A Case against Exclusive Reliance on Volumetric Mix Design

Airfield Asphalt User Producer Group

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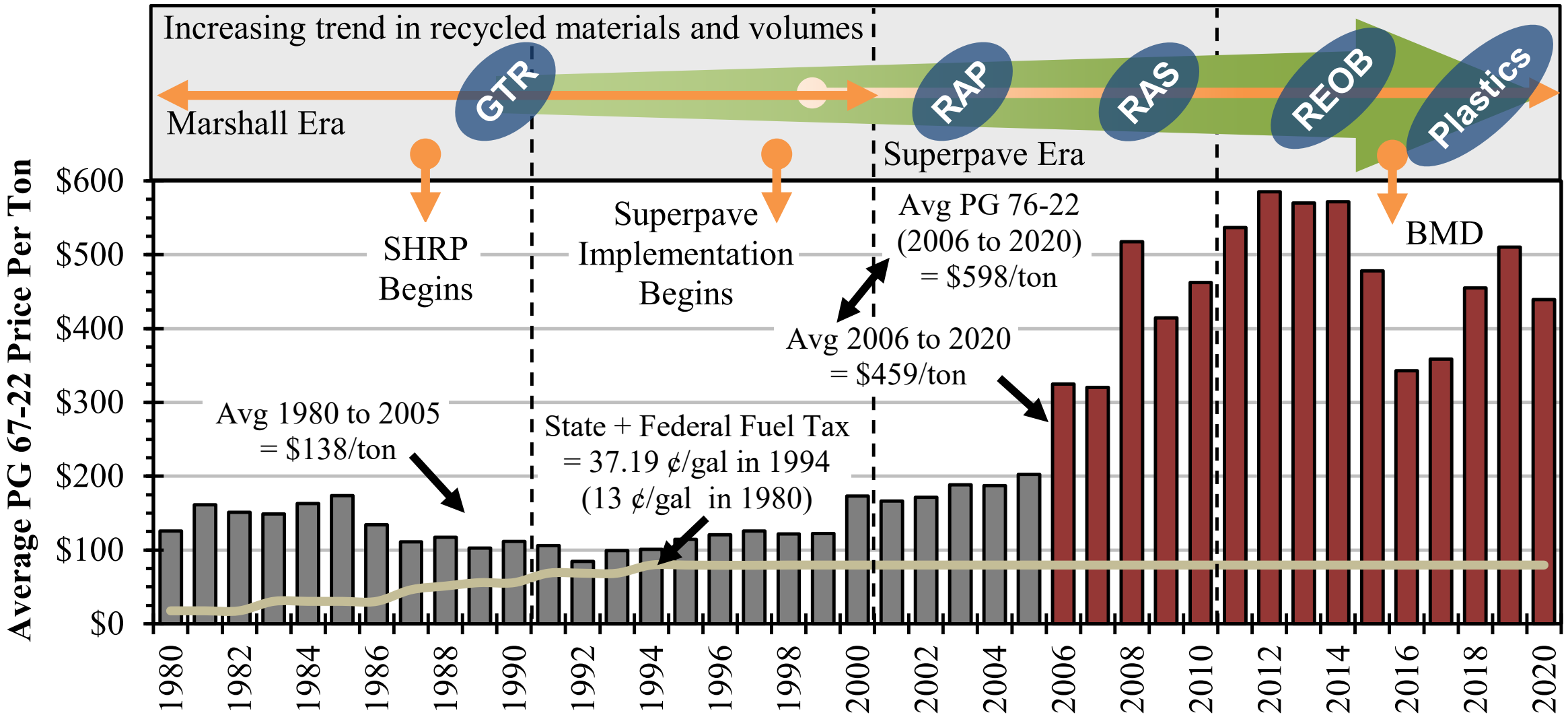
Overview

- 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

Overview

- Objective: present trends from a statewide database of 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
- Caveat: yes, this is highway data; still many overlapping areas with airfields, as will be discussed, and worthwhile lessons learned

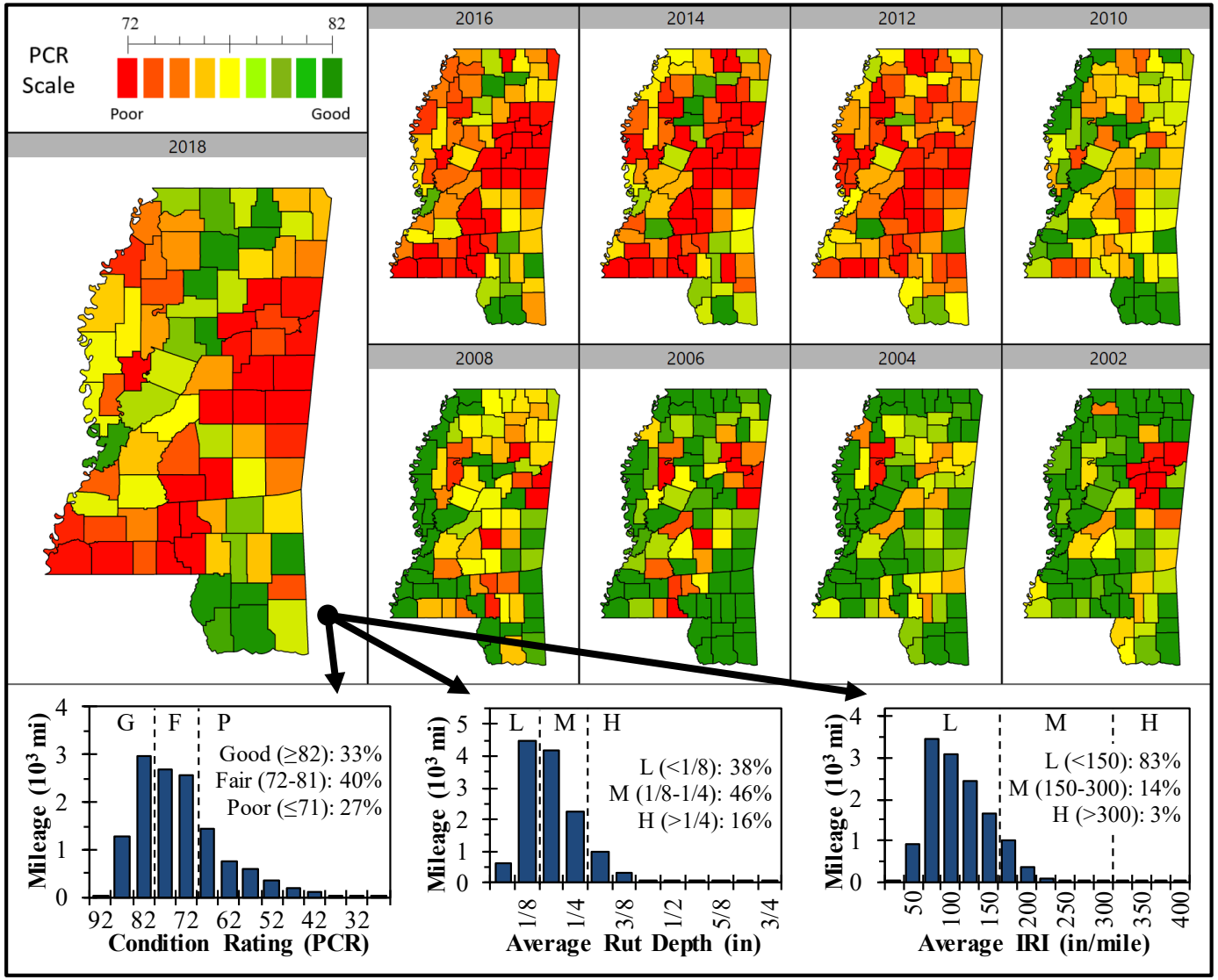
40-Year Trends (Big Picture)



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

Deteriorating Pavements

- Mississippi DOT pavement condition ratings trending wrong direction
- Biggest distress? Cracking (dry mixes)



What about Airfield Pavements?

- Material costs are a factor
- Recycled materials are less of a factor, though still a factor (RAP)
- Fuel tax not a factor, but funding still has constraints
- Distresses may differ slightly, but environmental/durability issues (e.g. weathering, raveling, linear cracking, block cracking) are still the limiting factor
  (Rushing et al. 2014, Robinson 2019)

Age (yr)	Surface Area (%)	Avg PCI	Contribution to PCI Reduction (%)		
			Climate	Load	Other
< 7	9	91	50	44	6
7 to 15	15	85	88	5	7
15 to 25	23	68	82	12	6
25 +	52	51	84	10	6

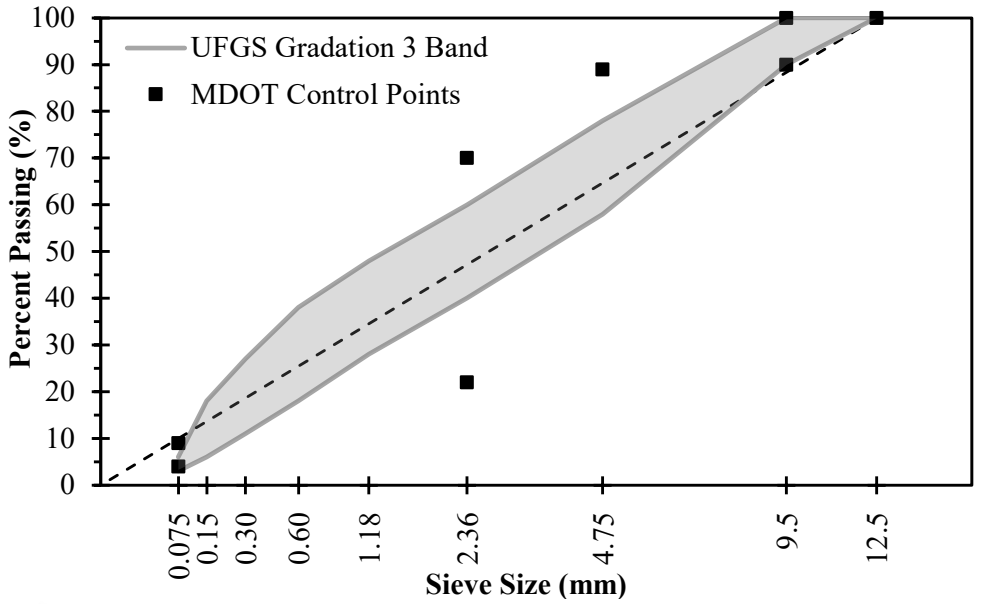
Army airfield data from Rushing et al. (2014)

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.)

What about Airfield Mix Design Specifications?

- MDOT and UFGS specs not that different (aggregate properties included)
- Biggest difference: gradation bands



UFGS Airfield vs. MDOT Highway Mix Design Specifications

Property	UFGS	MDOT
RAP, % (max.)	20 (not allowed in surface except shoulders)	20 in surface 30 in underlying
N_{des} (or blows)	50, 75	50, 65, 85
$V_{a,\ des}$, %	4.0	4.0
VMA, % (min.)	13.0, 14.0, 15.0 (for gradations 1, 2, 3)	13.0, 14.0, 15.0 (for 19, 12.5, 9.5 mm)
Dust Proportion	0.8 – 1.2	0.8 – 1.6
TSR, % (min.)	75	85
Wet S_t, psi	60	---
Interior Coating, %	---	≥ 95
Boil Test Coating, %	---	≥ 95
Stability, lb (min.)	1350, 2150 (Marshall)	---
Flow, 0.01 in.	8 – 18, 8 – 16 (Marshall)	---

Key Findings from Mix Design Database

Database trends discussed in five categories

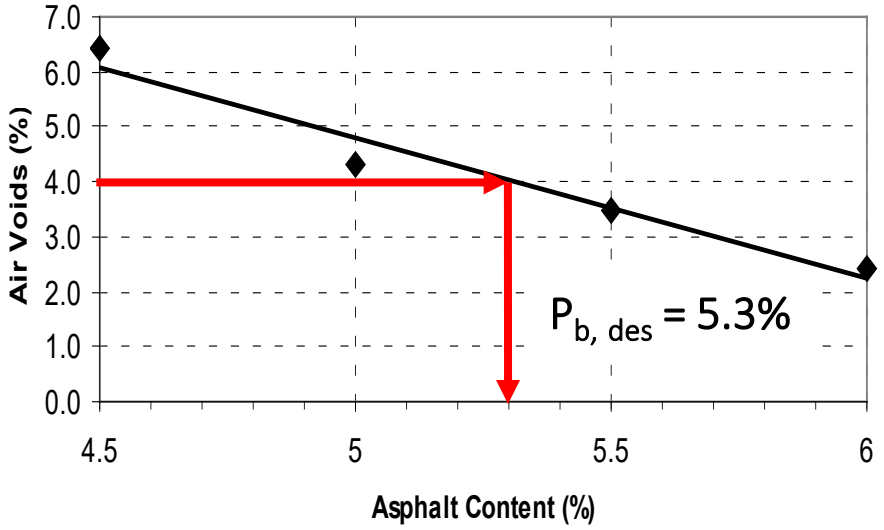
1. VMA
2. G_{sb} and *Abs*
3. RAP Content
4. Coarse vs. Fine Gradations
5. N_{des}

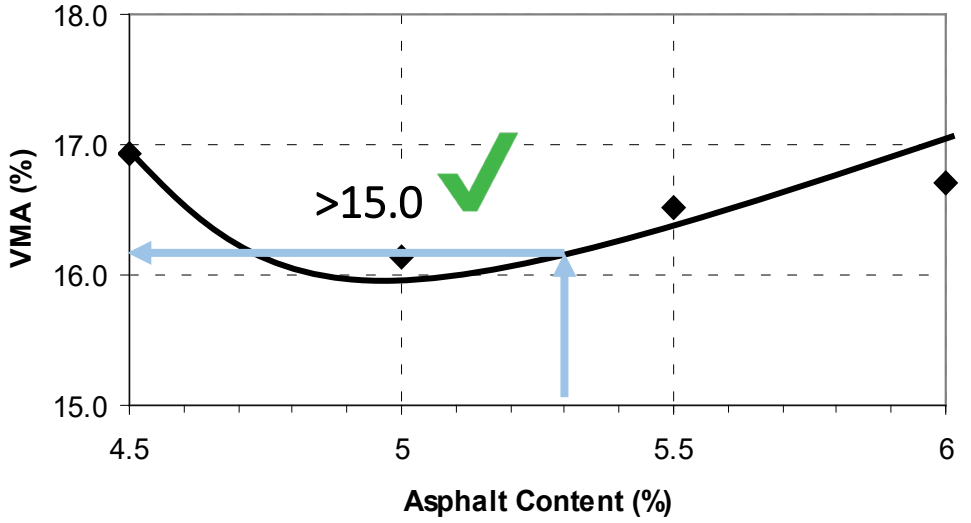
1. VMA

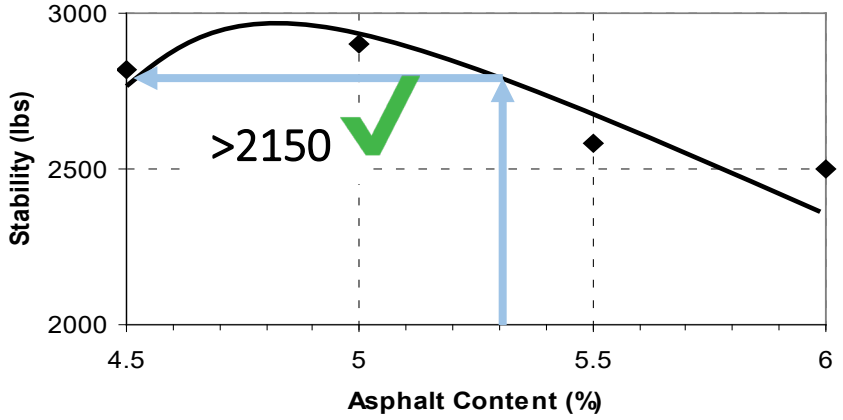
- VMA controls design asphalt content
- Common misconception that V_a controls design asphalt content because of the typical steps of performing a mix design

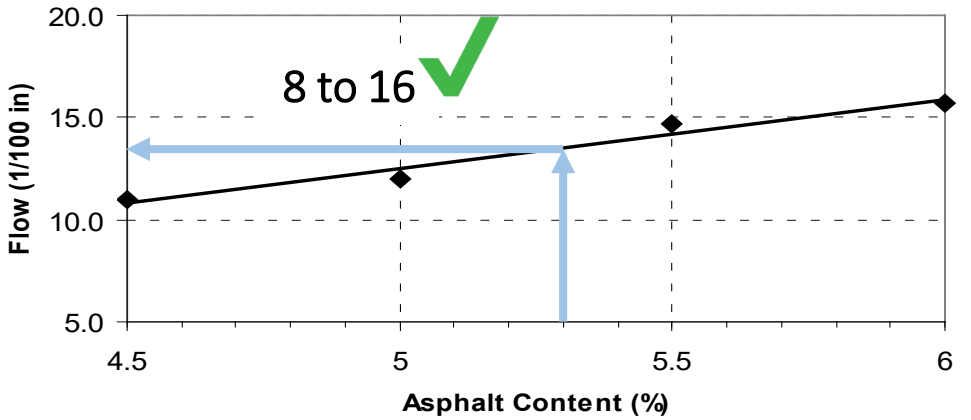
1. Performing a Mix Design

1. Select asphalt content at 4.0% V_a
2. Check that other properties are okay at that asphalt content
3. If so, check moisture susceptibility





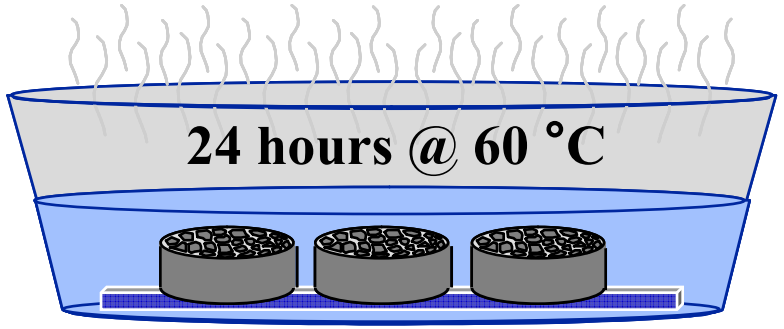




1. Moisture Susceptibility

- TSR = ratio of wet to dry indirect tensile strength (S_t)

3 unconditioned specimens

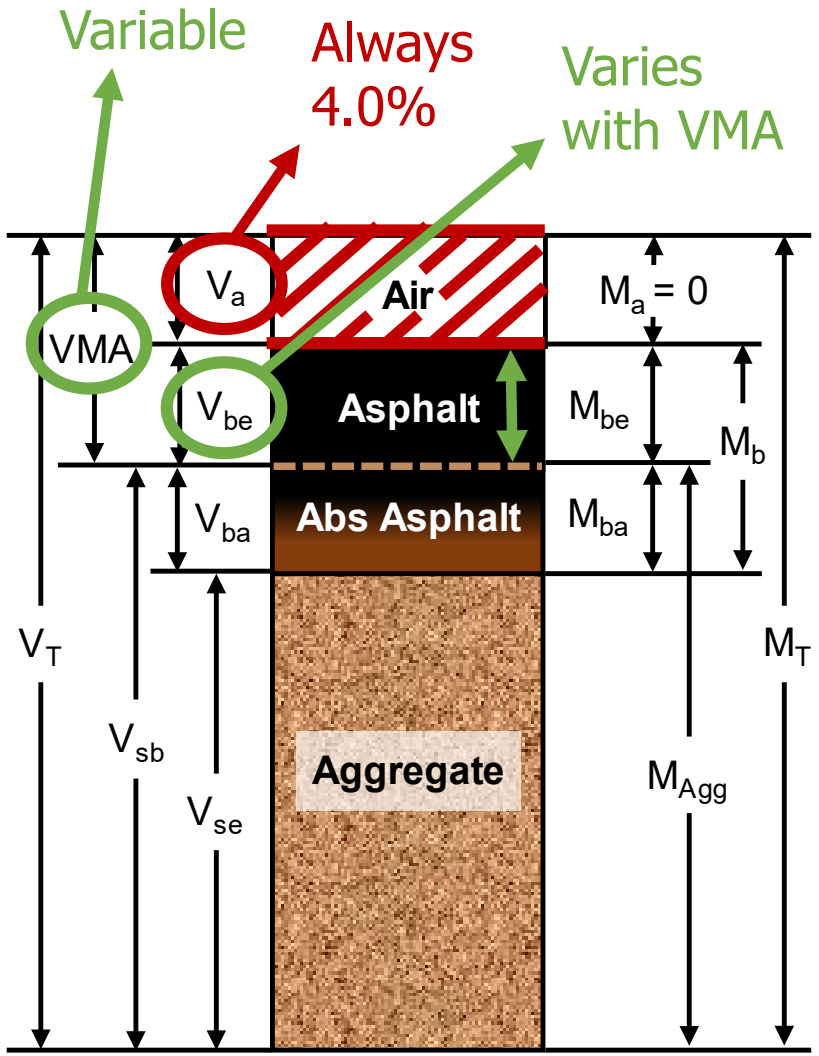


3 moisture-conditioned specimens

$$TSR = \frac{Wet}{Dry} \geq 75\%$$

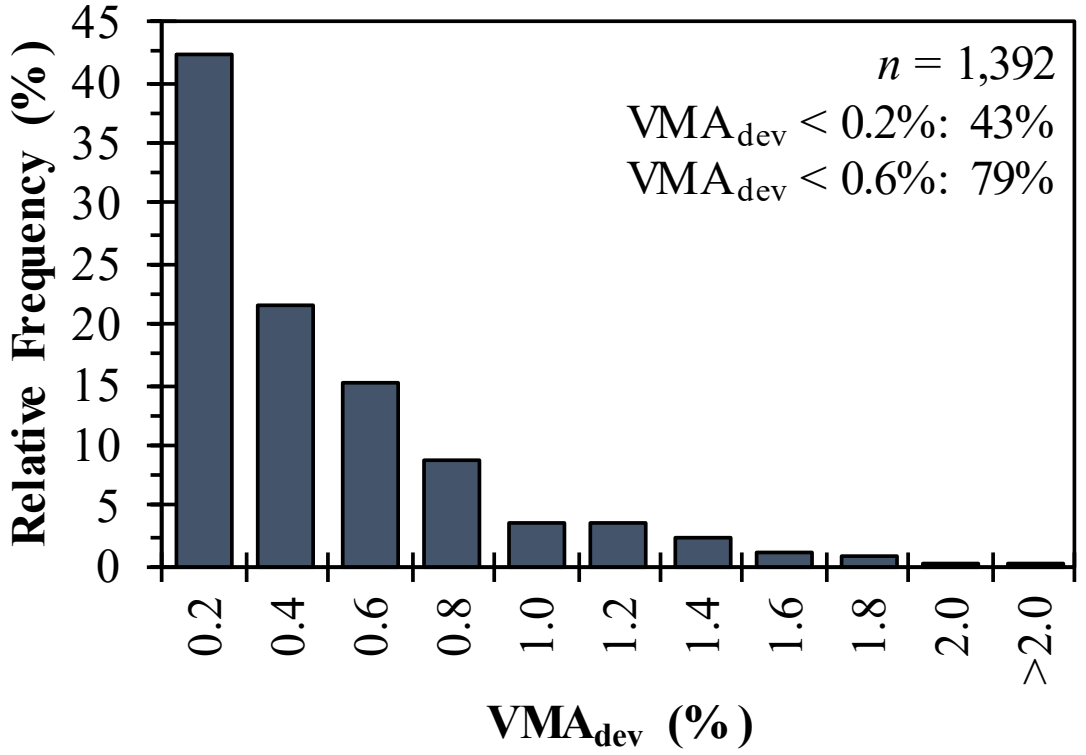
1. VMA

- V_a appears on the surface to determine $P_{b,\ des}$, but…
  - $V_{a,\ des}$ is **fixed** and will always be 4.0%
  - VMA is **not fixed**
  - $V_{be} = VMA - V_{a,\ des}$
  - V_{be} fluctuates with VMA (i.e. aggregate blend)
- So, VMA effectively controls asphalt content



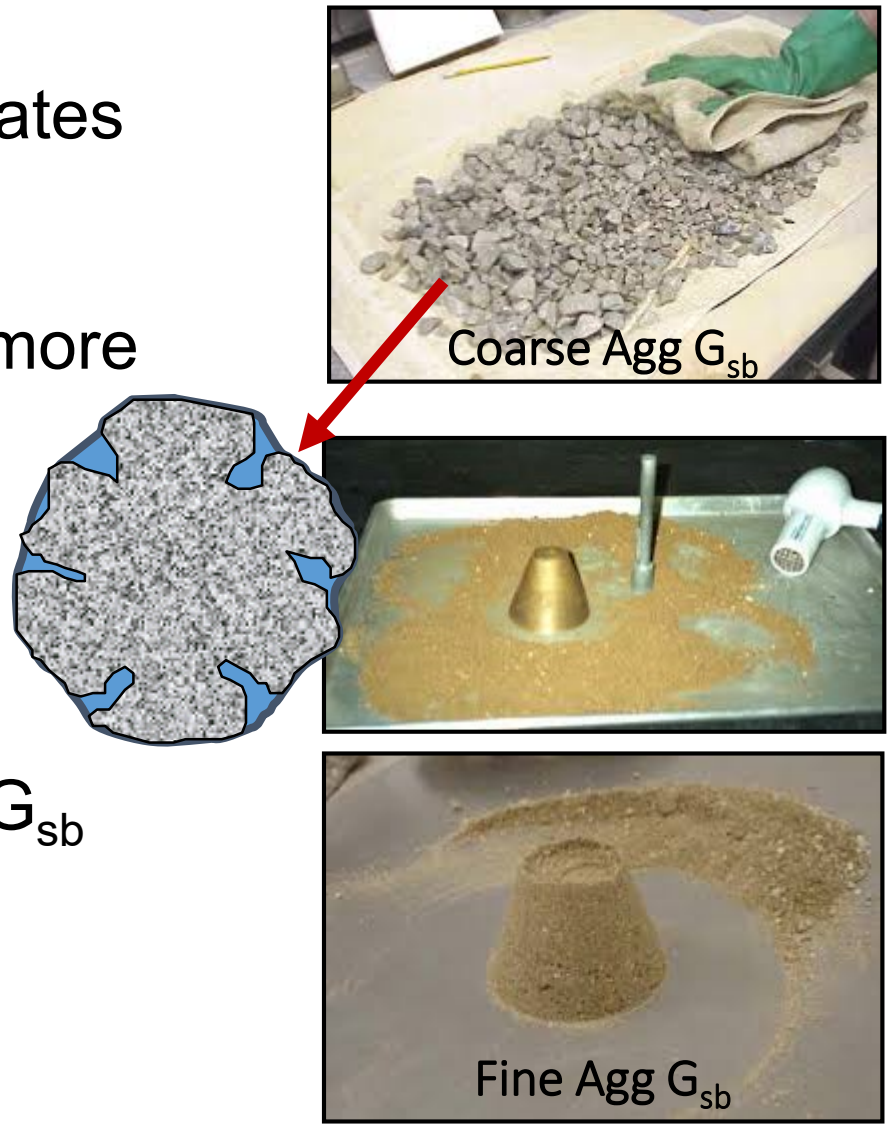
1. VMA Trends

- 80% of mixes are within 0.6% of minimum VMA (VMA_{min})
- Being skewed heavily towards VMA_{min} suggests mix optimization based on VMA
- We know binder is most expensive component of a mix
- In a low-bid environment, VMA will generally be as close to VMA_{min} as reasonably possible to maintain an economical mix



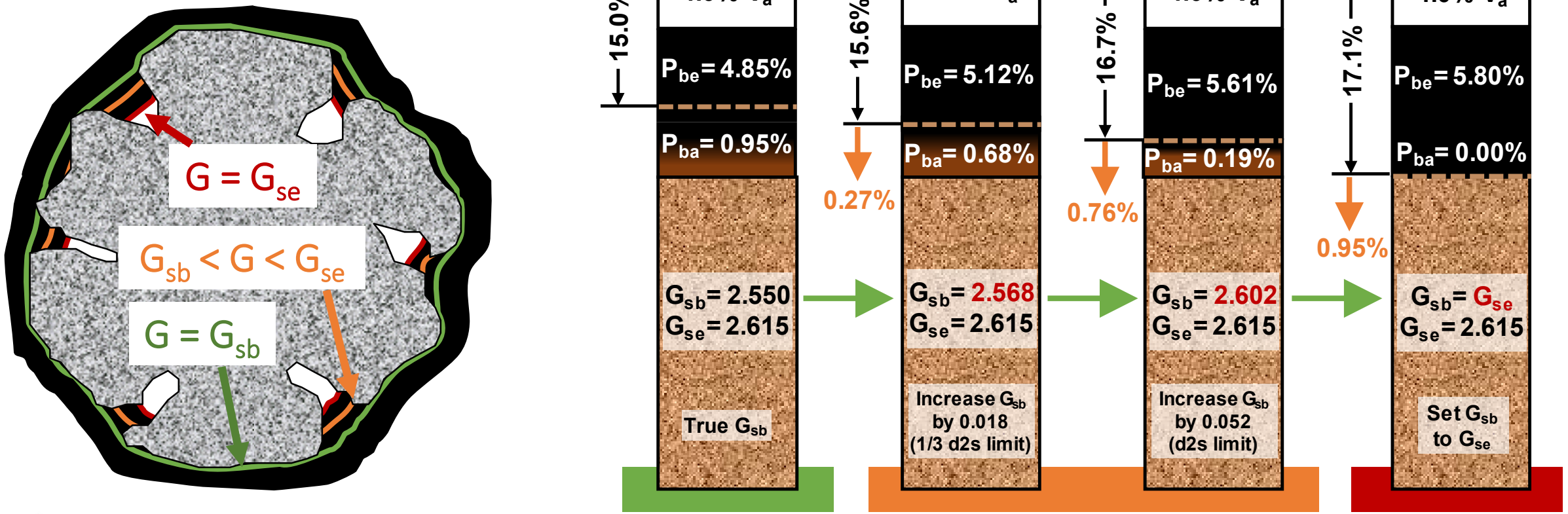
1. VMA Dependency on G_{sb}

- VMA calculation depends on G_{sb}; G_{sb} complicates matters
- Unlike G_{mb}, G_{mm}, etc. (fairly foolproof), G_{sb} is more operator dependent and inherently variable
- AASHTO/ASTM d2*s* for 50/50 coarse/fine agg. blend is 0.052
- This offers large window to find a “favorable” G_{sb}
- Generally, you will find inflated G_{sb} values (achieved by drying agg. past SSD condition)



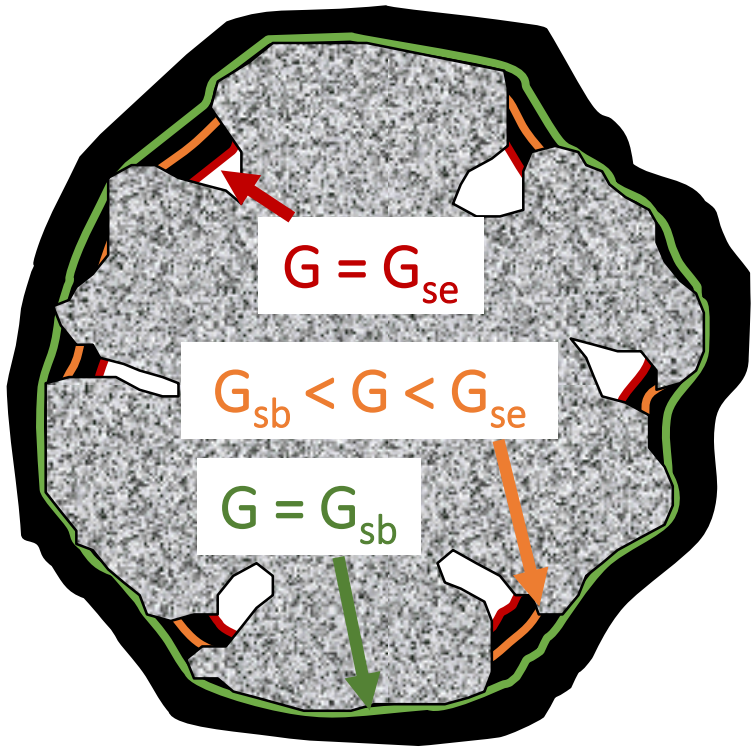
1. G_{sb} Effect on VMA

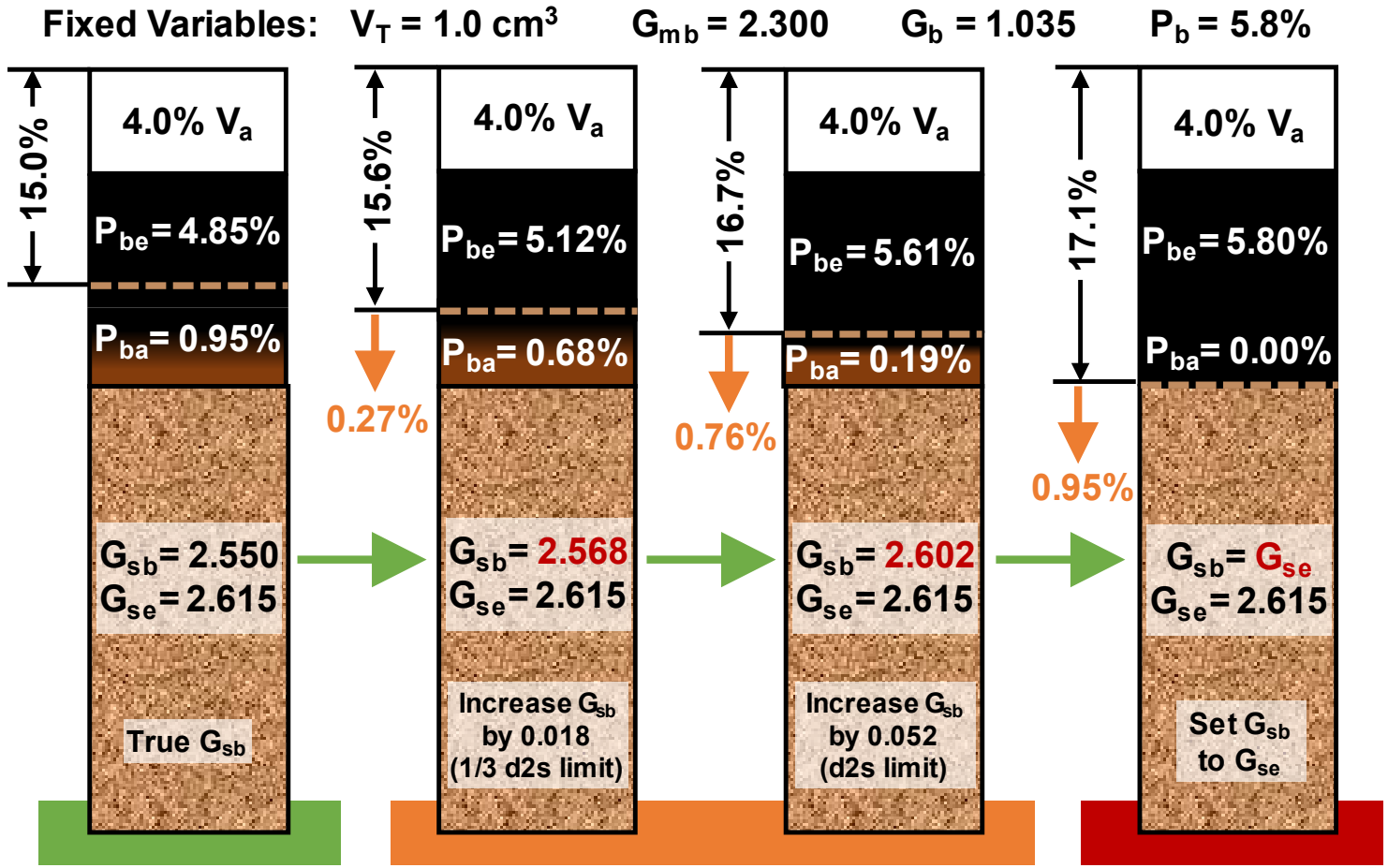
- Inflating G_{sb} (even within d2s limits), increases the *calculated* VMA



1. G_{sb} Effect on VMA

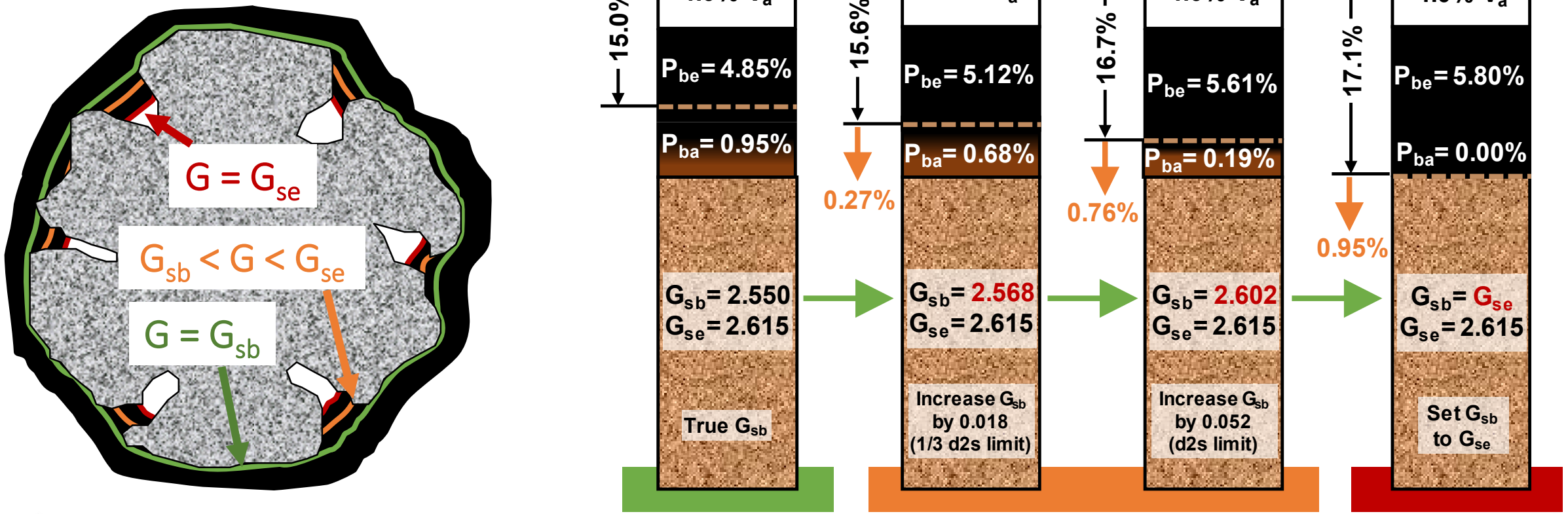
- This provides a VMA "buffer" where gradation can be tweaked to bring *calculated* VMA back down to a more conservative value





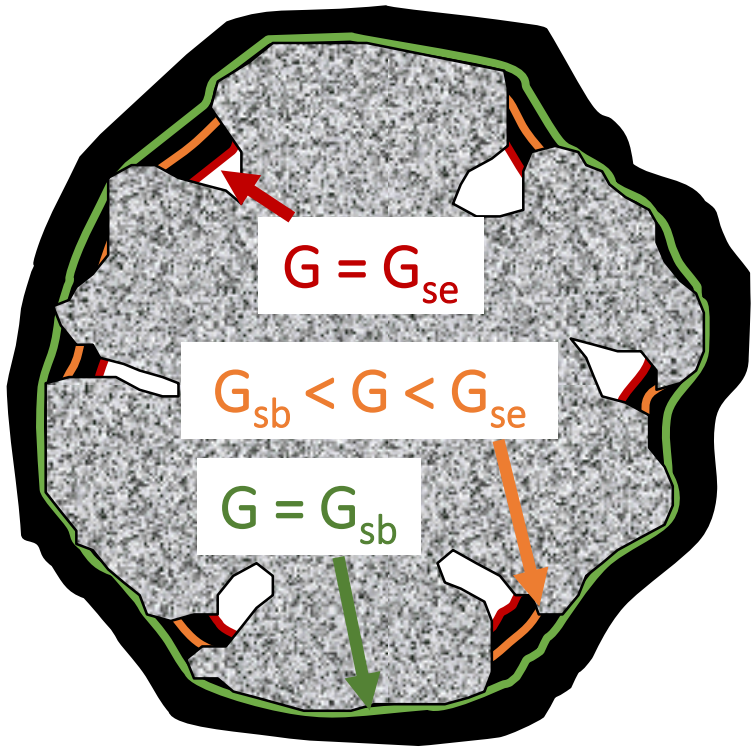
1. G_{sb} Effect on VMA

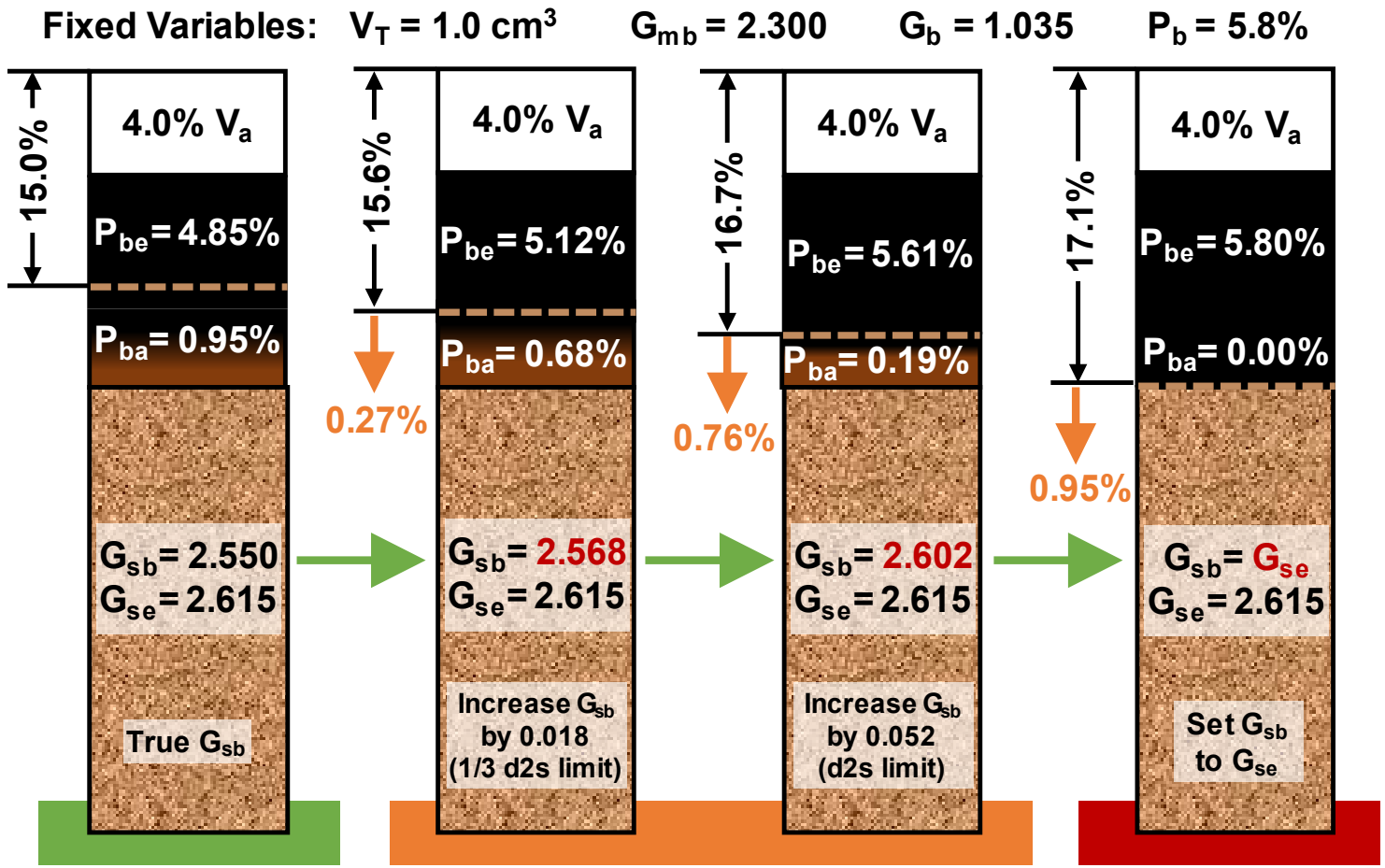
- Because *actual* VMA decreased, V_a is fixed, V_{be} is then decreased



1. G_{sb} Effect on VMA

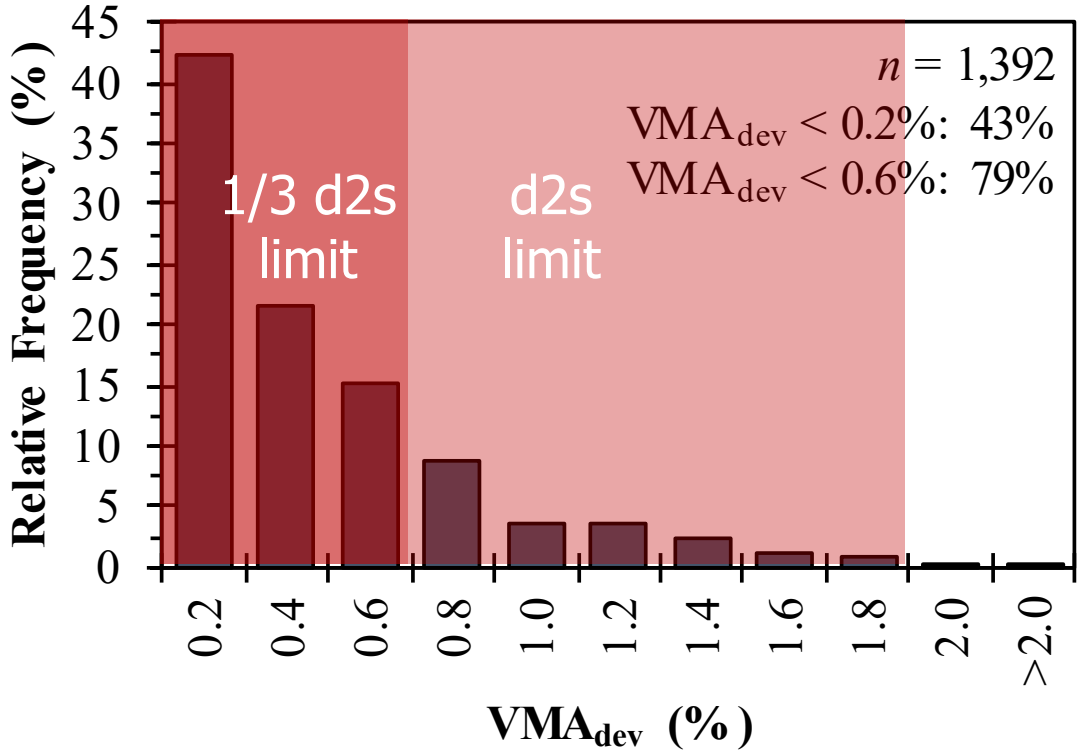
- Now, *actual* VMA and V_{be} are lower than desired, although *calculated* VMA says, “I’m fine, everything is fine.” You have a dry mix.





1. G_{sb} Effect on VMA

- Putting G_{sb}-VMA relationships back in context of MDOT database…
- 80% of mixes could be failing VMA but calculate as passing with G_{sb} inflated by 1/3 d2s limit, resulting in up to 0.3% asphalt reduction
- With G_{sb} inflated the d2s limit, this could be the case for 99% of mixes, resulting in up to 0.8% asphalt reduction
- G_{sb} inflation allows manipulation and economization of mixes

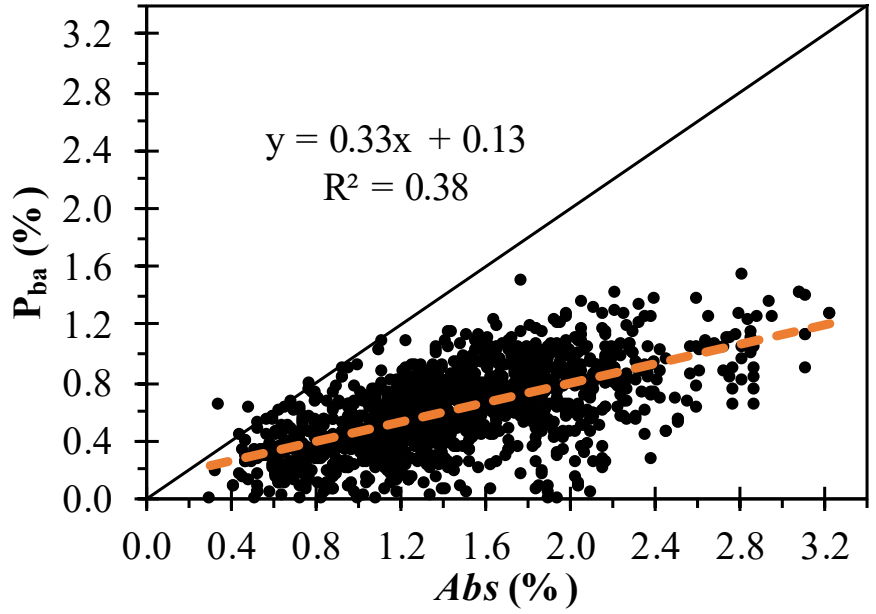


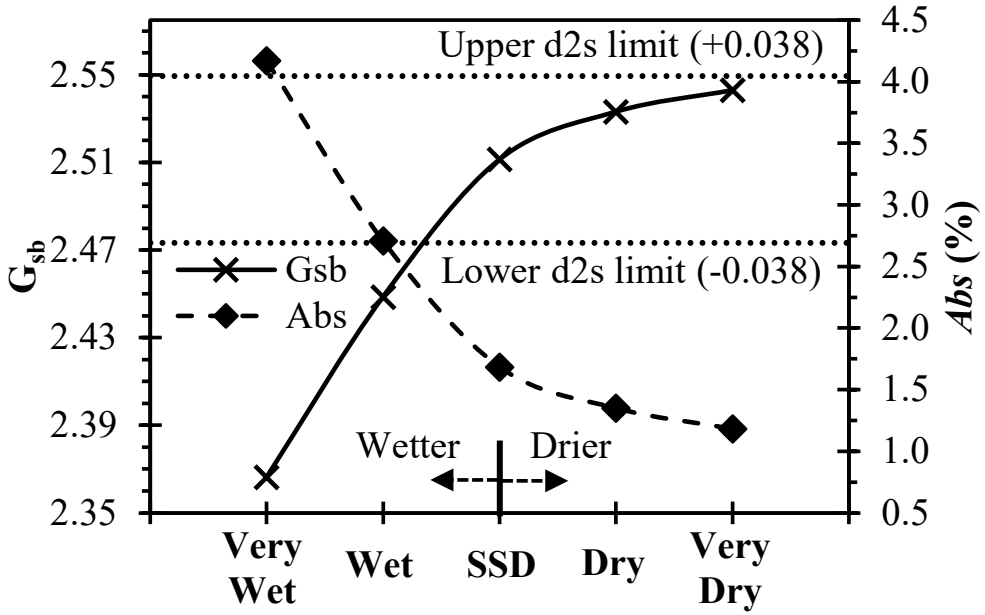
2. G_{sb} and *Abs*

- Can you tell if G_{sb} might be inflated?
  - VMA will look okay
  - P_b might not be noticeable unless it is really low
  - Low P_{ba} could be low-absorption aggregate or inflated G_{sb} – may not be obvious
- Some suggest you can compare P_{ba} to *Abs* using rules of thumb

2. G_{sb} and *Abs*

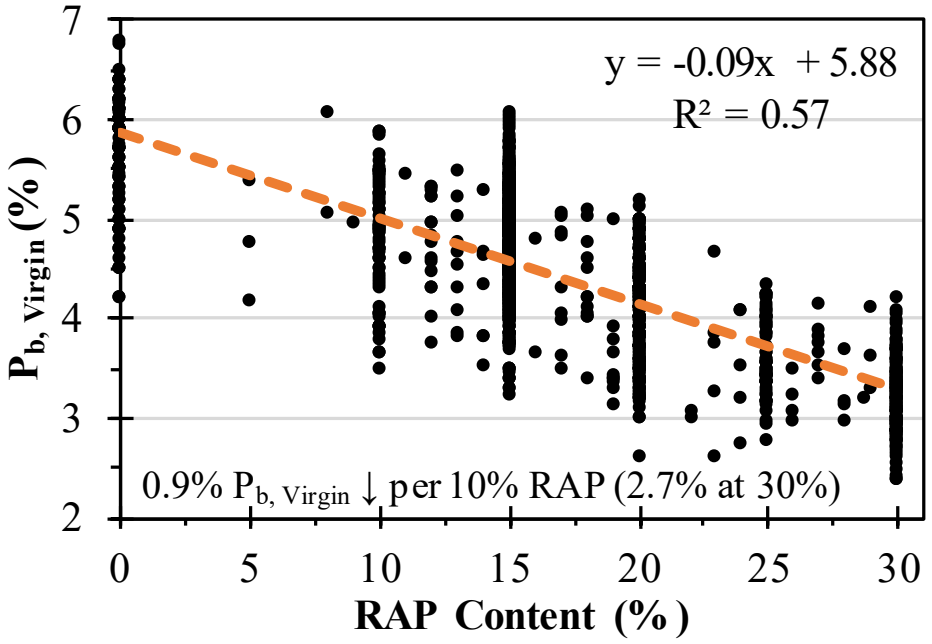
- There is a relationship between P_{ba} and *Abs* on average (less reliable for any one specific case due to scatter)
- However, an inflated G_{sb} will yield a deflated *Abs*, so low P_{ba} will not stand out in comparison to a low *Abs* (i.e. rule of thumb will check out)

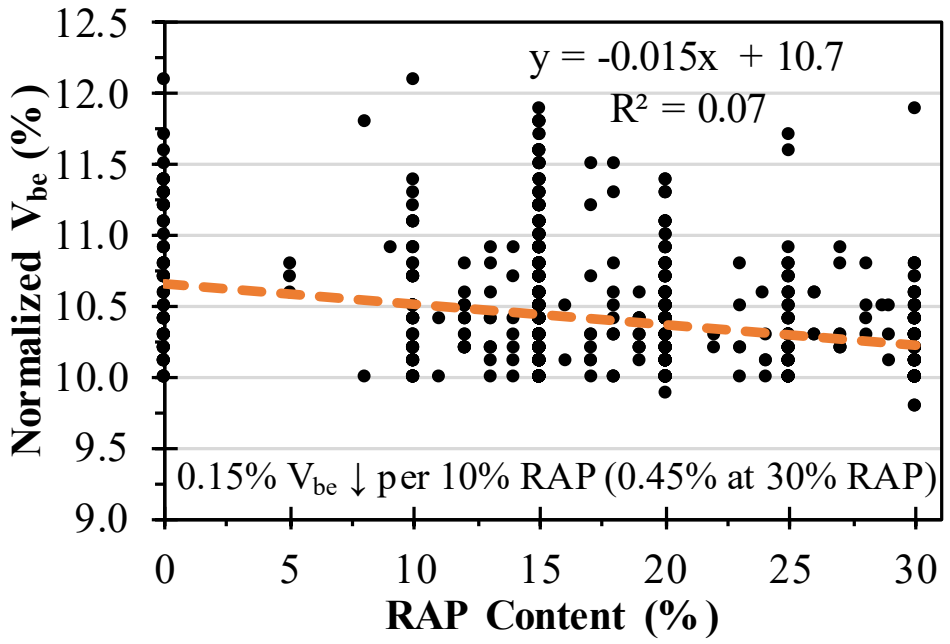




3. RAP Content

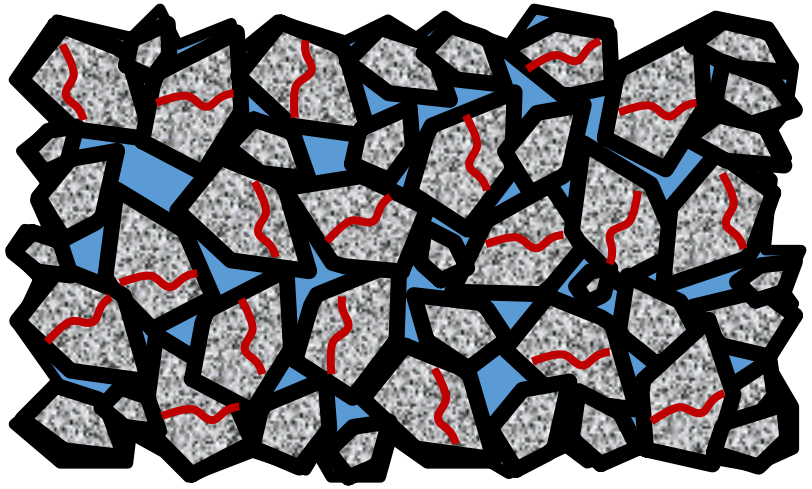
- Intuitively, binder demand would increase with RAP content, all other factors being equal
- In practice, V_{be} actually drops (0.45% V_{be}, or 0.2% P_{be}, at 30% RAP)
- Unintended consequence – concerning in light of stiffer RAP binder

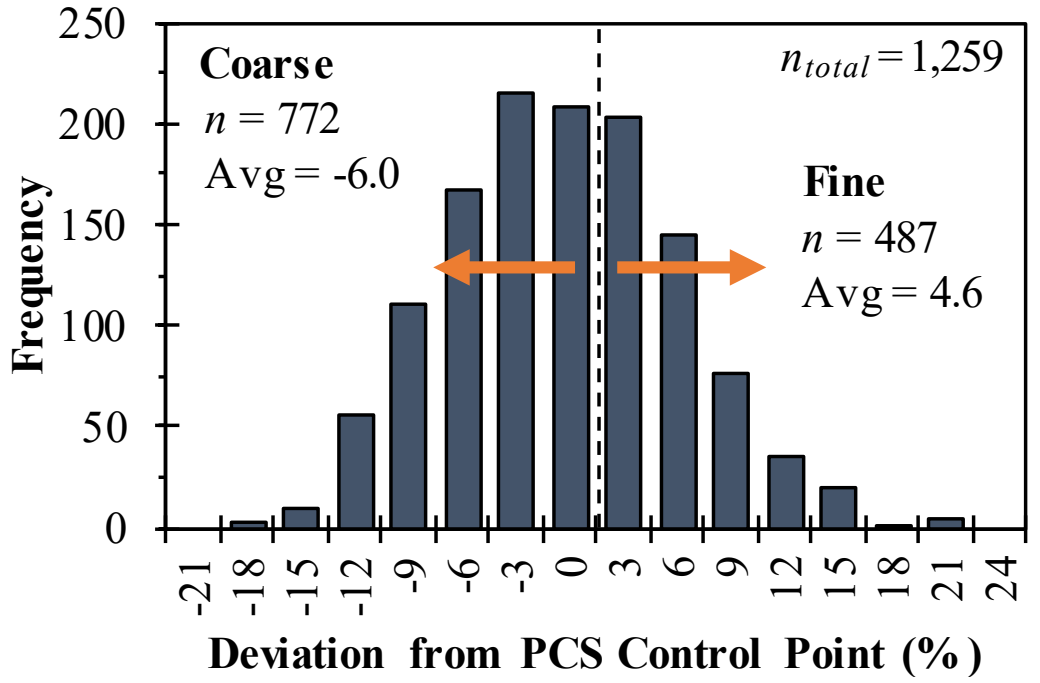




4. Coarse vs. Fine Gradations

- Common thought is that finer gradations could be used to obtain richer asphalt mixes
- Finer gradations have more surface area; therefore, binder demand is greater and asphalt content will go up -- Right???

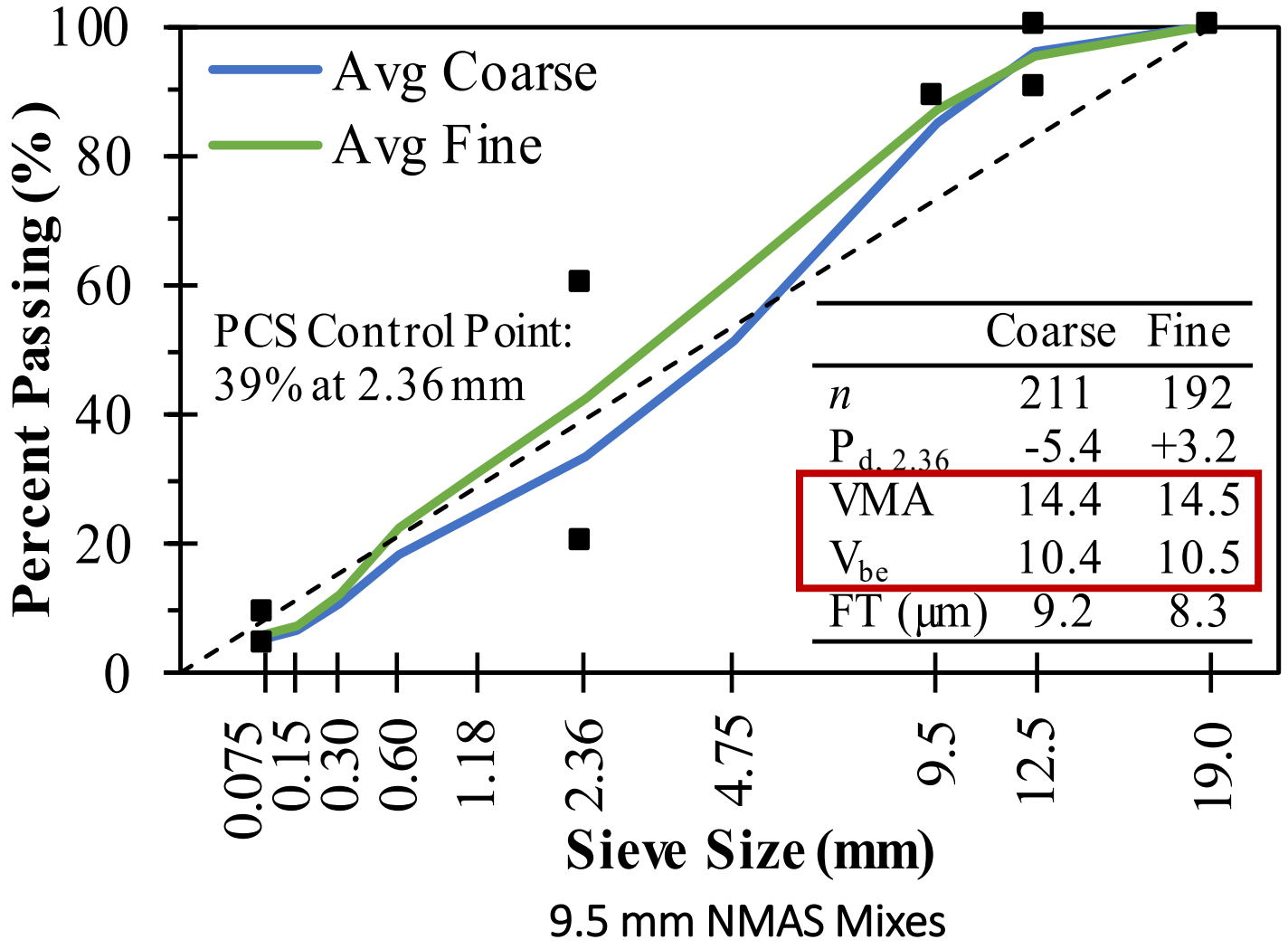




Distribution of Coarse vs Fine for MDOT Mixes

4. Coarse vs. Fine Gradations

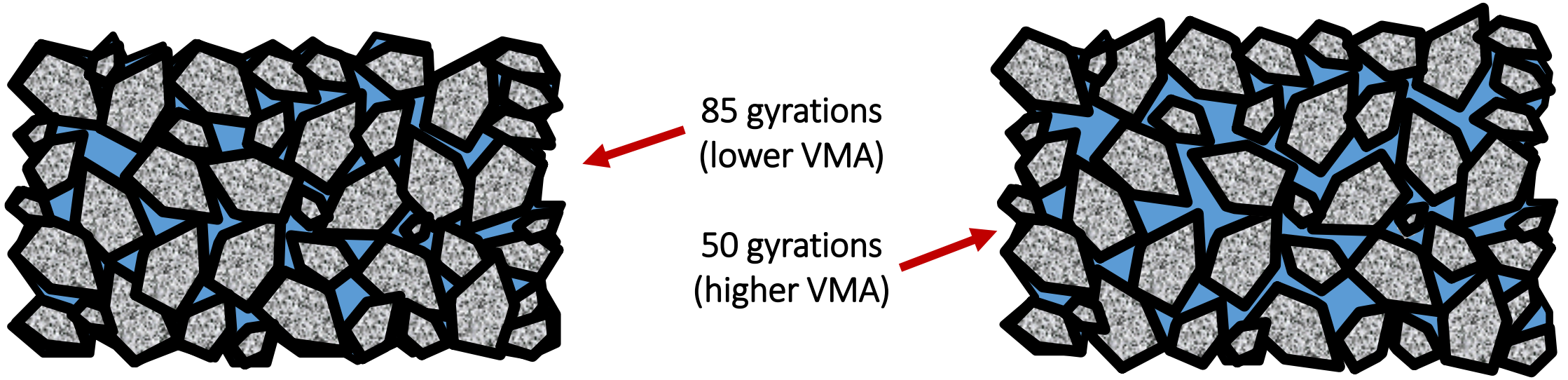
- Gradation type has no impact in practice
- V_{be} is 10.4 vs 10.5%; P_{be} change of 0.04% (basically no difference)
- Min. VMA criteria didn't change, so asphalt content didn't change



9.5 mm NMAS Mixes

5. Decreasing N_{des} Level

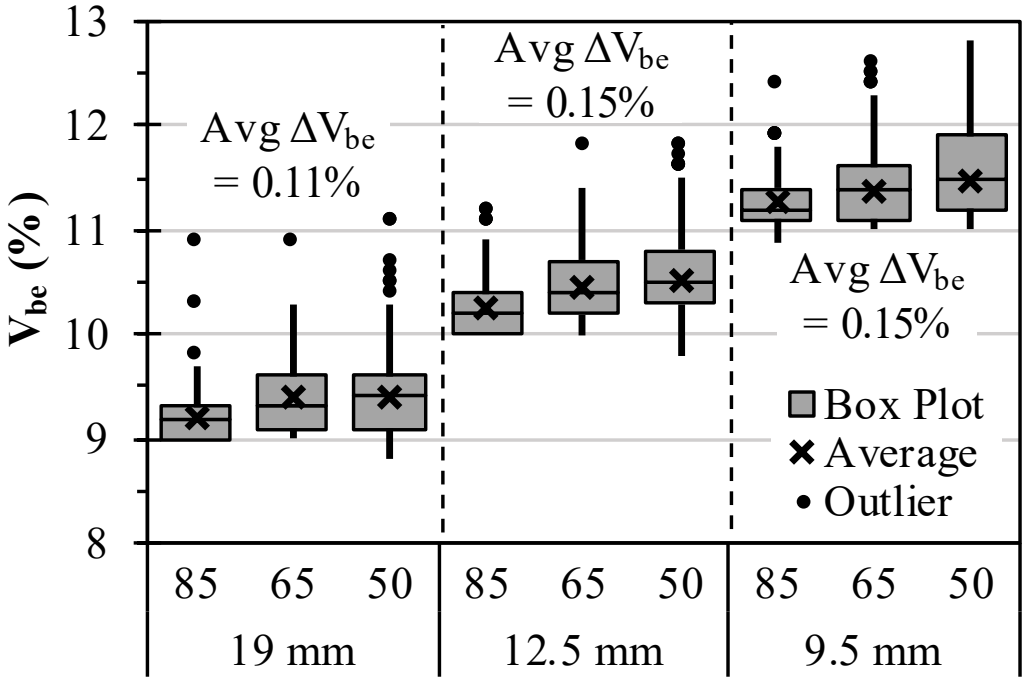
- Another common suggestion to increase asphalt content is reduce N_{des}
- Less compaction → looser agg skeleton → higher VMA → higher V_{be}

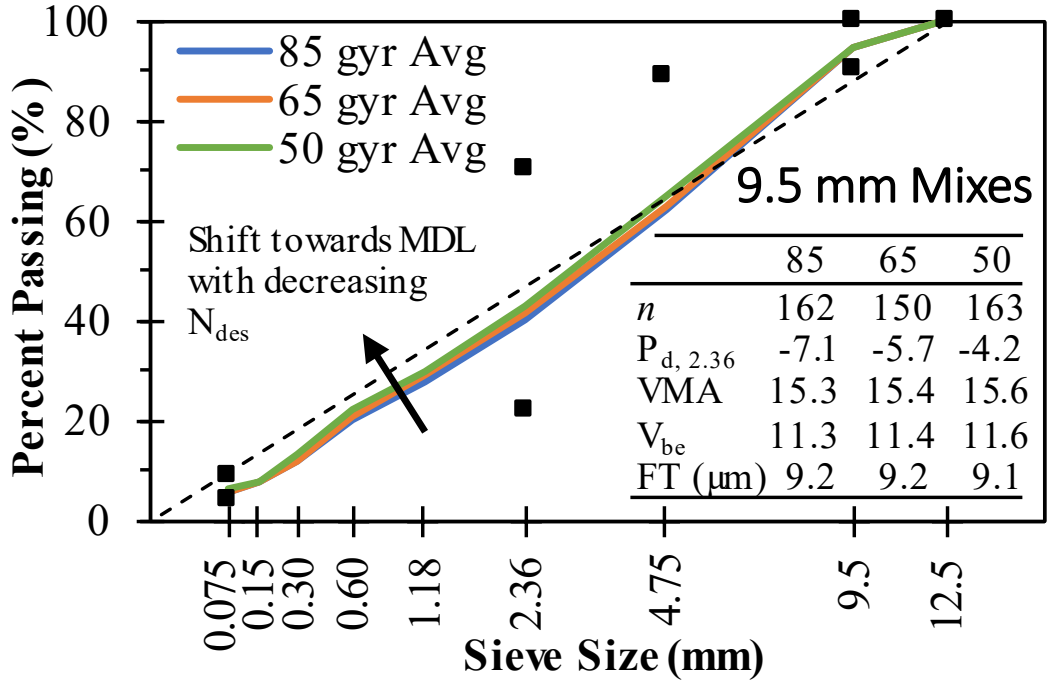


Rule of Thumb: 30 gyr = 1% VMA = 0.4% P_{be}

5. Decreasing N_{des} Level

- In practice, changing N_{des} has no meaningful impact because nothing prevents the mix designer from adjusting the agg. blend and/or gradation
- Since VMA_{min} didn't change, mix designer can choose to bring VMA back down by filling voids with aggregate – it's cheaper than binder

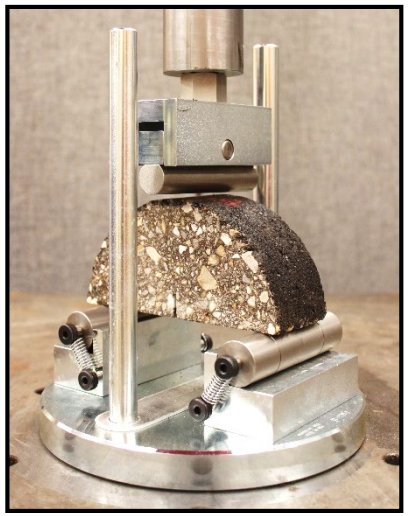


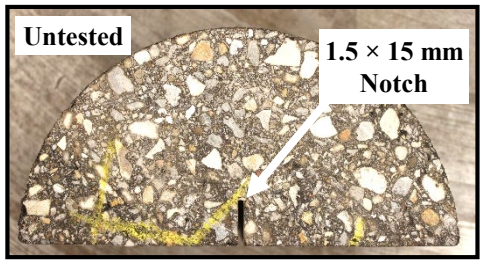


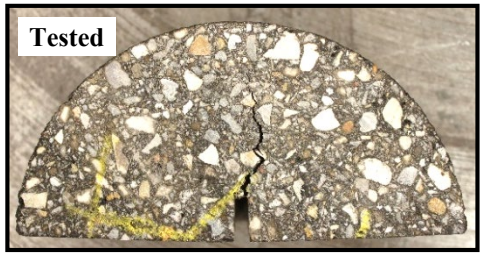
Summary

- Data from practice across an entire state supports numerous other studies consisting of smaller datasets that 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

Example Mechanical Tests



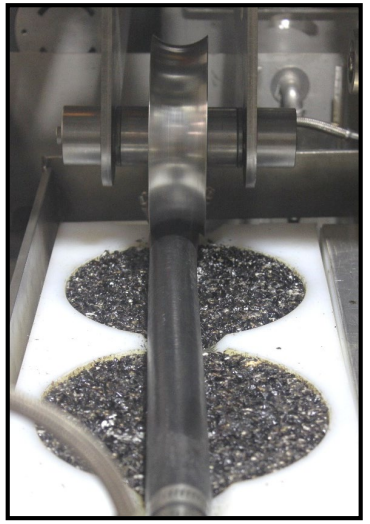




Semi-Circular Bend Test

Dynamic Modulus Test

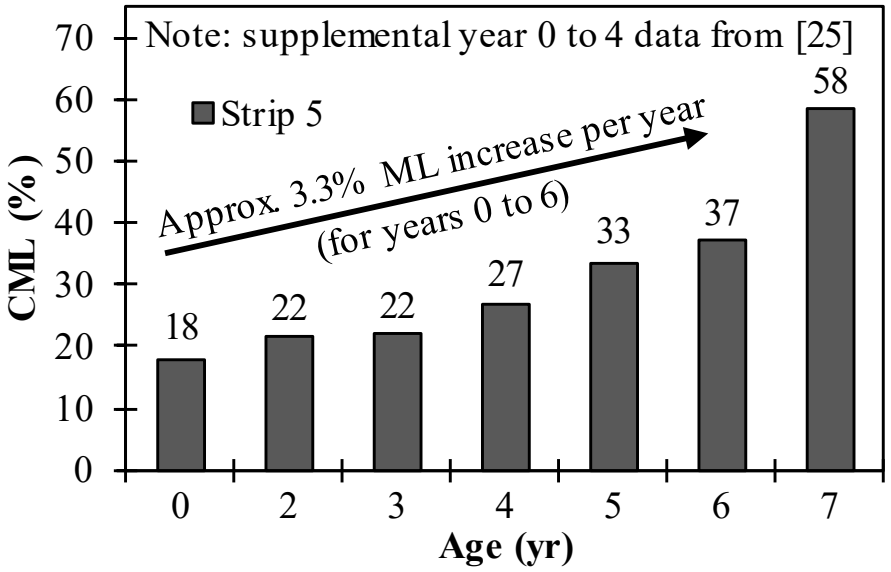
Cantabro Durability Test

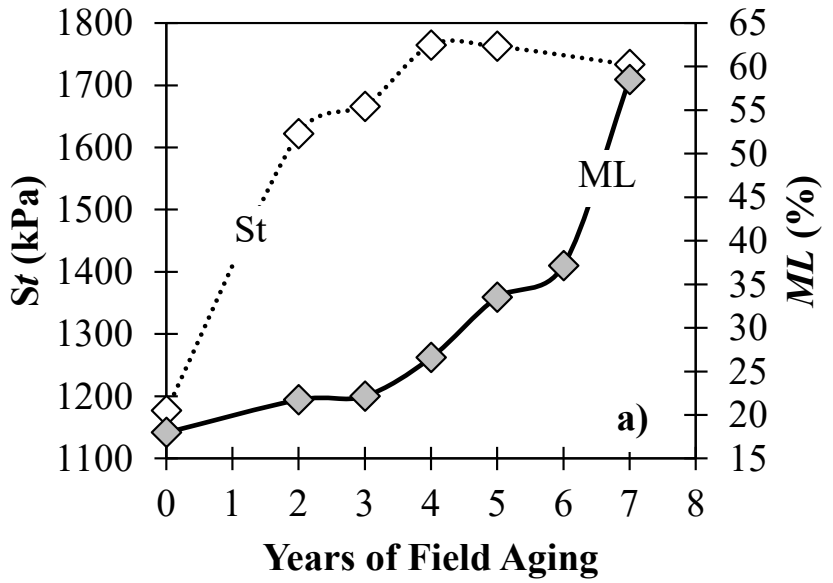


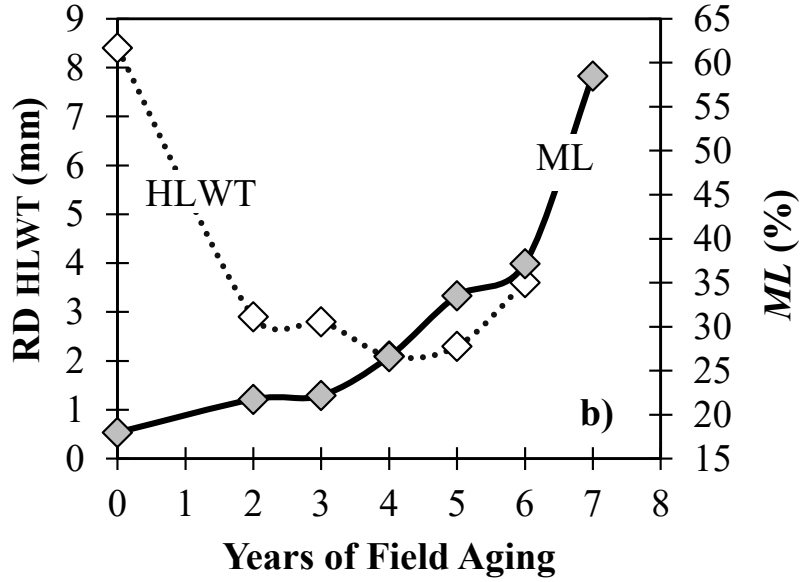
Loaded Wheel Tracking Test

Mechanical Test Discussion Teaser

- Important considerations
  - "Balanced" mix design (i.e. balancing rutting and cracking ends of spectrum)
  - Logical test outputs (e.g. gets worse with age)
  - Test time and cost
  - Ability to perform during plant production for QC







Questions?

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