Evaluating Nearly 15 Years of Volumetric Asphalt Mix Designs for an Entire State DOT

Asphalt Contractors Association of Florida
2021 Asphalt Conference and Expo
Nov 30th – Dec 1st, 2021

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Acknowledgements

- Jonathan Easterling
  Materials Engineer & Plant Manager, Huey P. Stockstill, LLC
- Griffin Sullivan
  State Materials Engineer, Mississippi DOT
- Alex Middleton
  Assistant State Research Engineer, Mississippi DOT
- Isaac Howard
  Professor, Mississippi State University

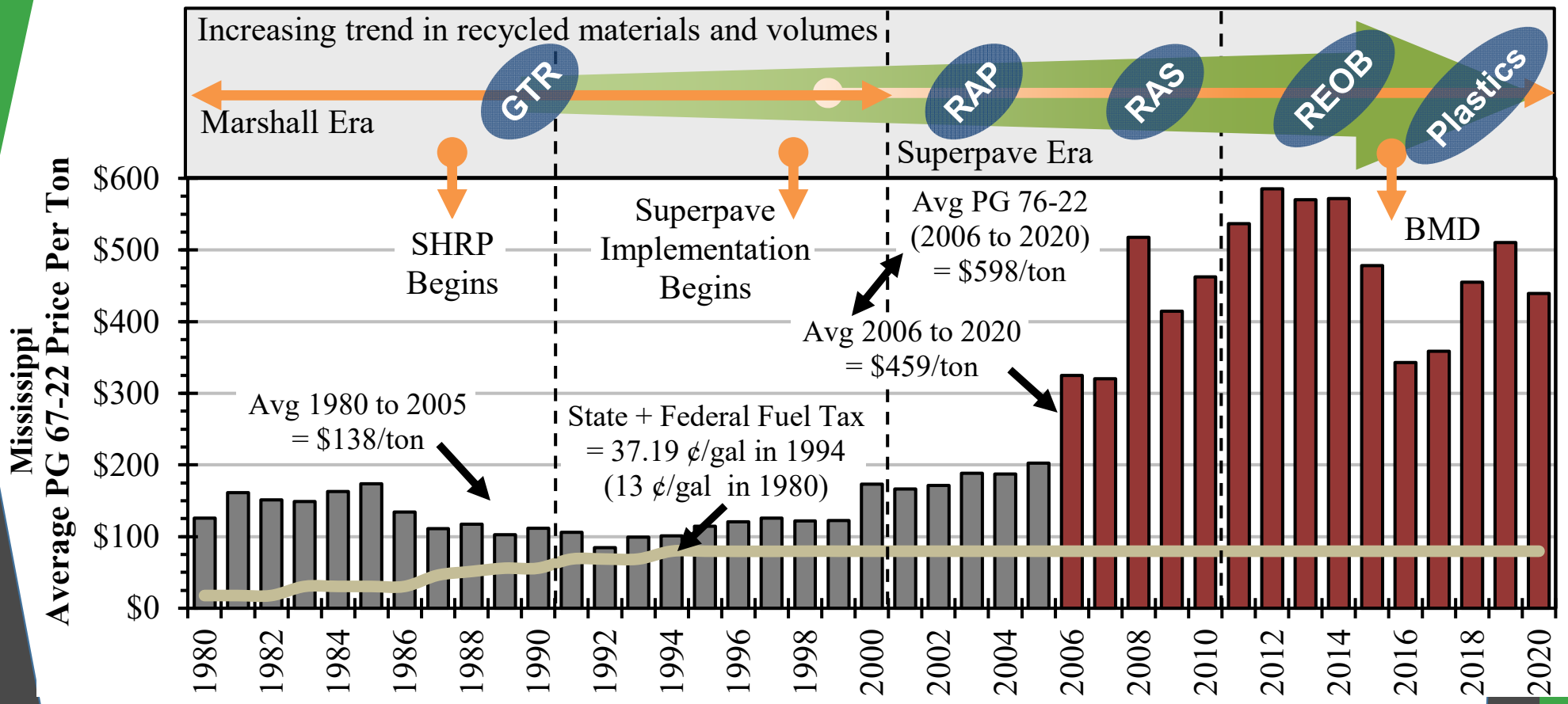
Overview

- 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 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

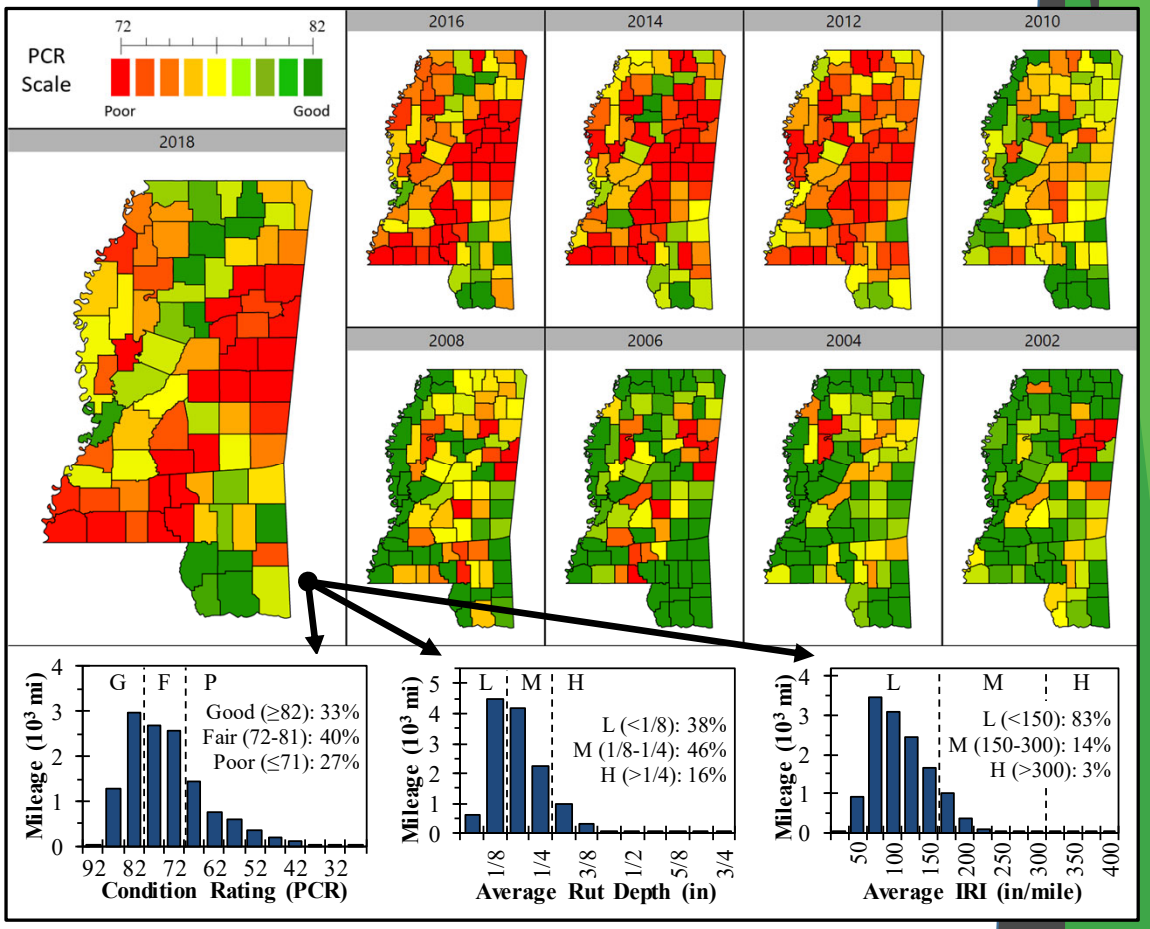
Motivations: 40-Year Trends



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

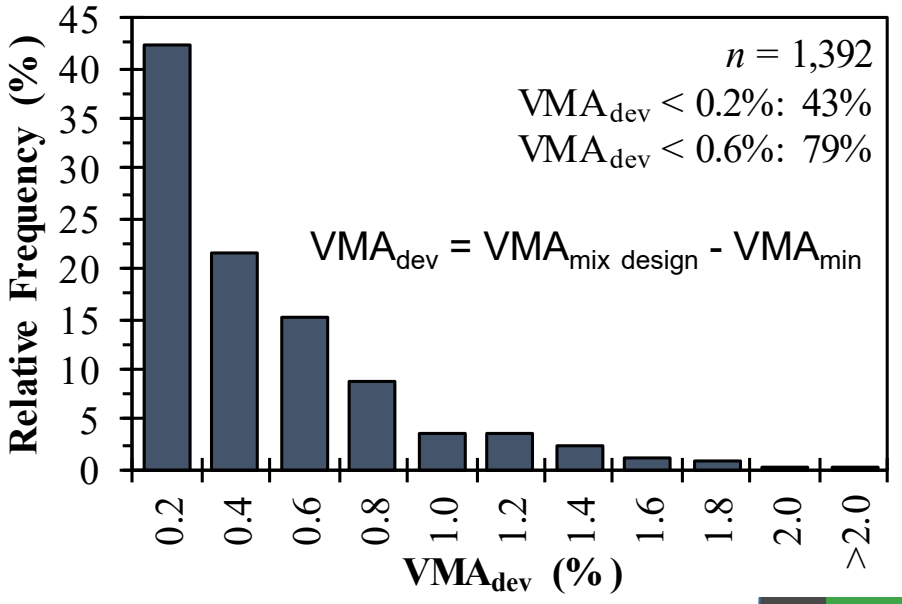
1. VMA
2. G_{sb} and *Abs*
3. RAP Content
4. N_{des}
5. Coarse vs. Fine Gradations

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

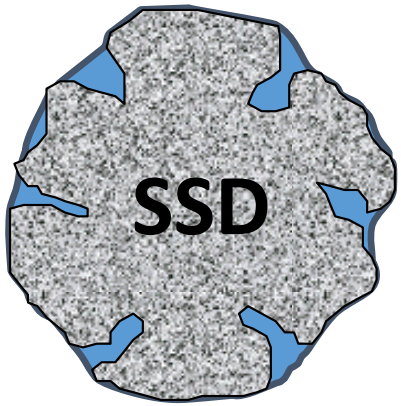
MDOT VMA Levels

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



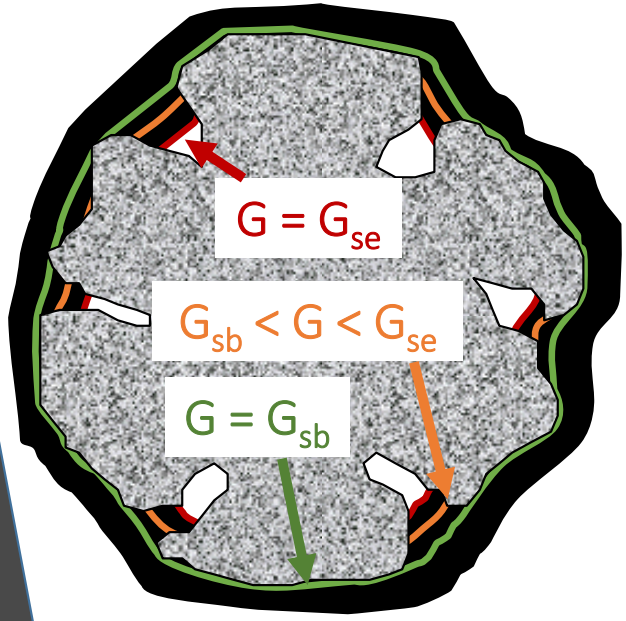
1. VMA Dependency on G_{sb}

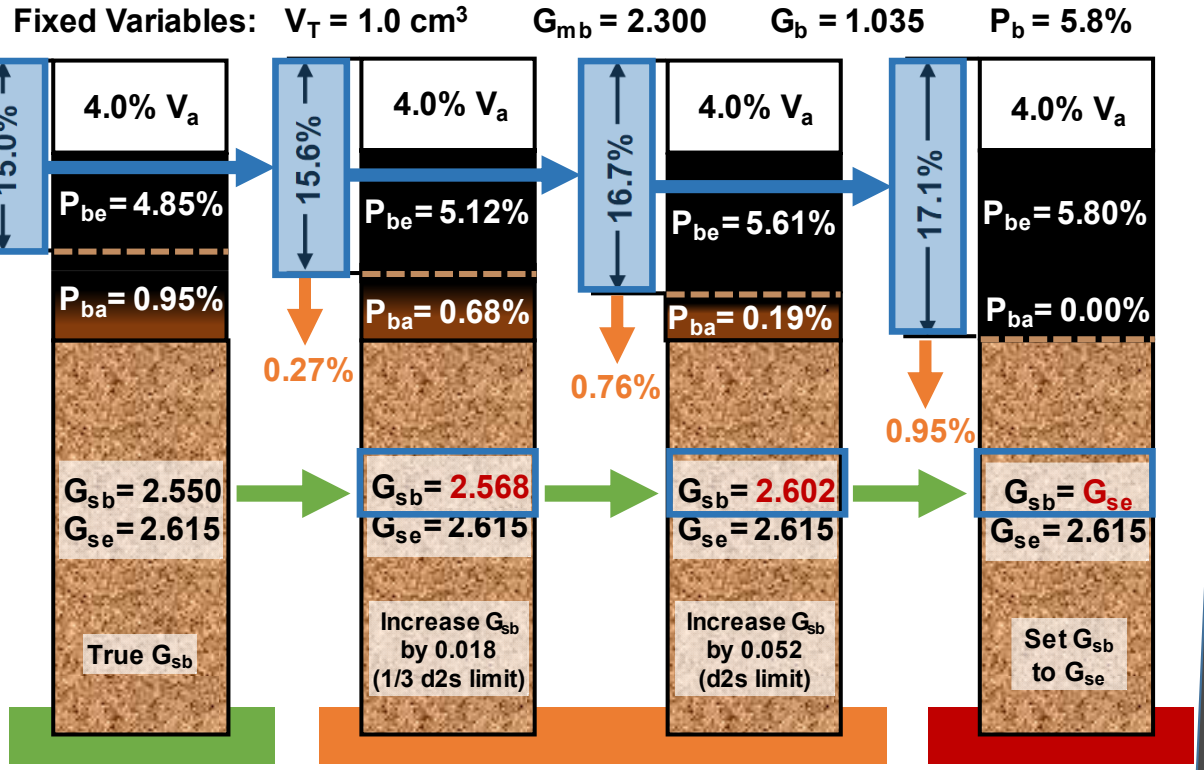
- Concern with VMA trend is that VMA depends on G_{sb} (inherently operator dependent and variable)
- AASHTO d2*s* for 50/50 coarse/fine agg. blend: 0.052
- High d2*s* means a measured G_{sb} and true G_{sb} can be the "same" by d2*s* standards even though they are quite different
- Primary concern is with inflated G_{sb} values (associated with aggregate dried past SSD condition)



1. VMA Dependency on G_{sb}

Inflating G_{sb} increases *calculated* VMA; if gradation is designed so that *calculated* VMA just meets VMA_{min}; *actual* VMA (and V_{be}) will be below minimum requirements



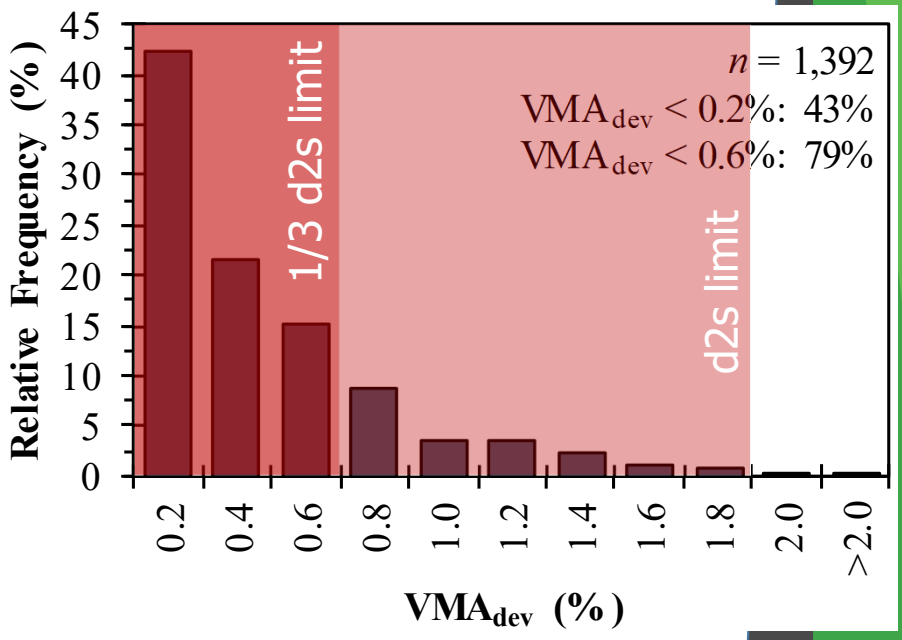


1. VMA Dependency on G_{sb}

- 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 d2*s* limit	80%	Up to 0.3%
d2*s* limit	99%	Up to 0.8%

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



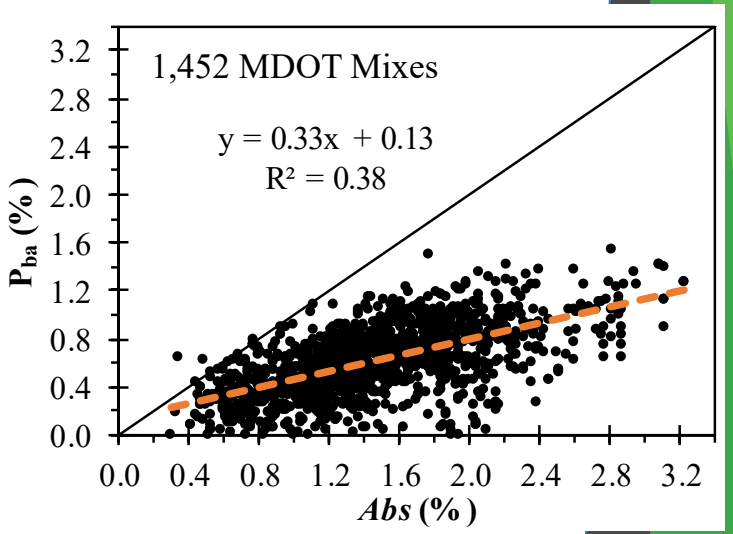
2. G_{sb} and *Abs*: Practices by State

- 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 SEAUPG 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)

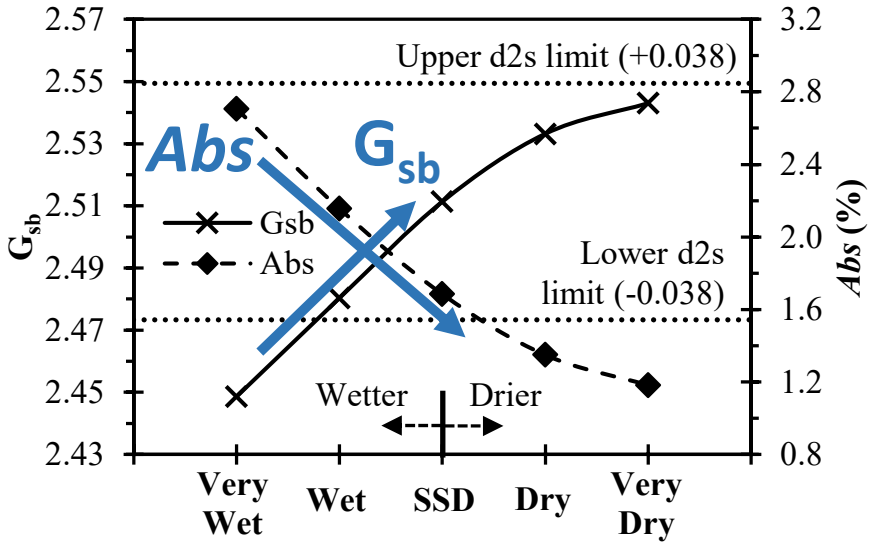
2. G_{sb} and *Abs*: Evaluating Reasonableness

- Large d2*s* limit and typical G_{sb} practices open door for high variability with 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

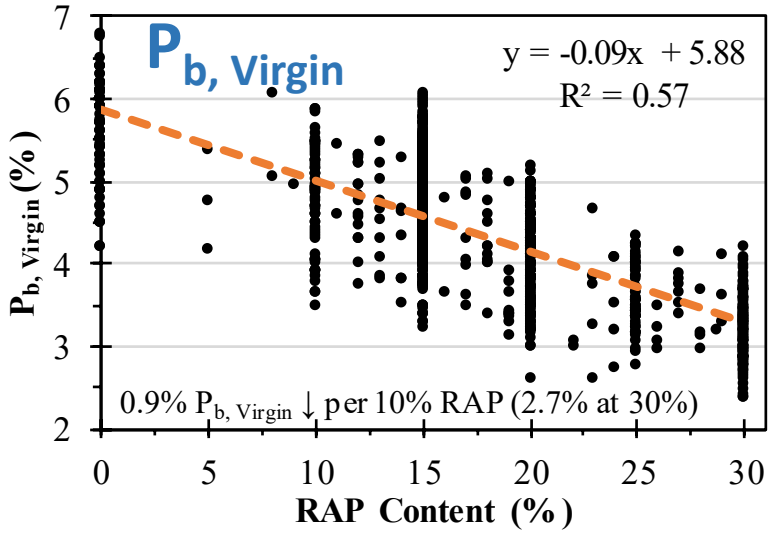
- P_{ba}-to-*Abs* rules have limitations because inflating G_{sb} deflates *Abs*
- Low P_{ba} values will not be obvious in comparison to deflated *Abs* values (i.e. rule of thumb may not pinpoint G_{sb} problem)

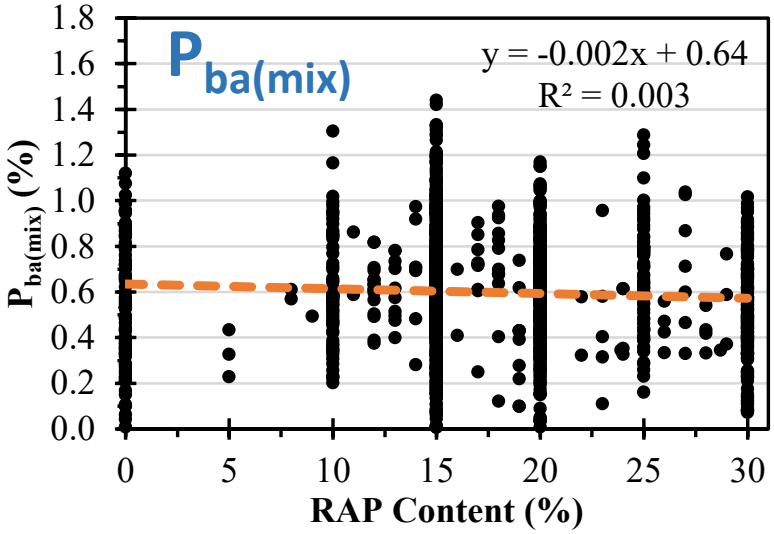


G_{sb} and *Abs* for Typical Mississippi Crushed Gravel

3. RAP Content

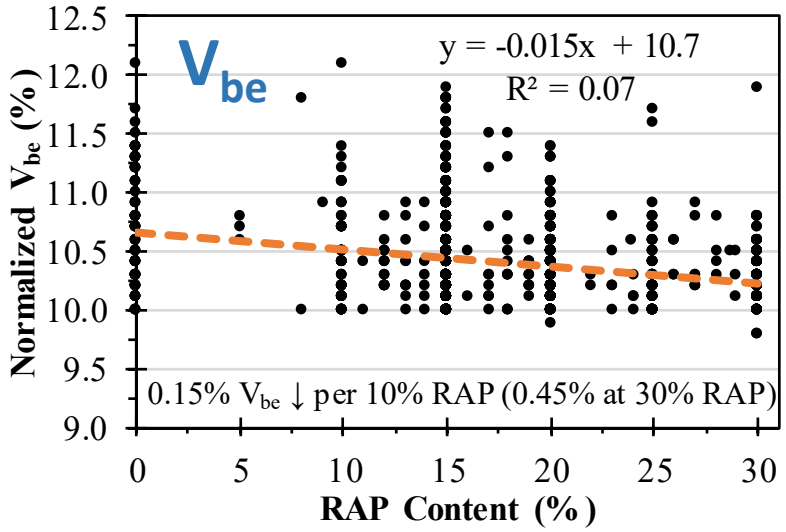
- Virgin binder demand decreases with RAP content
- Absorbed asphalt does not change in any meaningful way
- These are intuitive outcomes





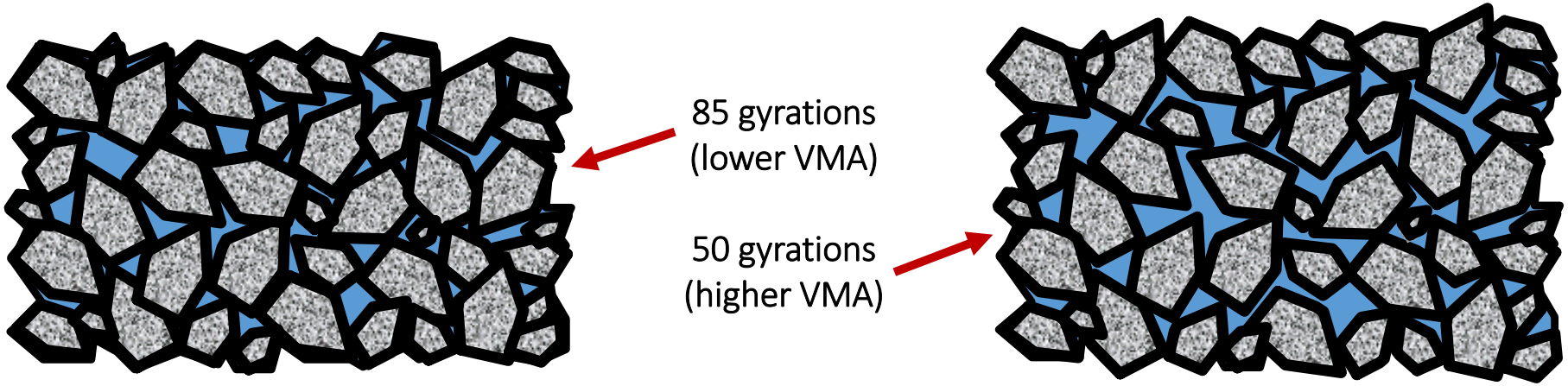
3. RAP Content

- Intuitively, total binder demand would increase with RAP content, all other factors being equal
- In practice, V_{be} actually drops (0.45% V_{be}, or 0.2% P_{be}, at 30% RAP)
- Unintended consequence concerning in light of stiffer RAP binder
- Issue would grow if G_{se} was used in place of G_{sb} for RAP



4. Decreasing N_{des} Level

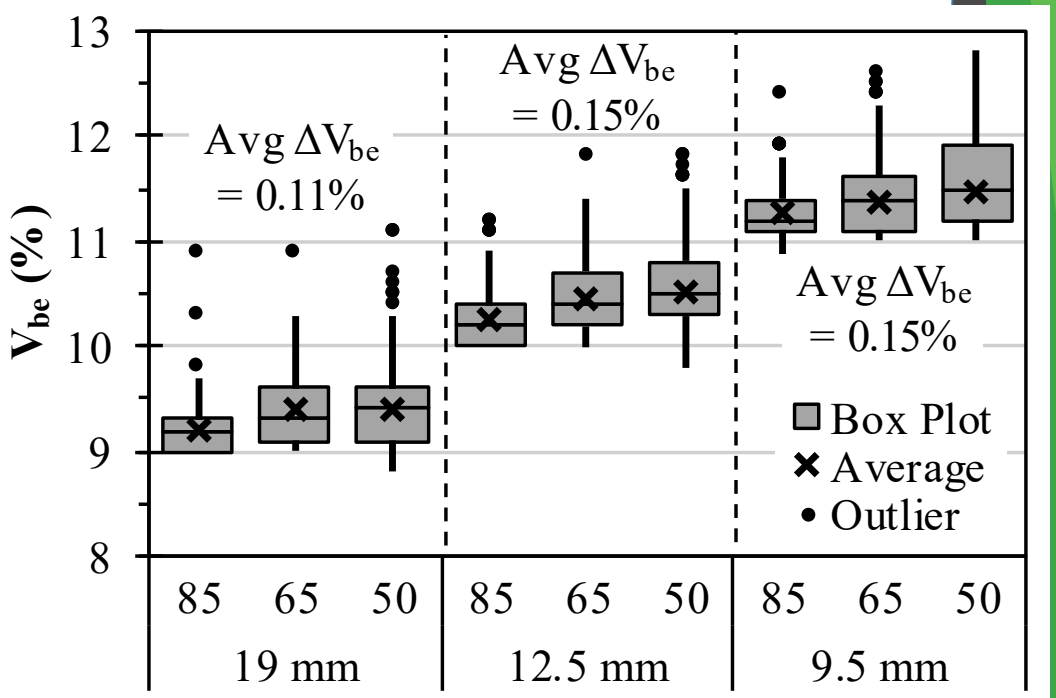
- A common suggestion to increase asphalt content is reduce N_{des}
- This works if all other factors held constant
- Less compaction → looser agg skeleton → higher VMA → higher V_{be}



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

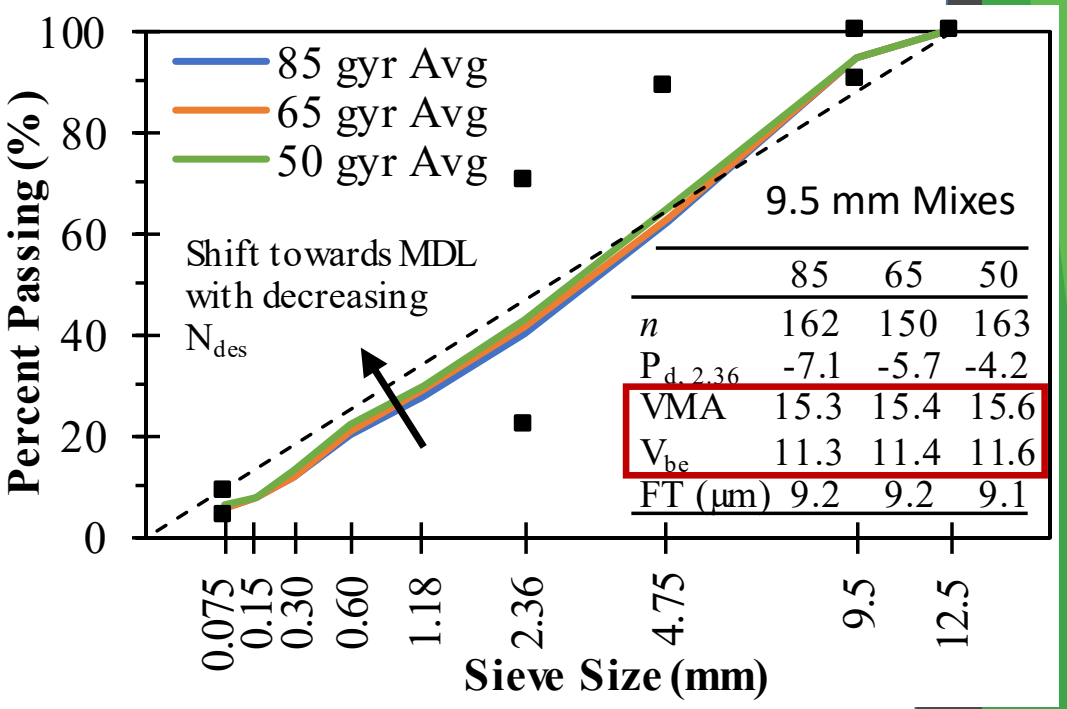


4. Decreasing N_{des} Level

- Changing N_{des} has little impact because nothing prevents mix designer from adjusting aggregate blend and/or gradation

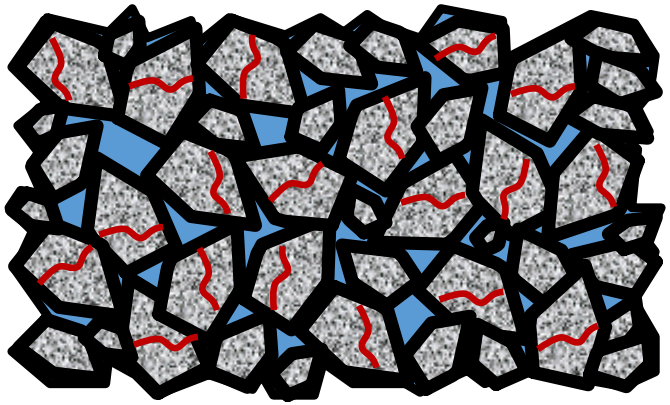
- Since VMA_{min} did not change, mix designer can bring VMA back toward VMA_{min} by filling voids with aggregate (more economical than binder)

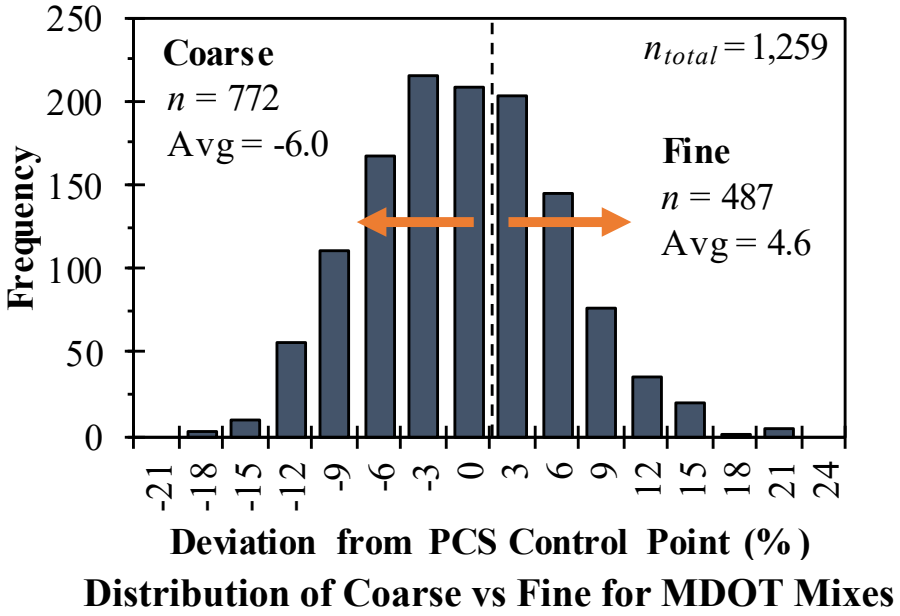
- MDOT database illustrates that gradations shift toward max density line in practice



5. Coarse vs. Fine Gradations

- Common misconception is that finer gradations could be used to combat dry mixes
- Finer gradations have more surface area, so the thought is that binder demand is greater and asphalt content will go up

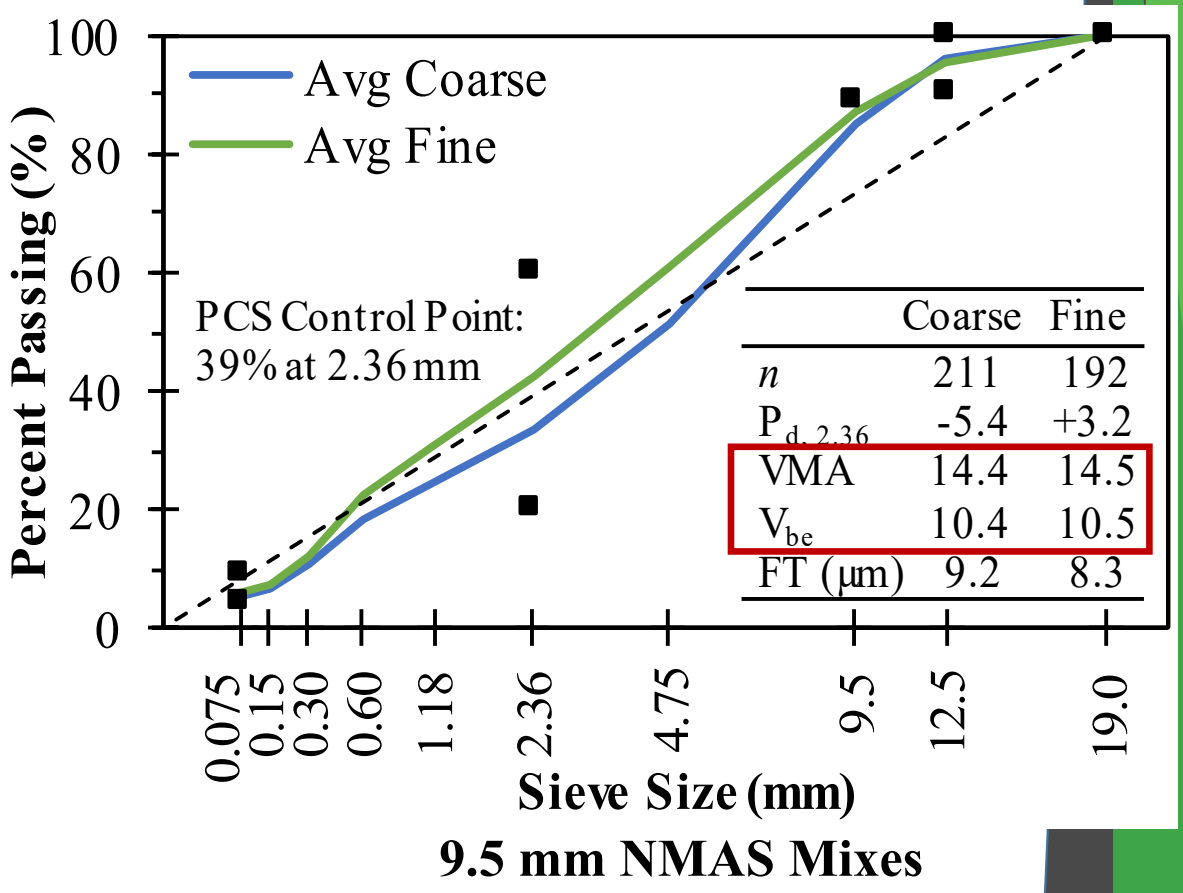




Distribution of Coarse vs Fine for MDOT Mixes

5. Coarse vs. Fine Gradations

- In practice, gradation type has no impact
- V_{be} is 10.4 vs 10.5%; P_{be} change of 0.04% (basically no difference)
- VMA_{min} criteria did not change, so asphalt content did not change



	Coarse	Fine
n	211	192
$P_{d,2.36}$	-5.4	+3.2
VMA	14.4	14.5
V_{be}	10.4	10.5
FT (μm)	9.2	8.3

Summary

- Data from practice across an entire state supports numerous other studies consisting of smaller datasets (e.g. may only evaluate one factor at a time)
- Volumetric-only mix design is not fully capable of dealing with present-day mixes
- Mechanical tests are needed, perhaps more now than when they were sought during SHRP

Questions?

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