

Asphalt Materials Quality Assurance (QA) Practices



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Introduction

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- FHWA COOPERATIVE AGREEMENT No. 693JJ31850010
“Development and Deployment of Innovative Asphalt Pavement Technologies”
 - University of Nevada at Reno
 - Applied Research Associates, Inc.
 - Paragon Technical Services, Inc.

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Background & Acknowledgements

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- FHWA TechBrief
- <https://www.fhwa.dot.gov/pavement/asphalt/hif20033.pdf>
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TechBrief

The Asphalt Pavement Technology Program is an integrated national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with state highway agencies, industry and academia, the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement suggestions, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

Office of Preconstruction,
Construction, and
Pavements
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Federal Highway Administration

Asphalt Materials Quality Assurance Practices

This Technical Brief provides an overview of asphalt materials quality assurance with a focus on acceptance risks and potential strategies for minimizing them.

The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies. This document references American Association of State Highway and Transportation Officials (AASHTO) standards which are private, voluntary standards that are not required under Federal law.

Introduction

Many State Highway Agencies (SHAs) have asphalt material design standards, policies, test methods, practices and specifications associated with quality assurance (QA). QA is defined as "All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service" (1). QA involves continued evaluation of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, maintenance, and the interactions of these activities. There are six core elements of a QA program. They are contractor quality control (QC), agency acceptance, independent assurance (IA), dispute resolution, laboratory accreditation, and personnel certification. Agency specifications outline the proper application of QA, but not everyone always interprets the specifications the same nor uses them the same way. This is particularly important with the trend of reduced SHA staffing and increased contractor responsibility for asphalt mixture design and QC activities (2). Therefore, agency acceptance responsibility is critically important in a QA program. The public's money is spent on asphalt materials and SHAs ultimately have responsibility to verify that the public is getting what it pays for.

Performing QA results in assigning separate responsibilities to the SHA and the contractor. These responsibilities typically include design, SHA acceptance activities and contractor QC. In assigning these responsibilities it is possible to inadvertently create increased risk related to acceptance. Examples include those related to sampling, testing, inspecting and/or reporting as well as many more. These risks can occur if the contractor is assigned responsibility for activities that otherwise would be performed by the SHA. Risk can also occur if activities are performed by the contractor that benefit from SHA controls (monitoring) to assure that risks related to acceptance is minimized, but inadequate controls are in place.

It Is Important – Why?

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- QA is defined as *“All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service”*
- Important for:
 - Agencies
 - Contractors
 - Taxpayers
- Responsibilities Assigned to Different Parties

6 Core Elements of a Quality Assurance (QA) Program



AASHTO R-10

Standard Recommended Practice for Definition of Terms Related to Quality and Statistics

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- An acceptance plan is defined as an

“...agreed upon process for evaluating the acceptability of a lot of material. It includes: lot size and sample size (i.e., number of samples), quality measure, acceptance limit(s), evaluation of risks, and pay adjustment provisions”

- Risks
 - Statistical - (β) & (α)
 - Engineering – Performance

Themes

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1. Is lab mixed material different than plant produced material?
2. For today's mixtures, are volumetric properties alone adequate?

Abbreviations & Acronyms

- Abs. = water absorption
- Acc. = acceptance
- G = specific gravity
- D/A = dust to effective asphalt ratio
- G_{mb} = bulk specific gravity of mixture
- G_{mm} = maximum specific gravity of mixture
- G_{sa} = apparent specific gravity of aggregate
- G_{sb} = bulk specific gravity of aggregate
- G_{se} = effective specific gravity of aggregate
- M.D. = mixture design
- NCAT = National Center for Asphalt Technology
- P_b = percent binder
- P_{ba} = percent absorbed binder
- P_{be} = percent effective binder
- P_s = percent aggregate
- P200 = percent aggregate passing the 0.075 mm (No. 200) sieve
- P2.36 = percent aggregate passing the 2.36 mm (No. 8) sieve
- QA = quality assurance
- R = correlation coefficient
- RAP = reclaimed asphalt pavement
- RAS = reclaimed asphalt shingles
- t/NMAS = thickness to nominal maximum aggregate size
- V_a = percent air voids
- Ver. = verification
- VFA = percent voids filled with asphalt
- VMA = percent voids in the mineral aggregate

Timing Potential QA Risks

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- **Mixture Design**

- Materials: laboratory mixed

- **Verification**

- Materials: plant produced
- Initial check between laboratory and plant produced materials
- Laboratory mixture design \neq Plant produced material

- **Acceptance**

- Materials: plant produced

Examples of Potential Risks

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Timing of Risk	Potential QA Risk Item
Mixture Design	Ignition Furnace Asphalt Correction Factor
Mixture Design	Aggregate Specific Gravity
Mixture Design	RAM Specific Gravity
Verification	Mixture Adjustments
Acceptance	Aggregate Specific Gravity
Acceptance	Relationship of Properties
Acceptance	Recycled Materials



Image: Pixabay

Ignition Furnace Correction Factor

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Asphalt Binder Content (P_b):

- Ignition furnace correction factor needed
- Unique to each furnace and mixture

Correction factor:

- Mixing samples of known asphalt binder content
- Extractions to verify

Agency needs to test



Ignition Furnace Correction Factor

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Risk Mitigation Strategies:

- Only allow the DOT to prepare its own CF test samples
- Per AASHTO T 308 (a private, voluntary standard), for each mixture and each ignition furnace, conduct unique CF determinations
 - Don't allow sharing of CFs between multiple ignition furnaces, even if they are the same brand in the same laboratory
- Verify with solvent extraction



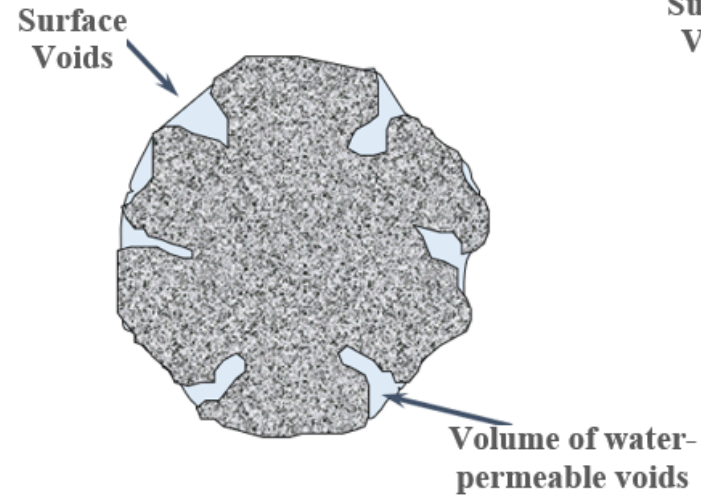
Aggregate Specific Gravity: Defined

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$$\text{Specific Gravity } (G) = \frac{\text{Density of Aggregate}}{\text{Density of Water}}$$

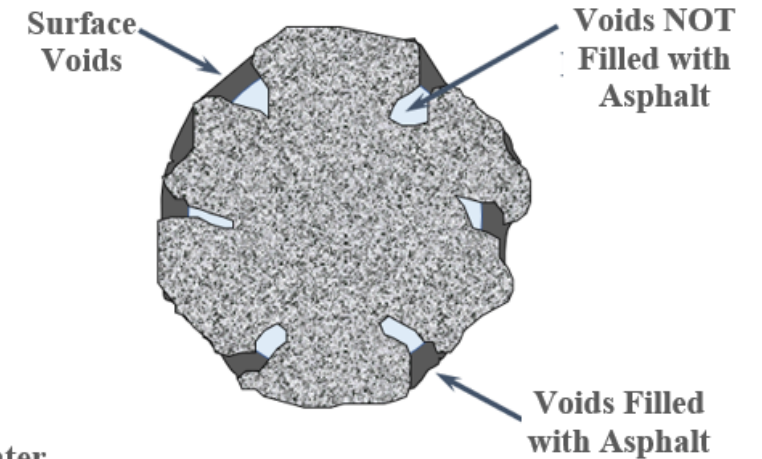
$$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$$

Bulk Specific Gravity, Dry



$$G_{sb} = \frac{\text{Mass, oven dry}}{\text{Volume of Aggregate + Surface Voids}}$$

Effective Specific Gravity



$$G_{se} = \frac{\text{Mass, oven dry}}{\text{Effective Volume of Voids}}$$

Image: University of Nevada Reno

Aggregate Specific Gravity: Relationship

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- $G_{sa} \geq G_{se} \geq G_{sb}$ (ALWAYS!)
- G_{se} typically assumed midway between G_{sa} and G_{sb}
Asphalt absorption typically about 50% of water absorption
- $G_{sb} > G_{se}$ then negative asphalt absorption (what does that mean?)
- Is there Relationship between G_{sb} and VMA?

Aggregate Specific Gravity: Importance

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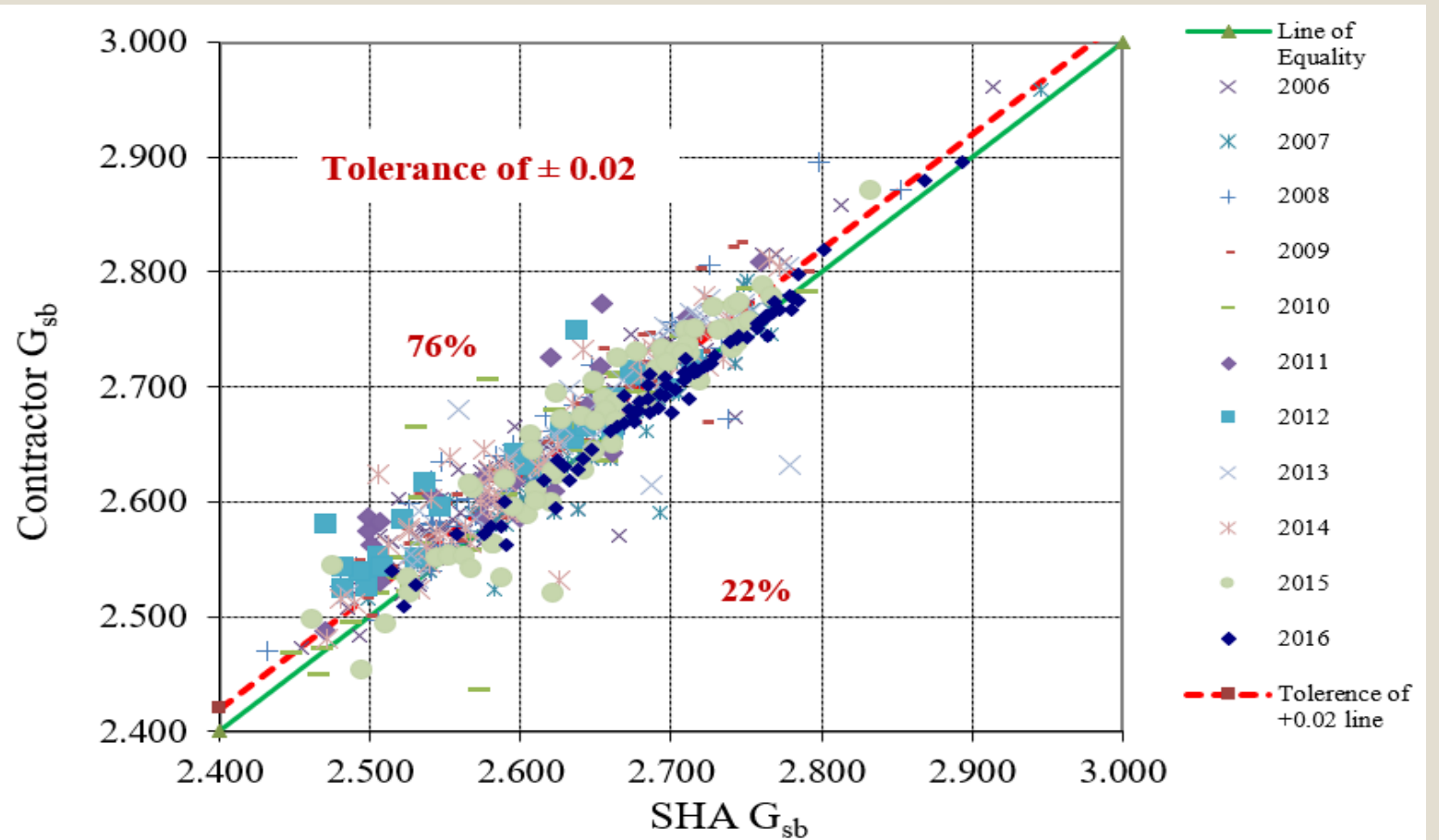
- For test results on a given aggregate:
 - Higher the specific gravity  artificially higher VMA

Artificially High		Lower Asphalt Content (%)
G_{sb}	VMA (%)	
0.010	0.3	0.15
0.020	0.6	0.30
0.040	1.2	0.60

Aggregate Specific Gravity: Tolerance

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- Normal Distribution or Bias?
- Should a state use the contractor's results if within a tolerance?



Aggregate Specific Gravities

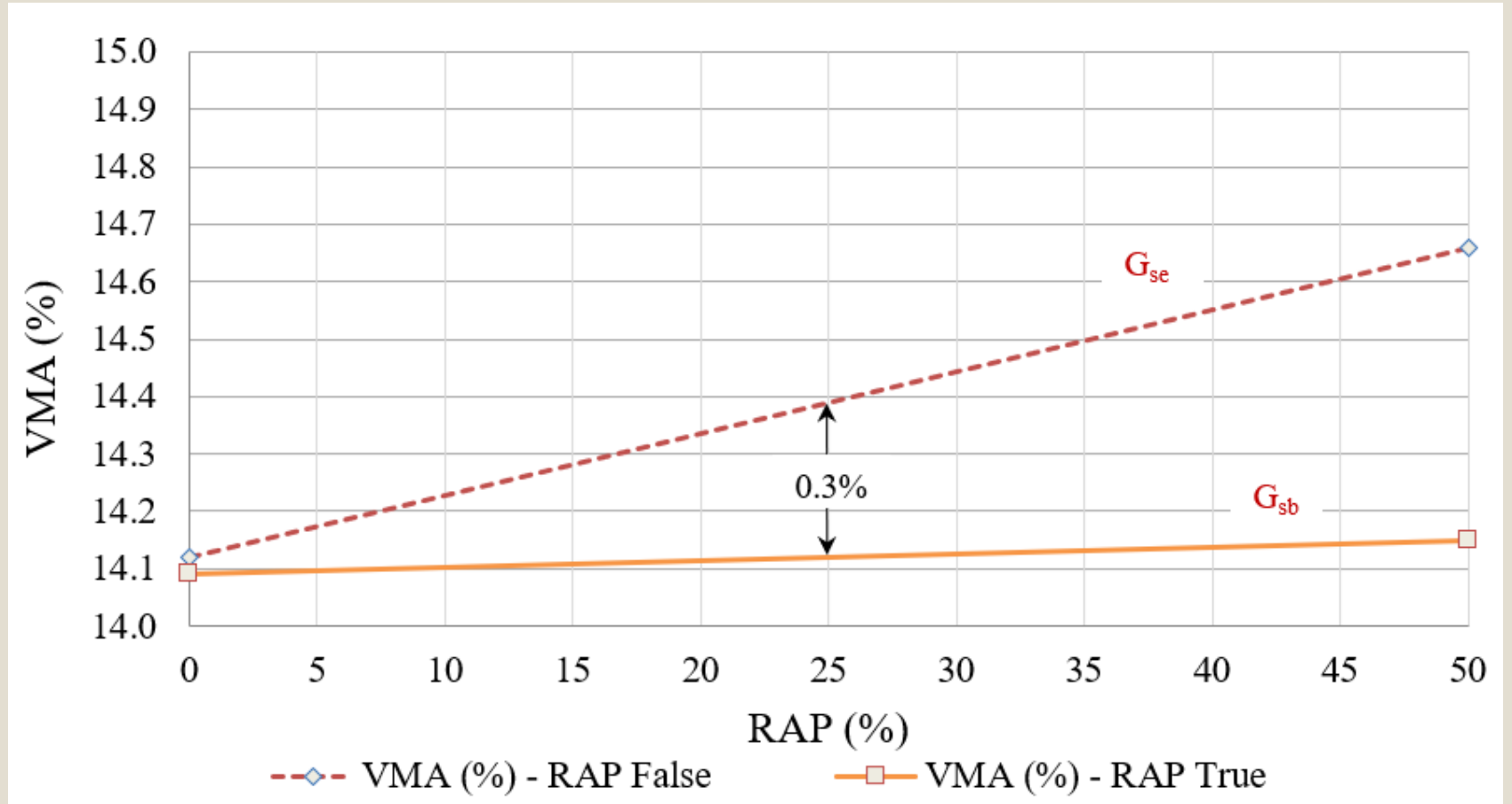
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Risk Mitigation Strategies

- Routinely measure source G_{sb} and compare to mixture designs value. Some DOTs do this:
 - For individual mixture design with variable aggregates
 - By bench for quarries annually = “book” value used by DOT and Contractor
 - Fixed frequencies (e.g. 1/6 months) depending on source variability
 - Verify mix design G_{sb} during project startup evaluation
- Include reporting G_{sa} , G_{se} , G_{sb} , %Abs, P_{ba} in mixture design submittals
 - Verify $G_{sa} > G_{se} > G_{sb}$ and P_{ba} are reasonable
- Don't use tolerances to compare DOT & Contractor G_{sb} during mixture design
- Analyze differences in DOT and Contractor G_{sb} values and share results

VMA Inflation with G_{se} Use

- VMA errors result in lower effective binder content
- With RAP Agency should G_{sb}



RAP: Gsb Example

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Example if using G_{se}:

- 20% RAP
- $G_{sb} = 2.609$
- $G_{se} = 2.732$
- Water absorption = 1.0%
- Using G_{se} was similar to using:
 - ✦ 0.024 higher G_{sb} in the composite
 - ✦ 0.6% VMA (artificially high)
 - ✦ 0.3% lower AC

RAP: G_{sb}

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Risk Mitigation Strategies

- Don't allow the use of G_{se} for RAP materials in place of G_{sb}
- Don't allow the use of estimates of G_{sb}
- Use RAP G_{sb} for all materials in mixture design
- Monitor/Verify G_{sb} during production

Mixture Adjustments

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- NCHRP Report 818 - *Comparing the Volumetric and Mechanical Properties of Laboratory and Field Specimens of Asphalt Concrete*
- Volumetric and mechanistic properties of design (LL), production (PL), and construction (PF) specimens
 - Volumetric properties: AV, VMA, VFA, G_{sb} , G_{mm} , P_{ba} , P and gradation
 - Mechanistic properties: loaded wheel tracking rut depth, axial dynamic modulus, and indirect tension dynamic modulus
- Impact of baghouse fines return, delay in specimen fabrication, aggregate absorption, aggregate hardness, and stockpile moisture content

NCHRP Report 818 Conclusions

- Air voids: Stockpile moisture had a significant effect on the difference between design and production specimens
- Asphalt binder content: Return of baghouse fines was significant in the difference between design and production and as constructed specimens
 - Aggregate absorption was significant on the measured difference between design and production specimens
- Aggregate gradation: Return of the baghouse fines was significant in the difference between the aggregate passing the #200 sieve of design and production as well as construction specimens
 - Aggregate hardness was significant in the differences between the percent passing the #200 sieve of design and production and as constructed specimens

NCHRP Report 818 Conclusions

Comparison	Property	Single Operator Confidence Limit	Maximum Acceptable Range
Design (LL) - Production (PL)	AV, %	0.8	± 1.3
Design (LL) - Production (PL)	VMA, %	1.2	± 2.0
Design (LL) - Production (PL)	VFA, %	5.4	± 9.1
Design (LL) - Production (PL)	AC, %	0.2	± 0.30
Design (LL) - Construction (PF)	AC, %	0.020	± 0.30
Production (PL) – Construction (PF)	AC, %	0.014	± 0.30
Design (LL) - Production (PL)	G _{mm}	0.5	± 0.034
Design (LL) - Construction (PF)	G _{mm}	0.2	± 0.022
Production (PL) – Construction (PF)	G _{mm}	0.013	± 0.030
Design (LL) - Production (PL)	G _{sb}	0.019	± 0.024
Design (LL) - Construction (PF)	G _{sb}	0.7	± 0.032
Production (PL) – Construction (PF)	G _{sb}	0.2	± 0.029
Design (LL) - Production (PL)	% passing#200	0.018	± 0.80
Design (LL) - Construction (PF)	% passing#200	0.017	± 1.2
Production (PL) – Construction (PF)	% passing#200	0.5	± 0.80

Mixture Adjustments: General Rules of Thumb

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- **Binder Content Adjustments**
 - $\pm 0.1\%$ binder content $\approx \pm 0.25\%$ air voids (inverse relationship)
 - Small binder content change \approx no effect on VMA
- **Aggregate Adjustments**
 - $\pm 1.0\%$ P200 $\approx 0.3\%$ to 1.0% VMA (inverse relationship)
 - Coarse gradation: -P2.36 increases VMA
 - Fine gradation: +P2.36 increases VMA

Keep the binder in the mixture

Mixture Adjustments: General Rules of Thumb

- Changes in VMA

	Fine Gradation	Straight Gradation	Coarse Gradation
P200: 8% to 3%	+1.6	+0.5%	+0.3%
P200: Fine to Coarse	-0.5	+0.1%	-0.1%
Crushed: 80% to 100%	+0.3	+1.1%	+1.0%

Keep the binder in the mixture

Mixture Adjustments

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Risk Mitigation Strategies

- In standard specification indicate how to address differences in mixture design and plant produced mixtures
 - Only Allow Gradation Adjustments before Asphalt Binder Adjustments
 - ✦ This includes Baghouse Fines Adjustments & Wasting if Necessary
 - Include VMA and dust to asphalt ratio (D/A) acceptance criteria on plant produced mixture equal to AASHTO M323 minimum VMA and maximum D/A
 - Only Allow Baghouse Fines to be Returned to the Drum if Interlocked and Accurately Metered

Keep the asphalt binder in the mixture

Mixture Adjustments: What If's

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Equations:

$$1. V_a = \left(1 - \frac{G_{mb}}{G_{mm}}\right) * 100$$

$$2. VMA = \left(100 - \frac{G_{mb} * P_s}{G_{sb}}\right)$$

$$3. VFA = \frac{VMA - V_a}{VMA} * 100$$

$$4. P_{be} = VMA - V_a$$

Relationships:

- When G_{mm} changes by +0.010, V_a changes by +0.4%
- When G_{mb} changes by +0.010, V_a changes by -0.4%
- When G_{mb} changes by +0.010, VMA changes by -0.4%
- When G_{sb} changes by +0.010, VMA changes by +0.3%

Aggregate Specific Gravity: Absorption Check

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- $G_{sa} \geq G_{se} \geq G_{sb}$ (ALWAYS!)

Aggregate Sp.G.	Meaning	Asphalt Abs. (% of water)
$G_{sa} = G_{sb}$	no absorption (water or asphalt)	---
$G_{se} = G_{sb}$	no asphalt absorption	0
$G_{se} = G_{sa}$	asphalt absorption equals water absorption	100

- G_{se} typically assumed to be halfway between G_{sa} and G_{sb}

Asphalt absorption typically about 50% of water absorption

Aggregate Specific Gravity: Absorption Check

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- For a given mixture design, the relationship between G_{sa} and G_{se} and G_{sb} **should not** change (within test variability)
- **May** change due to:
 - Mixture temperature
 - Time at mixture temperature
 - Aggregate change (“heavy vs. light” aggregate)
- **Aggregate Control Chart**
 - Identify trends before issues show up

Aggregate Specific Gravity: Absorption Check

- Absorbed Binder (P_{ba})
 - Percent by weight of aggregate

$$P_{ba} = 100 * \frac{(G_{se} - G_{sb})}{(G_{sb} G_{se})} * G_b$$

- P_{ba} should be consistent

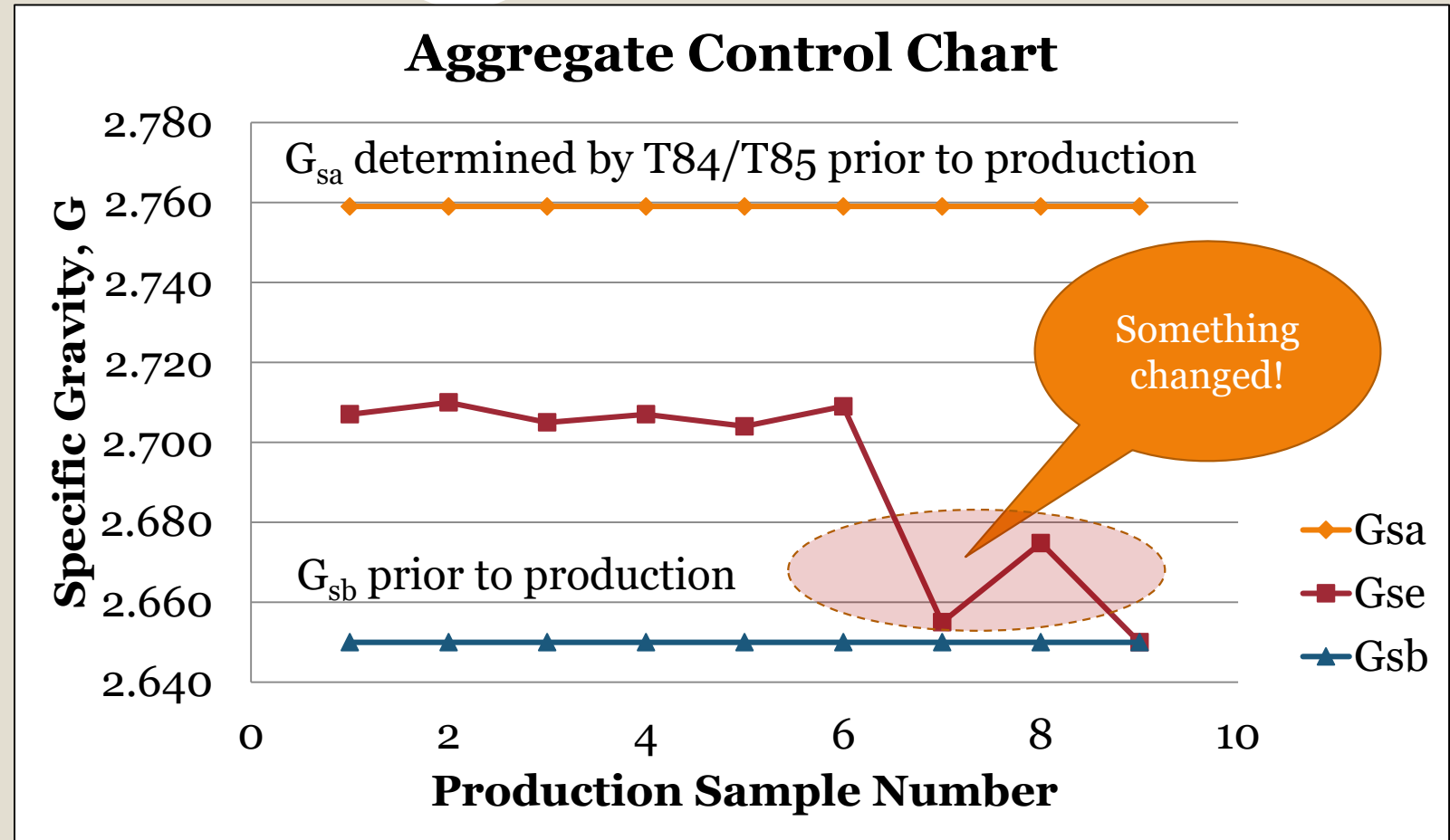
**Agency monitor absorption
If ΔP_{ba} measure G_{sb}**

Test Number	Production G_{se} Values		Design Values		Absorption Checks		
	Individual	Avg of Last 4	Gsa	Gsb	Abs, %	Pba, %	Pba / Abs
1	2.650		2.700	2.600	1.42	0.71	50
2	2.656		2.700	2.600	1.42	0.80	56
3	2.635		2.700	2.600	1.42	0.50	35
4	2.646	2.647	2.700	2.600	1.42	0.66	46
5	2.665	2.651	2.700	2.600	1.42	0.92	65
6	2.636	2.646	2.700	2.600	1.42	0.51	36
7	2.670	2.654	2.700	2.600	1.42	0.99	70
8	2.660	2.658	2.700	2.600	1.42	0.85	60
9	2.666	2.658	2.700	2.600	1.42	0.94	66
10	2.669	2.666	2.700	2.600	1.42	0.99	70
11	2.659	2.664	2.700	2.600	1.42	0.84	59
12	2.643	2.659	2.700	2.600	1.42	0.62	44
13	2.664	2.659	2.700	2.600	1.42	0.92	65
14	2.650	2.654	2.700	2.600	1.42	0.84	59
15	2.652	2.652	2.700	2.600	1.42	0.67	47
16	2.657	2.656	2.700	2.600	1.42	0.71	50
17	2.645	2.651	2.700	2.600	1.42	0.73	51
18	2.672	2.657	2.700	2.600	1.42	0.82	58
19	2.661	2.659	2.700	2.600	1.42	0.65	46
20	2.652	2.658	2.700	2.600	1.42	1.03	73
21	2.666	2.663	2.700	2.600	1.42	0.87	61
22	2.656	2.659	2.700	2.600	1.42	0.75	53
23	2.648	2.656	2.700	2.600	1.42	0.94	66
24	2.646	2.654	2.700	2.600	1.42	0.80	56
25	2.659	2.652	2.700	2.600	1.42	0.68	48
26	2.647	2.650	2.700	2.600	1.42	0.66	46

Aggregate Specific Gravity: Control Chart

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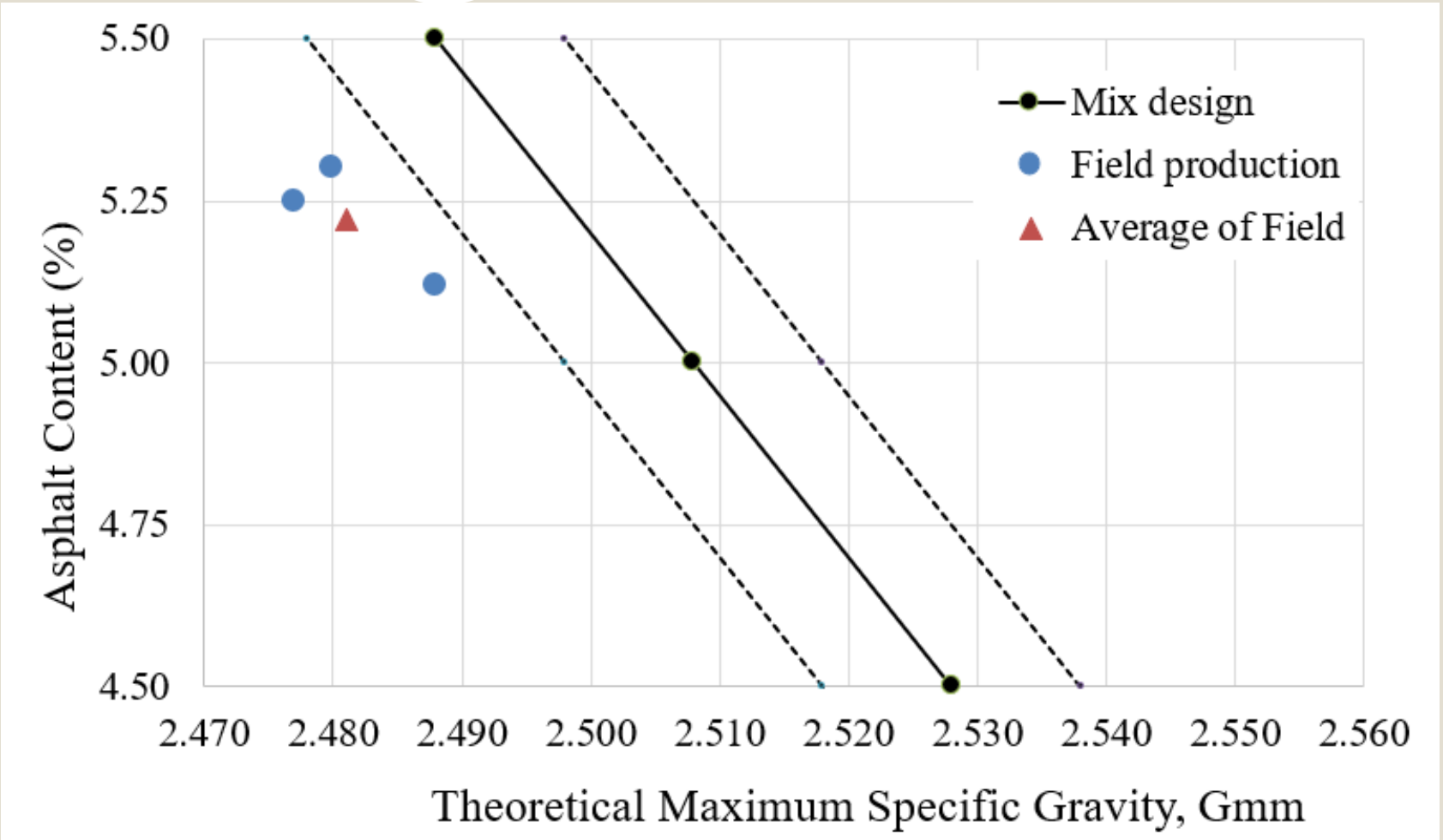
- Relationship between G_{sx} 's should not change
- Measure & plot G_{se} from G_{mm} and P_b



Relationship of Properties: Asphalt Content vs. G_{mm}

- Is relationship from Lab to Field Rational?

Agency monitoring MD & Field production trends

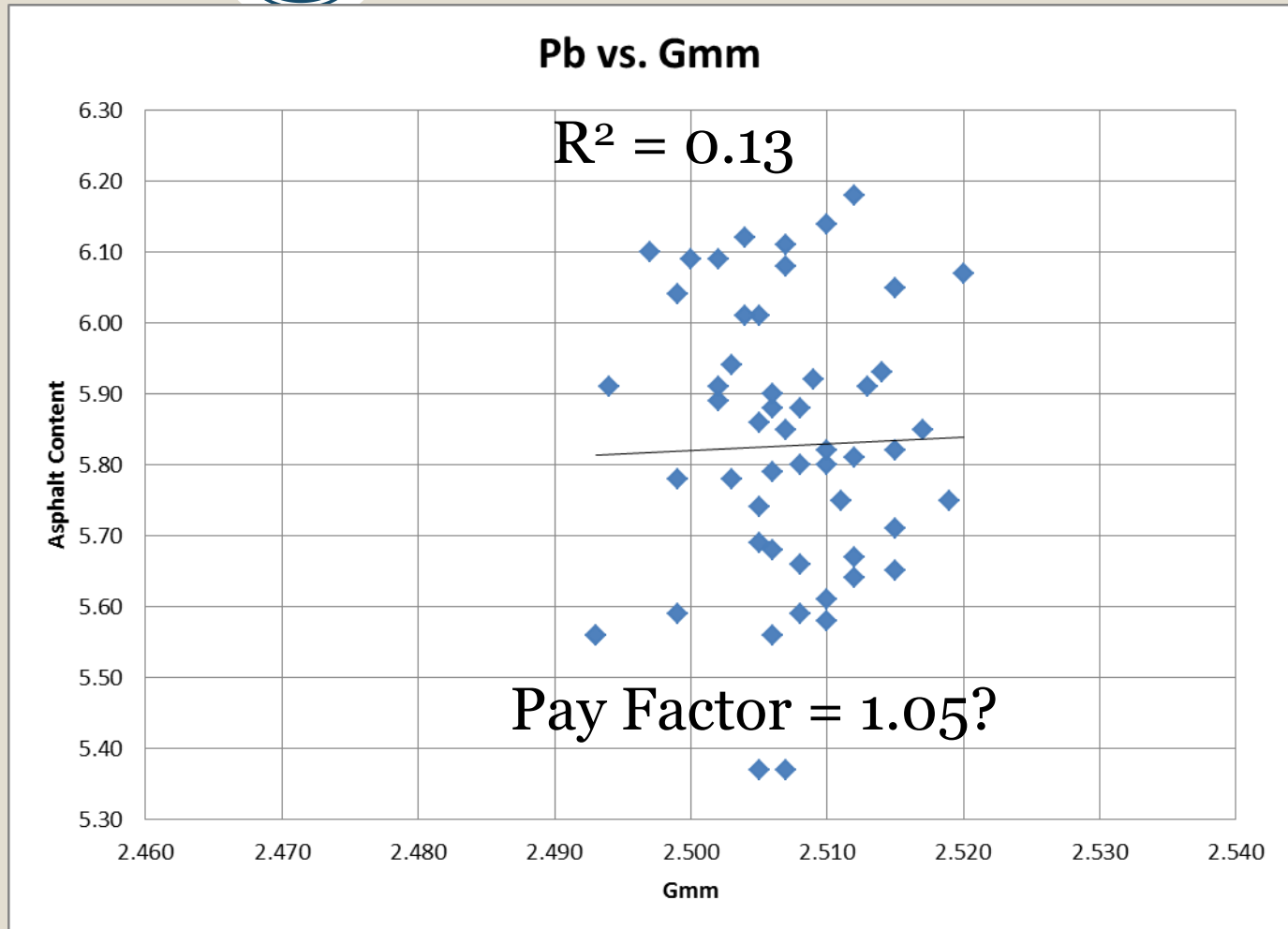


Relationship of Properties: Asphalt Content vs. G_{mm}

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- Is relationship between P_b and G_{mm} rationale?

**Agency monitoring
relationship**



Aggregate Specific Gravity: Summary

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Risk Mitigation Strategies

- Monitor aggregate and mixture specific gravities and absorption during production to assure:
 - $G_{sa} > G_{se} > G_{sb}$.
 - G_{mm} decreases as AC increases.
 - P_{ba} is about 50 percent of water absorption
- Plots (control chart) requirements for above
- Specification provisions - what is done when if specific gravities and/or absorption change
- Verify the mix design G_{sb} during a project startup evaluation

RAP in Acceptance

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- The question is often asked, “*How do you know you are getting the specified quantity of RAS or RAP?*”

Risk Mitigation Strategies

- Plant calibrations and verification on a regularly frequency
- Have RAP and RAS production and stockpile QC program
- Have a specification item for reconciling plant control data logger reports with loadout tickets and/or plant stockpile inventory and asphalt binder inventory at individual project level
- Survey dedicated RAP stockpiles
- Have Inspectors at Asphalt Plants

Recycled Materials: RAP

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- Recordation
 - Minnesota DOT

Agency monitoring Plant Reports

```
English - Mix: 'SPWEB340BN301' 274 TPH @ 389 F 5.29 %A/C Mix 1: 45.2 Top T: 40.17 7/11/2018 6:08:51 AM
(Tank #0 : '50S-20' 1.033 SpGr @ 227 F 5.7 %A/C) 3.92 %A/C + + + + %A/C
VScale RScale +A/C DstLss Vir 1 Vir 2 Vir 3 Vir 4 Vir 5 W/R6 Rap 7 Rap 8 Acc 10 ImpM11 Dust12
Measured By: none none none none Tach Tach none Tach Tach Tach Tach
Moisture % 3.9 2.7 N/A N/A 4.0 4.0 3.2 3.2 3.2 3.7 2.7 1.0 1.000 0.0 0
Rate JTPH 147 50 10.7 0.0 34 74 46 46 0 0 61 0 0.00 0.0 0.0
Total1 T 33.3 11.0 1.70 0.0 5.5 11.0 7.4 7.4 0.0 0.0 9.9 0.0 0.0 0.0 0.0
Total2 T 23113 9142.8 1406.3 0.0 4058.7 8899.9 4382.6 6469.0 1220.1 0.0 8156.0 0.0 0.0 0.0 0.0
Blend Perc.- 74.6 25.4 0.0 0.0 13.1 20.3 17.7 17.7 0.0 0.0 23.3 0.0 0.0 0.0 0.0
Errors 0 0 0 N/A 0 0 0 0 0 0 0 0 0 0 0
```

Recycled Materials: RAP and RAS

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RAS Cold Feed System:

- Scalping screen over bins
- Steep sidewall bins
- Air cannons and/or vibrators on bins
- Reverse weigh system for better feed rate control
- Uniform feed
- Empty bins at night

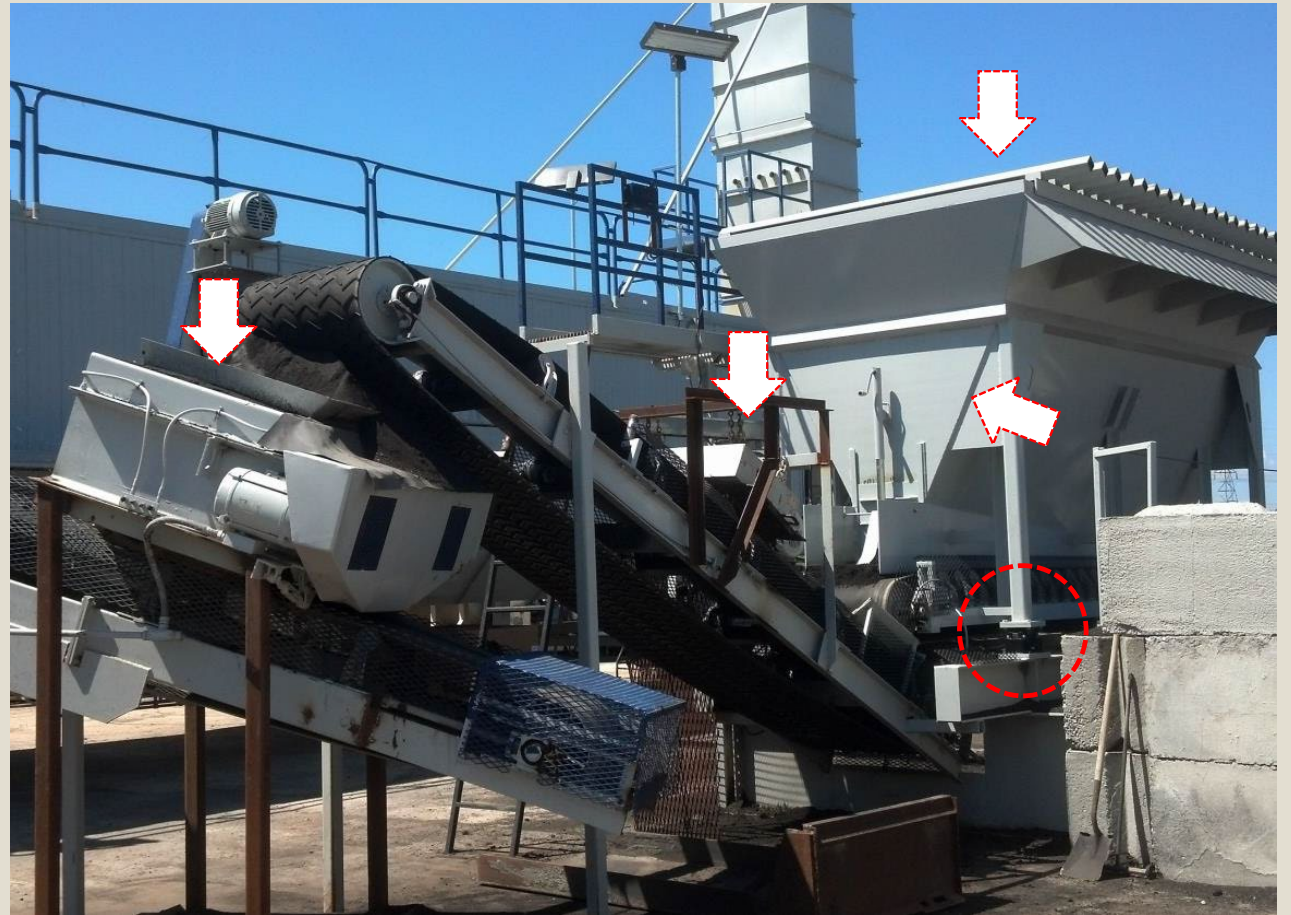


Image NAPA and NCAT

Summary

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- Engineering and statistical risks exist with potential costs
- Risks have changed with Method to QA specification transition
- Risks exist because specifications lack detail
- Lack of detail leads to different “interpretation” of specification intent
 - Example be explicit about “re-testing”
- DOT responsibility to review of policies, design standards, test methods, practices and specifications for QA acceptance risk
- Make changed based on risks identified
- Communicate and train on changes.

Maine DOT

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- Experienced significant AC overlay raveling statewide
 - Estimated 20% loss of pavements' service life at \$15 million cost in 1 year
- MDOT identified 7 potential causes:
 - Higher production p200 w/o production D/A criteria.
 - No aggregate durability test
 - Insufficient t/NMAS criteria, more permeable pavements
 - Not verifying G_{sb} led to inaccurate volumetric properties
 - Higher than desirable permeability from multiple causes
 - No moisture susceptibility test



Image Adam Hand

Maine DOT

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- Items to improve test methods, specifications and practices to reduce identified risks:
 - Improve the weighting of pay factors for p200 sieve; p200 from mix design to construction criteria and/or implement field-produced D/A
 - Improve the acceptance and validation process for the G_{sb}
 - Implement HWTT moisture susceptibility testing HWTT stripping inflection point
 - Implement durability test for fine and coarse aggregates like Micro-Deval
 - Establish guidelines for thin overlays including t/NMAS, gradation type (coarse versus fine).

Useful AASHTO Standard Applicable to Risk

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- AASHTO Standard Recommended Practice R-9, *Acceptance Sampling Plans for Highway Construction*
- AASHTO Standard Recommended Practice R-10, *Definitions of Terms Related to Quality and Statistics Used in Highway Construction*
- AASHTO Standard Recommended Practice R-42 *Developing a Quality Acceptance Plan for Hot Mix Asphalt (HMA)*

Thank you



QUESTIONS / COMMENTS:

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