Responsible Incorporation of High RAP Contents and Recycling Agents in Surface Asphalt Mixtures: A Virginia Approach

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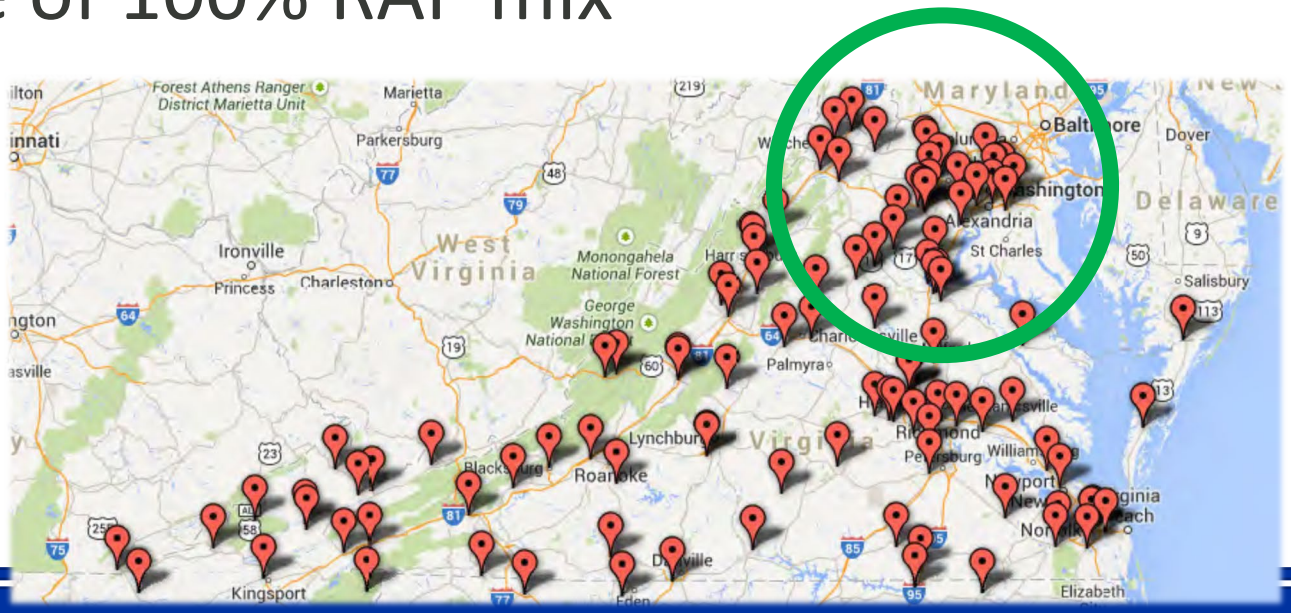
State of the RAP in Virginia

Background, Specifications, History, and Motivations

Background on RAP in Virginia

- RAP is owned by the asphalt producer
- Estimated ~10 million tons statewide
  - Approximately 75% in urban areas
- Could pave ~8,410 lane-mile of 100% RAP mix



VDOT Current Specifications

- ≤ 30% RAP in unmodified dense-graded surface and intermediate courses
- ≤ 35% RAP in base courses
- ≤ 20% RAP in PG 70-22 Stone Matrix Asphalt mixtures (SMAs)
- ≤ 15% RAP in PG 76-22 (dense-graded and SMAs)

History

2007

- Specifications for higher % of RAP (up to 30%)
- No need to adjust the virgin binder grade

2013

- Considering the feasibility of using up to 45% RAP
- Trial sections were constructed
- 0.4% RAP correction factor for %AC by ignition furnace

2017

BMD

2019 - 2021

- Construction of field trials to evaluate high RAP mixes designed following the Balanced Mix Design (BMD) special provision

Motivations to Using More RAP

- Increased interest in recycled / reclaimed materials
  - Environmental impacts
  - Cost reduction
  - Industry factors
- Virginia DOT Stance
  - Encourage material recycling / reclaiming
  - Encourage cost reduction measures
  - Encourage innovation
  - ***Ensure quality materials and performance***

BMD High RAP Mixtures

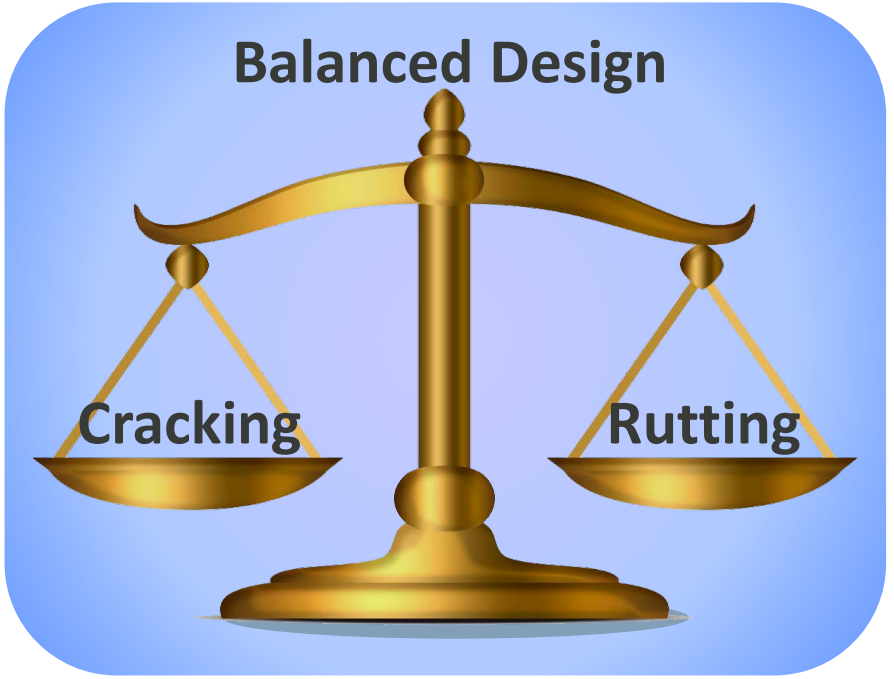
Specifications, Challenges, Field Trials, and Test Results

Virginia's BMD Specifications

Cracking

Indirect Tensile (IDT) Test (ASTM D8225)

CT index ≥ 70



Rutting

Asphalt Pavement Analyzer (APA) Rut Test (AASHTO T 340)

RD < 8.0 mm

Durability

Cantabro Mass Loss Test (AASHTO TP 108)

CML < 7.5 %

Moisture Damage

Tensile Strength Ratio Test (AASHTO T 283)

TSR > 80 %

Approach to High RAP Use

- High RAP mixes ***MUST*** perform ***equal to*** or ***better*** than conventional / typical mixes
  - BMD method to evaluate design & production
  - Pilot projects and field performance to validate BMD criteria
  - APT and modelling to verify initial BMD criteria

Approach A: Volumetric Design with Performance Verification		**Approach D:** Performance Design
Meet Volumetrics + Performance		**Meet Performance (regardless of volumetrics)**

Challenges of High RAP Mixtures

- Can be difficult to produce
  - Plant setup and capacity
- Determining RAP properties
  - Specific gravity, binder grade, binder availability and blending
- Maintaining consistency during production
  - Control / management of RAP stockpile
- Meeting volumetric and performance acceptance criteria
  - Changes needed to be made to improve the produced mix

BMD 2019 / 2020 High RAP Field Trials

Superior Stafford – July 2019

- SM-9.5 30% RAP PG64S-22
- SM-9.5 30% RAP PG58-28
- SM-9.5 40% RAP PG64S-22
- SM-9.5 40% RAP PG58-28
- SM-9.5 40% RAP PG64S-22, RA

Superior Leesburg – July 2020

- SM-9.5 30% RAP PG64S-22
- SM-9.5 40% RAP PG64S-22, RA
- SM-9.5 40% RAP PG58-28

Lee Hy Rockville – September 2020

- SM-12.5 30% RAP PG58-28

Colony Burkeville – August 2020

- SM-12.5 30% RAP PG64S-22
- SM-12.5 35% RAP PG58-28, RA
- SM-12.5 35% RAP PG58-28, fibers + RA

Superior Stafford – August 2020

- SM-12.5 30% RAP PG64S-22
- SM-12.5 40% RAP PG64S-22, RA
- SM-12.5 40% RAP PG58-28

Colony Powhatan – October 2020

- SM-12.5 30% RAP PG64S-22
- SM-12.5 40% RAP PG58-28

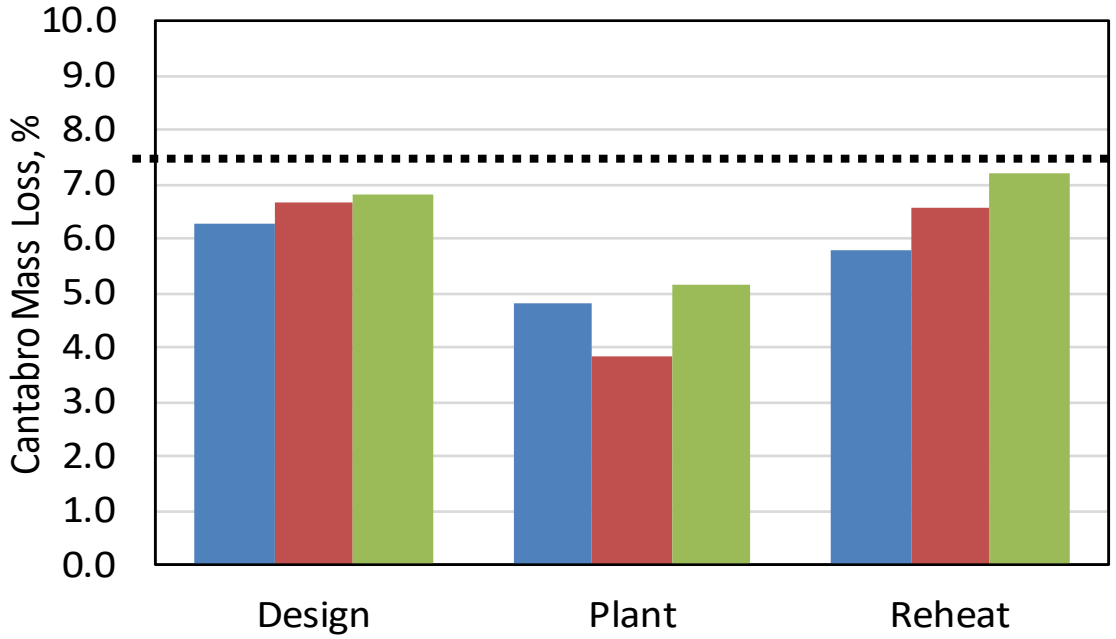
General Sampling Plan – Production

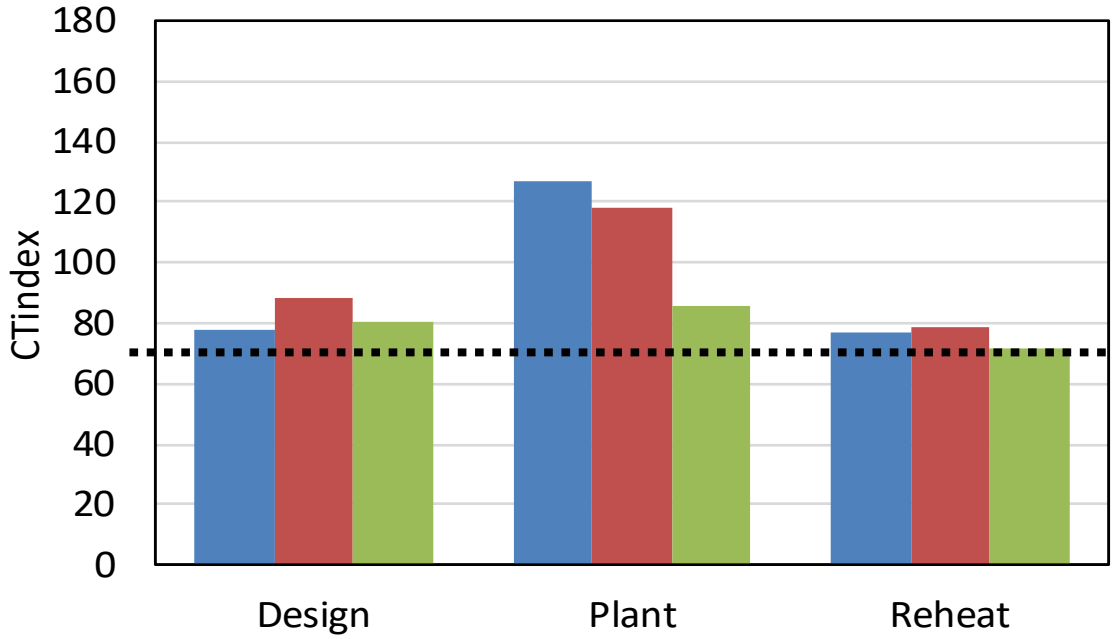
Daily Production	Producer-Made Pills (No Reheating)		Loose Mix Sampling	Cores (x10)
	Producer testing	VTRC testing	VTRC reheat testing	
Sublot A (T1)	3 Cantabro 5 Ideal-CT	3 Cantabro 5 Ideal-CT 4 APA	3 Cantabro 5 Ideal-CT 4 APA	Ideal-CT APA
Sublot B (T2)	3 Cantabro 5 Ideal-CT	4 APA	3 Cantabro 5 Ideal-CT 4 APA	
Sublot C (T3)	3 Cantabro 5 Ideal-CT	3 Cantabro 5 Ideal-CT 4 APA	3 Cantabro 5 Ideal-CT 4 APA	
Sublot D (T4)	3 Cantabro 5 Ideal-CT	4 APA	3 Cantabro 5 Ideal-CT 4 APA	

Initial Long-Term Oven Aging Protocol

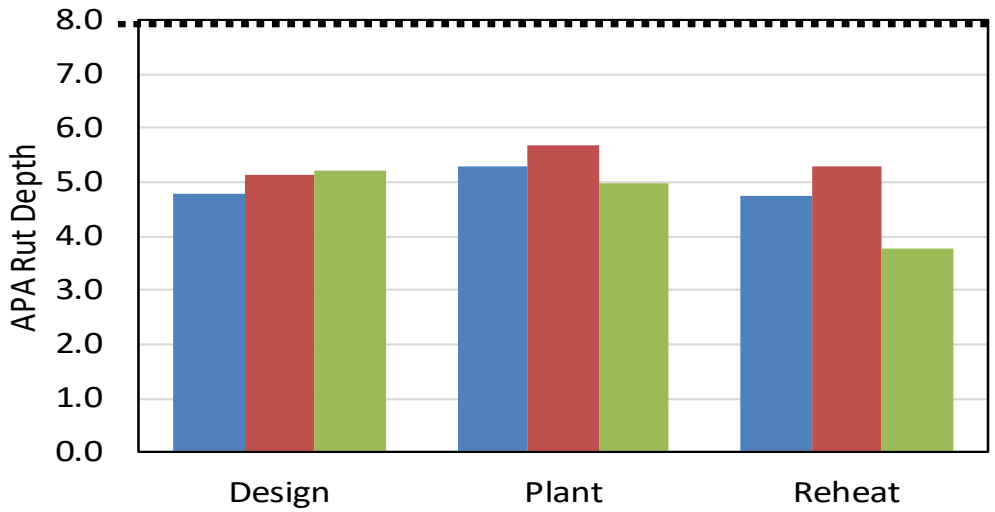
- Assuming mixes in Virginia experience overall cracking after 8 years of field aging:
  - **Loose mixture aging at 135°C**
    - ➢STOA at 135°C for 4 hrs followed by LTOA for ~8 hrs at 135°C
  - **Loose mixture aging at 95°C**
    - ➢STOA at 135°C for 4 hrs followed by LTOA for 3 days at 95°C
  - **Compacted mixture aging at 85°C**
    - ➢STOA at 135°C for 4 hrs followed by compaction then LTOA for 4 days of compacted specimens at 85°C

Durability – Cantabro Mass Loss at 25°C





30% RAP
PG 64S-22
40% RAP
PG 64S-22 + RA
40% RAP
PG 58-28



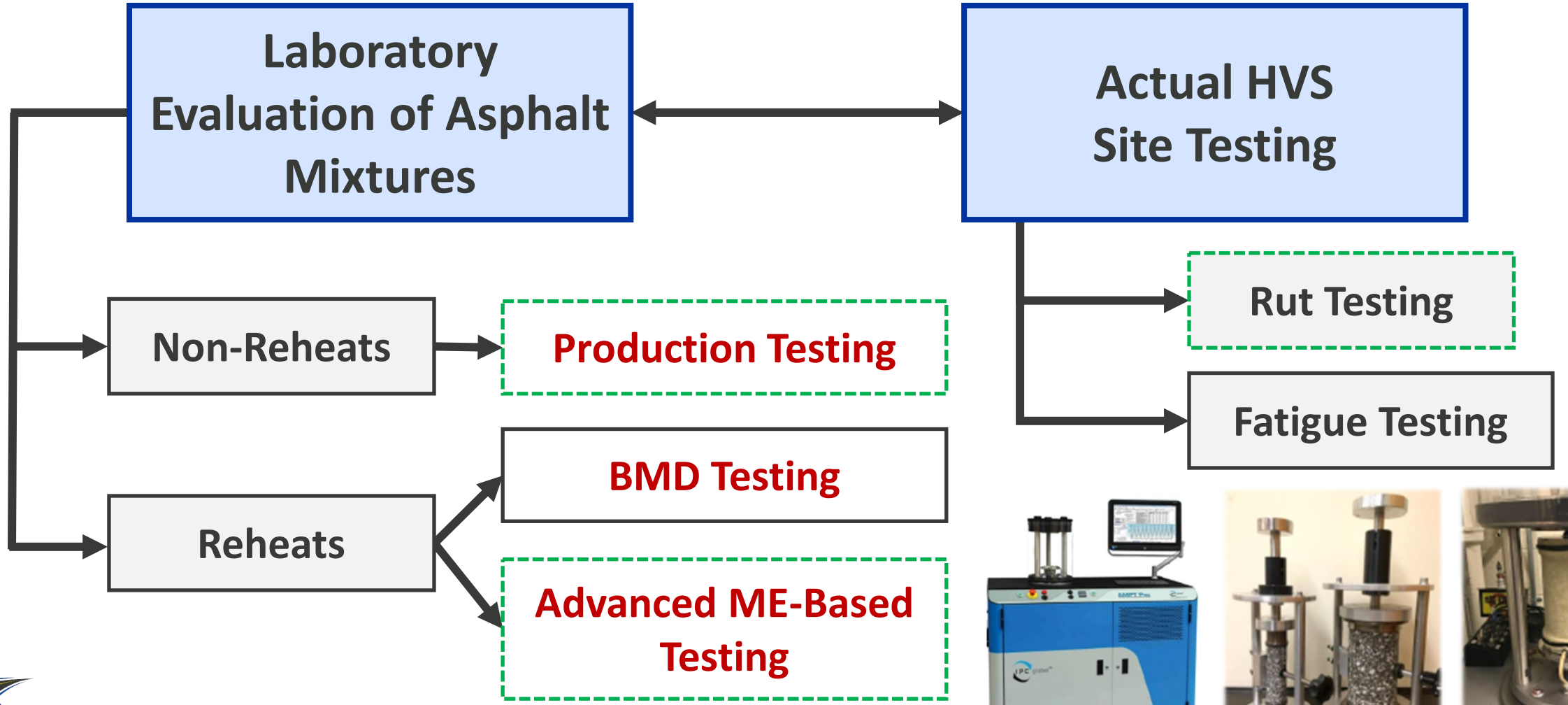
2020 HVS / APT Paved Mixtures

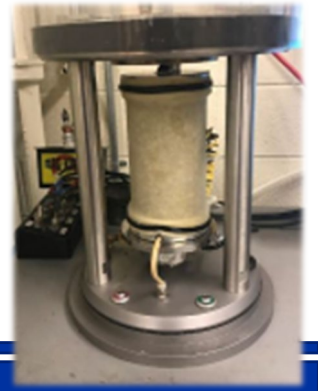
Boxley Salem – Spring / Summer 2019

- **Mix I:** SM-9.5A: 30% RAP + PG64S-22 – **Typical Mix**
- **Mix II:** SM-9.5A: 30% RAP + PG64S-22 – ***BMD***
- **Mix III:** SM-9.5A: 45% RAP + PG64S-22 – ***BMD***
- **Mix IV:** SM-9.5A: 45% RAP + PG58-28 – ***BMD***
- **Mix V:** SM-9.5A: 45% RAP + PG64S-22 + RA – ***BMD***
- **Mix VI:** SM-9.5A: 60% RAP + PG58-28 + RA – ***BMD***

→ **Two 1.5-inch lifts over compacted aggregate base**

HVS / APT Experimental Program





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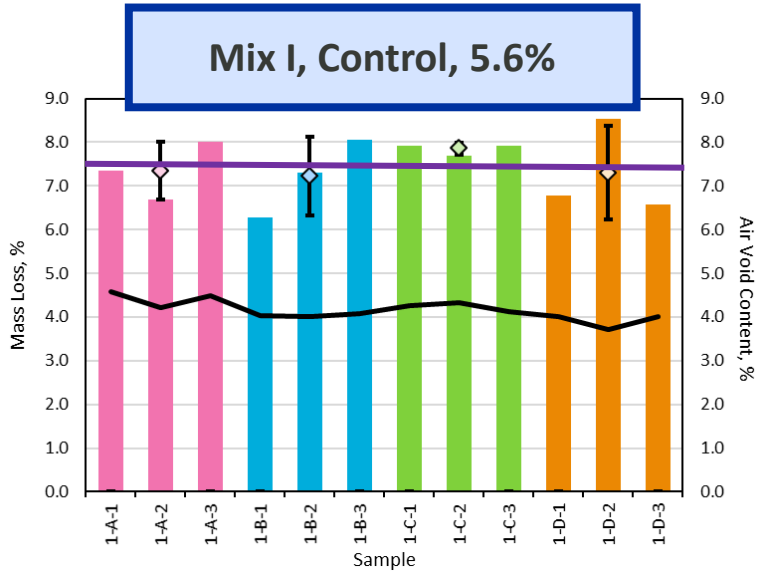
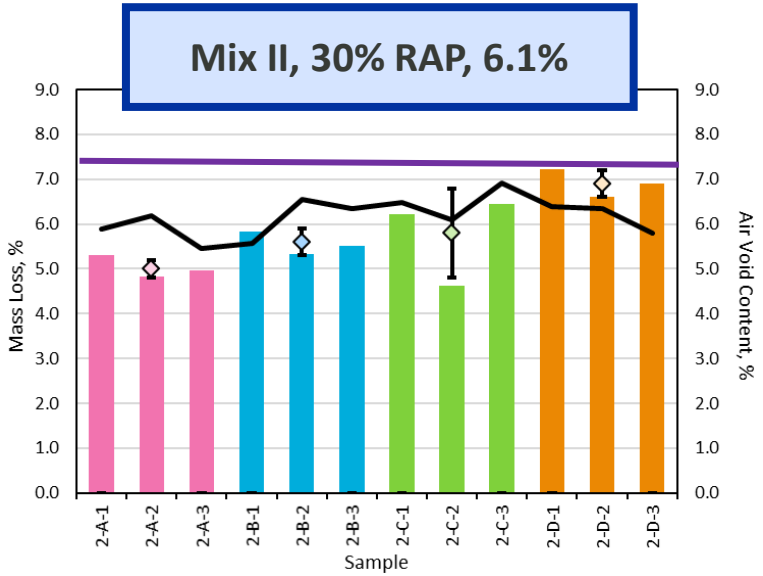
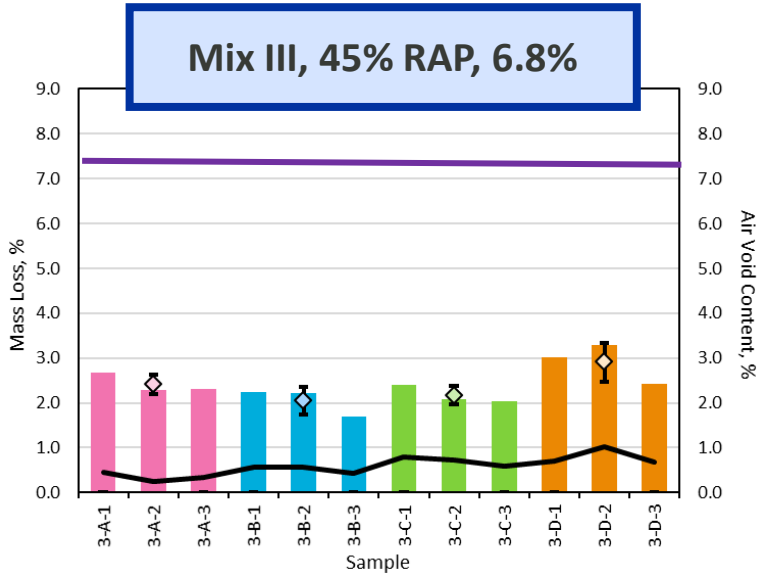
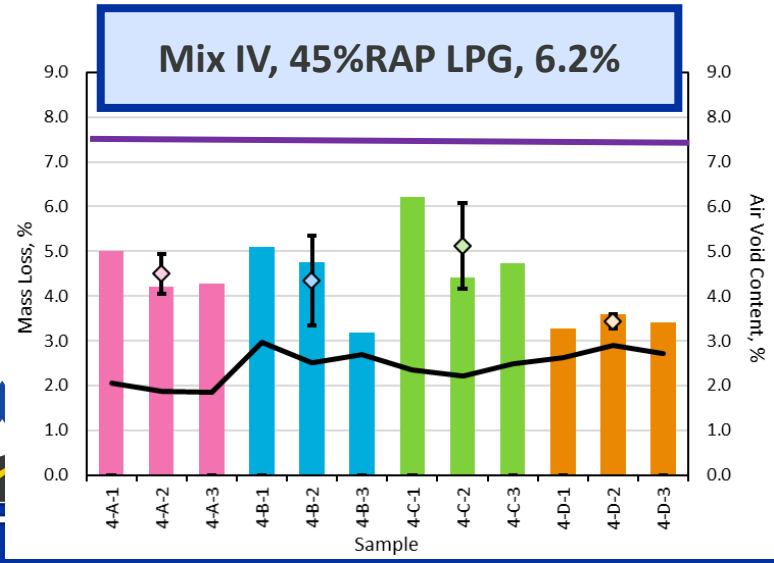
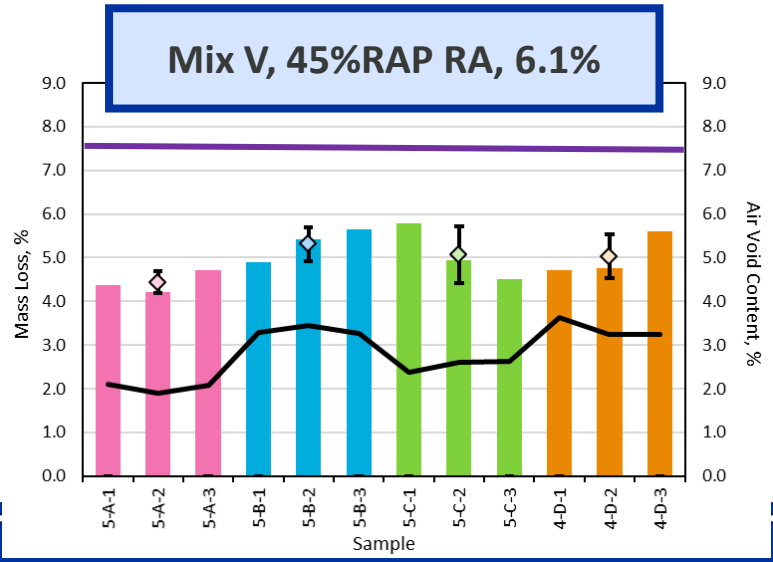
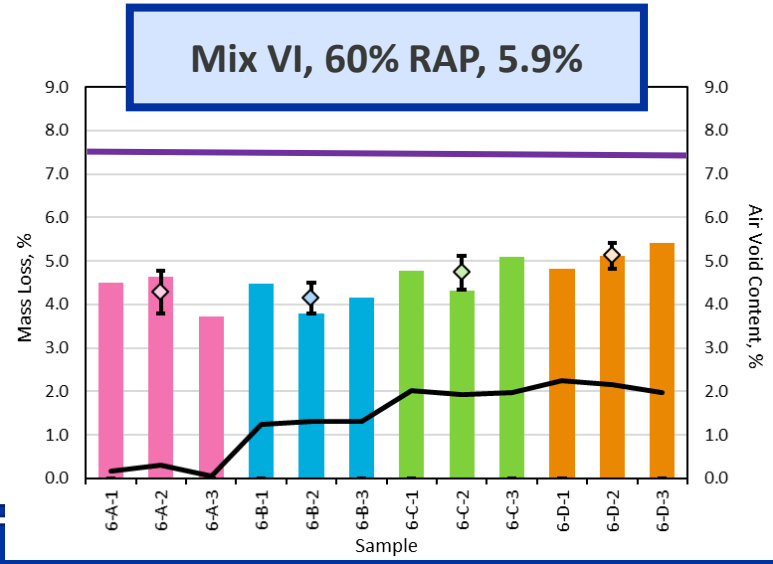




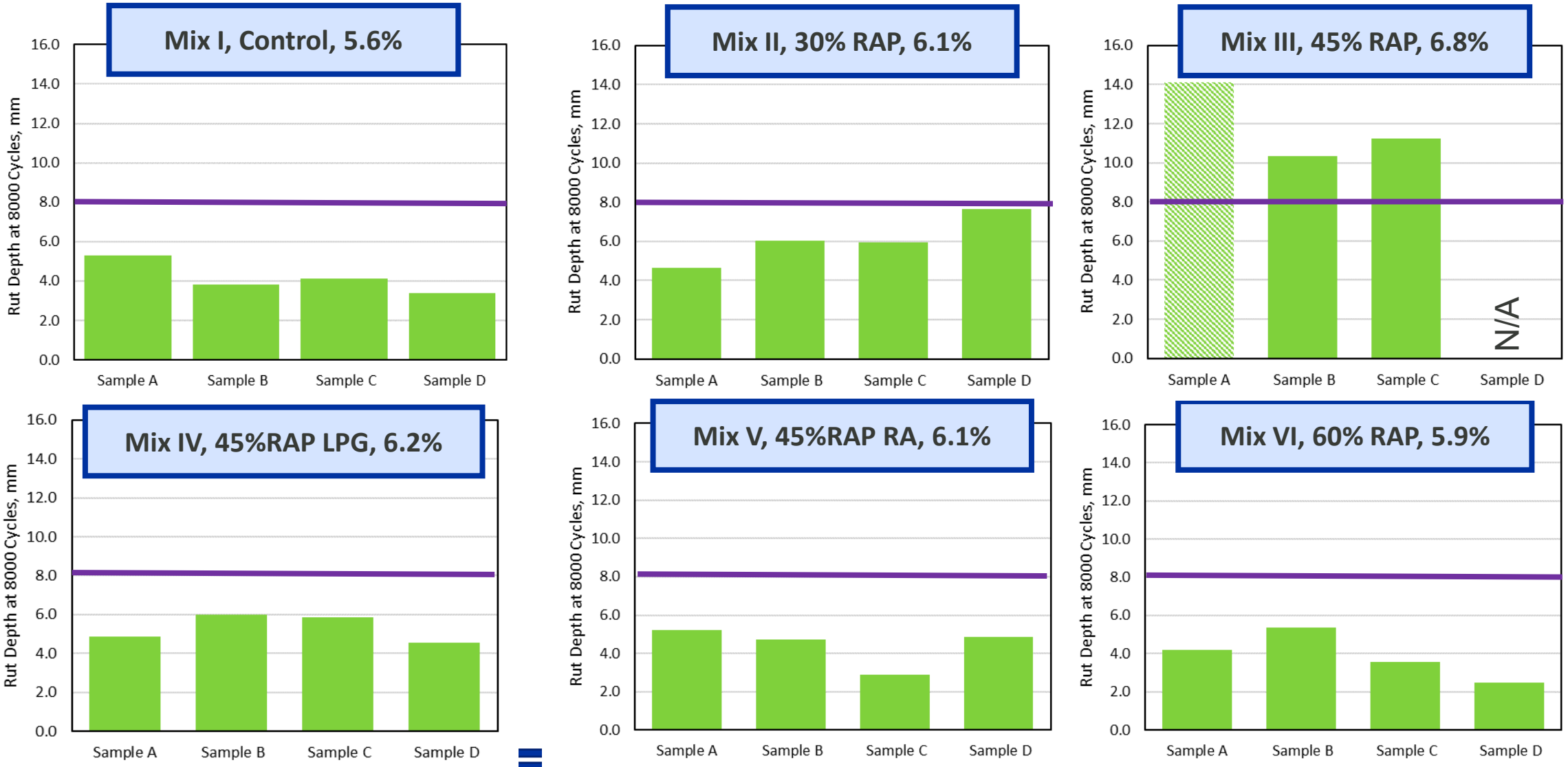




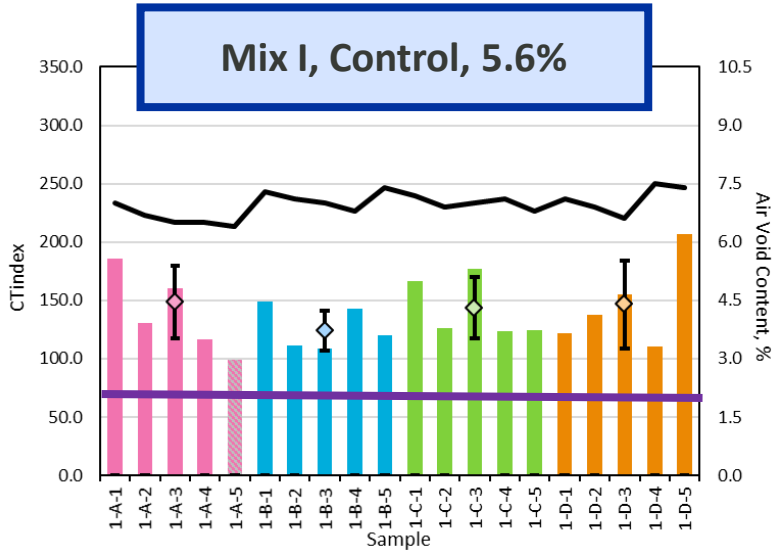


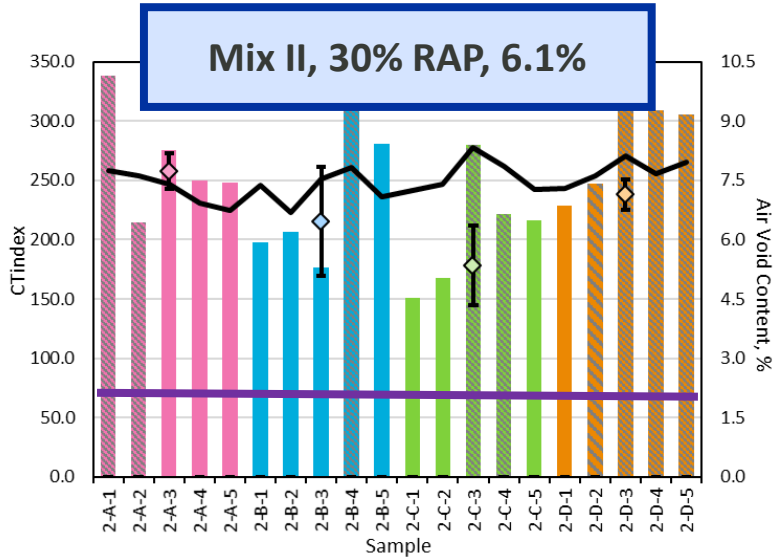


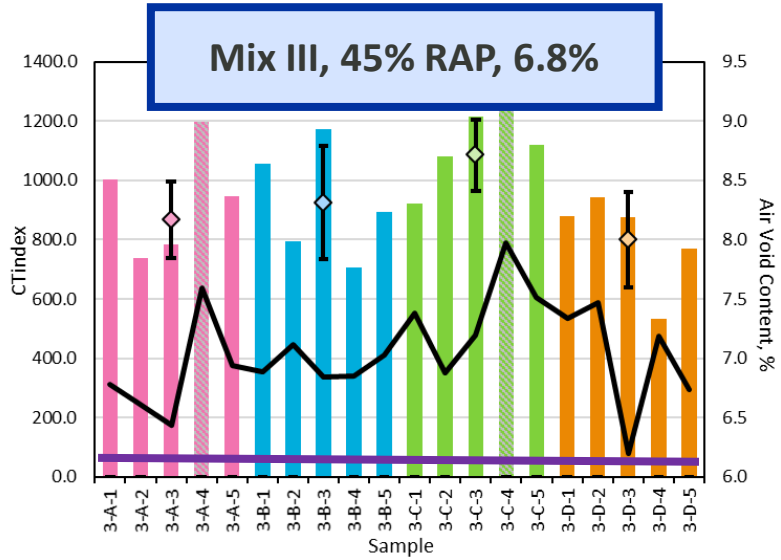
Rutting – APA Test at 64°C, 8000 cycles

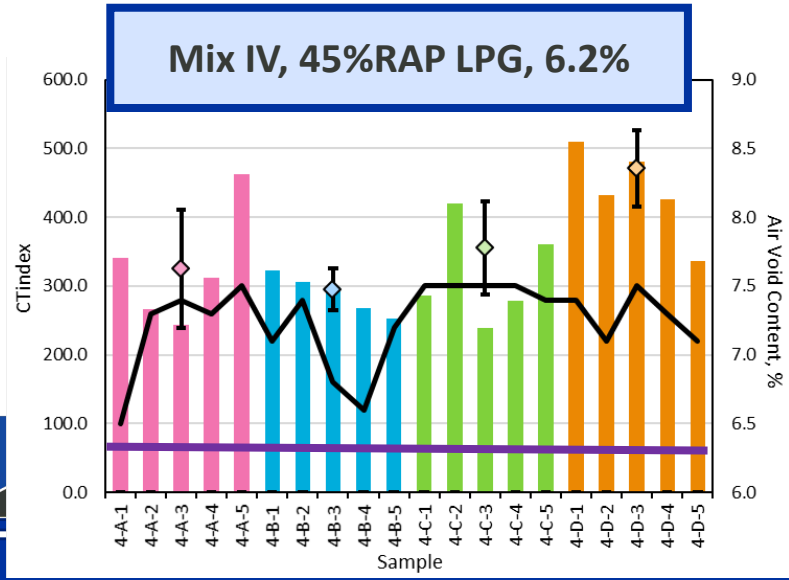


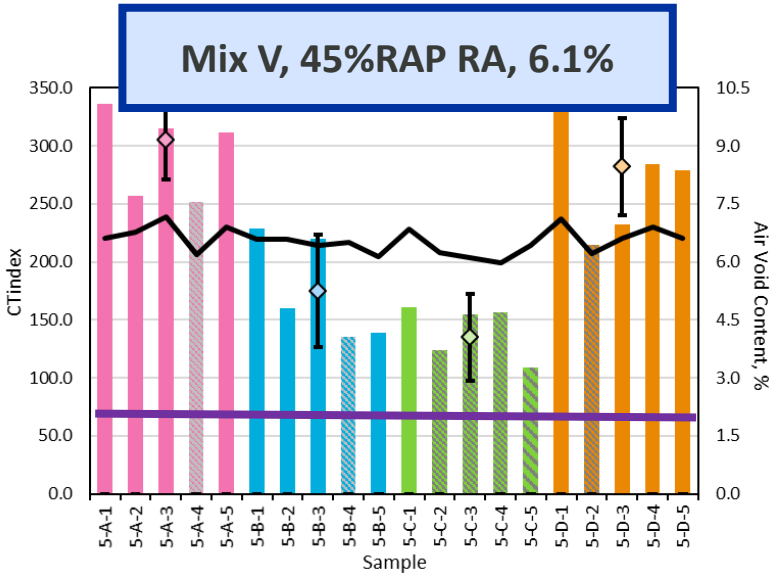
Cracking – IDT-CT (CT index) at 25°C

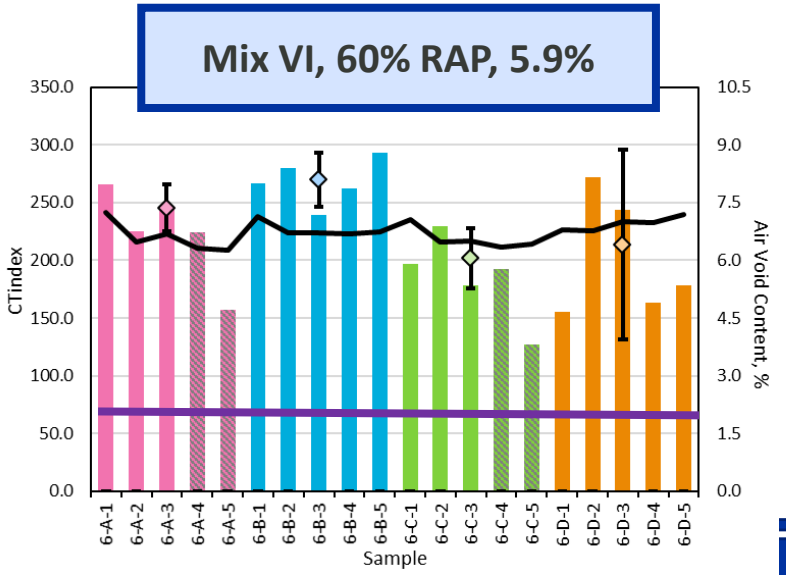




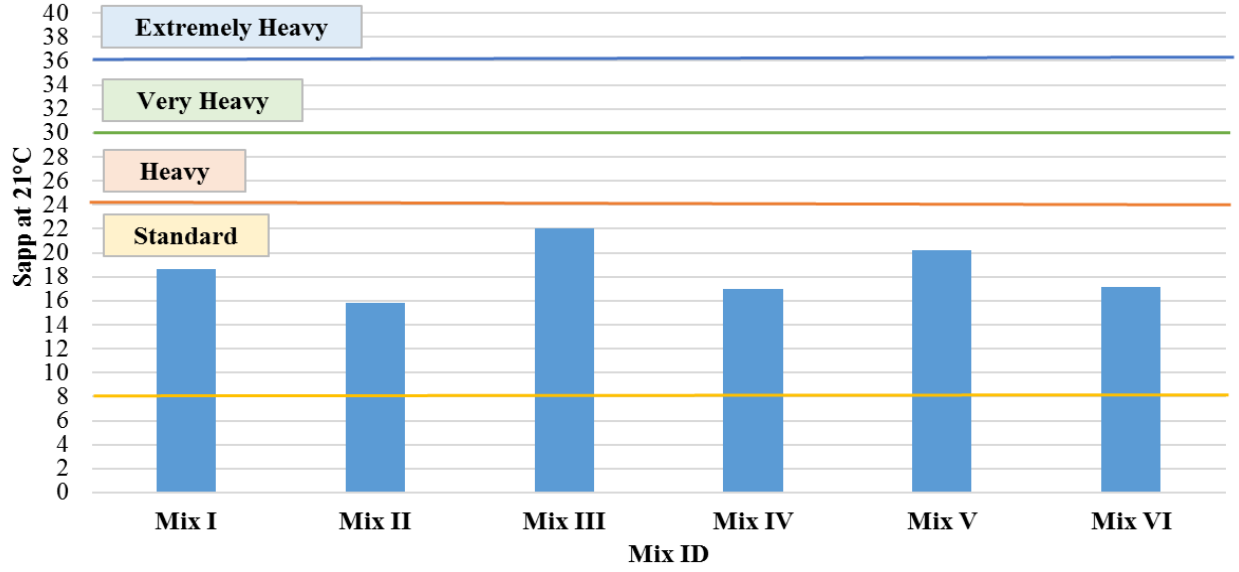


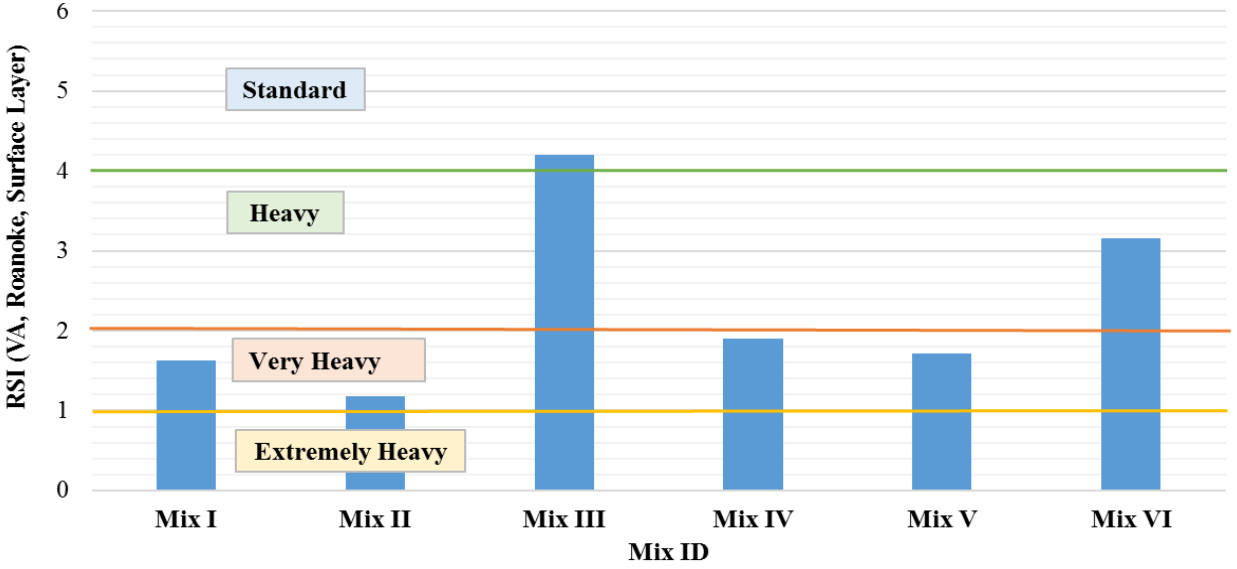




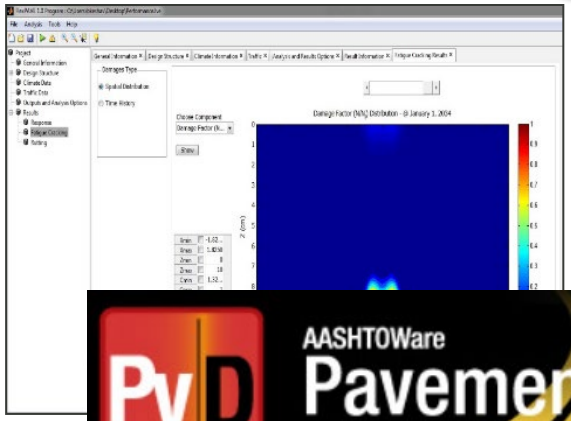


Fatigue and Rutting Advanced Testing





FlexPAVE



AASHTOWare Pavement ME Design

Pavement ME

Compare against CT_{index} and APA and refine limits

Recycling Agents' Acceptance

Experimental Program and Binder Rejuvenation

Asphalt Binders

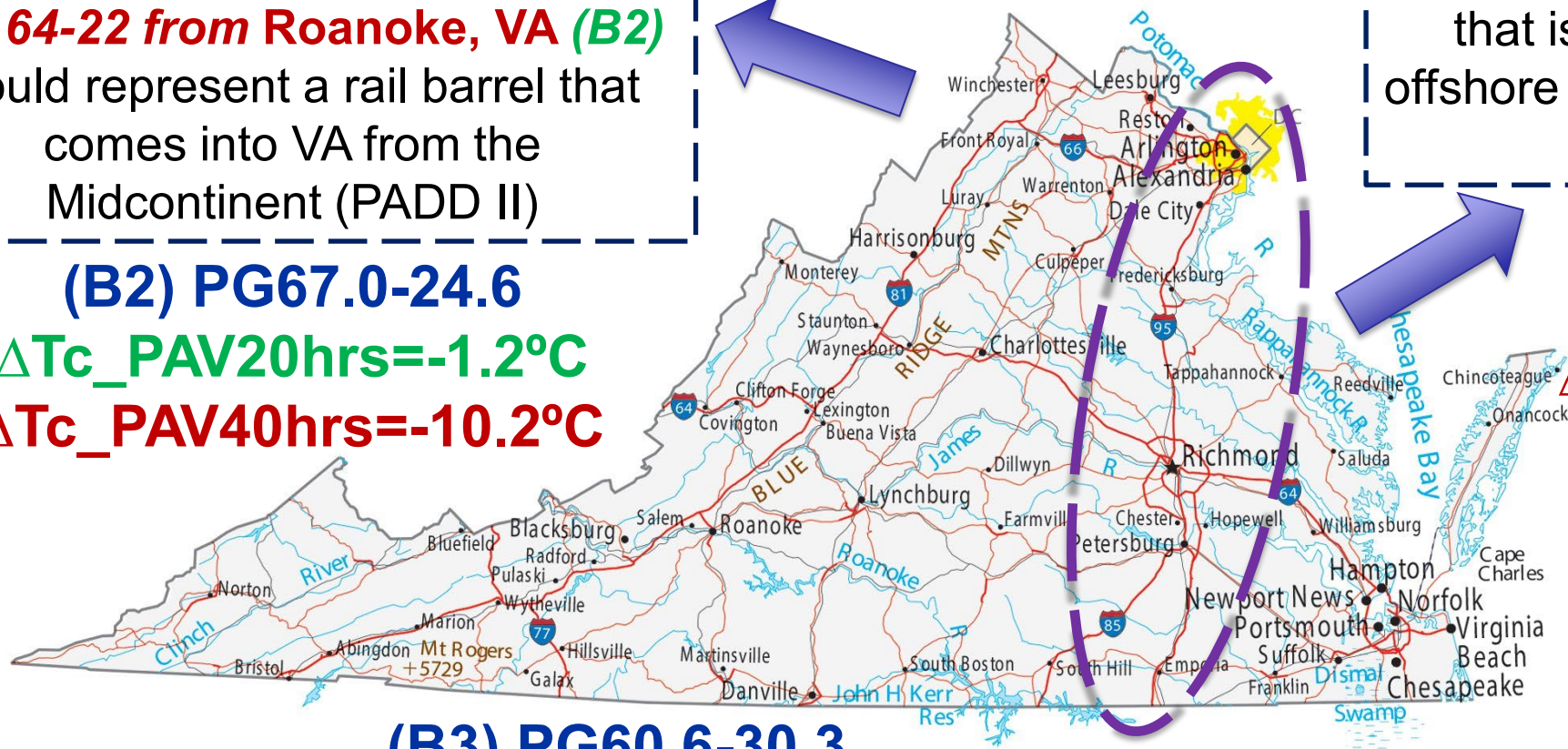
- **Factors:** PG and Rheology, crude oil source chemistry …

PG 64-22 from* Roanoke, VA *(B2) would represent a rail barrel that comes into VA from the Midcontinent (PADD II)

(B2) PG67.0-24.6
ΔTc_PAV20hrs=-1.2ºC
ΔTc_PAV40hrs=-10.2ºC

PG 64-22 from* Hopewell, VA *(B1) from a water born vessel barrel that is usually delivered from offshore via boat (Canada, Europe, Caribbean, Med)

(B1) PG68.1-22.4
ΔTc_PAV20hrs=-3.0ºC
ΔTc_PAV40hrs=-10.5ºC



(B3) PG60.6-30.3
ΔTc_PAV20hrs=+1.0ºC
ΔTc_PAV40hrs=-5.9ºC

PG 58-28 from* Greensboro, NC *(B3) this source is used to service the limited demand of VA customers

RAP Material

- **Factors:** PG and AC, Age & Geographical Location, Aggregate Mineralogy, Gradation & Clustering of RAP, & field projects

Mix with 45% RAP Boxley at Salem	Mix with 35% RAP Colony at Burkeville	Mix with 40% RAP Alan Myers at Chesapeake
		
- PG 95.5-7.9 & AC = 4.9% - ΔTc_PAV20hrs = -8.6ºC - Used in HVS AC Mixes	- PG 107.1-4.7 & AC = 5.2% - ΔTc_PAV20hrs = -4.7ºC - Used in 3 field pilots	- PG 94.5-10.3 & AC = 4.4% - ΔTc_PAV20hrs = -9.4ºC - Used for private projects

Evaluated Recycling Agents

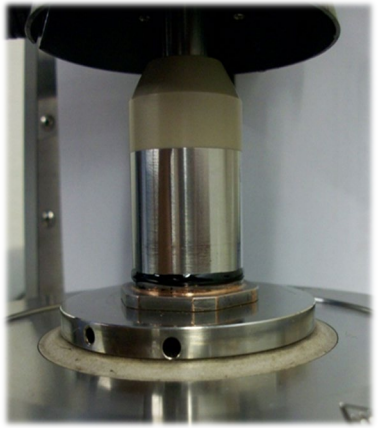
- Paraffinic Oil
  - RA1
- Aromatic Extracts
  - RA2
- Triglycerides and Fatty Acids
  - RA4, RA5, and RA6
- Others: Tall Oils and Fatty Acids
  - RA3

Testing Matrix and Dosage

Binder Source	RAP Source	Name	Recycling Agents						No RA
			RA1	RA2	RA3	RA4	RA5	RA6	
Hopewell, VA	Boxley (PG 94)	**B1R1**	15.52%	4.29%	5.90%	6.25%		5.71%	
	Colony (PG 106)	**B1R2**		5.29%	5.70%	5.79%	8.49%	5.20%	
	Alan Myers (PG 94)	**B1R3**		3.80%	4.10%	4.50%	8.68%	3.90%	
Roanoke, VA	Boxley (PG 94)	**B2R1**			4.40%		9.31%	4.62%	
	Colony (PG 106)	**B2R2**				4.52%	8.49%		
	Alan Myers (PG 94)	**B2R3**	14.47%	3.52%	2.60%				
Greensboro, NC	Boxley (PG 94)	**B3R1**							0.00%
	Colony (PG 106)	**B3R2**				1.21%			
	Alan Myers (PG 94)	**B3R3**							0.00%

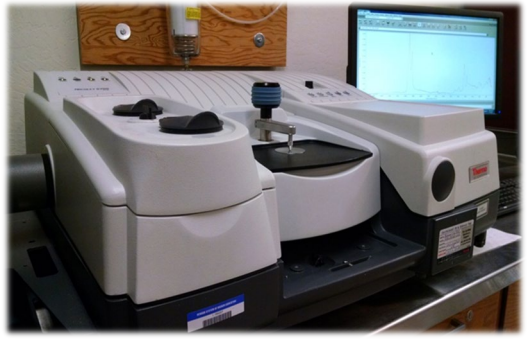
Dosage (lowest!) provided by manufacturer by total weight of virgin binder to meet a PG64-22

Experimental Program

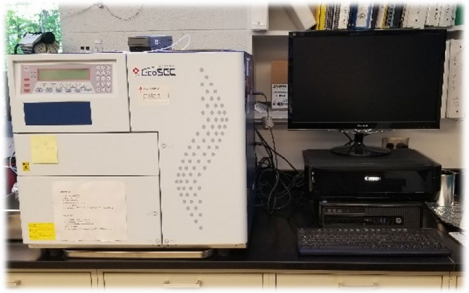


Evaluation of RAP-RA-Binder Blends at Various Aging Levels

Rheology ⟷ **Chemistry**



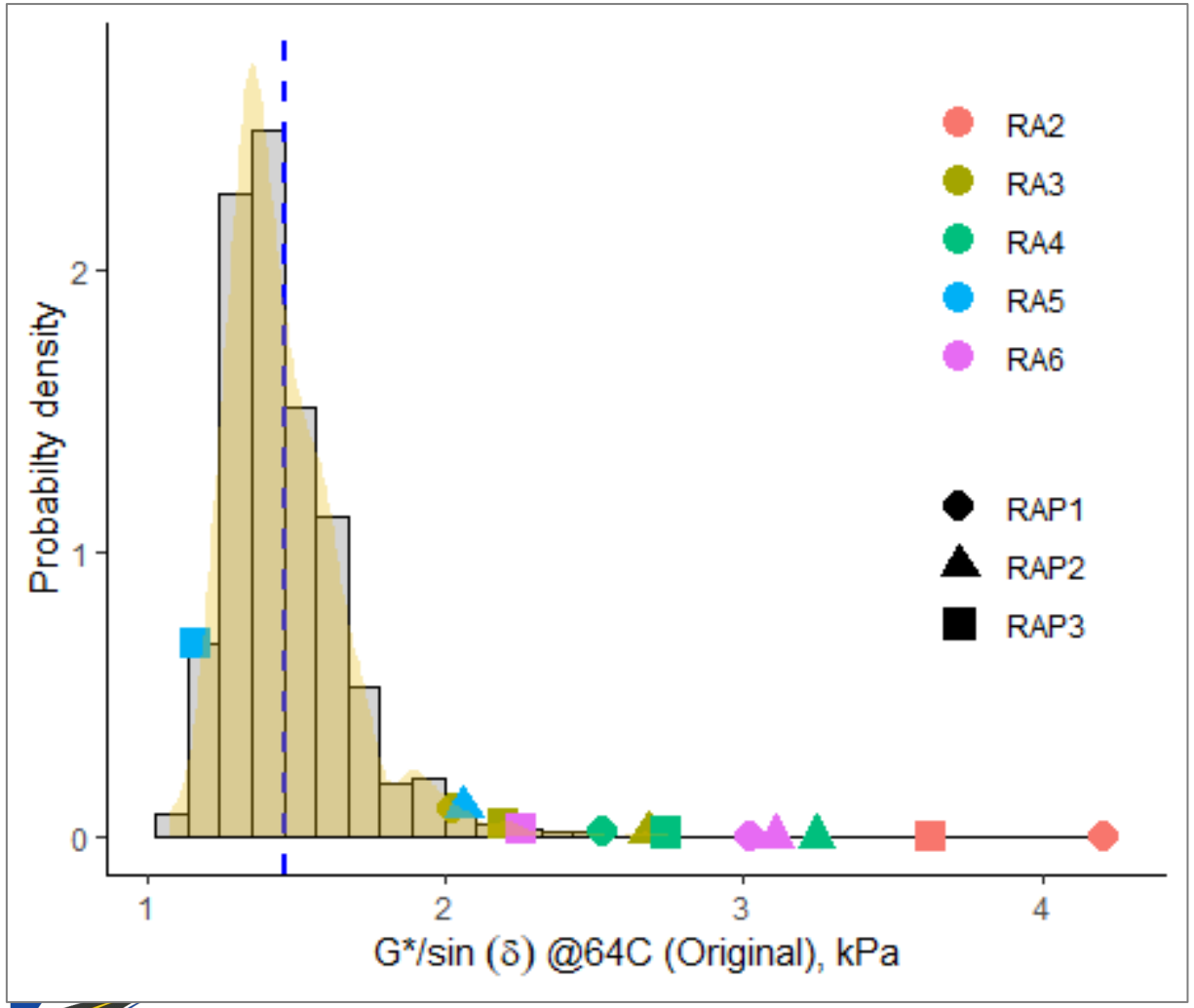
- **DSR:** PG High & Int Temp
- **DSR**: Frequency Sweep Test (G-R parameter, R-value, LSV, and others)
- **BBR**: T_S T_m & ΔT_c
- Evaluation of **PAV** and **Double PAV** conditions

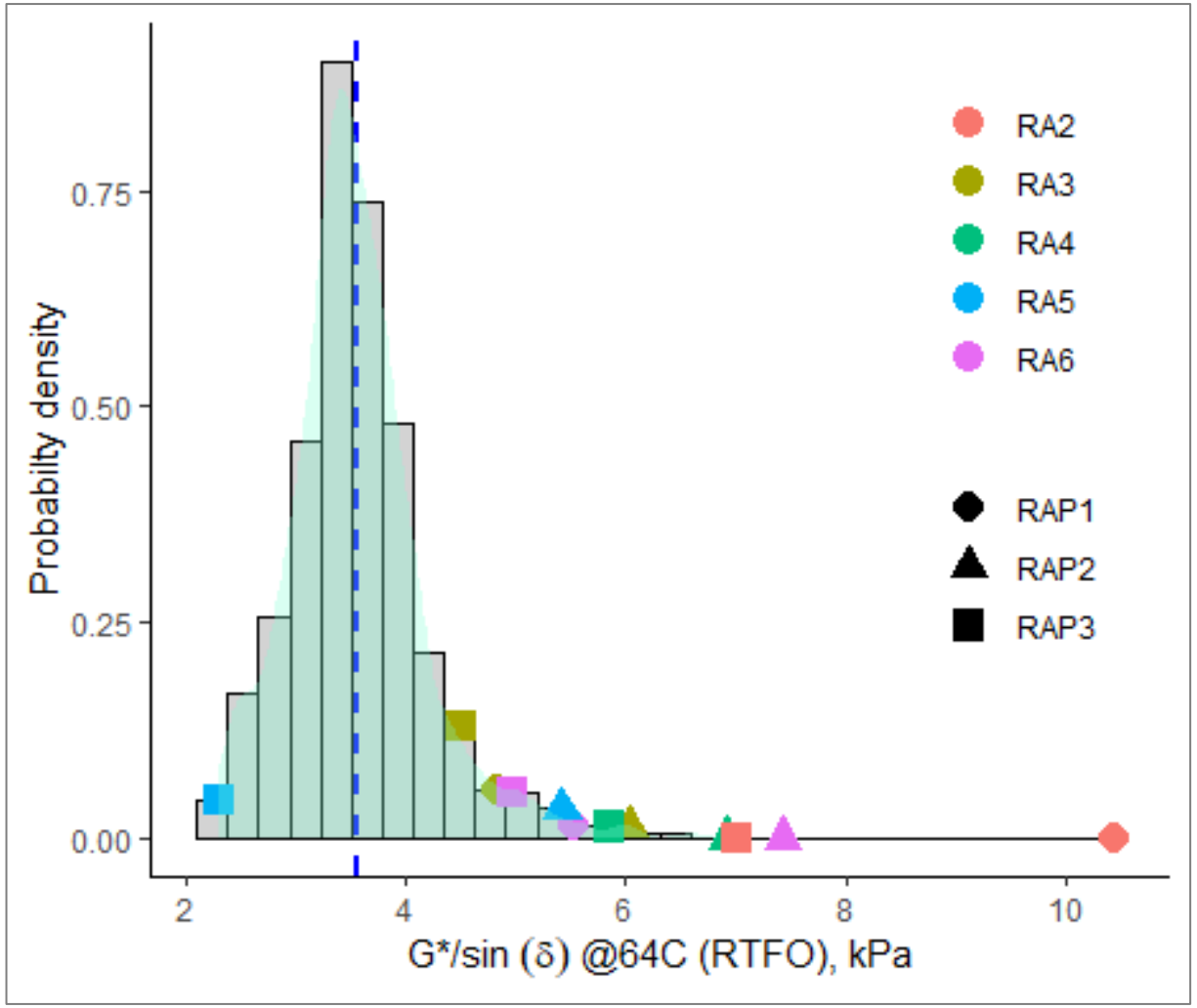


- **GPC:** Molecular Distribution
- **FTIR**: Functional Groups through absorbance quantification

Selection of fewer blends to be evaluated as *Mortars and Mixes*

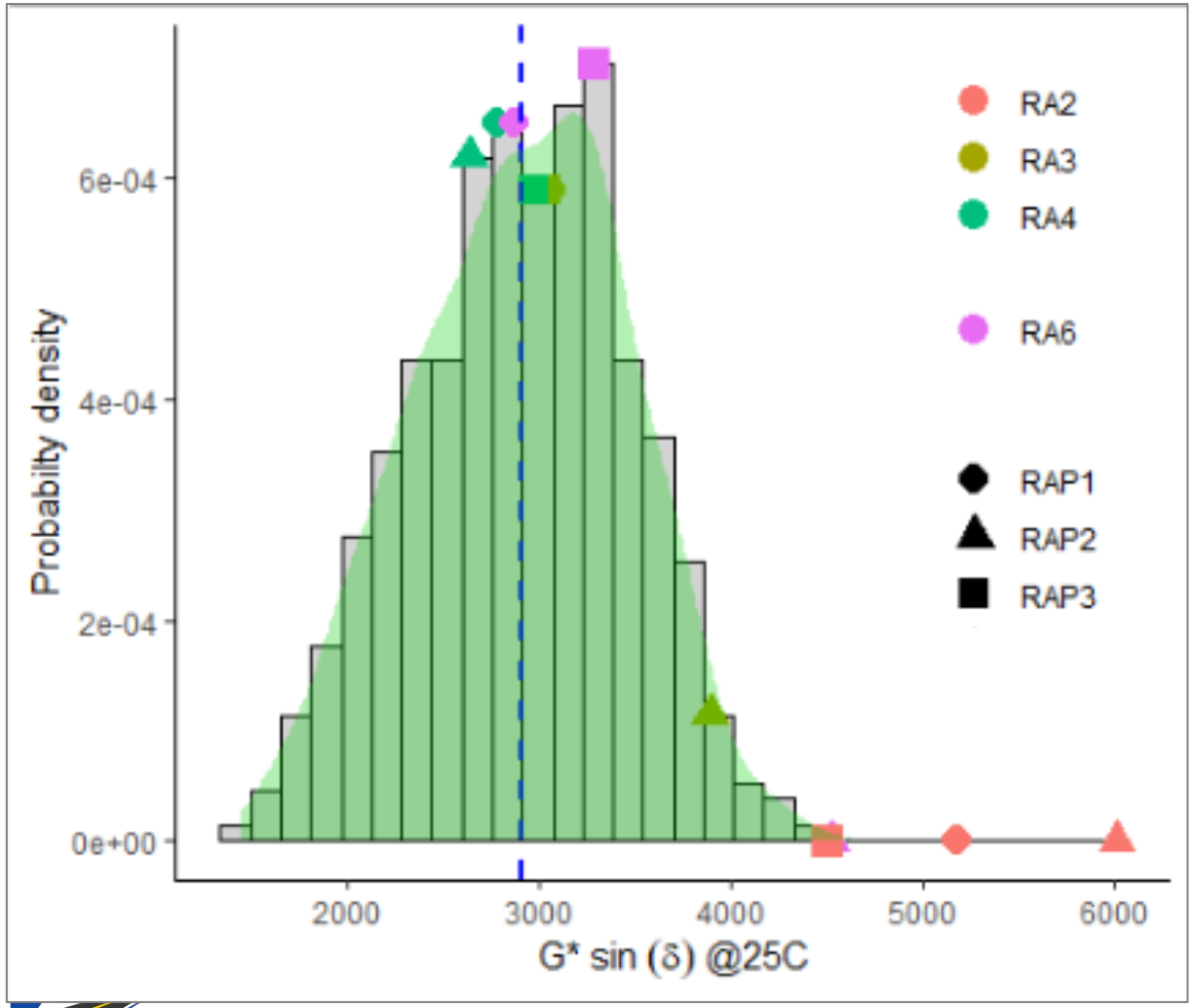
Assessment of Binder Rejuvenation – B1

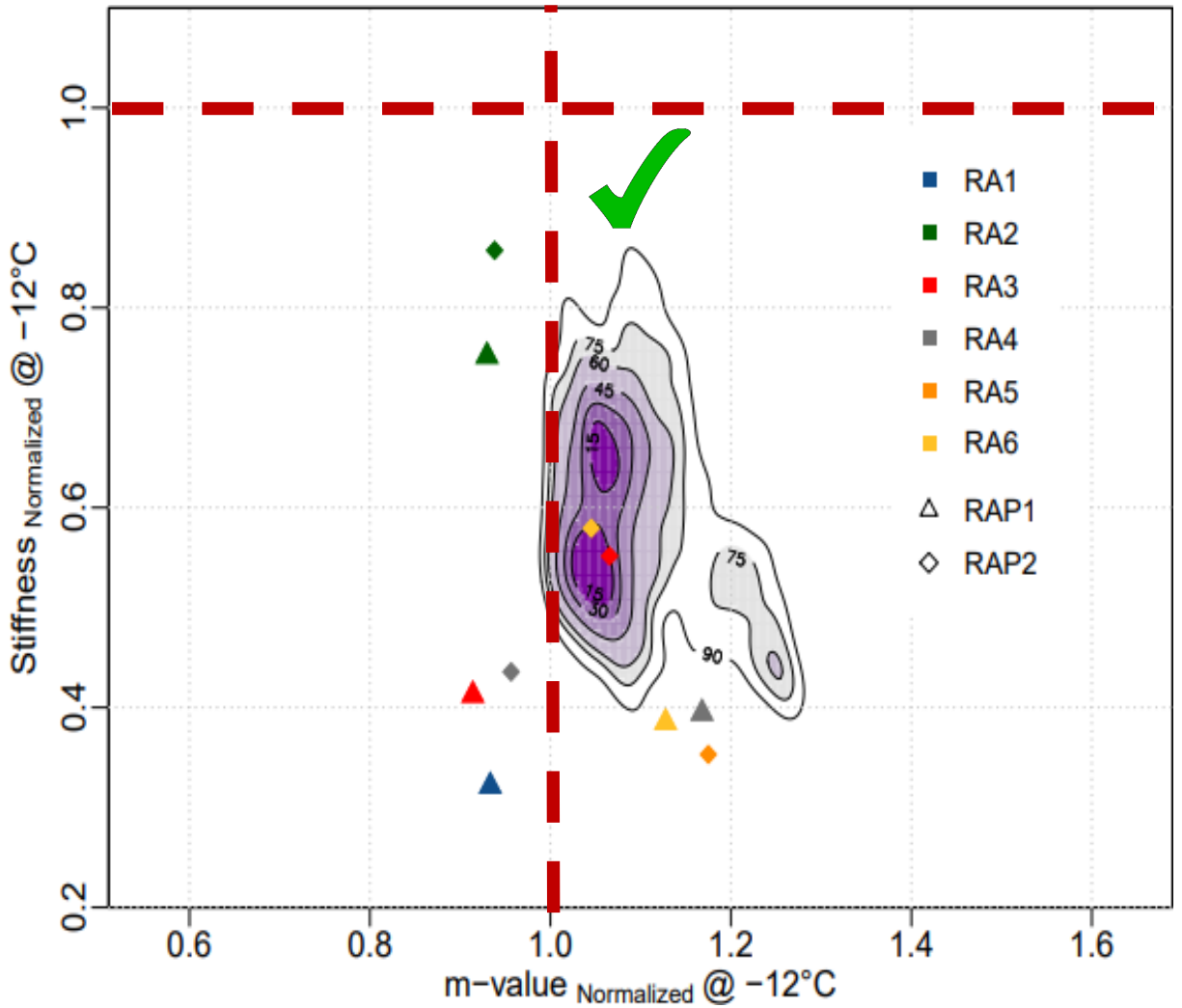




Mean value of the distribution

Assessment of Binder Rejuvenation – B1





Mean value of the distribution

Closing Remarks

Summary of Findings, Gaps & Ongoing work, and Lessons Learned

Summary of Findings

- Mixtures with high RAP contents produced using softer binders and / or recycling agents *may be designed and produced consistently* to meet current BMD performance thresholds and volumetric mix design requirements.

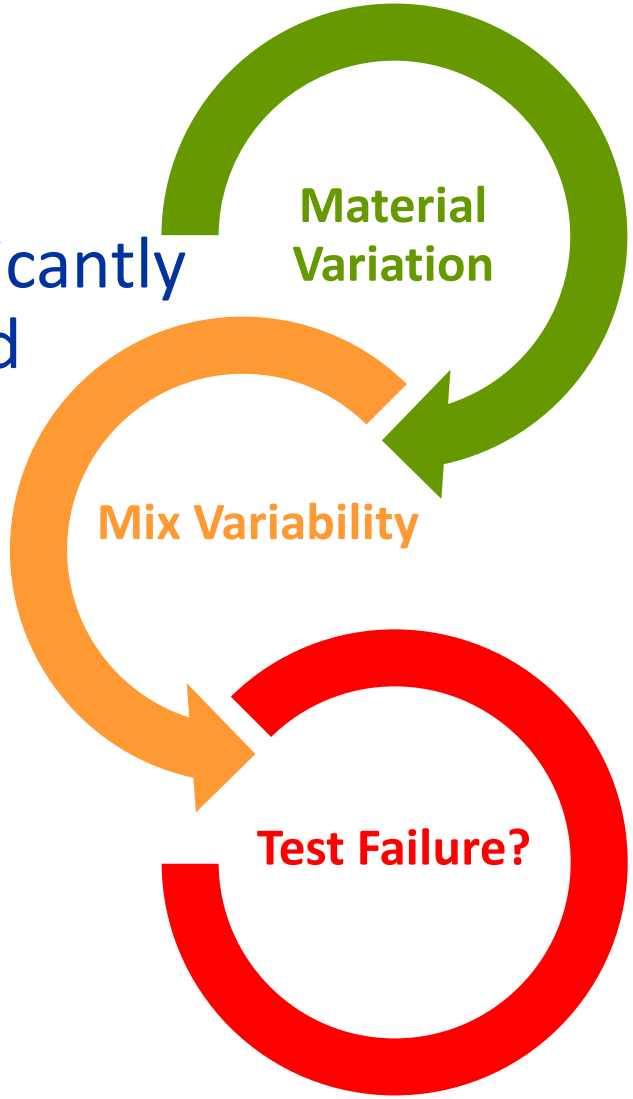
- Viewed through the BMD performance test, an *equal or better performance* can expected for these mixtures compared to counterpart typical mixtures.

Gaps and on-Going Work

- Evaluate how volumetric and gradation properties influence the results of each performance test across a wide variety of mixtures is needed.
- Determine different performance criteria for Cantabro and IDT-CT tests to be applied to non-reheat specimen testing.
- Investigate the long-term laboratory and field performance of such mixtures *is ongoing* to further evaluate the conclusions made.

Lessons Learned – Design to Production

- Control of RAP stockpile is very important
  - RAP changes from design to production can significantly impact mix properties (e.g., AC, gradation, SG) and performance
- Consistency is a key!
  - Source material consistency
  - RAP processing and management
  - Proper sampling techniques and good specimen fabrication practices



Acknowledgments

Stacey Diefenderfer,
Ph.D., P.E, ***VTRC***

Ilker Boz,
Ph.D. ***VTRC***

Danny Martinez
M.S., ***VTRC***

Gerardo Flintsch, Ph.D.,
P.E, ***VTech***

Shane Underwood,
Ph.D., ***NCSU***

Cassie Castorena, Ph.D.,
NCSU

Acknowledgement

- VTRC Leadership Team, Staff, and Technicians
- VTech Leadership Team, Staff, and Technicians
- NCSU Graduate Students, Staff, and Technicians
- VDOT Materials Division
- VDOT Districts
- VA Contractors
- Asphalt Binder Suppliers
- Recycling Agents Suppliers

VTRC
Virginia Transportation
Research Council

Thank You!

VDOT
Virginia Department of Transportation

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