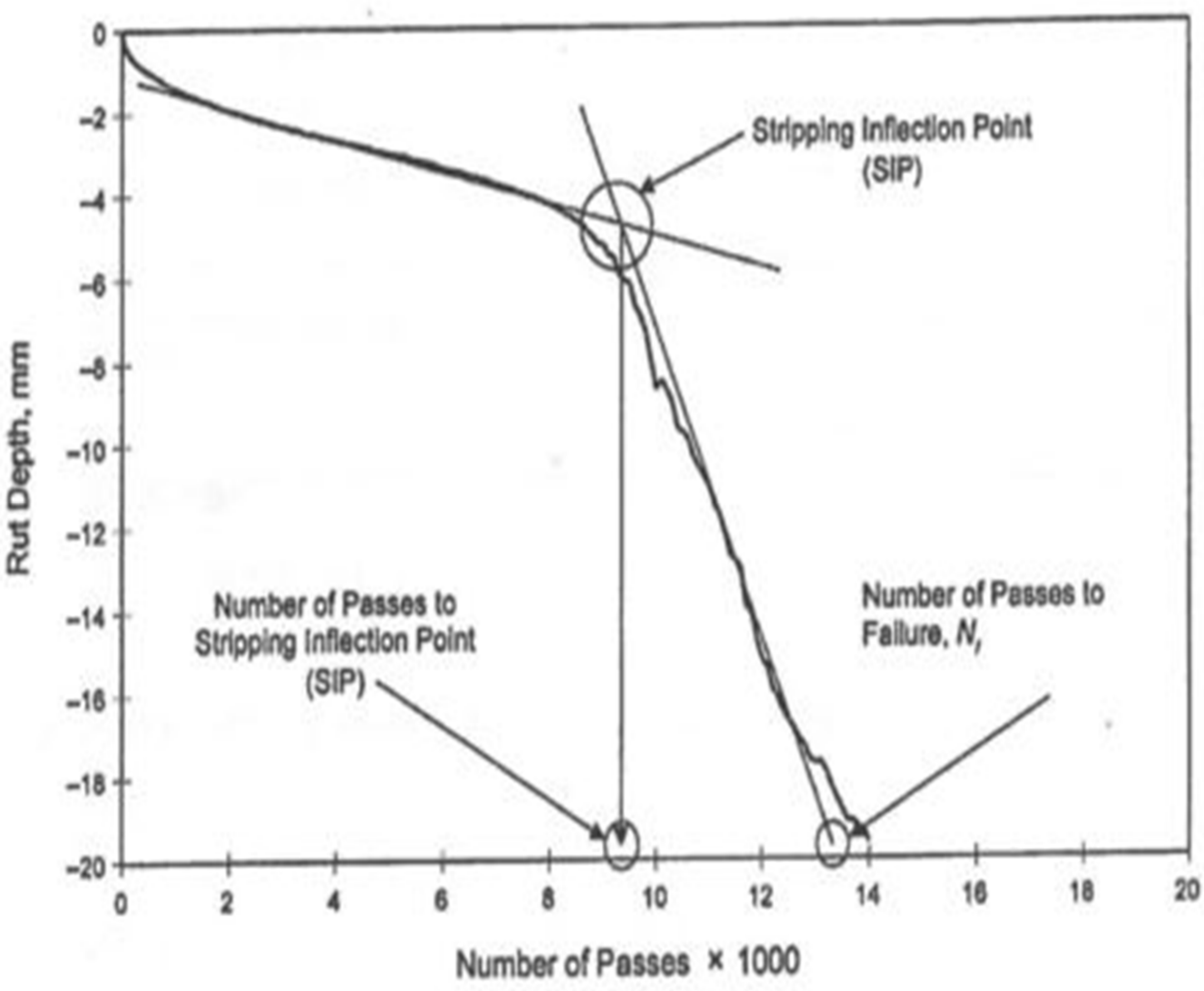
Hamburg Plot

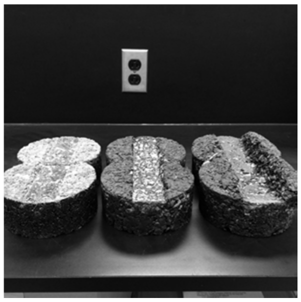


15

Hamburg Plot



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



16

Hamburg Wheel Tracker Job Special Provision *2018 Season*

401 BP Only (mm)	402 (mm)	403 SMA (mm)	403 Non-SMA, NMAS <190 (mm)	% Pay
<4	<4	<3	<3	101
>14	>16	>10	>10	Deficient

17

QC/QA 2019 Season

- QC: 1 per 10,000 tons
- QA: 1 per 10,000 tons
- ***Up to 3% incentive for FI in range and Hamburg is <12.5 mm***
- ***2% disincentive for low FI***
- ***No incentive for Hamburg***
- ***Hamburg must meet spec***
- ***1% incentive for greater field density (94-97%)***
- Favorable comparison: QA and QC are within 30%

18

2019

Flexibility Index	
NMAS < 190 mm	% of Contract Price
< 2.0	98
2.0- 3.9	100
4.0-7.9	102
≥ 8.0	103

Hamburg		
PG Grade, High Temperature, Contract Grade	Minimum Wheel Passes	Max. Rut Depth (mm)
58S-xx	5000	12.5
64S-22	7500	12.5
64H-22	15,000	12.5
64V-22	20,000	12.5

19

Also in this 2019 JSP

4.0 Design Gyrations. The number (N) of gyrations required for gyratory compaction shall be in accordance with Sec 403.4.5. At the option of the contractor, the number of gyrations and air voids may be lowered. Mixtures having lowered gyrations shall have a minimum VMA of 1.0% above the minimum according to Sec 403.4.6.2 and a design air voids of between 4.0% to 3.0%. The minimum gyration level shall be in accordance with the following:

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

6.0 Elevated Density. Sublots with a QC density test result which compares favorably with QA and has a result of 97% – 94% shall receive a 1% incentive based on bituminous mixture unit price.

20

2020 SEASON

- 10 projects
- JSP

21

Also in this 2019 JSP

4.0 Design Gyrations. The number (N) of gyrations required for gyratory compaction shall be in accordance with Sec 403.4.5. At the option of the contractor, the number of gyrations and air voids may be lowered. Mixtures having lowered gyrations shall have a minimum VMA of 1.0% above the minimum according to Sec 403.4.6.2 and a design air voids of between 4.0% to 3.0%. The minimum gyration level shall be in accordance with the following:

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

6.0 Elevated Density. Sublots with a QC density test result which compares favorably with QA and has a result of 97% – 94% shall receive a 1% incentive based on bituminous mixture unit price.

QC/QA
2020 Season

- No change from 2019 season
- QC: 1 per 10,000 tons
- QA: 1 per 10,000 tons
- Up to 3% incentive for FI in range and Hamburg is <12.5 mm
- 2% disincentive for low FI
- No incentive for Hamburg
- Hamburg must meet spec
- 1% incentive for greater field density (94-97%)
- Favorable comparison: QA and QC are within 30%

22

2020 JSP

Superpave Performance Testing and Increased Density - JSP

1.0 Performance Testing. Quality Control (QC) testing for Flexibility Index and Hamburg Wheel Tracking will be required by the contractor at a frequency of 1/10,000 tons for the mainline pavement. The random testing location will be determined by the engineer. QC testing will be completed by the contractor at no cost to the commission. Incentive/disincentive payment will be calculated based upon the mixture cost for the tonnage represented by the sample, generally 10,000 tons. Incentive up to a maximum of 3% of the mixture item cost will be paid if the Flexibility Index results are within the incentive range and the Hamburg results are below 12.5mm. The engineer will also perform a set of tests at the 1/10,000 interval for Quality Assurance (QA). A favorable comparison will be achieved if the results for QA and QC are within 30%. In addition a 1% incentive is being offered for sublots with qualifying density results above 94%.

2.0 Flexibility Index (FI) Testing. The FI testing will be completed in accordance with Illinois Test Procedure 405 dated 01/01/16 available at http://www.modot.org/business/contractor_resources/forms.htm In lieu of the Flexibility Index, the Ideal CT may be substituted using the limits shown below. The Ideal CT shall be completed in accordance with ASTM D8225 when used.

FLEXIBILITY INDEX	Ideal CT	Percent of Contract Price
NMAS <190	NMAS <190	
< 2.0	< 32	98%
2.0 – 3.9	32 – 60	100%
4.0 – 7.9	60 - 97	102%
>8.0	> 97	103%

3.0 Hamburg Wheel Tracking. Hamburg Wheel Track testing will be completed in accordance with AASHTO T324

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.

23

Incentive/Disincentive

Flexibility Index OR Ideal CT Cracking Index

FLEXIBILITY INDEX	Ideal CT	Percent of Contract Price
NMAS <190	NMAS <190	
< 2.0	< 32	98%
2.0 – 3.9	32 – 60	100%
4.0 – 7.9	60 – 97	102%
>8.0	> 97	103%

24

2020 JSP

Superpave Performance Testing and Increased Density - JSP

1.0 Performance Testing. Quality Control (QC) testing for Flexibility Index and Hamburg Wheel Tracking will be required by the contractor at a frequency of 1/10,000 tons for the mainline pavement. The random testing location will be determined by the engineer. QC testing will be completed by the contractor at no cost to the commission. Incentive/disincentive payment will be calculated based upon the mixture cost for the tonnage represented by the sample, generally 10,000 tons. Incentive up to a maximum of 3% of the mixture item cost will be paid if the Flexibility Index results are within the incentive range and the Hamburg results are below 12.5mm. The engineer will also perform a set of tests at the 1/10,000 interval for Quality Assurance (QA). A favorable comparison will be achieved if the results for QA and QC are within 30%. In addition a 1% incentive is being offered for sublots with qualifying density results above 94%.

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***Determined by the binder grade specified in the contract.**

Hamburg Rut Depth Requirements

*Binder Contract Grade

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

MODULE 11

RECORD KEEPING & EXCHANGE OF DATA

11-1-05 Revision
1-2-09 Revision
4-22-09 Revision
11-17-10 Revision
12-28-16 Revision

MODULE 11

RECORD KEEPING &
EXCHANGE OF DATA

11-1-05 Revision
1-2-09 Revision
4-22-09 Revision
11-17-10 Revision
12-28-16 Revision

*** PROCESS REVIEW TEAM NOTED 2008**

2

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***

3

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.

4

DOCUMENTS On Hand

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

5

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*

6

CALIBRATION

Equipment	Req'ment	Interval (month)
Gyro	Calibrate	12
Gyro	Verify	Daily; when moved
Gyro molds	Dimensions	12
Thermometer	Calibrate	6
Vacuum	Pressure	12
Pycnometer	Calibrate	Daily
Ignition oven	Verify	12 or when moved

7

CALIBRATION, Cont'd.

Equipment	Req'ment	Interval (month)
Nuclear gage	Drift & stability	1
Shakers	Sieving thorough-ness	12
Sieves	Physical condition	6
Ovens	Verify settings	4
Balances	Verify	12 or when moved
Timers	Accuracy	6

8

QC RECORDS

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

9

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

10

MODULE 12

CONTRACT ADMINISTRATION

12-28-06
11-18-09
12-28-16

MODULE 12

CONTRACT ADMINISTRATION

12-28-06
11-18-09
12-28-16

www.modot.mo.gov

Missouri Asphalt Pavement Association

MoDOT

QC/QA Process Team

A Cooperative Effort Between MAPA and MoDOT

March, 2005

www.modot.mo.gov

Team Members

- Kyle Phillips
  - Herzog Contractors
- Jennifer Breuer
  - Superior-Bowen
- Bruce Loesch
  - APAC-Missouri
- Steve Jackson
  - Pace Construction
- Glen Graham
  - Girardeau Contractors
- Gary Butterworth
  - District 4
- Larry Brooks
  - District 6
- Jim Preuss
  - District 8
- Dennis Bryant
  - Const. & Mat'ls.
- Jason Ewalt
  - Const. & Mat'ls.
- Joe Schroer
  - Const. & Mat'ls.

3

#1
Can I (MoDOT) direct a routine QC loose-mix sample to an area on the roadway that appears to have a mix problem?

4

#2
Am I (MoDOT) restricted to testing only the locations where the random samples fall?

5

#3
Can I direct my random QA test to an area on the roadway that looks like it may have a quality problem?

6

#4
Didn't you tell me earlier that MoDOT could test anywhere, any time?

7

#5
Does it matter how I choose my random numbers?

8

#6
When should I give the random numbers to QC?

9

#7
The contractor is sampling mix directly out of the trucks and using the results to adjust the plant. Is that okay?

10

#8
Can't the "self tests" be used to tweak the plant in advance of the random test?

11

#9
The contractor doesn't want to give me the results of the "self-tests." Can I insist on getting them?

12

#10

Can "self-test" results be used to determine removal limits?

13

#11

There are test specimens in the field laboratory that I can't identify. I can't be there all the time to witness all the testing. How do I know that the correct samples are used to determine payment?

14

#12

My QA sample does not compare favorably with QC. QC says my testing is in error. Now what do I do?

15

#13

We have checked everything and it turns out that QA and QC test results are both valid. The results are still unfavorable. What does the contractor get paid?

16

#14(a)

The plant is running smoothly, I have confidence in QC's testing and our comparisons are favorable. Do I need to continue running so many QA tests?

17

#14(b)

What about the frequency of dry-back…Can we cut back if the results are consistent?

18

#15

What constitutes a favorable comparison when running a QC split?

19

#16

I observe extra density core holes in the mat that I can't account for. Should I be concerned?

20

#17

Can I take the joint density cores at the same longitudinal location as the random mat density samples or should I use a separate random number?

21

#18

Due to stage construction, less than 4 sublots in a particular lot have an unconfined joint. Should the deduction for low unconfined joint density apply to the entire lot?

22

#19

What is this QC/QA project checklist that I'm hearing about?

23

Checklist Items

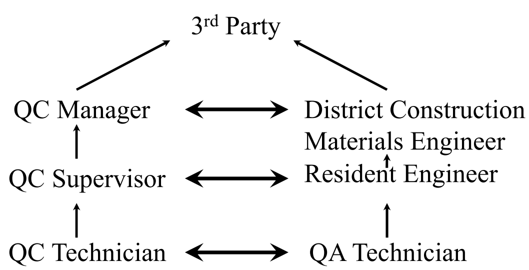
- Review QC Plan
- Random No. Method
- Sample Identification
- Location of QC Lab
- Rice Dryback?
- Dispute Resolution
- Paperwork Sharing
- Pay Factor Spreadsheet Version
- Test Method Options
- Job Mix Approval
- Specifications to Review
- Anything Else Important to the Project

24

#20
I have a disagreement with QC that we can't resolve. What do I do now?

25

Conflict Resolution
Example



26

#21
Do the Specifications require that the QC lab be located at the asphalt plant?

27

#22
My random QA test results indicate that the sublot that it fell within should be removed. The random QC results are above the removal limit. The comparison for the entire lot is favorable. What should I do?

#23
Can the TSR sample be taken at the asphalt plant?

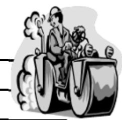
29

#24
It seems to take an awfully long time getting results from my counterpart. Within what time-frame should I expect results?

30

#25(a)

In a small quantity situation, is it necessary to remove and replace mixture that is out of the specification limits by only a small amount?



31

#25(b)

The small quantity deduction is more punitive that if PWL were calculated. Is it an option to use PWL to calculate the deduction on a small quantity project?

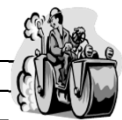
32

#26

The contractor is using something called a notched-wedge to construct the longitudinal joint. Where is the unconfined joint density measured?

33

#27
Can the contractor take more than one density core at each random location?



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QC/QA Project Checklist

Review QC Plan:

• **Method of generating, securing and providing random numbers for loose mix, density cores and tsr.**

• **Describe method of identifying samples.**

• **Where will QC lab be located?**

• **Is dryback necessary?**

• **Dispute resolution chart** (be specific. Identify specific individuals by name and time limits for a resolution before escalating to the next level)

• **How will paperwork be shared?**

• **What QLA version of the spreadsheet will be used?**

• **How will QC results be given to QA and QA to QC?**

• **What test methods will be used that are different from what is taught at UMR Level 2 training?**

• **Have Job Mixes been approved and/or transferred?**

• **Specifications to review:**

403.5.2.1 Shoulder Density
403.5.2.3 Longitudinal Joint Density
403.13.2 Segregation
403.15 Compaction – rollers and temperature limits
403.15.2 Defective Mixture
403.15.4 Density Measurement – lift thickness and testing
403.17.3.1 Calibration schedule

• **Miscellaneous**

- **Discuss sample retention for both QC and QA**
- **Field adjustments to Job Mix Formulas**
- **Opportunity to witness each other's loose mix samples**
- **Handling of density samples – marking and chain-of-custody**

SECTION 403 FAQ

(Revised 03-22-11)
(Revised 12-28-16)

INTRODUCTION

This document was developed, and will be maintained, to clarify the intent of the specifications, reduce conflict in the QC/QA environment and improve uniformity of contract administration across the state.

This is not a contract document and cannot be enforced as such. The Resident Engineer always has the latitude to react in an appropriate way to job specific circumstances, but decisions should be consistent with the underlying intent of guiding specifications and policies.

For this discussion, QC refers to the contractor's representative performing Quality Control testing. QA refers to MoDOT's representative performing Quality Assurance testing.

QUESTIONS AND ANSWERS

#1

Can I direct a routine QC loose-mix sample to an area on the roadway that appears to have a mix problem?

It is critical that routine tests, as defined in the contractor's QC plan, be at random locations. It is critical because any manipulation of the random numbers introduces bias. Keep in mind that the QC test results are used to statistically define a population of data. Bias causes inaccuracy in that statistical calculation.

#2

Am I (MoDOT) restricted to testing only the locations where the random samples fall?

No. MoDOT can take a sample anywhere, at any time if there is concern about a problem area, but this should be treated as an "extra" sample. These "extra" samples are used to determine if problem areas are acceptable, or to help define limits of a problem.

#3

Can I direct my random QA test an area on the roadway that looks like it may a quality problem?

No. The QA test that will be used for comparison to QC should be taken at a random location unless adjusted for a specific reason. For example, a test should not be taken in the middle of a busy intersection because that would be contrary to public interest. Also, Sec 403.23.7.1.4 allows samples to be separated by a minimum of 200 tons. Remember, bias causes problems with our statistics and is not in the interest of either MoDOT or the contractor.

#4

Didn't you tell me earlier that MoDOT could test anywhere any time?

Yes. The test frequencies listed in the specifications are minimums. QA always has the option to take additional tests. The random QA sample is used for comparison to QC and determines whether QC tests adequately define the characteristics of the entire lot. The "additional" QA test is used only to determine if an isolated area has a problem, or to help define the limits of a problem.

#5

Does it matter how I choose my random numbers?

The best way to generate random numbers is to use the spreadsheet, because that eliminates any question of bias. The latest version of the spreadsheet can be found on the MODOT web page under business/contractor_resources/forms – Materials Related.

A random number chart is okay, but be sure to choose random number pairs either row by row, or column by column. In other words, don't jump around on the chart, because that can introduce unintentional bias. Random number generators on a calculator are satisfactory as long as the selections aren't intentionally biased.

When using any method other than the spreadsheet to generate random numbers for roadway density cores, the pairs should be recorded once at the beginning of the lot and provided to QC at the completion of the lot. This will assure transparency of the random number selection process.

#6

When should I give the random numbers to QC?

This issue has caused a great deal of conflict statewide. To restore confidence in the process, the following procedures will be used:

> Random numbers will be generated in advance, by lot, and a printout of those numbers will be sealed in an envelope. At least one lot should be prepared in advance and kept in a secure location in the field laboratory. The QA inspector will also keep a copy in his possession. Random numbers will be given to QC between 100 and 150 tons in advance of the test. The intent is to give QC enough time to get any ongoing tests to a stopping point and to get out to the roadway in time. This should not give the plant operator enough time to adjust production and work any resulting change through the silo. When the sampling for a lot is completed, the envelope for that lot will be opened to demonstrate that the random numbers were not manipulated during production.

Random numbers for density cores should also be generated in advance. They can be provided to QC when rolling is complete.

QC and QA need to work together in good faith to make this process run smoothly. Occasionally random tests will fall close together. If QC is at a critical point in a test when the next random number comes up, QA should make an adjustment. QA should be aware that this policy creates some real challenges for QC and use appropriate judgment. There should be less conflict because both sides have their cards on the table.

As a professional courtesy, QA should give QC a reasonable opportunity to witness random QA roadway sampling.

#7

The contractor is sampling mix directly out of the trucks and using the results to adjust the plant. Is that okay?

Yes, but the samples should be marked as such if they are tested in the field laboratory. The contractor has the option of doing extra testing. These "self-tests" or "truck tests" are used to see how the mix is doing between random tests. Only the random QC tests are used to calculate pay.

#8

Can't the "self tests" be used to tweak the plant in advance of the random test?

Not if the random test locations are given 100 to 150 tons in advance as outlined earlier. There would be no way to complete a test and adjust the plant in time.

#9

The contractor doesn't want to give me the results of the "self-tests." Can I insist on getting them?

There is no reason to demand "self-test" results. If the random testing is being done correctly, the results will accurately define general production characteristics. If there is reason to be concerned about an isolated area, take an extra QA test.

#10

Can "self-test" results be used to determine removal limits?

EPG 403 reads as follows: *"QC self-test results may be used to help define the limits of removal as long as the self-test(s) are well documented"*.

A self-test will be considered well documented if the following minimum criteria are met:

1. The puck is available and is clearly labeled
2. The gyratory printout is made available

3. The printout from the AC test is made available

The resident engineer has the option to determine removal limits based on puck height, provided that the self-test data is consistent with previous production.

#11

There are test specimens in the field laboratory that I can't identify. I can't be there all the time to witness all the testing. How do I know that the correct samples are used to determine payment?

There is no legitimate reason for unidentified samples to be in the Field laboratory. The QA inspector should insist that all test specimens in the field laboratory be marked as soon as they are cool enough. The identifying mark should be permanent, unique, and indicate what the sample is.

#12

My QA sample does not compare favorably with QC. QC says my testing is in error. Now what do I do?

QA and QC should be given the opportunity to witness each other's sampling and testing. Doing so will head off a lot of conflict.

Copies of all test methods should be readily available in the field laboratory. Testing procedure must follow an approved test method. If either party has an issue with the other's test procedure, an objection should be raised at that time. By doing this promptly, the issue can be resolved while it is still possible to re-create the test. If a decision is made to test a retained sample, the test should be run jointly so that testing procedure is taken off the table as a variable.

EPG 403 reads as follows: *"If the comparison is not favorable, the first step is to review both QC and QA test results to see if there is any noticeable error. If no errors are found, testing of the retained samples may be performed. Judgment must be used in determining which retained sample(s) to test. When testing a retained sample, the entire suite of tests (%AC, V_a, and VMA) should be performed to verify the validity of the original test results. If the test results of the retained sample confirm the original test results, the original test results are used to determine the PWL. If the test results of the retained sample verify that the original test results were incorrect, the test results of the retained sample are used to determine the PWL."*

#13

We have checked everything and it turns out that QA and QC test results are both valid. The results are still unfavorable. What does the contractor get paid?

EPG 403 reads as follows: *"If the QC and QA test results have been determined to be valid and the comparison is still unfavorable, the test results from the random,* *independent QA sample will be included in the PWL calculation. The QA test results of QC retained samples or the test results from any additional QA samples will not be used in the PWL calculation. As an example, lot 3 has been completed and consists of 4 sublots. A favorable comparison was not obtained but it was determined that the QC and QA test results are valid. Therefore, the PWL calculation will include the QC test results from all 4 of the sublots and the test results of the random, independent QA sample (n = 5).”*

When the random QA test results are included in the PWL calculation, all volumetric properties (%AC, VMA & V_A) for that sample will be used, even if only one of the three properties has an unfavorable comparison. There should not be an unfavorable comparison of density because QA randomly re-tests one of the QC cores.

#14

The plant is running smoothly, I have confidence in QC’s testing and our comparisons are favorable. Do I need to continue running so many QA tests?

EPG 403 reads as follows: *“The minimum sampling and testing requirements for both QC and QA, as shown in the table in Standard Specification Sec 403.19.3, have been modified as a result of the QC/QA Process Team. The guidelines set forth in this document should be followed.*”

The following table illustrates the differences. The frequency of testing of QC splits can be reduced when QC and QA become confident with each other’s sampling and testing procedures.

	Minimum by Spec	Early in project	Later in project
Random QA	1/4 sublots	1/lot	1/lot
QC Split	1/week	1/day	On days when there is no random QA

What about the frequency of dry-back. Can we cut back if the results are consistent?

The Engineering Policy Guide (403.19.3.1.2) contains the following language: “*the dry-back method should be performed on all samples taken in the first lot of mix produced. If the G_{mm} and the dry-back G_{mm} of a sample are within 0.002 of each other in all sublots of the first lot, the dry-back may be reduced to every other sublot. Otherwise, the dry-back will be required every sublot.”*

#15

What constitutes a favorable comparison when running a QC split?

Gmm should be within 0.005, Gmb should be within 0.010, and AC within 0.1%. If variances are larger both QA and QC should scrutinize sampling and testing procedures to identify the cause of the difference.

Isn't that a pretty tight comparison range for G_{mb}?

Yes, but for two technicians in the same lab it is attainable. If there are comparison problems, the retests should be run together to ascertain the cause of the discrepancy.

The 7-day requirement in Sec 403.17.2.3 notwithstanding, retained samples should not be discarded until all comparison issues with the lot are resolved. If space at the field lab is an issue, the sample should be stored at the project office.

#16

I observe extra density core holes in the mat that I can't account for. Should I be concerned?

The roadway inspector should assure that the density cores taken from the roadway are the same ones tested in the lab. The preferred procedure is for a MoDOT inspector to take possession of the cores as soon as they are cut, and deliver them directly to QA at the plant. This needs to be done promptly so that testing of the density cores can proceed without delay. When specific job circumstances make this procedure impractical, the roadway inspector may dry the core with a paper towel and mark the side using a permanent felt-tipped marker. The identifying mark should be unique and readily identifiable when the sample arrives at the plant. A signature, along with lot and sublot, is one example of an identifying mark. When marked in this fashion, it is acceptable for the contractor to deliver the QC cores to the lab.

The roadway inspector will select one QC core roadway locations per lot to cut a QA core. The QA core should be taken at the same offset as the QC core and within 6 inches longitudinally. The roadway inspector will take possession of the QA core and deliver it directly to the lab. When calculating the G_{mb} for the QA core, the G_{mm} will be the same as that used for the corresponding QC Core. The comparison will be favorable when the G_{mb} of the QA core and the QC core at that same location (or the average of the QC cores if specified in the QC plan) is within 0.010.

If the comparison is not immediately favorable, QC and QA will rerun both cores in each other's presence to check for testing errors. If the comparison is still outside the acceptable limit, the resident engineer will determine if either core is non-representative due to damage, roadway surface irregularities etc. If both cores are representative, an average of QC and QA will be used for that sublot.

#17

Can I take the joint density cores at the same longitudinal location as the random mat density samples or should I use a separate random number?

Either way is acceptable to MoDOT. If QC prefers one method over the other, then they should be accommodated.

#18

Due to stage construction, less than 4 sublots in a particular lot have an unconfined joint. Should the deduction for low unconfined joint density apply to the entire lot?

No. The deduction should only apply to those sublots which have an unconfined joint density sample. The spreadsheet has been modified to assist with this determination.

#19

What is this QC/QA project checklist that I'm hearing about?

A checklist was developed for QC and QA to run through before work begins. It is intended to reduce conflict by working out the day to day details of how to conduct business in advance of all the pressures of production. The industry/MoDOT task force developed an acceptable checklist but any other that accomplishes the same thing is acceptable.

One of the key elements of any checklist is to clearly define a conflict escalation procedure. Far too many conflicts lay unresolved for too long. Conflicts that QC and QA cannot resolve between themselves should be promptly escalated.

#20

I have a disagreement with QC that we can't resolve. What do I do now?

The vast majority of issues between QC and QA can be resolved by consulting the QC Plan, the Test Method or the contract documents. If a dispute cannot be resolved within a few hours of taking these initial steps, it should be escalated.

Time frames and escalation levels (including the names of the individuals) should be discussed when going through the checklist. Unresolved issues lead to an atmosphere of mistrust in the QC/QA environment.

Decisions should always be timely and made at the lowest **appropriate** level.

#21

Do the Specifications require that the QC lab be located at the asphalt plant?

No. The contractor is required to provide an appropriately equipped QC laboratory. The contractor is also required to provide office space at the asphalt plant for the QA inspector to work on records and reports. Usually these 2 requirements are met with one structure, but not always. The intent of the specification will be met if the QA inspector is provided with suitable facilities at the plant, but the lab is located offsite at a location appropriate to the work under progress. For example, the contractor may elect to place the laboratory at a location between the jobsite and the plant.

#22

My random QA test results indicate that the sublot that it fell within should be removed. The random QC results are above the removal limit. The comparison for the entire lot is favorable. What should I do?

EPG 403 reads as follows: "*If the QA test results fall below the removal limits for density and/or air voids, the mix should stay in place if a favorable comparison has been obtained with the QC test results. Again, a favorable comparison signifies that the QC test results adequately define the characteristics of the lot and are, therefore, acceptable. If the QA test results fall below the removal limits and a favorable comparison has not been obtained, dispute resolution should be initiated to determine whether or not the mix should stay in place.*"

#23

Can the TSR sample be taken at the asphalt plant?

Yes, the test method allows that. Since it is easier to take a larger sample at the plant, the QA sample should be at least 250 pounds. 125 pounds should be sent to the Central Laboratory for testing and the other half kept by the RE as a retained sample.. The inspector should write the Mix Number and sample ID on the box. TSR samples need not be taken at random locations but can be taken when it is convenient to production.

#24

It seems to take an awfully long time getting results from my counterpart. Within what time-frame should I expect results?

Sec 403.17.1.1 of the Standard Specifications requires QC to provide all **raw** data to the engineer no later than the beginning of the day following the test. Raw data, of course, is subject to revision.

Sec 403.23.7.1 requires QA to make the QLA no more than 24 hours after receipt of the contractor's test results. Best management practice is for QA review the QLA with QC before processing the report.

These are guidelines that should be adhered to unless there is a compelling reason to do otherwise. If problems are persistent they should be escalated quickly for resolution. In general, it is a good practice to provide PWL calculations to the contractor for work that is paid for on each estimate.

#25

In a small quantity situation is it necessary to remove and replace Mixture that is out of the specification limits by only a small amount?

The following guidance will be added to the construction manual under Sec 403.19.3.2.1 – Small Quantities: "The resident engineer should use engineering judgment when mixture placed under this section fails to meet specifications. If the laboratory compacted air voids are less than 2.5%, or the roadway density is less than 90.0% or more than 98%, the material should be removed and replaced. If asphalt content is above or below the target value by more than 0.3%, or if the roadway density is less than 91.5%, the mixture may be allowed to remain in place with an appropriate deduction. Mixture that is out of specification by a minor amount may be left in place with no deduction"

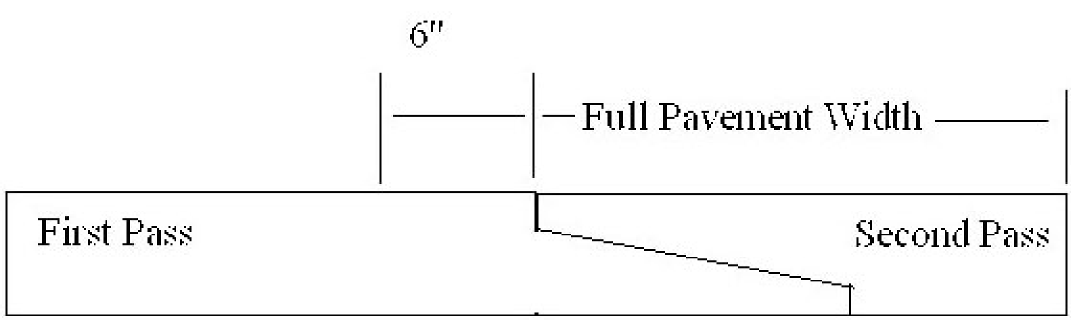
The small quantity deduction is more punitive than if PWL were calculated. Is it an option to use PWL to calculate the deduction on a small quantity project?

Yes, if the contractor has it spelled out in the quality control plan.

 # 26

The contractor is using something called a notched-wedge to construct the longitudinal joint. Where is the unconfined joint density measured?

The Notched-Wedge is marketed by a company called, Trans Tech. There are similar products on the market as well, but in general they look like the sketch below:

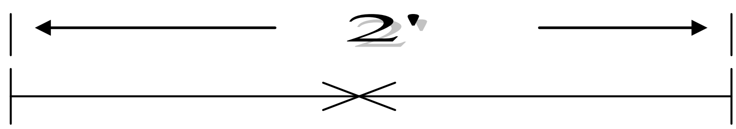


Unconfined joint density should be measured on the first pass in the 6 inches adjacent to the vertical notch (if the contractor is taking 6 inch density cores the location should be adjusted as necessary to avoid the vertical face of the notch.) On the second pass, the entire width of the lane is fair game for random density testing, including the entire wedge section.

#27

Can the contractor take more than one density core at each random location?

Yes. Specifications allows up to 3 cores at each random location, but only if the routine is spelled out in the QC plan. In the drawing below, the X represents the station and offset of the random location. Best management practice is for QA to mark that location on the pavement. The first density core should have that marking on it. Any additional cores should be taken along a straight line, parallel to the centerline, within 1 foot either side of the random location. The practice of drawing a 2 foot diameter circle and sampling anywhere within it has been disallowed by specification since 2004.



Appendix

APPENDIX

GLOSSARY

11-1-05 Revision

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.