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TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Superpave Volumetric Mix Design—Beyond the Basics

October 30, 2023

1:00 – 2:30 PM

NOVEMBER 2022 UPDATE

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING



REGISTERED CONTINUING EDUCATION PROGRAM

Purpose Statement

This webinar will share key properties that need to be included in the design and acceptance of asphalt mixtures. Presenters will share how to strengthen quality assurance programs in the design and acceptance of asphalt mixtures.

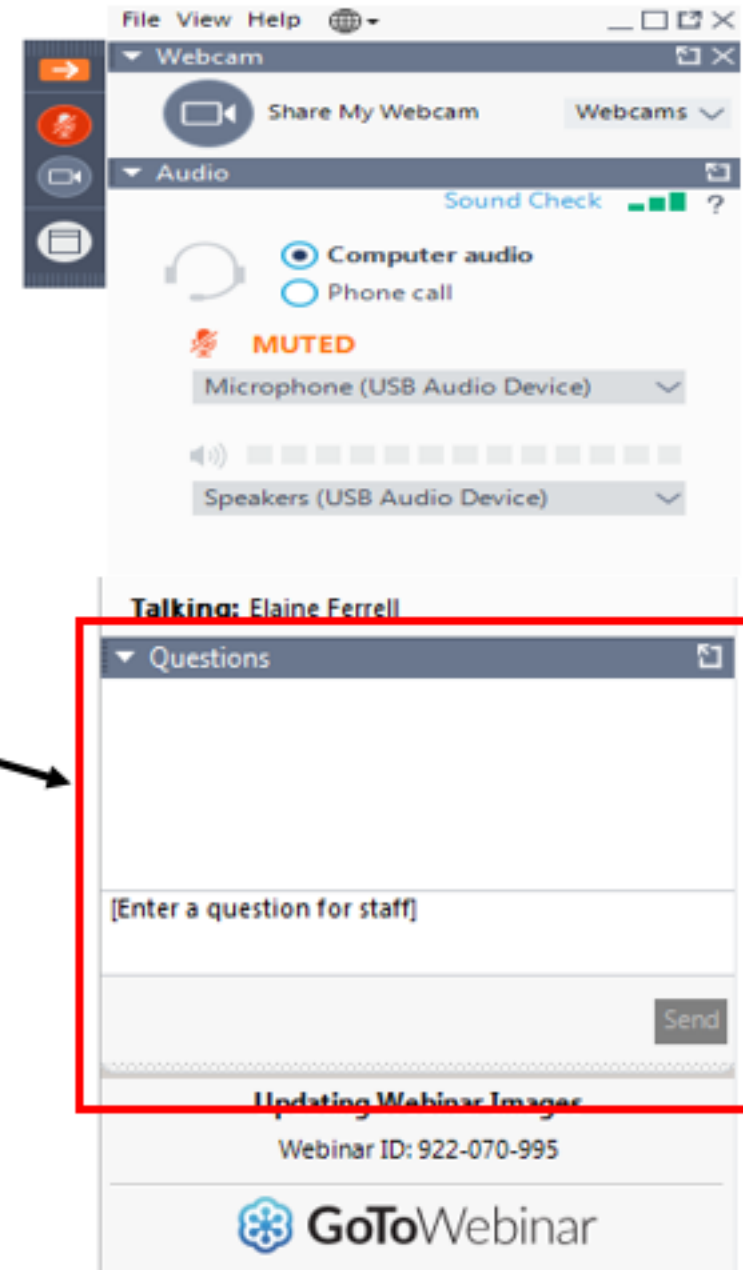
Learning Objectives

At the end of this webinar, you will be able to:

- (1) Identify key properties that need to be included in the design and acceptance of asphalt mixtures
- (2) Strengthen your quality assurance program in the design and acceptance of asphalt mixture
- (3) Determine key relationships that should be evaluated throughout the process

Questions and Answers

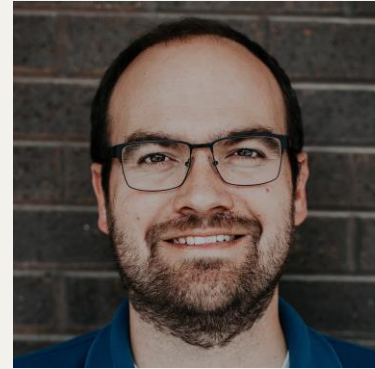
- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters



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Superpave Volumetric Mix Design – Beyond the Basics

*Unintended Consequences of Volumetric Design: Key Findings
from the Mississippi Department of Transportation Database*

Ben C. Cox, PhD, PE

*Senior Research Engineer
US Army Corps of Engineers, ERDC*



Acknowledgements

- Jonathan Easterling, Huey P. Stockstill, LLC
- Griffin Sullivan, Mississippi DOT
- Alex Middleton, Mississippi DOT
- Isaac Howard, Mississippi State University
- Jessica Lewis, Mississippi State University

Overview

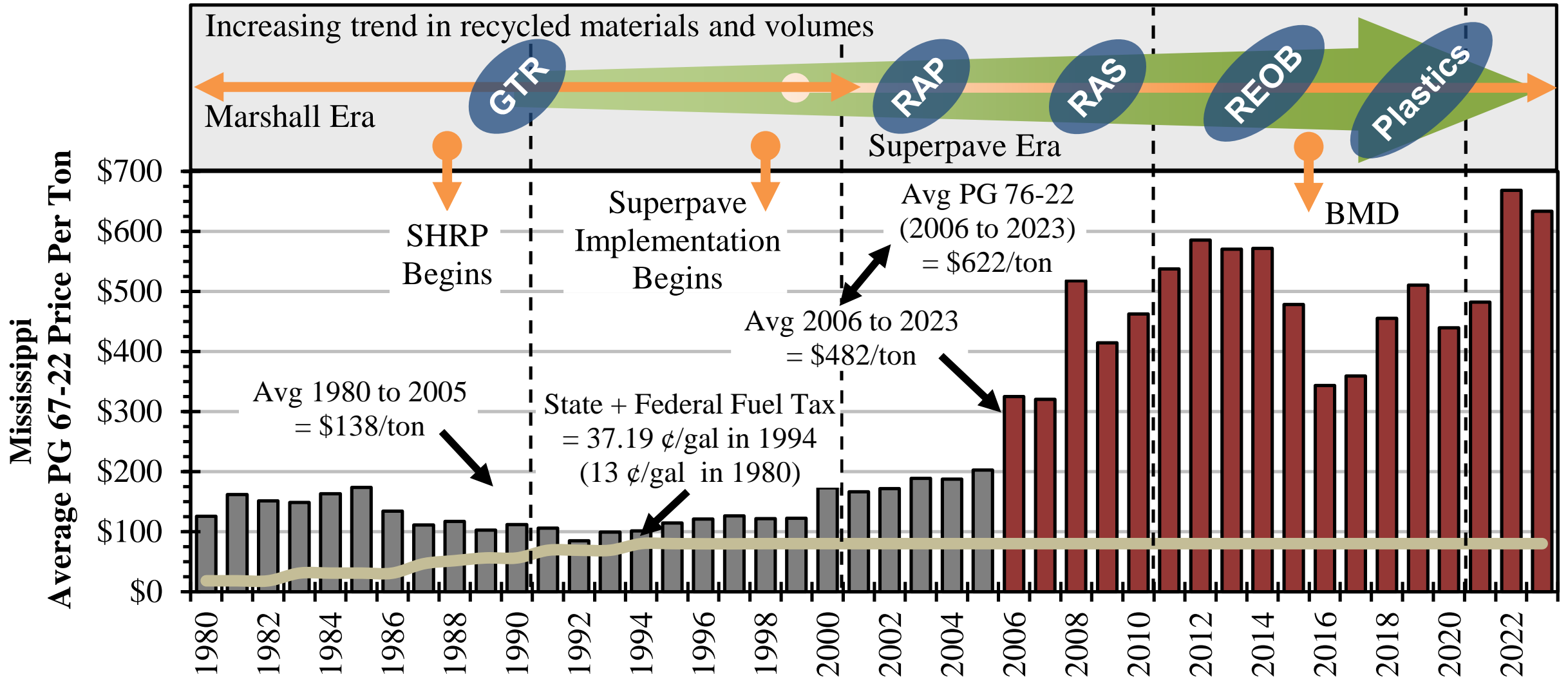
- Objective: present trends from a statewide database of all 1,452 volumetric mix designs approved by Mississippi DOT between 2005 and 2018
- Data highlights several issues and unintended consequences of exclusive (or near-exclusive) reliance on volumetrics
- Data builds a case for:
 - Greater emphasis on monitoring key volumetric parameters
 - Reintegrating mechanical tests

Motivations for This Exercise

- Asphalt industry strained by multiple factors in recent years
 - Increased asphalt binder costs
 - Limited funding
 - Pressure to recycle
 - Deteriorating pavement networks
- Mix design should account for market in which it is used
- Today's market much different than when current volumetric mix design practices were developed



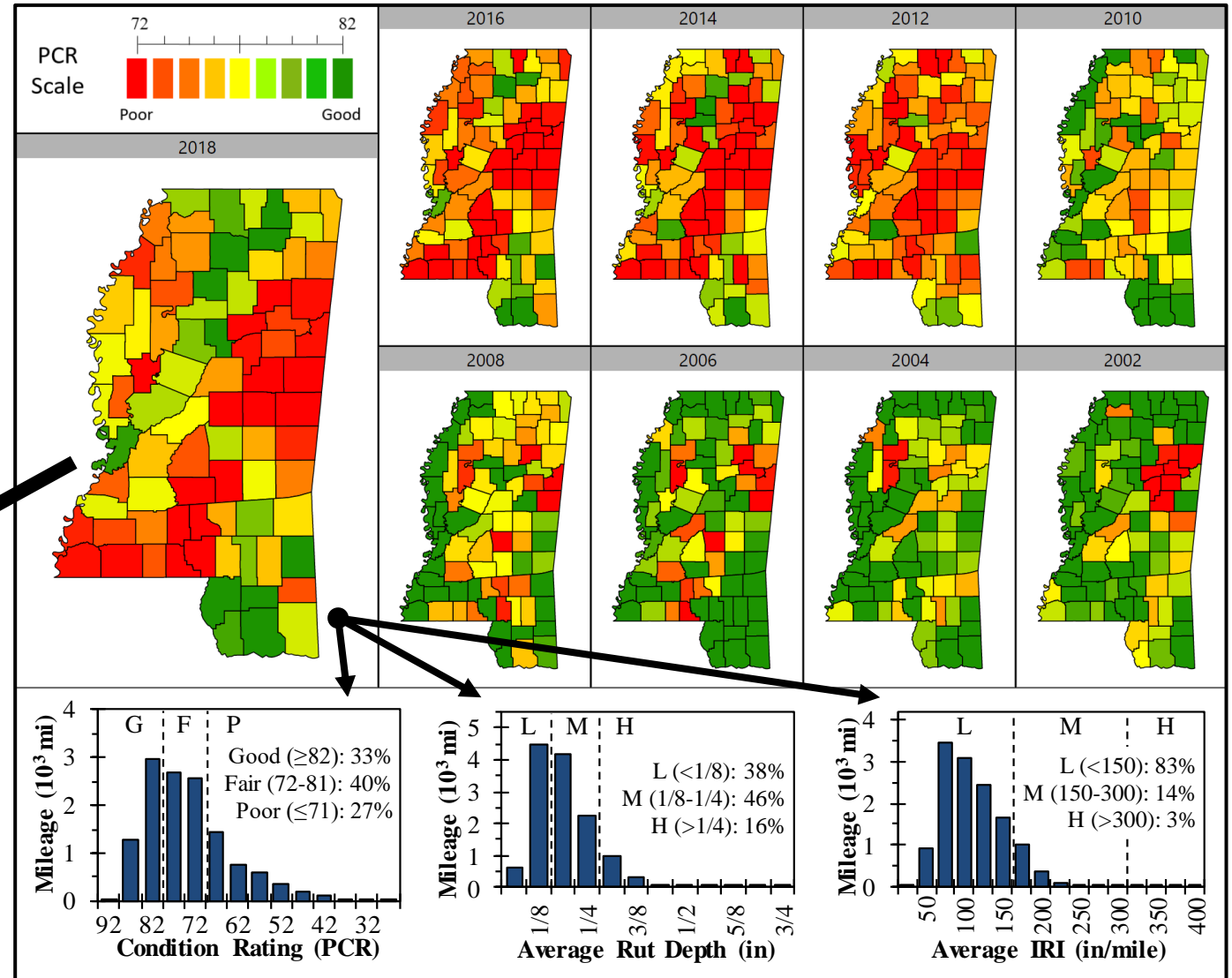
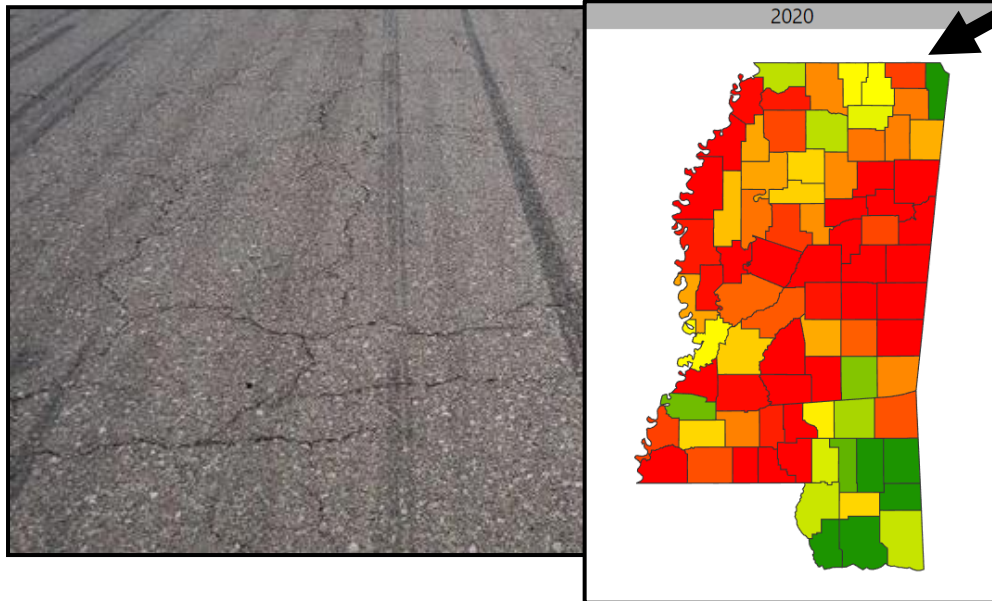
Motivations: 40-Year Trends



Market now is very different than when Superpave was developed and implemented

Motivations: Deteriorating Pavements

- Mississippi DOT pavement condition ratings trending wrong direction
- Most notable factor: cracking (dry mixes)



Mix Design Database

- 1,452 MDOT approved Superpave mix designs from 2005 to 2018
- Database quick-look
 - **Mix Types:** DGA (1,308), SMA (84), other (60)
 - **NMAS:** 19 mm (381), 12.5 mm (403), 9.5 mm (475), other (49)
 - **N_{des}:** 50 gyr (468), 65 gyr (393), 85 gyr (447)
- Properties
 - General classification (mix type, NMAS, etc.)
 - Aggregates (gradation, gravities, etc.)
 - Asphalt binder (source, PG grade, etc.)
 - Mixtures (gravities, design volumetrics, etc.)

Mix Design Database Observations

Trends discussed in five categories **(three discussed today)**

1. **VMA**
2. **G_{sb} and *Abs***
3. RAP Content (*see Cox et al. 2022*)
4. **N_{des}**
5. Coarse vs. Fine Gradations (*see Cox et al. 2022*)

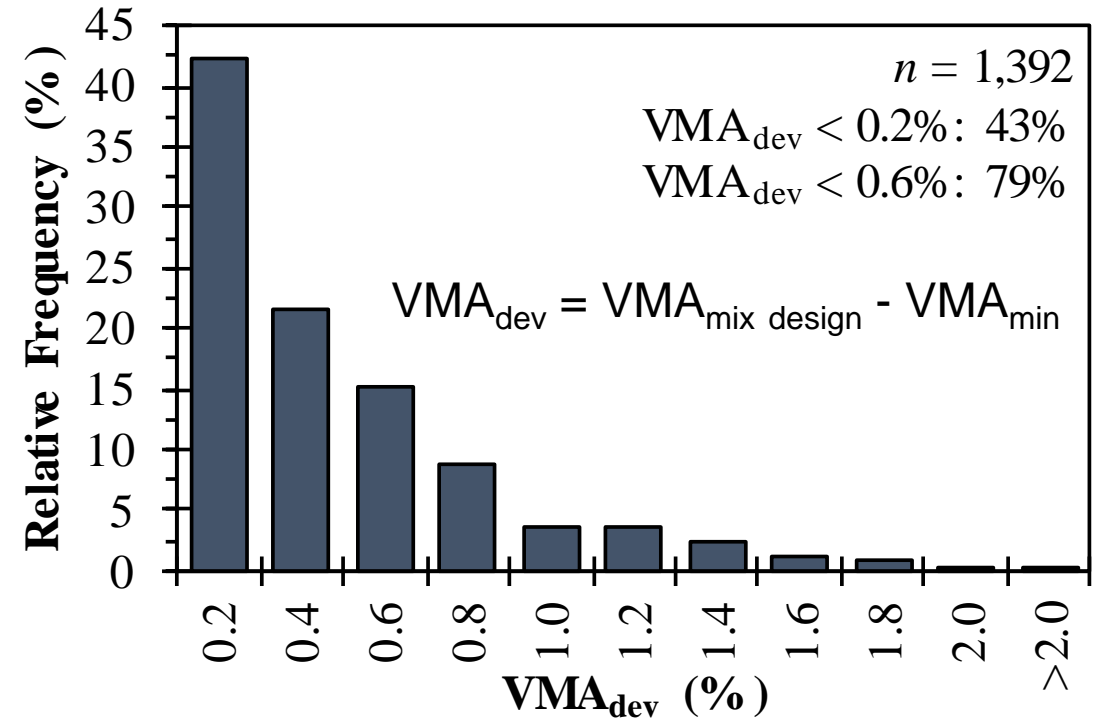
Cox, B.C., Easterling, J., Sullivan, W.G., Middleton, A., and Howard, I.L. (2022). Data Mining Statewide Department of Transportation Volumetrically Designed Asphalt Mixture Records. *Transportation Research Record*, 2676(5), 242-262. <https://doi.org/10.1177/03611981211061356>

1. VMA Trends

- 80% of all DGA and SMA mixes are within 0.6% of minimum VMA (VMA_{min})
- Skew towards VMA_{min} indicates mix optimization based on VMA (i.e. VMA controls asphalt content)
- VMA will generally be as close to VMA_{min} as reasonably possible to maintain an economical mix

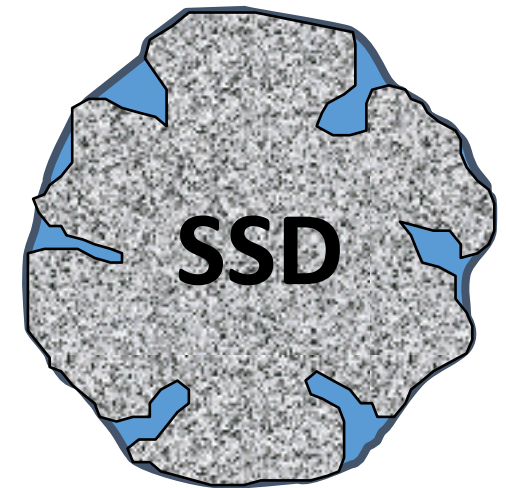
MDOT VMA Levels

NMAS (mm)	VMA_{min} (%)
19.0	13.0
12.5	14.0
9.5	15.0



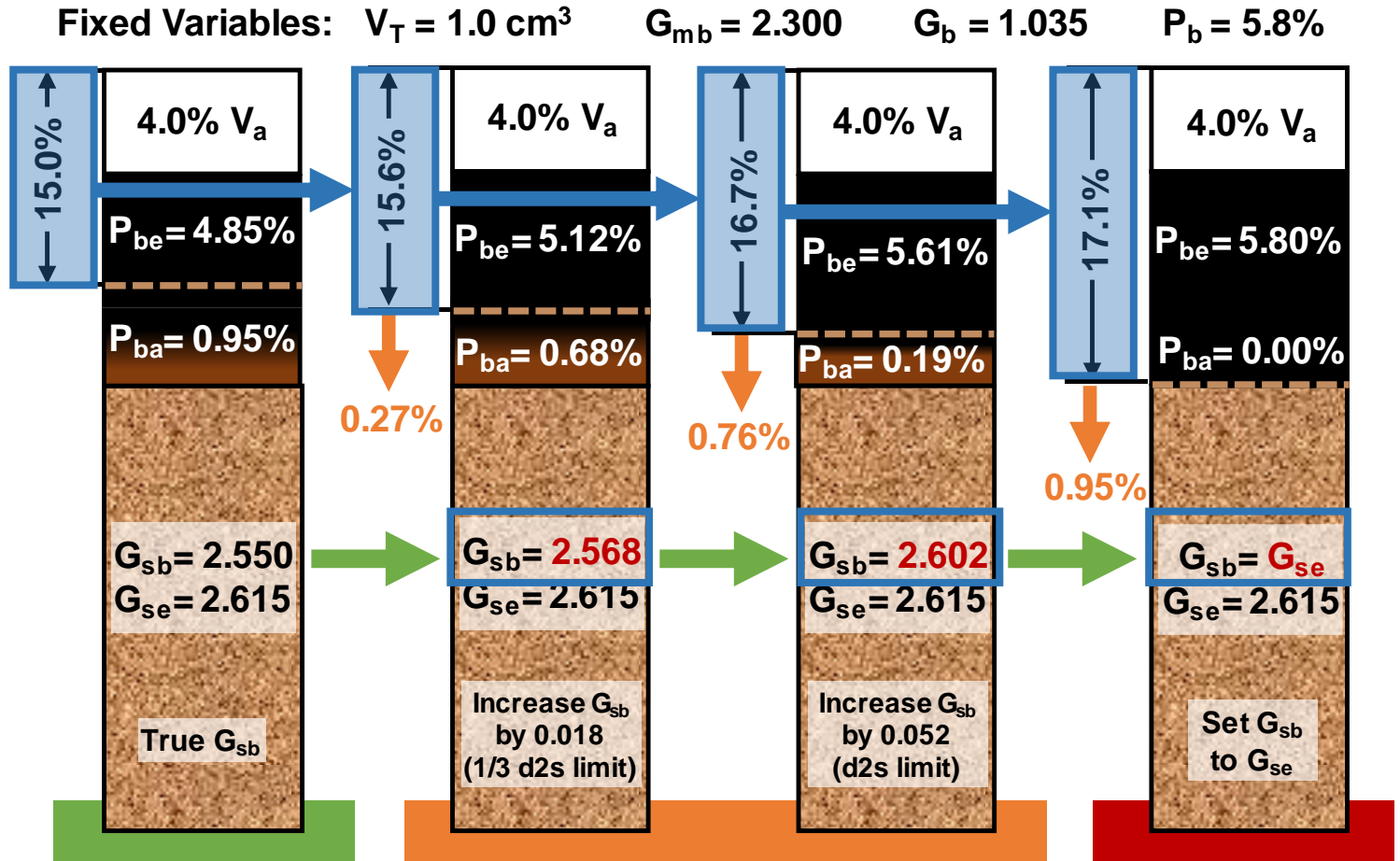
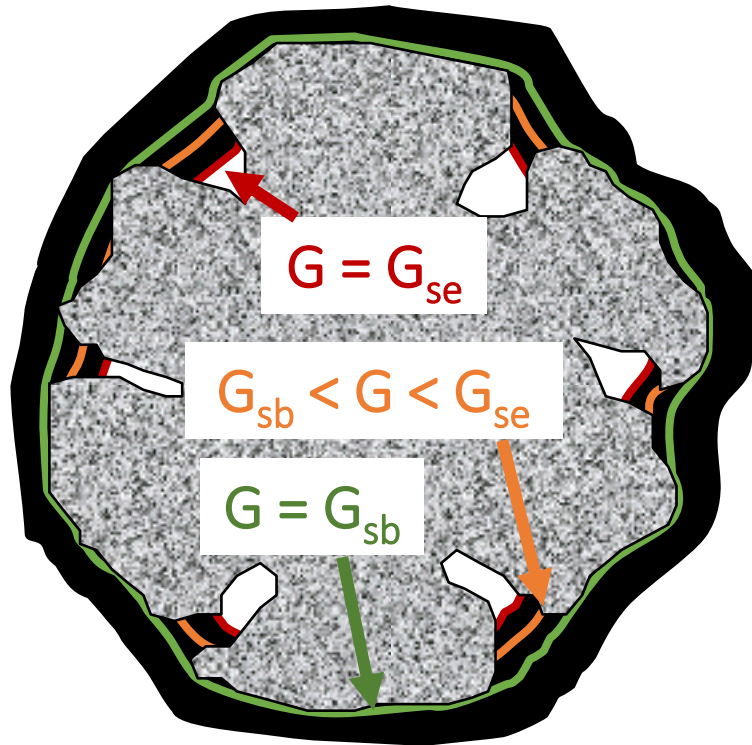
1. VMA Dependency on G_{sb}

- Concern with VMA trend is that VMA depends on G_{sb} (inherently operator dependent and variable)
- AASHTO d2s for 50/50 coarse/fine agg. blend: 0.052
- High d2s provides room to find a “favorable” G_{sb} that is the “same” as the true G_{sb} by d2s standards
- Primary concern is with inflated G_{sb} values (achieved by drying agg. past SSD condition)



1. VMA Dependency on G_{sb}

Inflating G_{sb} increases calculated VMA; gradation can be tweaked to bring calculated VMA back near VMA_{min} ; actual VMA (and V_{be}) are below minimum requirements

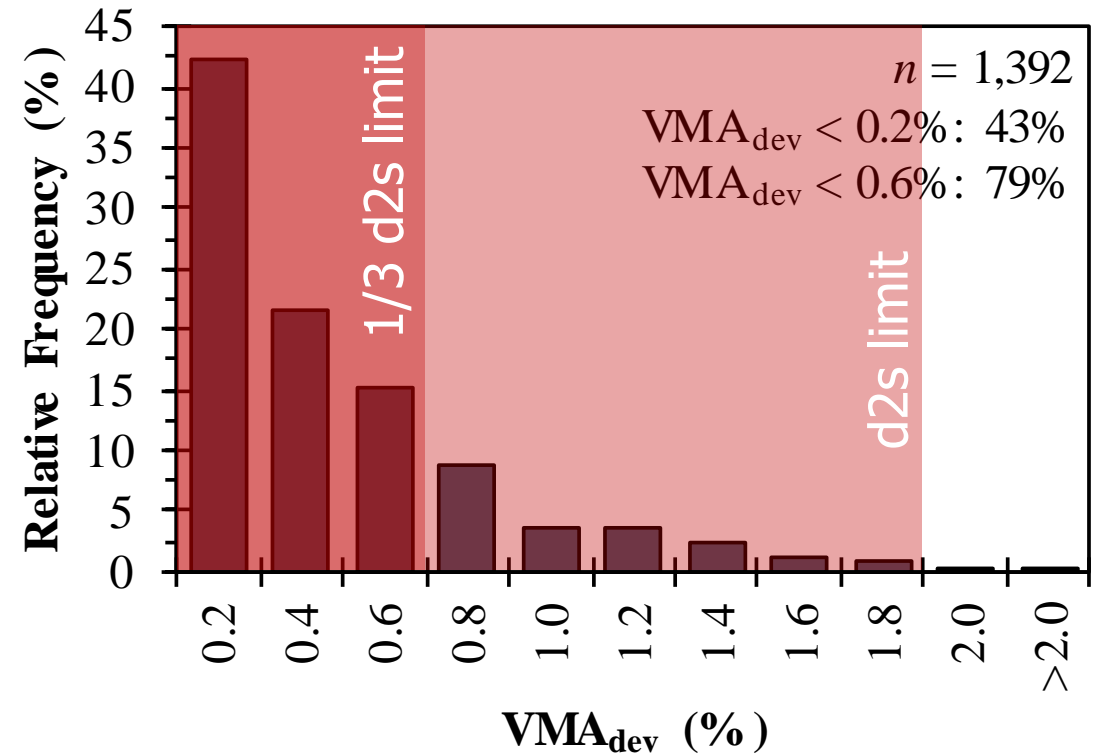


1. VMA Dependency on G_{sb}

- In context of MDOT database trends:

G_{sb} Inflation Amount	% Mixes where VMA_{calc} may pass but VMA_{actual} fails	Corresponding Reduction in $P_{b, des}$
1/3 d2s limit	80%	Up to 0.3%
d2s limit	99%	Up to 0.8%

- G_{sb} variability, if exploited, allows VMA manipulation and can easily result in dry mixes



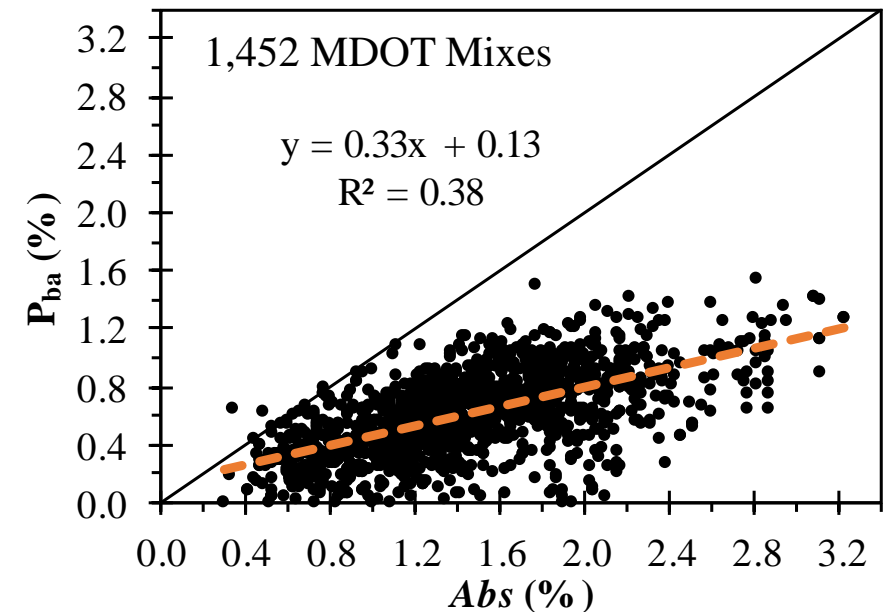
2. G_{sb} and *Abs*: Practices by State

- Numerous differences among states regarding handling of G_{sb}
- G_{sb} is generally not monitored once mix design is established
- Some states indirectly account for G_{sb} using G_{se} -to- G_{sb} corrections; this requires an accurate initial G_{sb} , accurate P_b measurements, and constant P_{ba}

		MDOT	Other Southeastern Asphalt User Producer Group States
Aggregate	P_{200} for AASHTO T85	Washed	Washed (4), Unwashed (3), Not specified (6)
	G_{sb} test frequency	At mix design	At mix design (10), 1 per year (2), 1 per 2 weeks (1)
	Tested by	Contractor	Contractor (10), Contractor and/or DOT/approved lab (3)
RAP	Max allowed	30%	30% (7), 35% (3), others
	Gravity for VMA calculation	G_{sb} from extraction	G_{se} (5), Estimate G_{sb} from G_{se} (3), Either (4), G_{sb} from extraction (1)
Production	G_{se} -to- G_{sb} correction for VMA calculation	No	No (10), Yes (3)

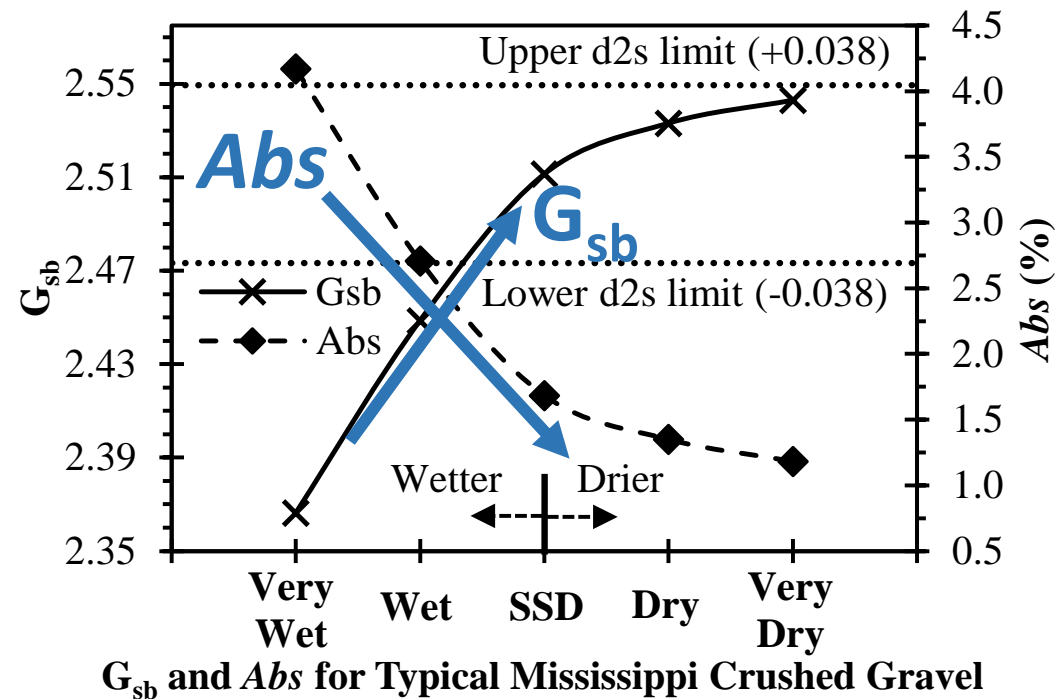
2. G_{sb} and *Abs*: Evaluating Reasonableness

- Large d_{2s} limit and typical G_{sb} practices open door for inflated G_{sb} values
- Is it possible to tell if G_{sb} might be inflated?
 - Reported VMA will likely seem reasonable
 - P_b may not seem unreasonable unless really low
 - Low P_{ba} could be due to low-absorption aggregate or inflated G_{sb} – may not be obvious
- P_{ba} -to-*Abs* rules of thumb are sometimes used to check G_{sb}
- Relationship between P_{ba} and *Abs* exists on average (less reliable for any one specific case due to scatter)



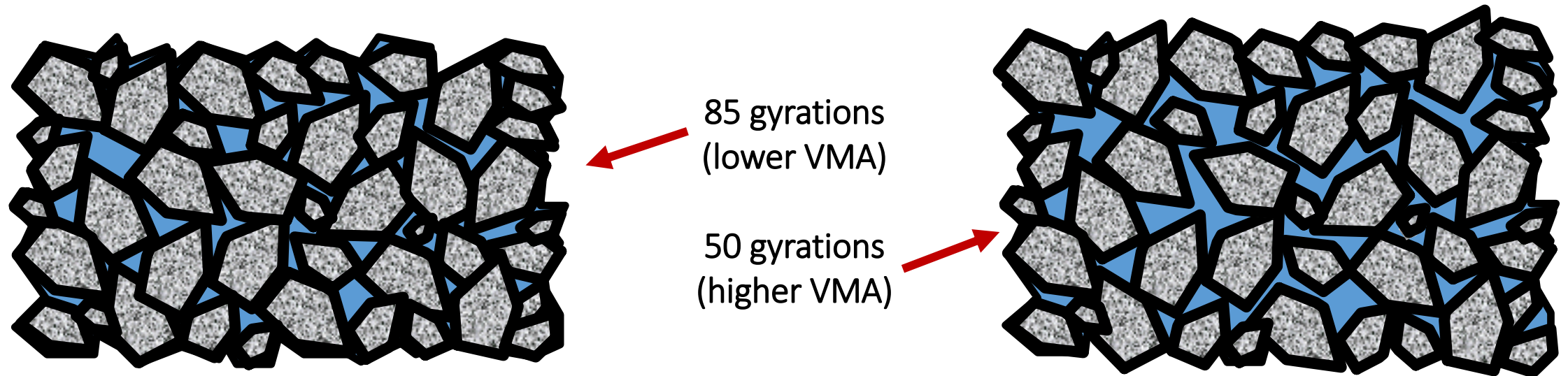
2. G_{sb} and Abs : Evaluating Reasonableness

- P_{ba} -to- Abs rules have limitations because inflating G_{sb} deflates Abs
- Low P_{ba} values will not be obvious in comparison to deflated Abs values (i.e. rule of thumb may not pinpoint G_{sb} problem)



4. Decreasing N_{des} Level

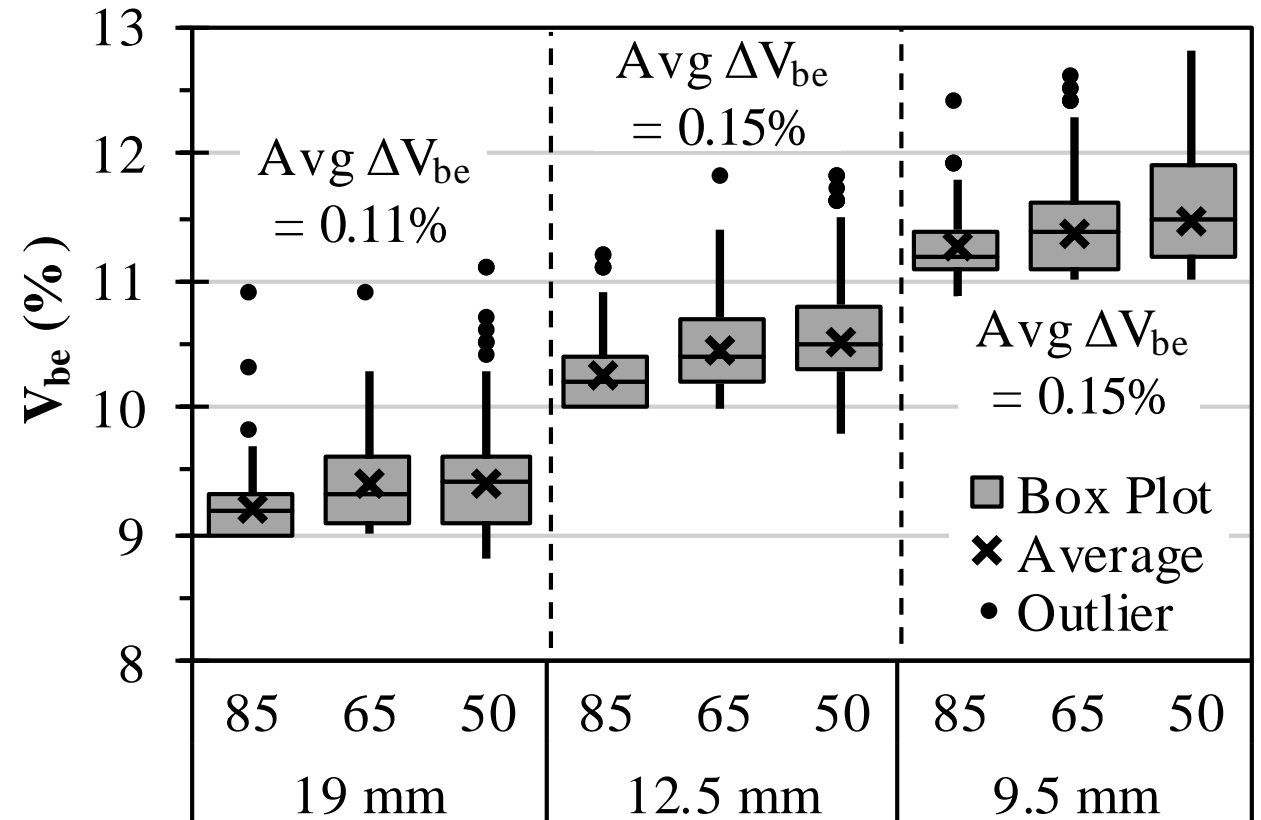
- A common suggestion to increase asphalt content is reduce N_{des}
- This works if all other factors held constant
- Less compaction \rightarrow looser agg skeleton \rightarrow higher VMA \rightarrow higher V_{be}



Rule of Thumb: 30 gyr reduction = 1% VMA = 0.4% P_{be}

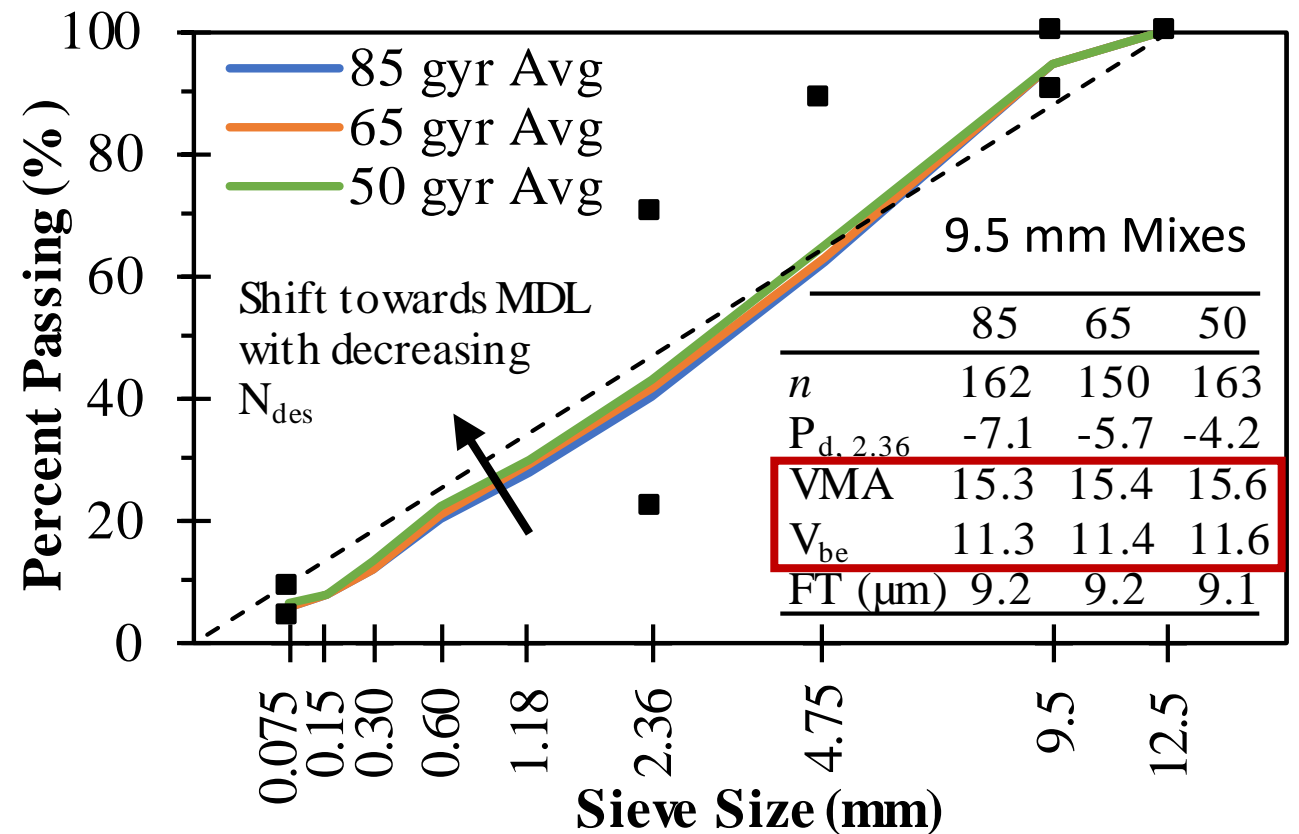
4. Decreasing N_{des} Level

- In practice, changing N_{des} has little impact
- For 35 gyr reduction (85 to 50), V_{be} increases about 0.3% on average
- This equates to 0.14% P_{be} increase, which is miniscule compared to the cited 0.4% P_{be} increase



4. Decreasing N_{des} Level

- Changing N_{des} has little impact because nothing prevents mix designer from adjusting aggregate blend and/or gradation
- Since VMA_{min} did not change, mix designer can bring VMA back toward VMA_{min} by filling voids with aggregate (more economical than binder)
- MDOT database illustrates that gradations shift toward max density line in practice



Mississippi's Takeaway

- Data from practice across an entire state supports numerous other smaller studies (e.g. may only evaluate one factor at a time)
- Statewide mix design trends are largely driven by how G_{sb} and VMA are handled – G_{sb} is a key lynchpin
- At a minimum, volumetric mix design practices need greater emphasis on G_{sb} and VMA
- Concern exists within Mississippi that volumetric-only mix design is not fully capable of dealing with complexities of present-day mixes, and Mississippi feels mechanical tests are needed, perhaps more now than when they were sought during SHRP

Path Forward in Mississippi

To build on findings from the MDOT database...



MDOT State Study 321 – Durability Improvements by Way of a Holistic Assessment of the MS Department of Transportation’s Asphalt Practices

-- Jessica V. Lewis, PhD Student

- Examine all factors related to delivering a ton of asphalt mix to MDOT (lab work, field projects, industry & agency advisory boards)
- Continue improving AASHTO T401

A Case Against Exclusive Reliance on Volumetric Mixture Characterization and the Advancement of a Viable Alternative

-- Jonathan Easterling, PhD Candidate

- Use quality control data from a single mixture produced over several years at a single asphalt production facility
- Establish initial precision statement for AASHTO T401 and improve lab conditioning protocols that can be deployed with T401

Thank you!



Ben Cox
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Indiana DOT Adjustments: Determining Gsb for Mix Design and Production, and Using Vbe instead of VMA for Acceptance

Matt Beeson, PE

Director, Division of Materials and Tests

Indiana DOT

Determining Gsb for Mix Design and Production

- Before 2014
- INDOT ran T84/T85 on each agg source and ledge combo annually
- Published a list
- HMA Mix Designers could run T84/T85, submit values
 - If within d2s, INDOT accepted
 - T 84 = 0.066
 - T 85 = 0.038

Determining Gsb for Mix Design and Production

- Problem
 - District Engineers approving designs didn't understand role of Gsb
 - Central Office Engineers understood role of Gsb, didn't see designs
- 2013 review showed major problem
- Many designs were being submitted with all aggregates at the high end of d2s

Real Mix Design Example

- 19.0 mm mixture
- $G_{sb} = 2.665$
- $G_{mm} = 2.490$
- $G_{mb} = 2.390$
- $P_b = 4.1$
- $VMA = 13.6\%$

Real Mix Design Example

- 19.0 mm mixture
- $G_{sb} = 2.665$
- $G_{mm} = 2.490$
- $G_{mb} = 2.390$
- $P_b = 4.1$
- $VMA = 13.6\%$

Looks Good!

Real Mix Design Example

- 19.0 mm mixture
- $G_{sb} = 2.665$
- $G_{mm} = 2.490$
- $G_{mb} = 2.390$
- $P_b = 4.1$
- $VMA = 13.6\%$
- **$G_{se} = 2.651$**

Looks Good?

Real Mix Design Example

- $G_{sb} = 2.665$
- $G_{se} = 2.651$

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

- $P_{ba} = -0.20\%$

Uh Oh.

Real Mix Design Example

- $P_{ba} = -0.20\%$
- Negative Absorption
 - Obviously doesn't happen
 - Absorption actually happens when mix is produced
 - Where does it come from?
 - The effective asphalt content!

Real Mix Design Example

- 19.0 mm mixture
- **Real** Gsb = 2.600 ~~2.665~~
- Gse = 2.651
- **Real** Pba = 0.76% ~~-0.20%~~
- **Real** VMA = 11.8% ~~13.6%~~

Real Mix Design Example

- How much more binder to make it all balance?
- Fake Pba = -0.20%
- Real Pba = 0.76%
- $0.76\% - (-0.20\%) = 0.96\%$
- $Pb = 4.10\% + 0.96\% = 5.06\%$
- “Binder Deficient” by almost 1.0%

Initial Solution

- 2014
- Gsb list
 - INDOT data
 - 5 year moving average of all agg sources and products
 - HMA mix designs required to use these values

					1/1/2014	
INDOT HMA Aggregate Bulk Specific Gravities						
Source	Producer	Additional Info	Product	Gsb	Abs	
2109	Purdy Materials		Sand	2.568	2.03	
2110	Whitesville Mill Service		11	3.547	1.58	
2110	Whitesville Mill Service		Sand	3.403	2.77	

Shortcomings

- What about RAP?
 - INDOT allowed up to 40% ABR
 - RAP design Gsb value set at 2.640
 - This was the statewide average aggregate Gsb value
 - Still not accurate for a large portion of sources
- What about Gsb changes in the field?
 - Intentional or otherwise

Determining Gsb from extracted sample

- Centrifuge extraction with trichloroethylene
- Indiana TM 571
- Initial extraction through
- Effluent ran through



- As of 2022 we use auto-extractors

Determining Gsb from extracted sample

- Gradation, split the sample on the #4 sieve
- Retained on #4 sieve = T 85
- Passing #4 sieve = T 84
- Combined Gsb
- ITM 590



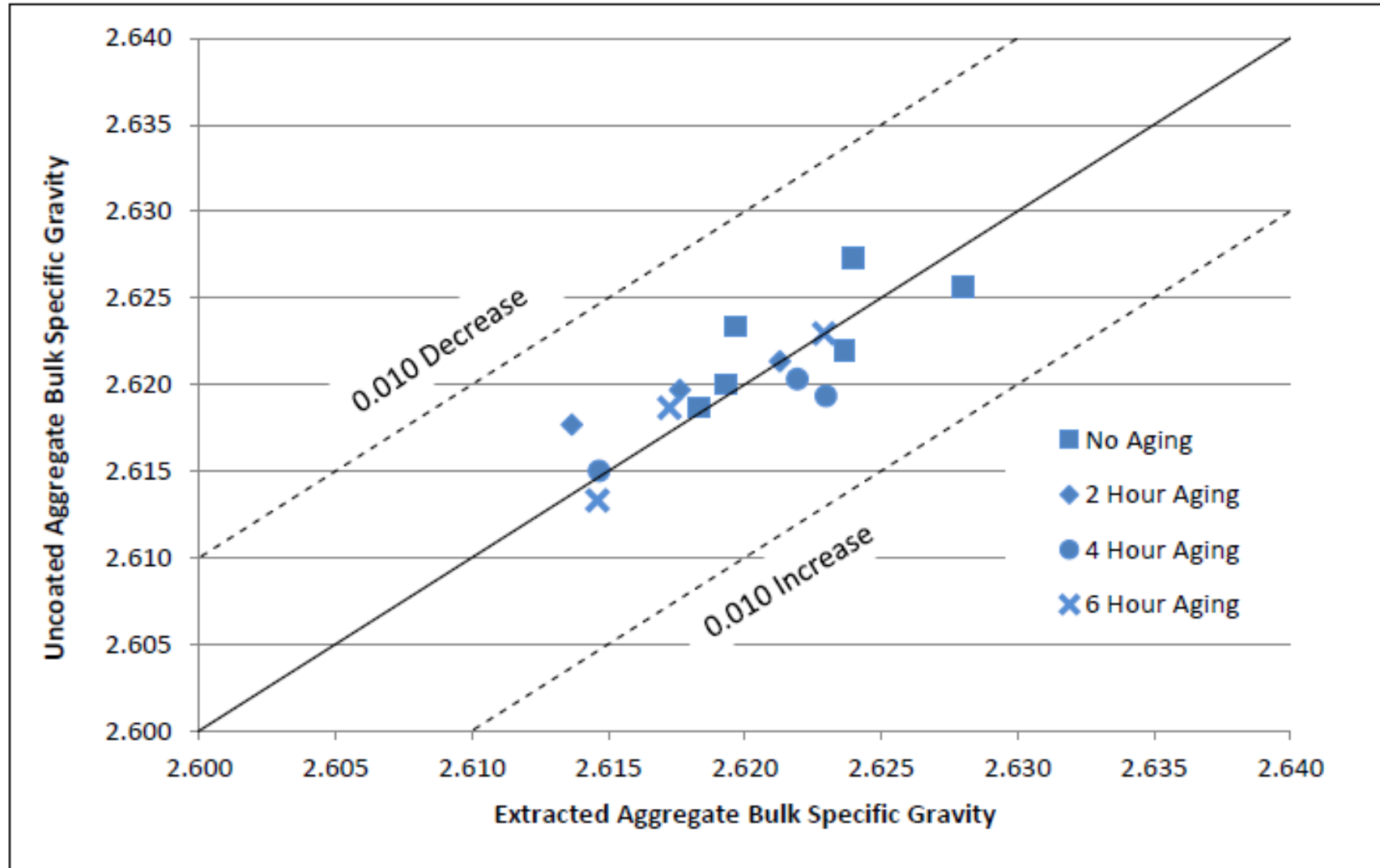
**INDIANA DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS**

**TOTAL AGGREGATE BULK SPECIFIC
GRAVITY DETERMINATION
FROM EXTRACTED HMA OR SMA MIXTURE
ITM No. 590-18**

Determining Gsb from extracted sample

- Is this accurate?
- Trial w/ 3 aggregates
 - Limestone coarse aggregate (similar to #57)
 - Limestone manufactured sand
 - Natural sand
- 18 samples, with #4 and minus #4 removed
- Gsb of each aggregate sample determined, 4.5% binder
- Various permutations, including different aging @150C
- Extraction
- Gsb of extracted aggregate


Determining Gsb from extracted sample



Determining Gsb from extracted sample

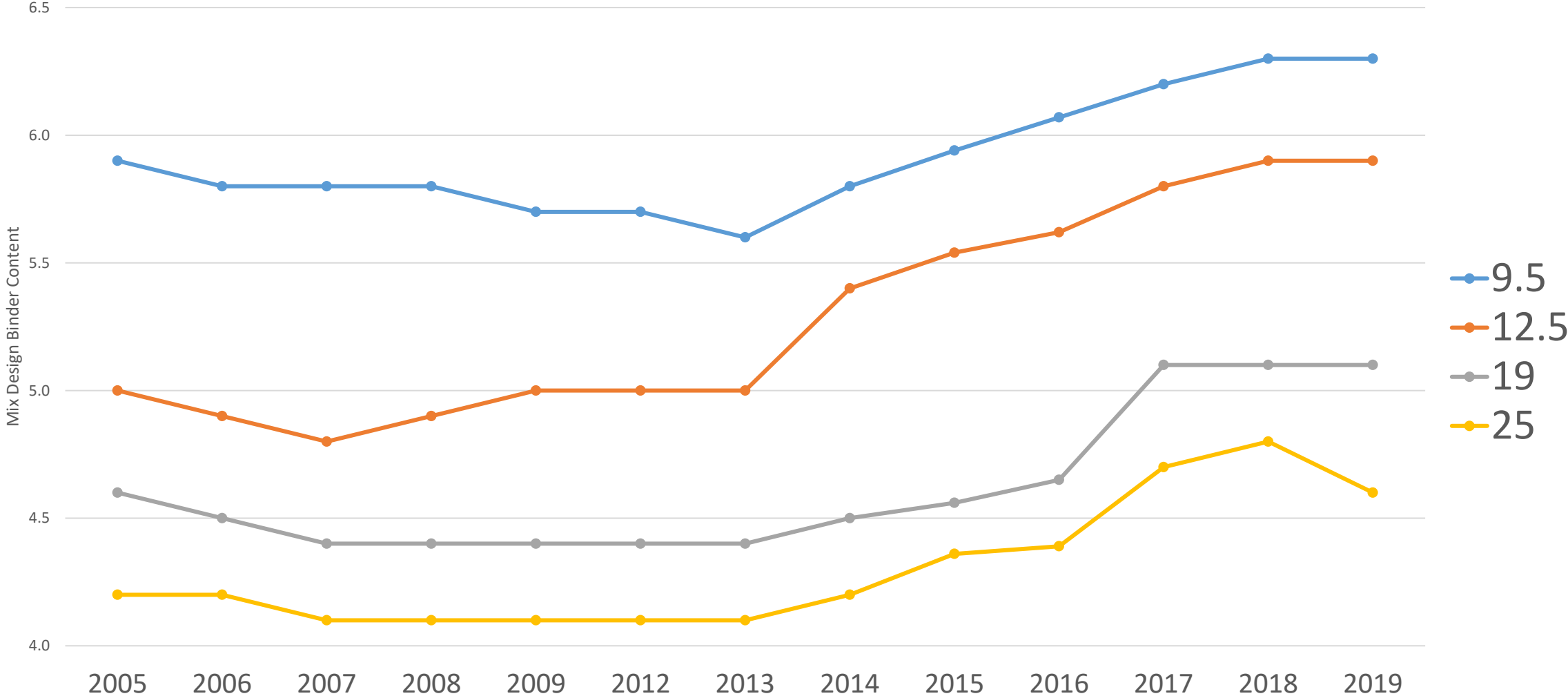
- Asphalt Mix Design and Acceptance Specifications: Ensuring Adequate Asphalt Binder Content
- Presented at CTAA/Published in proceedings
 - Many thanks to Gerry Huber

Implementation

- ITM 597 - QC/QA HMA Gsb Procedures
- 3 point moving average
 - 1) DMF Gsb value  from Gsb list
 - 2) Initial DMF startup
 - 3) After one lot of DMF production (3k tons surface, 5k tons base/int)
- This provides an “established Gsb”
- Additional testing randomly selected by DOT
- New value, new 3 point moving average
- If 3 point moving average changes by 0.020, new Gsb
 - Was originally 0.010 – compromise w/ Industry to 0.020

Indiana Binder Content Trends

Indiana Binder Content Trends



Vbe instead of VMA for Acceptance


Indiana DOT Asphalt Acceptance

- Plate Samples and Cores
- Percent Within Limits
 - Pre-2017: 35% Air Voids, 35% Density, 20% Binder, 10% VMA
 - 2017-2018: 30% Air Voids, 35% Density, 35% VMA
- 2017 change rationale
 - Binder Content target set by mix design
 - We really care about VMA
- What happened?


HMA Specification Revisions

- What is VMA?
 - A measure to ensure a mixture has enough effective asphalt content
- Volume of Effective Asphalt (V_{be})
 - Volume of asphalt available for use as binder
- $VMA = V_{be} + \text{Air Voids}$



HMA Specification Revisions

- Problem with VMA as field pay factor
 - VMA equals
 - Effective Asphalt + Air Voids
 - If Air Voids = DMF  **No problem**



HMA Specification Revisions

- Problem with VMA as field pay factor
 - VMA equals
 - Effective Asphalt + Air Voids
 - If Air Voids = DMF  **No problem**
- VMA spec = 15%
- Sublot Air Voids = 4%
- Sublot Vbe = Design Vbe = 11%



HMA Specification Revisions

- Problem with VMA as field pay factor
 - VMA is:
 - Effective Asphalt + Air Voids
 - If Air Voids = DMF  No problem
 - If Air Voids < DMF  Could be too much binder




HMA Specification Revisions

- Problem with VMA as field pay factor
 - VMA is:
 - Effective Asphalt + Air Voids
 - If Air Voids = DMF  No problem
 - If Air Voids < DMF  Could be too much binder
- VMA spec = 15%
- Sublot Air Voids = 3%
- Sublot Vbe = 12%




HMA Specification Revisions

- Problem with VMA as field pay factor
 - VMA is:
 - Effective Asphalt + Air Voids
 - If Air Voids = DMF  No problem
 - If Air Voids < DMF  Could be too much binder
 - To meet VMA spec, more binder required. Unlikely to be on purpose due to cost of binder.
- VMA spec = 15%
- Sublot Air Voids = 3%
- Sublot Vbe = 12%




HMA Specification Revisions

- Problem with VMA as field pay factor
 - VMA is:
 - Effective Asphalt + Air Voids
 - If Air Voids = DMF  No problem
 - If Air Voids < DMF  Could be too much binder
 - If Air Voids > DMF  **Not enough binder**

HMA Specification Revisions

- Problem with VMA as field pay factor
 - VMA is:
 - Effective Asphalt + Air Voids
 - If Air Voids = DMF  No problem
 - If Air Voids < DMF  Could be too much binder
 - If Air Voids > DMF  **Not enough binder**
- VMA spec = 15%
- Sublot Air Voids = 5%
- Sublot Vbe = 10%

HMA Specification Revisions

- Problem with VMA as field pay factor
 - VMA is:
 - Effective Asphalt + Air Voids
 - If Air Voids = DMF  No problem
 - If Air Voids < DMF  Could be too much binder
 - If Air Voids > DMF  Not enough binder
- VMA spec = 15%
- Sublot Air Voids = 5%
- Sublot Vbe = 10%
- **Incentive for HMA Producers to lean this direction**

Before and After

- Statewide average of all QA samples (around 4,000 samples)
 - 2018 Air Voids = 0.15% above DMF
 - 2019 Air Voids = 0.26% below DMF
- Difference of 0.41%

Before and After

- Benefits

- Finally measuring what we want
- Slightly less VMA in mixtures
 - 2018 = 0.80% over spec min
 - 2019 = 0.68% over (old) spec min
 - Easier to produce + compact
 - More desirable mix

Thank you!

Matt Beeson, P.E.

Director, Division of Materials and Tests

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Superpave Volumetric Mix Design – Beyond the Basics

“Tips and tricks for strengthening your quality assurance program”

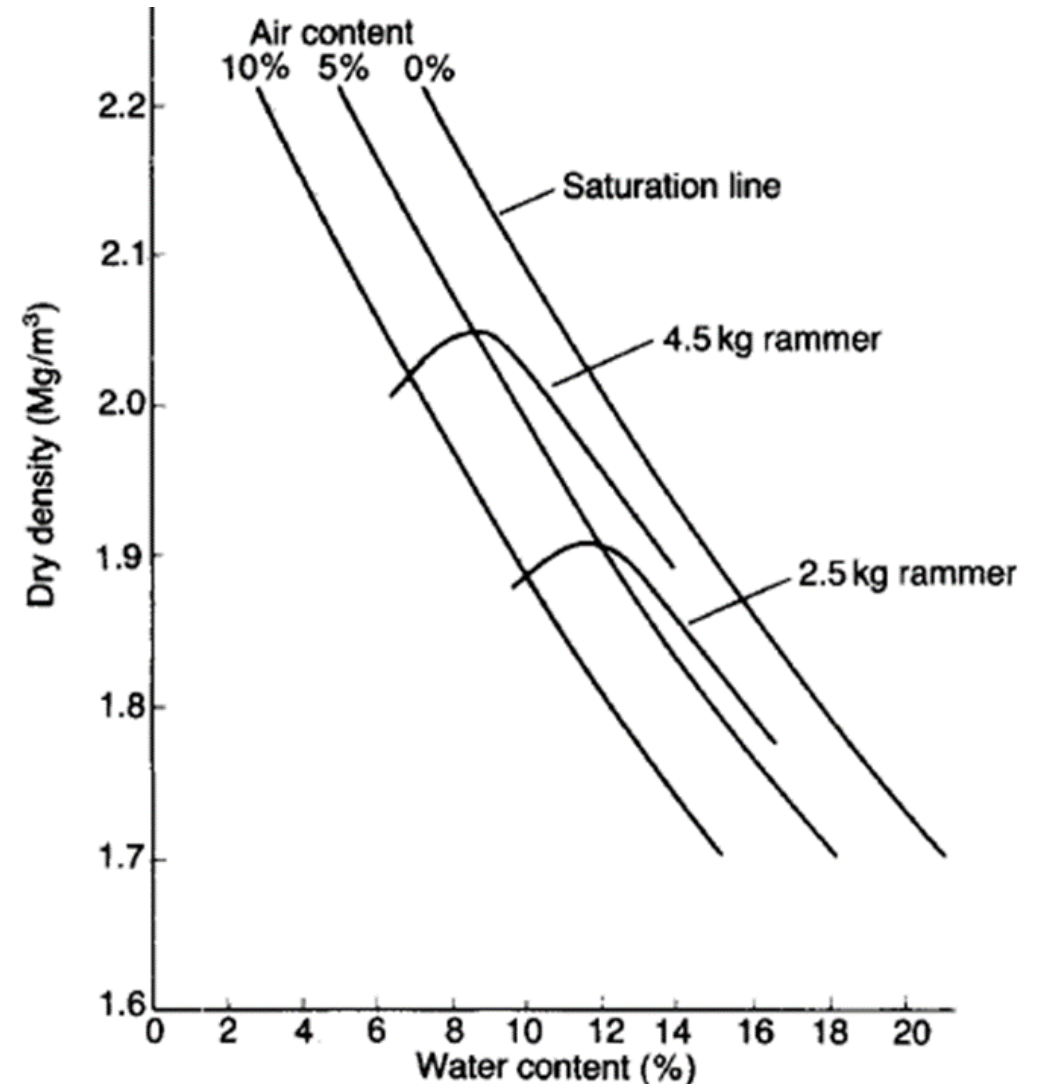
Dr. Geoffrey M. Rowe

Abatech Inc.



Our engineering foundation

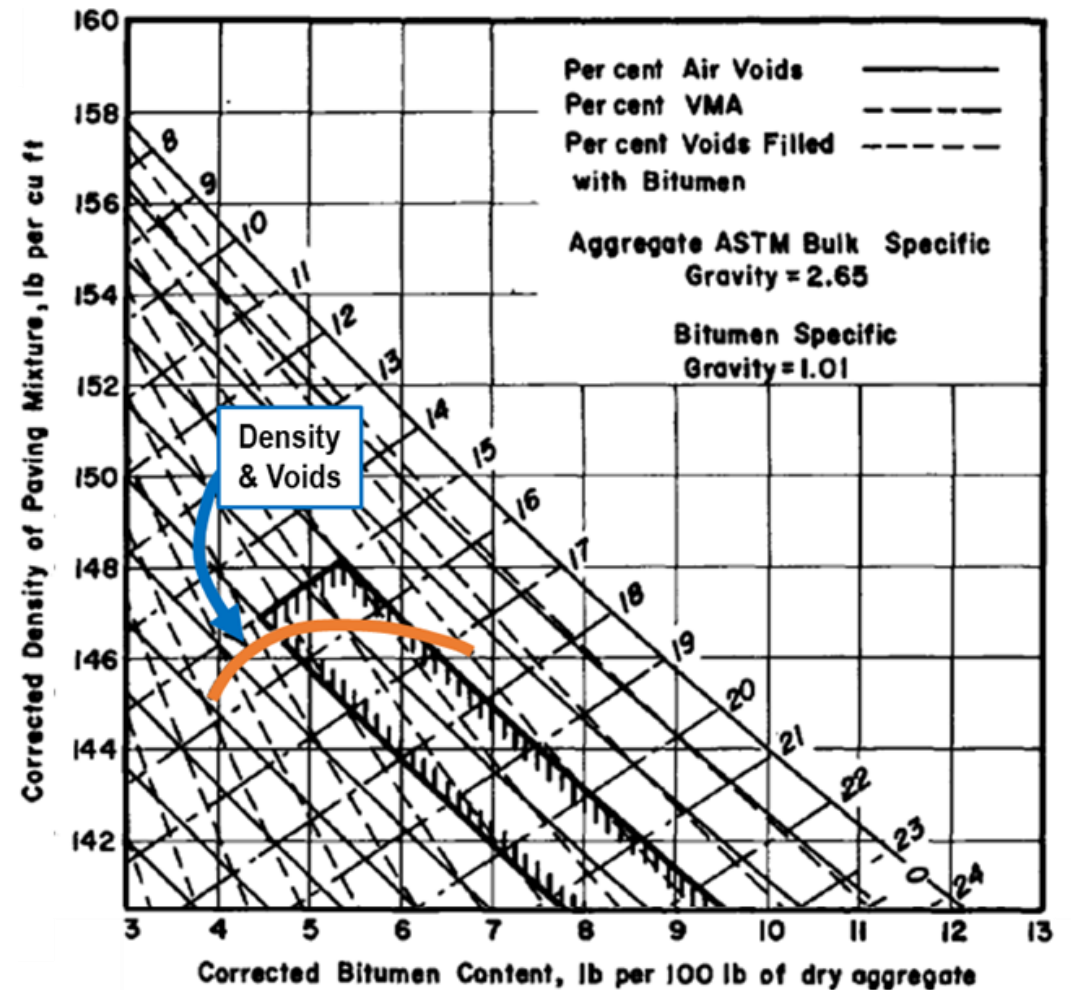
- With asphalt mix engineering we can borrow knowledge obtained from our analysis of soils
- Every Civil Engineer – will understand the use of Proctor curves for assessment of the compaction of soils
 - We need some voids, just like with asphalt mixes, to ensure grain on grain contact, to provide the high shear strengths that we desire



A “father” of our design method

- Norman McLeod provided us with the foundation of what has now been developed as the Asphalt Institute method of mix design – advocating for the use of VMA as a controlling parameter as a controlling parameter

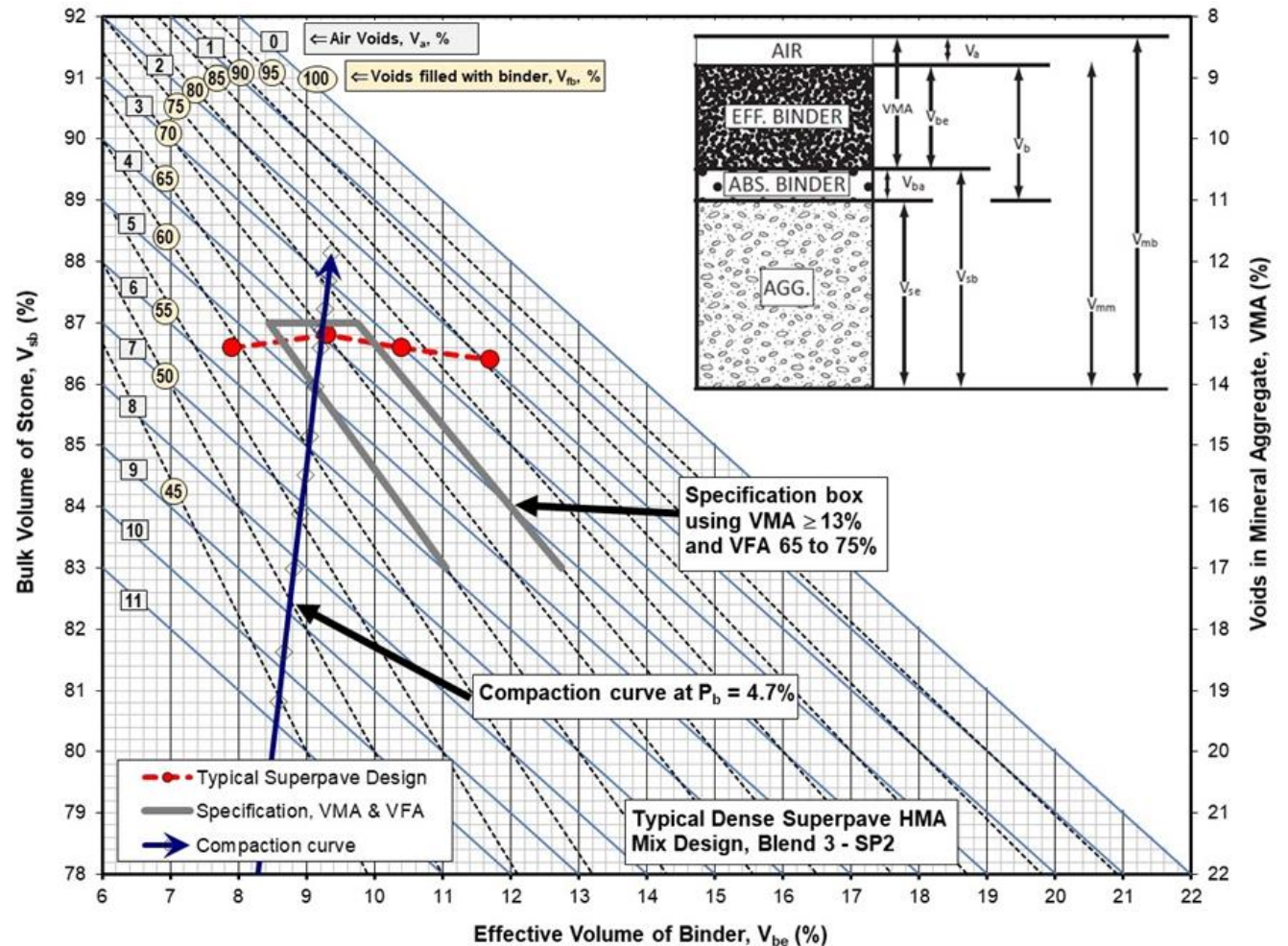
– The chart he presented in his 1959 paper has a limitation in that it is developed for a given specific gravity of aggregate (G_{sb}) and binder (G_b) – in the case shown 2.650 & 1.01



A volumetric chart

- Using the guidance obtained from soil mechanics and Norman McLeod, the chart was reformulated so that it is independent of the densities of the components

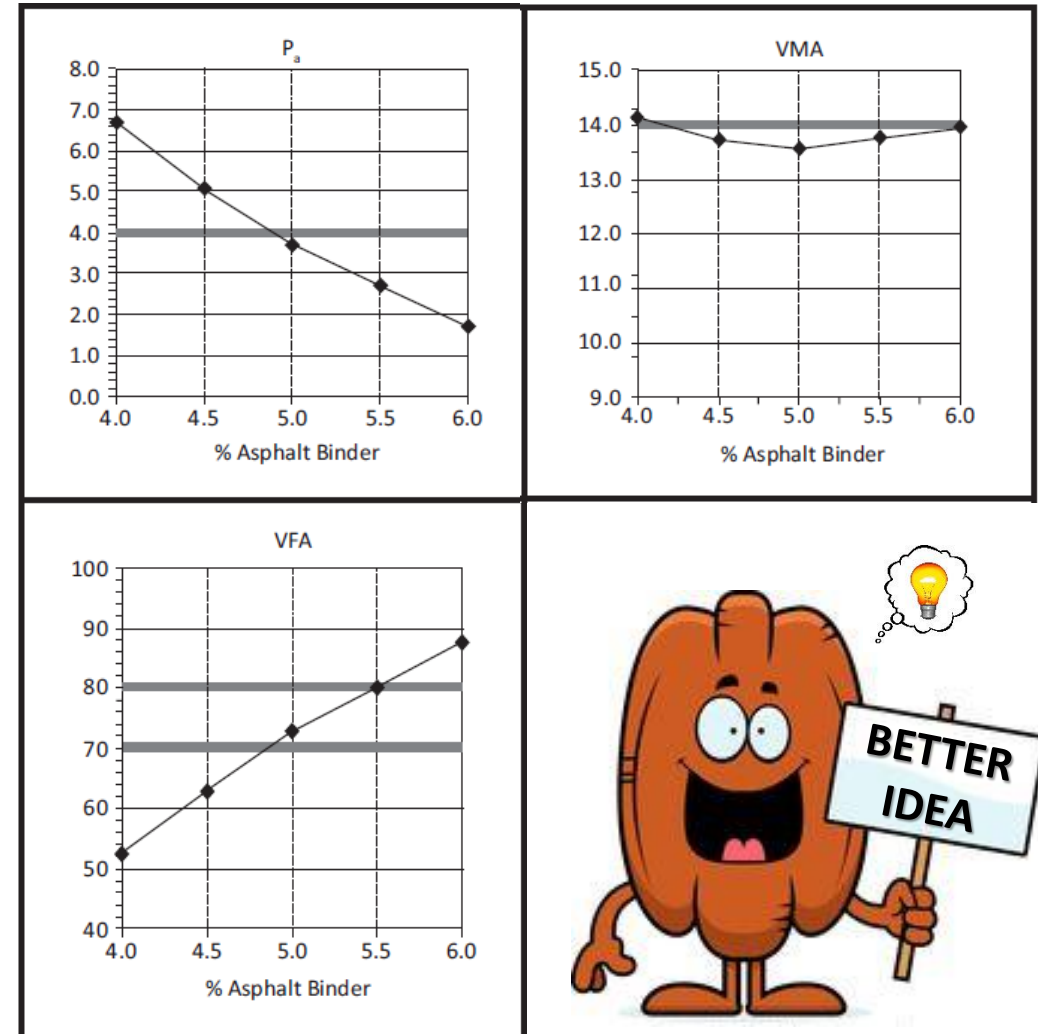
V_{be}
V_{sb}
VMA
V_a
V_{fa}



Volumetric charts ... or chart

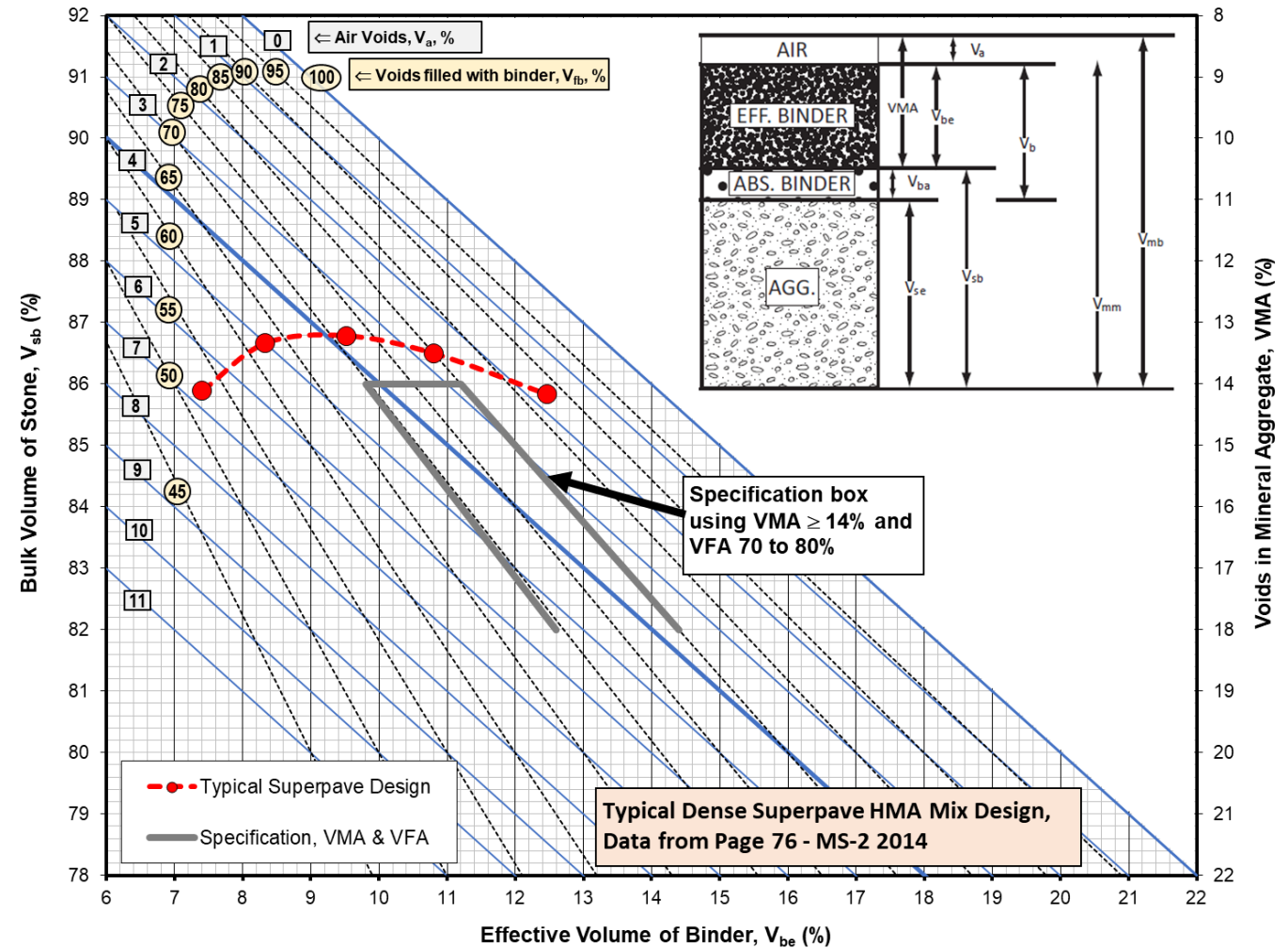
Typical Dense Superpave HMA Mix Design,
Data from Page 76 - MS-2 2014

- Since the mid 1940s mix designs with HMA have traditionally made use of plots of Air Voids, VMA and VFA (and/or compacted aggregate density, mix density, etc.) on separate plots against binder content
 - More recently, McLeod (some 60-years ago!) advocated the use of singular volumetric charts
 - However, current practice is to use individual graphs ... as shown



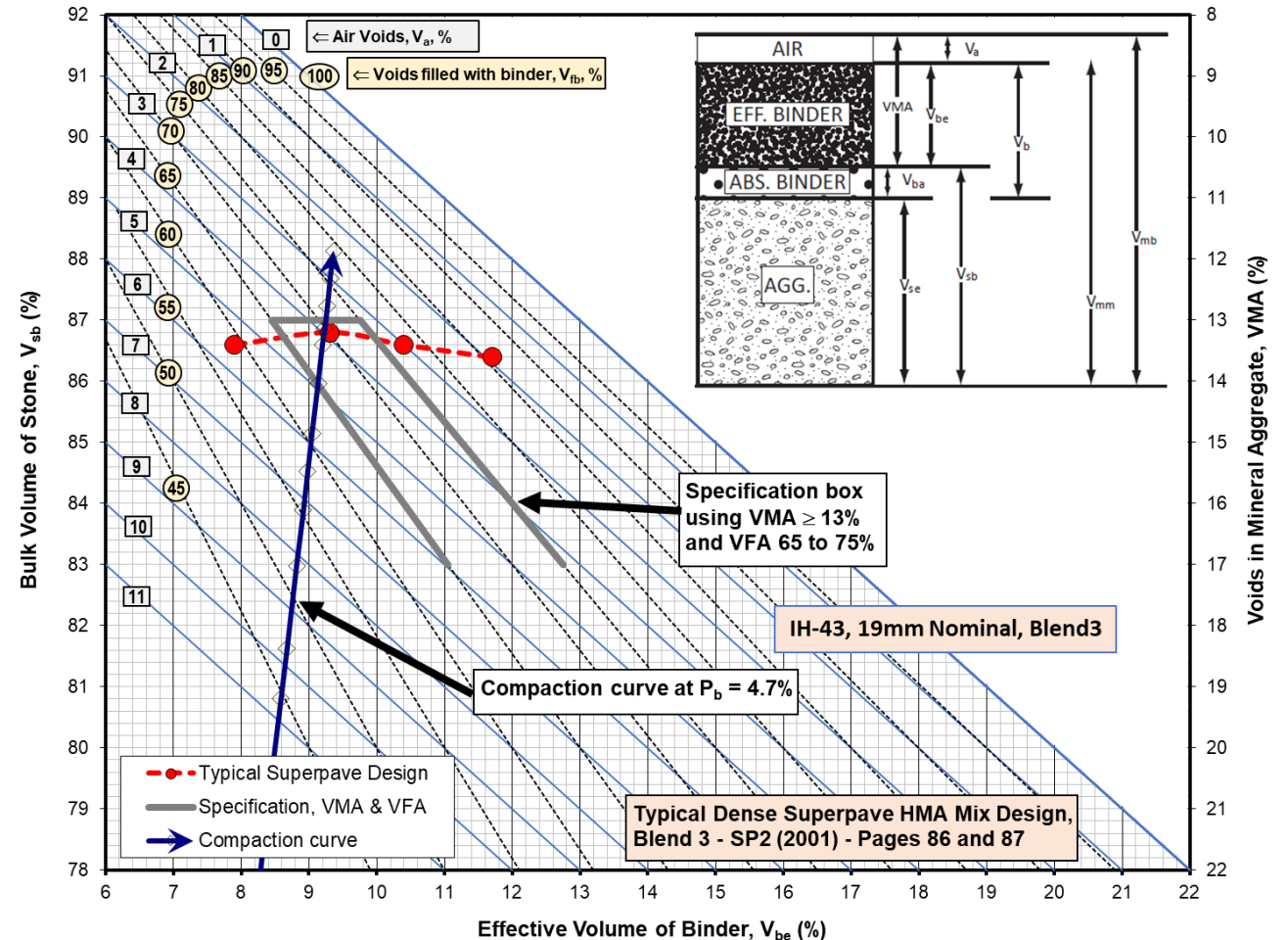
Combined Volumetric Chart

- Chart shows the same information in a single plot – but is more informative of direction needed with this design
 - Need to increase VMA by change to aggregate structure
 - Binder volume is insufficient at 4% with gradation – Pb with a passing design will be higher
 - For adequate durability we are generally looking for minimum 10% binder volume



Combined Volumetric Chart

- Example from SP-2 (2001 printing)
 - This design has a tight tolerance for VMA
- Note angle of compaction curve
 - Data during QC will lie around a line associated with this compaction curve



Other key items

- Interrelations – make sure we use and understand
- QC charts – must use in consistent manner for process control

Note the interrelationships

- In the lab – we measure G_{mm} and P_b
 - But normally consider these completely independent of each other
 - However, they can be combined in analysis
 - Why?
- From G_{mm} and P_b we can compute G_{se}
- For a mix design G_{se} should remain consistent – that is the rock in the ground should be a constant during production
 - If NOT – problems with VMA, density control, site voids, etc.
 - A variation in G_{se} may also alert the reviewer to problems in lab testing with either G_{mm} or P_b

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

Simple rearrangement – gives for G_{se} :

$$G_{se} = \frac{P_s}{\left(\frac{100}{G_{mm}} - \frac{P_b}{G_b}\right)} = \frac{(100 - P_b)}{\left(\frac{100}{G_{mm}} - \frac{P_b}{G_b}\right)}$$

... or for P_b – gives:

$$P_b = \frac{100 \left(\frac{G_{se}}{G_{mm}} - 1\right)}{\left(\frac{G_{se}}{G_b} - 1\right)}$$

*Note – we measure G_{mm} and P_b
 G_{se} – is given in the design*

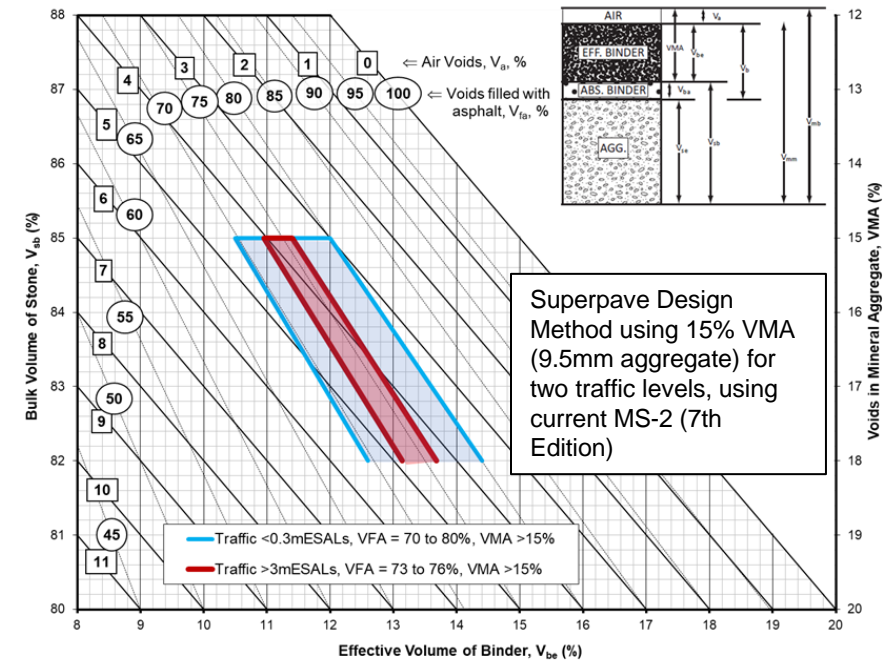
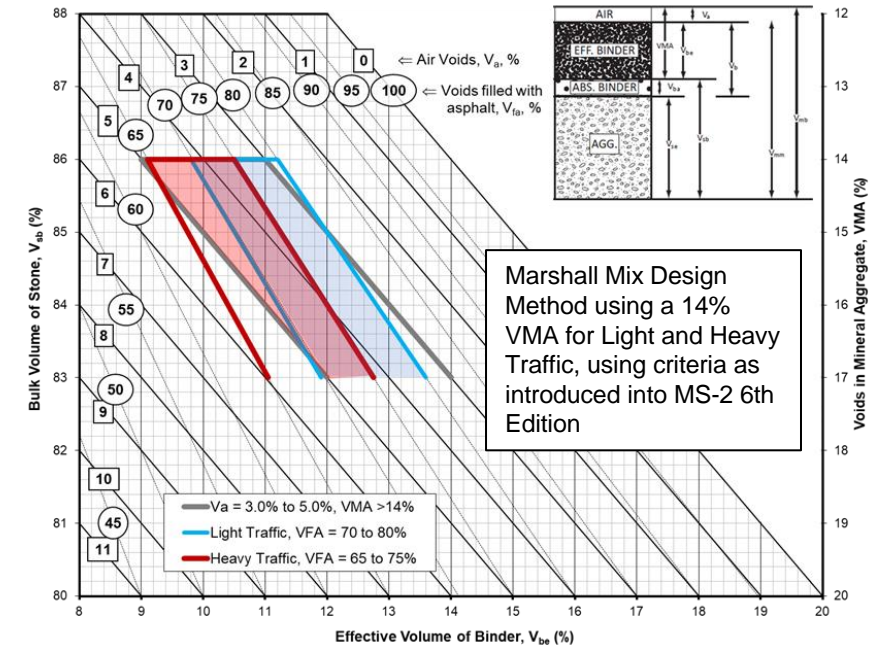
**Tolerance on G_{se} variation ... +/- 1.0% ...
... or I prefer +/- 0.020 (warning limit)**

Key parameters

- Consistency of G_{se}
 - The aggregate type in the ground can change due to geological considerations – but with a given mix design this should remain constant, we recommend max deviation of +/- 0.020. Others use a 1% criteria.
 - Any deviation beyond +/- 0.020, will alert us to one of the following:
 1. The binder content test is in error
 2. The G_{mm} (Rice) test is in error
 3. The aggregate source has a new value for Gse
- Percent binder absorbed
 - Since the G_{sb} is used with the VMA calculation and the G_{se} is calculated from G_{mm} and P_b this provides another check on the reasonableness of the laboratory measurements
- Trend charts
 - Trend charts with trigger points
 - CUSUM can be used with charts and other statistical methods

Specification development

- Example of review of two specifications
 - Example 1
 - Has V_a , V_{fa} and VMA limits
 - The V_a implies limits of 3.0 to 5.0% - but voids are in fact more limited due to V_{fa} controls
 - For heavy traffic the void is limited to 3.5 to 5.0%, whereas the range for voids for the lighter traffic depends on the VMA level
 - The minimum acceptable volume of binder is allowed to be lower for the heavier traffic volume
 - Example 2
 - Since the Superpave design is controlled by the use of a 4% air void content at design, the allowable binder contents by volume are then effectively 11.0 to 12.7% and $\geq 11.0\%$ for the higher and lower traffic volumes respectively.
 - Thus, the mix designer is allowed to use a higher binder for the lower traffic volumes by increasing the VMA of the aggregate structure.
 - The extra width, implied by the area in the figure provides no greater flexibility since the mix designer will try a target binder volume of 11.0% regardless of traffic volume since binder is the most expensive component in the mixture
- Comparing these two – the Example 1 forces a higher binder for the lower traffic volumes whereas Example 2 results effectively the same binder content for both traffic levels

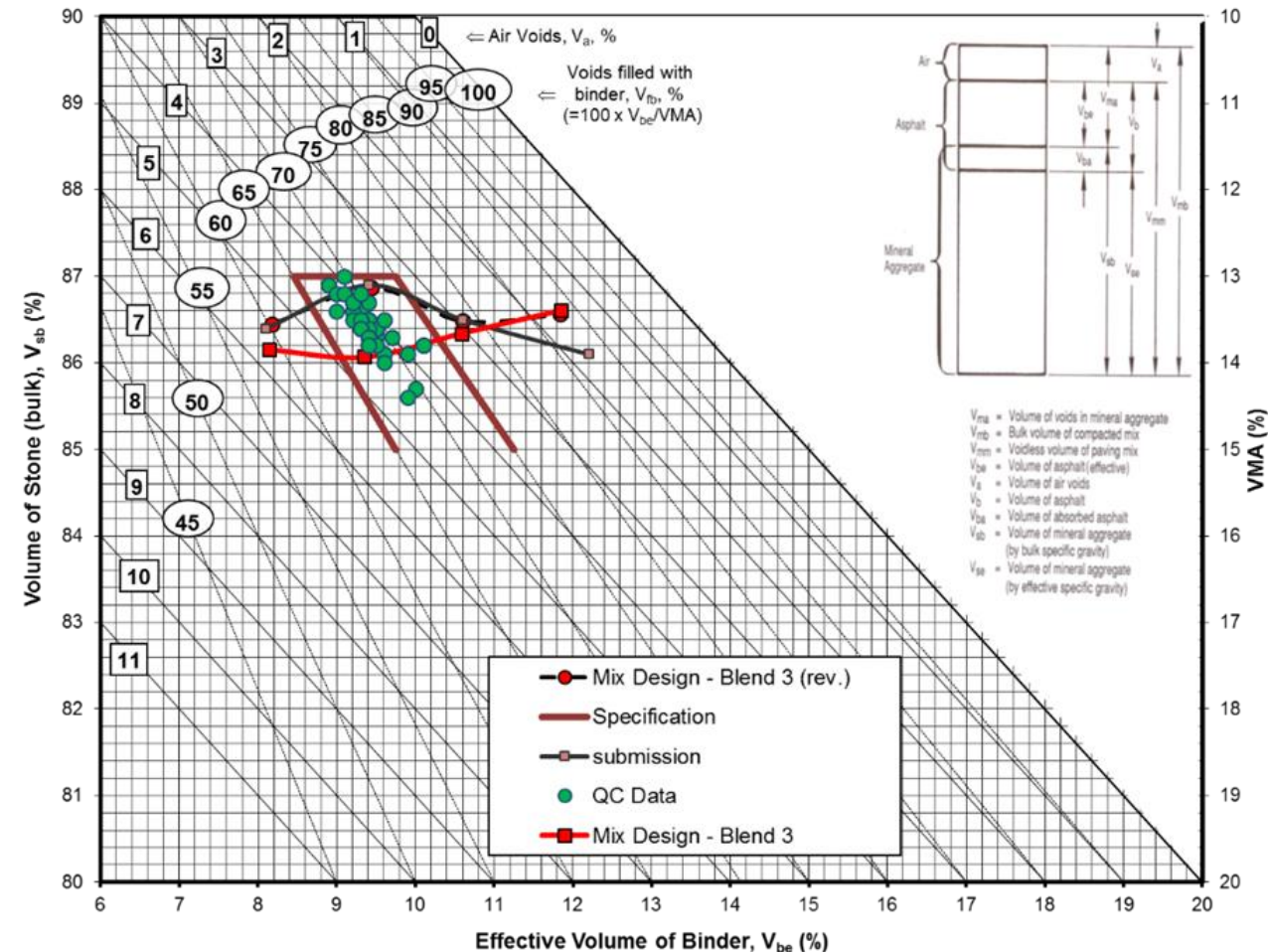


Production control and review - three examples are given ...

- Case study A
 - Two issues; 1) variation in G_{mm} during design and 2) QC data manipulated to ensure air voids in compliance
- Case study B
 - Excessive variation in V_{be} and VMA during construction
- Case study C
 - Variation in aggregate properties from design conditions

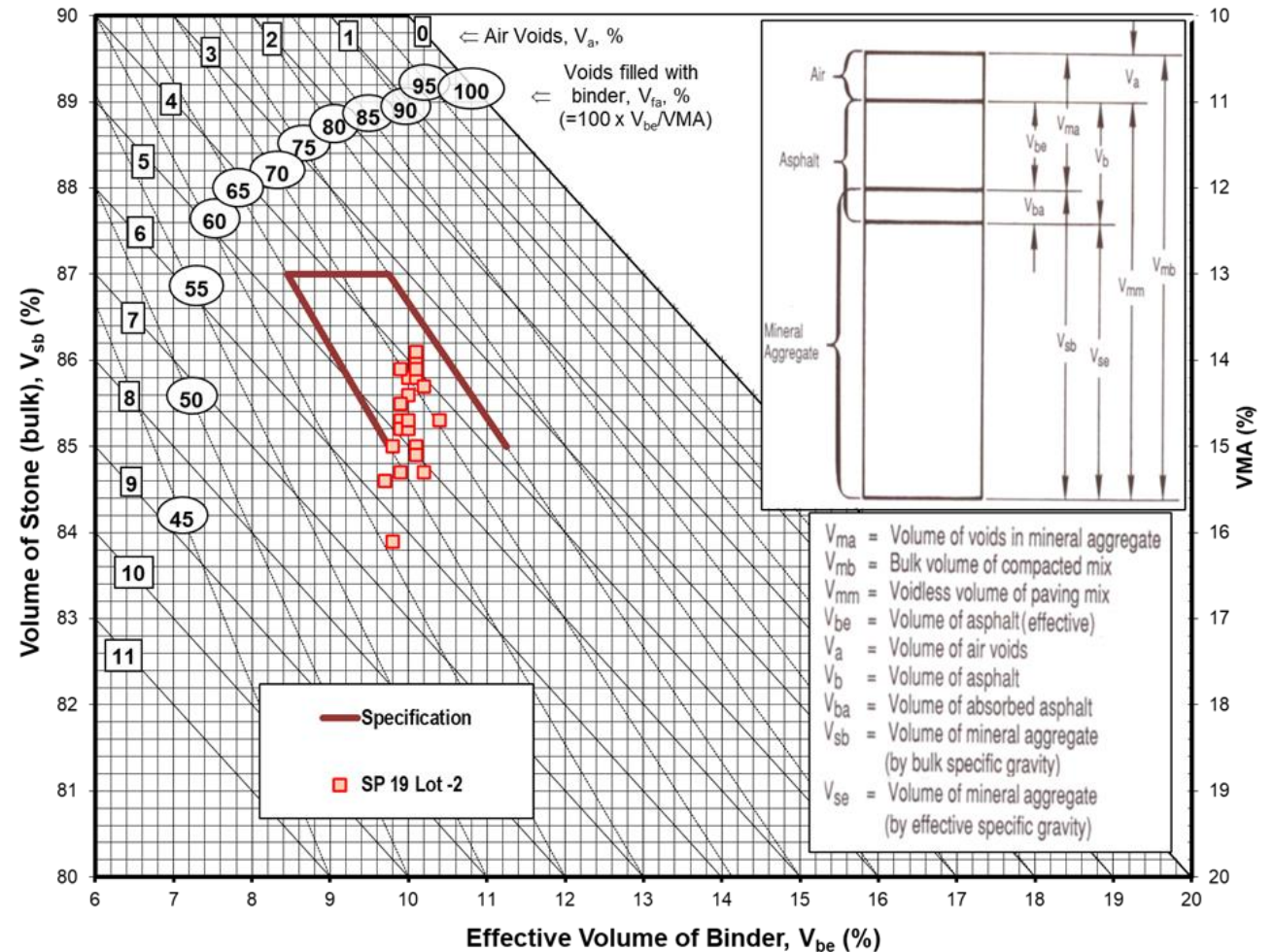
Case study A

- In this example we reviewed the mix design with a non-characteristic shape – the design was adjusted after it was observed that variation in G_{se} from G_{mm} and P_b measurements was unreasonable – an average G_{se} was adopted
- The QC void content shows non-physical trend of data – this should follow the shape of the compaction curve as shown earlier
 - 4.0% air voids reported for 10 consecutive instances!
 - No trend analysis performed



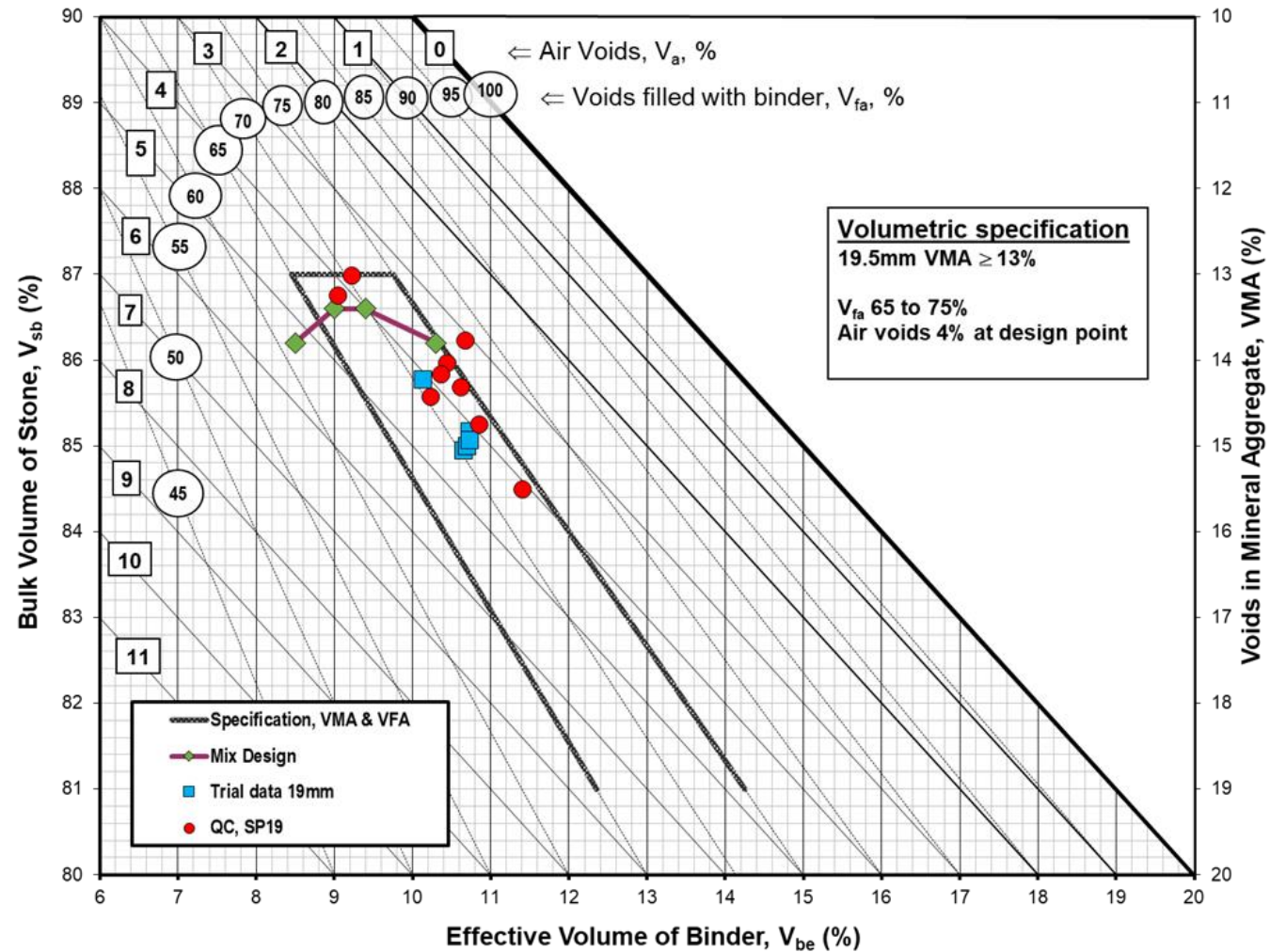
Case study A

- Compaction data reassessed with an estimated value of Gse shows correct trend
 - In this case a few locations show high voids, that is typical of any normal construction project (to see a few results that are outside the specification tolerances)



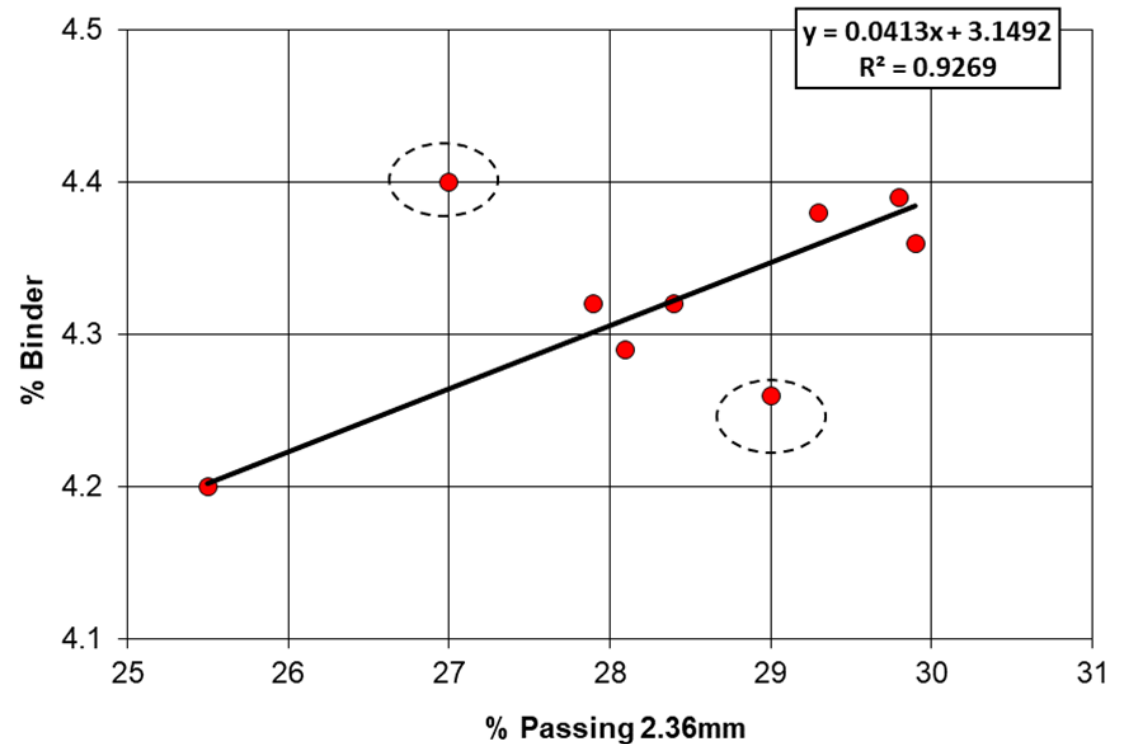
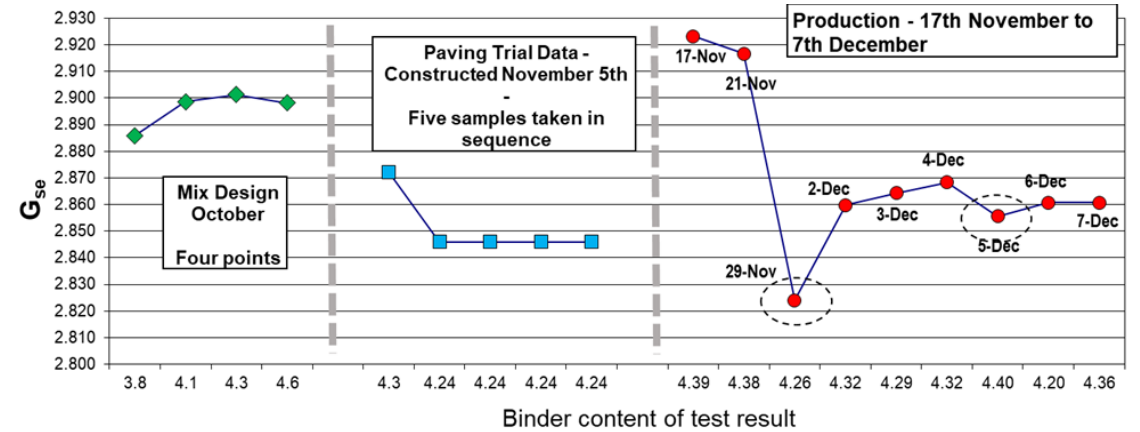
Case study B

- Excessive variation in VMA from the design
 - With variation in volume of binder!
 - Trend line in wrong direction



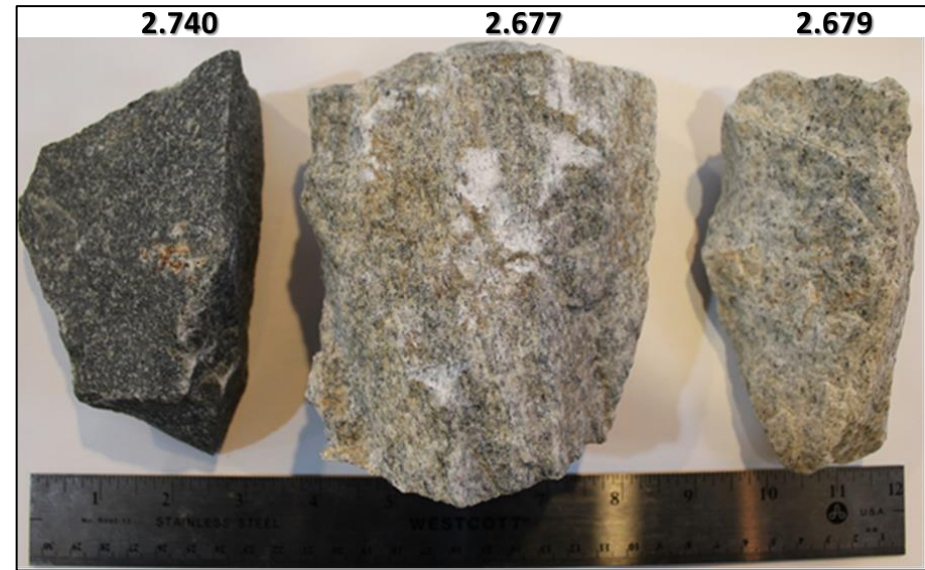
Case study B

- Design vs. other data on time line shows excessive variation of G_{se}
 - Possible some manipulation of data
- Analysis of gradation shows some segregation in results and also some outliers from expected production trend



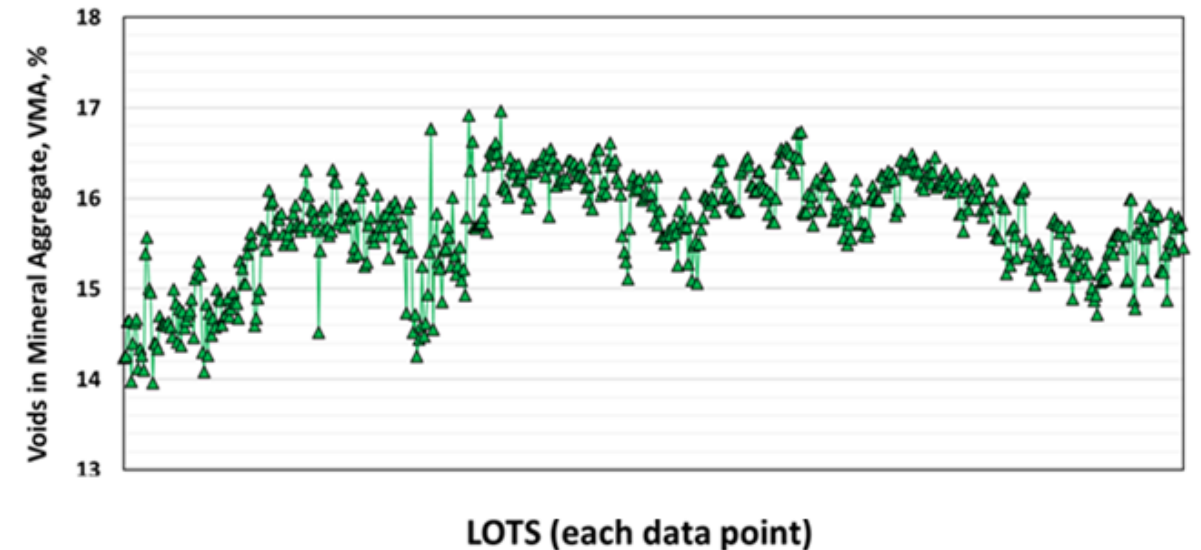
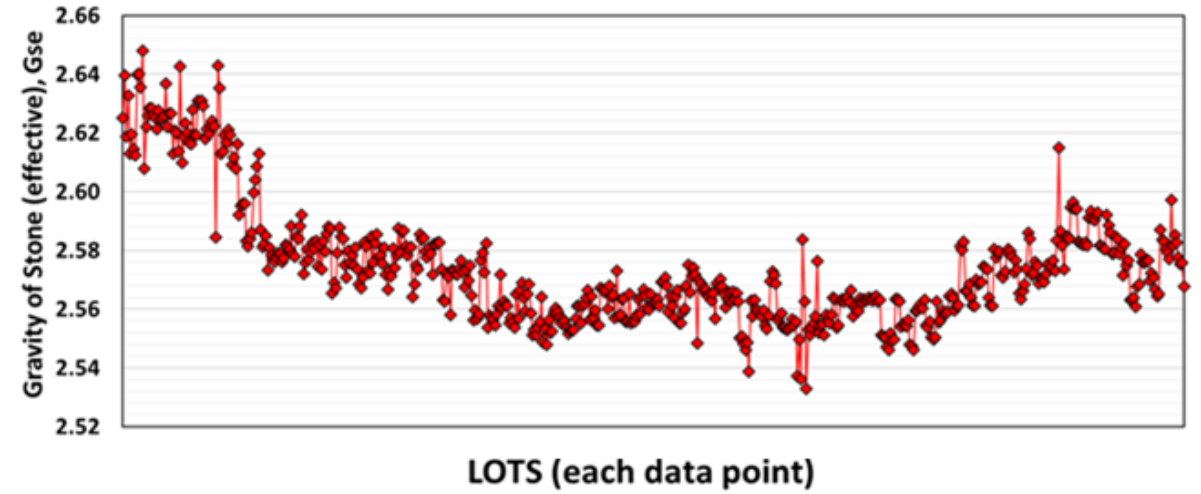
Case study B

- Two quarry faces being used and mixed in an uncontrolled manner
 - Each had very different aggregate properties which led to the significant variation in VMA



Case study C

- Very evident in this example to see change that occurs with aggregate properties with time
 - Points to importance of the need to use trend charges
 - AASHTO R-30 quality control plan – which should be implemented on all major projects in USA and other locations that make use of this method specifically refers to ASTM E2587 – Standard Practice for Use of Quality Control Charts in Statistical Process Control – which in turn has a section on use of CUSUM charts as well as other methods



Summary

- The data and discussion herein shows the need for a fresh consideration of some of our methods and analysis of QC data from construction projects
 - Use new chart to assist with data analysis
 - Controls on G_{mm} or G_{se} recommended in QC method
 - Check binder from analysis with calculations from G_{mm} using G_{se}
 - Use QC charts – on significant projects – CUSUM recommended



Thank you for your attention

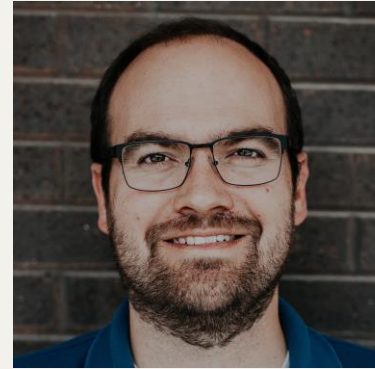


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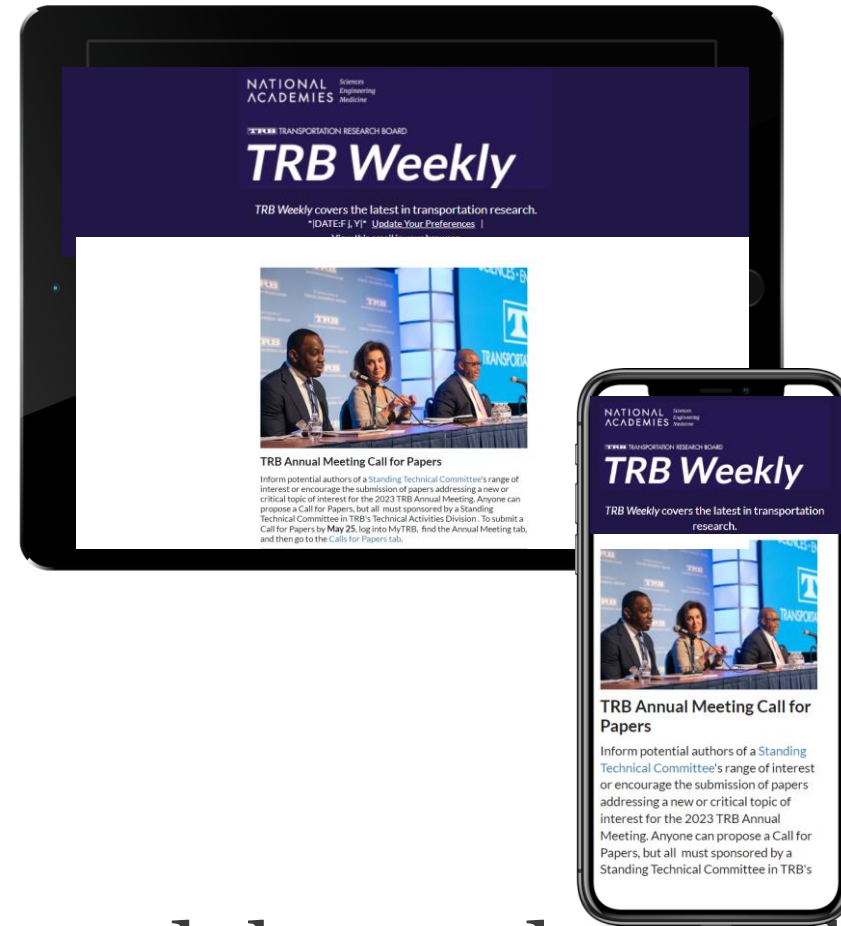
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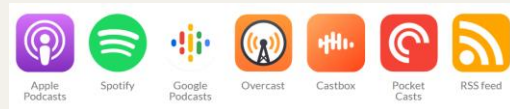
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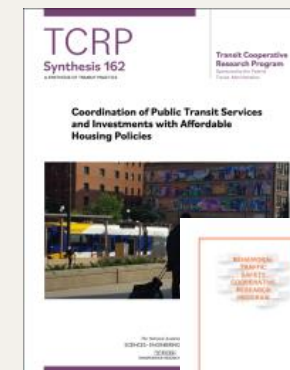
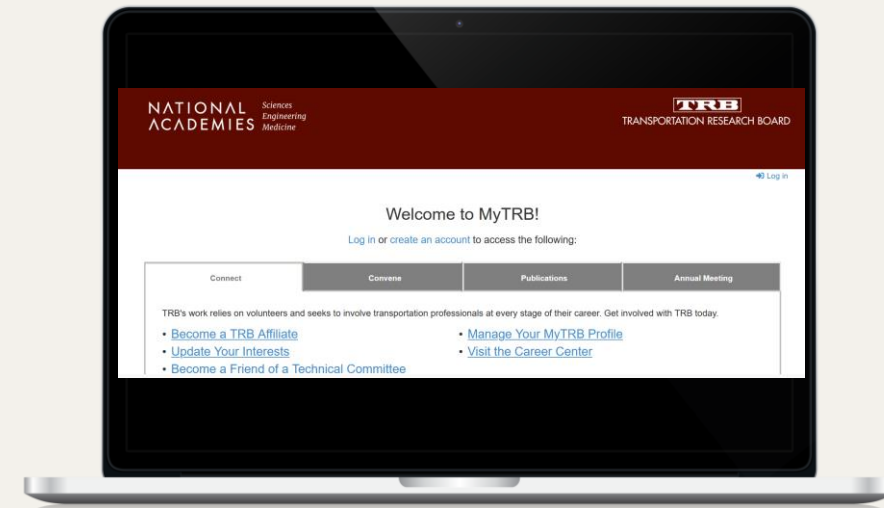
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