VTRC Virginia Transportation Research Council

AMAP Association of Modified Asphalt Producers

We Bring Innovation to Transportation

Responsible Incorporation of Additives in Asphalt Binders and Mixtures: *Virginia's Efforts Towards Sustainable Paving*

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Virginia Transportation Research Council (VTRC)

Association of Modified Asphalt Producers (AMAP) – 2023 Educational Workshop

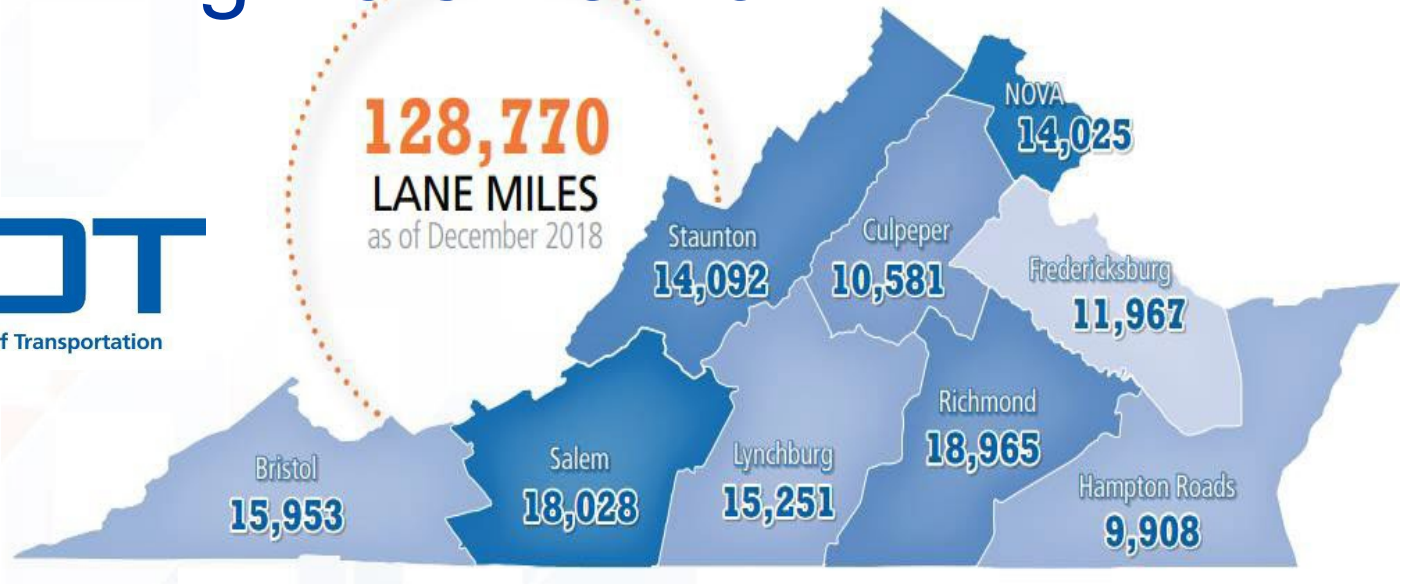
Wednesday March 15, 2023 - Williamsburg, VA

Outline

- ❑ A Glimpse of Virginia's Network
- ❑ Additives and Specifications
- ❑ Recycling Agents
- ❑ PMA and HP Binders and Mixtures
- ❑ Hybrid Rubber
- ❑ Recycled Plastics
- ❑ Closing Remarks

Virginia's Network

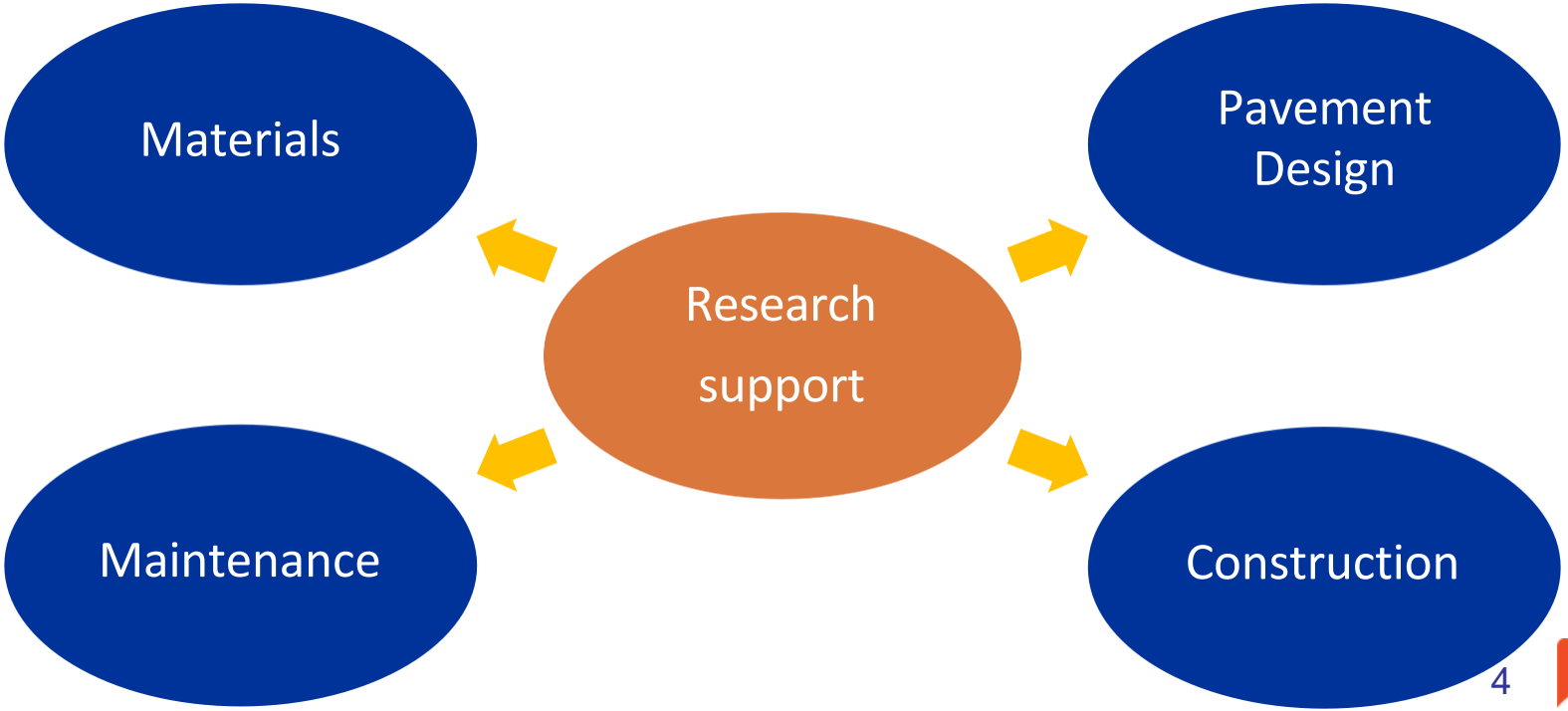
VDOT
Virginia Department of Transportation



- Third largest public roadway network in US
- Maintain all state roadway systems: interstate, primary, secondary, and frontage
- 98% of hard-surfaced roadways have asphalt surfaces

Mission and Major Goal

- In-Pursuit of Durability from Multiple Perspectives



Research and Innovation

Materials

- Adoption of Balanced Mix Design
  - Performance drives design, not only volumetrics
- Use of high performing mixes
  - Highly modified polymer mixes
  - Stone Matrix Asphalt (SMA)

- Evaluating additives/alternatives for improved performance
  - Recycling agents
  - Paving fabric interlayers
  - Rubber / Hybrid Rubber
  - Recycled Plastic Waste

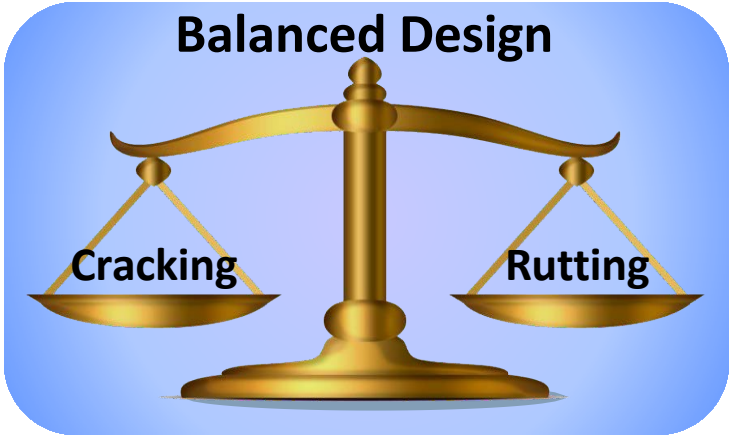
Balanced Mix Design

Virginia's 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 T 401)

CML ≤ 7.5 %

Moisture Damage

Tensile Strength Ratio Test (AASHTO T 283)

TSR ≥ 80 %

Resources and References

Virginia's Balanced Mix Design

- Initial Roadmap Development and Specification Verifications: https://tinyurl.com/yc3v5n2d
- 2019 Field Trials: https://tinyurl.com/ys3zekh9
- 2020 Field Trials: https://tinyurl.com/46xnj2r9
- Round Robin for IDEAL-CT / IDT-CT:
  - Phase I: https://tinyurl.com/587uxmx4
  - Phase II: https://tinyurl.com/27636cet
- High Temperature IDT (IDT-HT) and IDEAL-RT: https://tinyurl.com/vzh3am5f

Use of Recycling Agents

Introduction

- Introduction of special provisions and specifications to allow the use of relatively higher RAP contents in mixtures
  - Offset the continuously rising cost of oil
- Challenges arising from the use of high RAP mixtures
  - prone to premature cracking, compactibility, and workability
- Potential Solutions
  - Using a softer asphalt binder (lower Performance Grade)
  - **Using recycling agents**

Use of Recycling Agents
Classification Systems

- ASTM D4552, based on physical properties
  - Screen RAs for safety, handling, and durability purposes
- NCAT, based on chemical properties
  - Three categories: petroleum-based, organic or non-petroleum-based, and emulsion-based
- Nebraska, based on the nature of the source of RA
  - Highlights the effectiveness of RAs based on changes in low / high temperatures and cracking resistance
- Texas A&M, based on rejuvenation mechanism
  - Three categories: softeners, replenishers, and emulsifiers

Use of Recycling Agents

2019 and 2020 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

Boxley Salem – July 2019

- SM-9.5 26% RAP PG64S-22
- SM-9.5 26% RAP PG64S-22, RA1
- SM-9.5 26% RAP PG64S-22
- SM-9.5 26% RAP PG64S-22, RA2

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

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 + softener

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

Use of Recycling Agents

2020 BMD Experiment at VDOT APT

- Six (6) mixtures
  - SM-9.5A + 30% RAP (PG 64S-22) - typical production mix
  - SM-9.5A + 30% RAP (PG 64S-22) - BMD
  - SM-9.5A + 45% RAP (PG 64S-22) - BMD
  - SM-9.5A + 45% RAP (PG 58-28) - BMD
  - SM-9.5A + 45% RAP (PG 64S-22 + rejuvenator) - BMD
  - SM-9.5A + 60% RAP (PG 58-28 + rejuvenator) - BMD
- Two 1.5-inch lifts over compacted aggregate base
- Lab: BMD and advanced testing
- Site: Rutting and cracking testing experiments

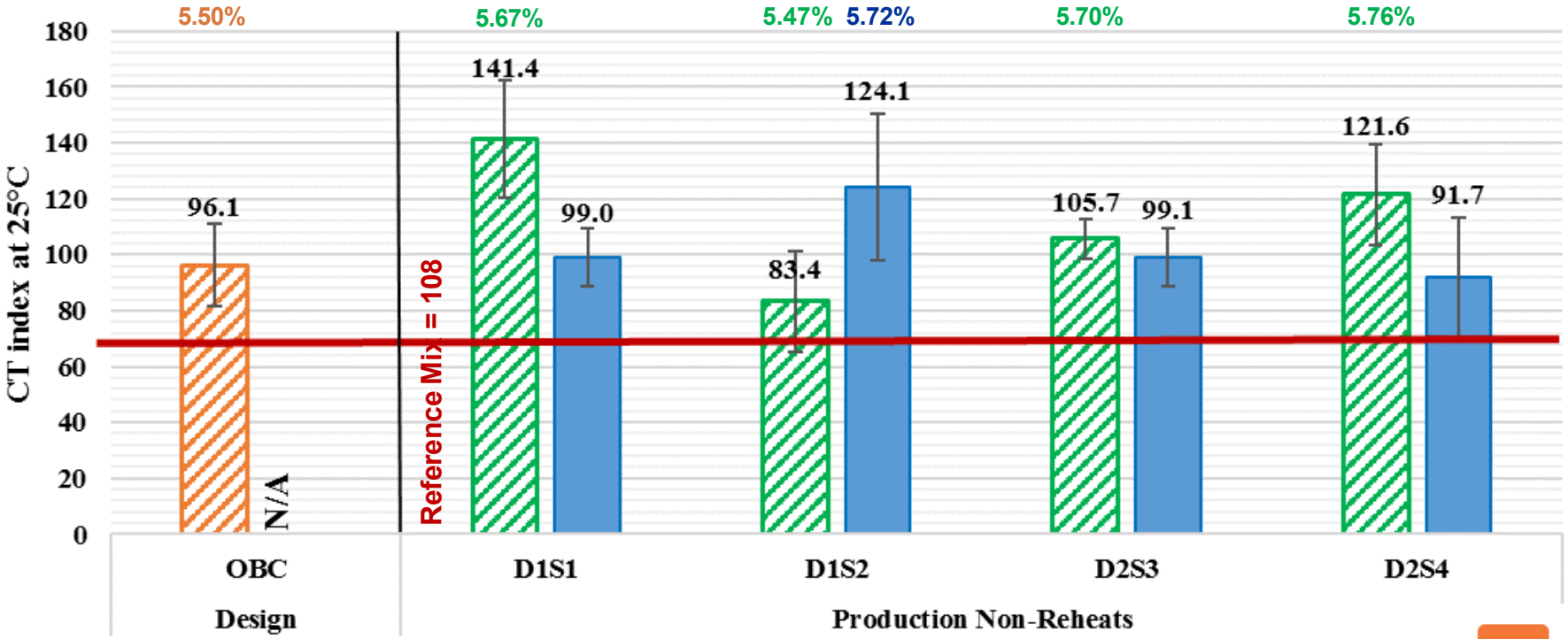
Use of Recycling Agents

HRAP with RA Trial – Summer 2022

Producer	Location	Mix Type: 40% RAP + PG64S-22 + RA
Superior Paving	Riverside Parkway, Ashburn, Virginia	Day 1 - Sample 1 (~500 tons)
		Day 1 - Sample 2 (~500 tons)
		Day 2 - Sample 3 (~500 tons)
		Day 2 - Sample 4 (~500 tons)

Use of Recycling Agents

Performance Data - Production



Use of Recycling Agents

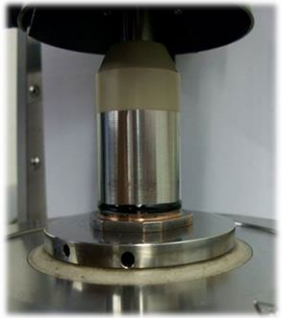
Findings and Conclusions

- Mixtures with high RAP contents and various recycling agents, as well as dense-graded asphalt mixtures containing various recycling agents *may be designed and produced consistently* to meet current BMD performance thresholds and volumetric mix design requirements.
- *Equal or better performance* is expected for these mixtures compared to counterpart typical mixtures.
- Work on investigating the long-term laboratory and field performance of such mixtures *is ongoing* to further evaluate the conclusions made.

Use of Recycling Agents
VDOT Ongoing Efforts

- Identify an engineered framework to evaluate recycling agents when incorporated into binder blends and corresponding mixtures with high content of recycled material:
  - Benchmarking
  - Working mechanism
  - Guidelines to approve or reject an RA product (APL)
  - Performance-based parameters & threshold limits / criteria for acceptance (Development, identification, or refinement)

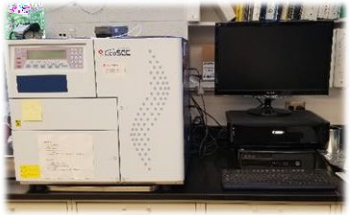
Use of Recycling Agents
Evaluation Methodology



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



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

Selection of fewer blends to be evaluated as *Mixes*

Highly Polymer Modified Mixtures

Introduction

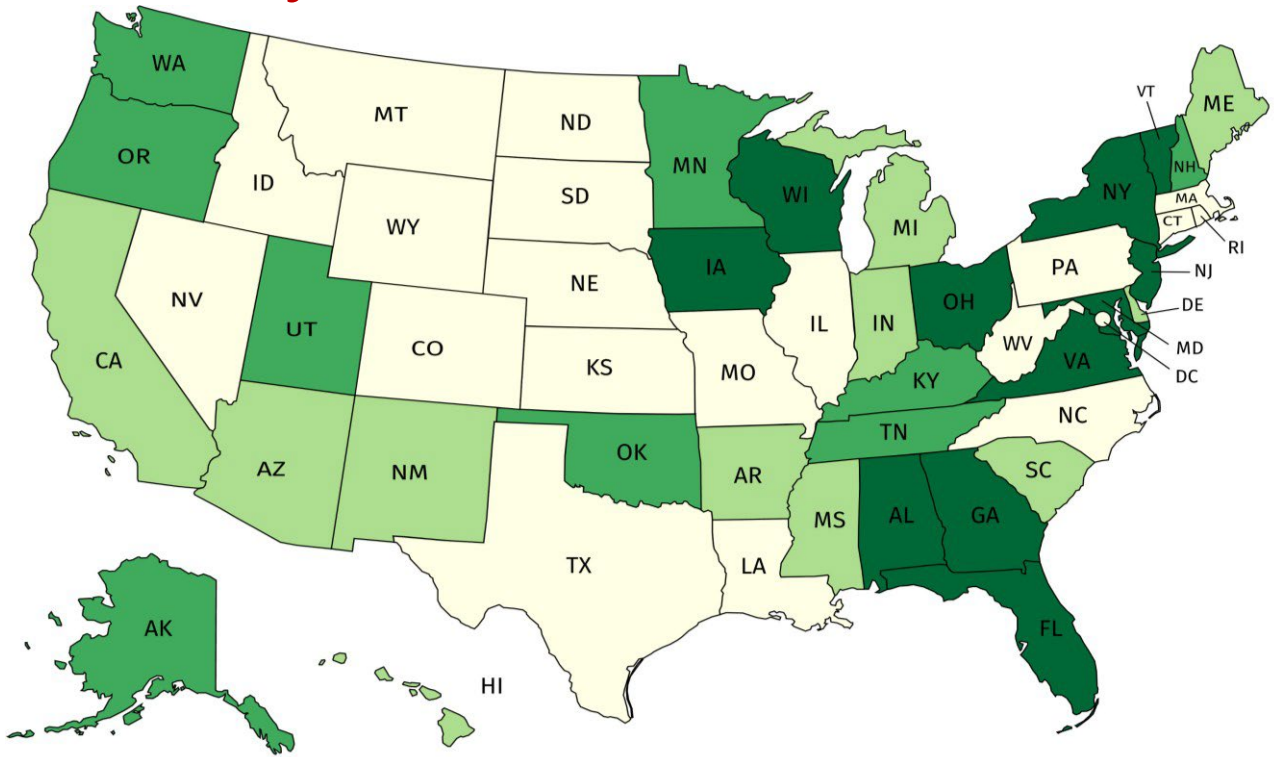
- HiMA / **HP** AC mixtures may offer additional advantages in flexible pavements subjected to heavy & slow-moving traffic loads.
  - ❑ ***New Construction:*** Consideration to fatigue cracking, rutting & shoving in AC layer, total rutting, and top-down cracking.
  - ❑ ***AC Overlay:*** Consideration to Reflective Cracking.

Definitions:

- **Polymer Modified Asphalt Binders *(PMA): 2 – 3 % polymer content.***
- **Highly Modified Asphalt Binders *(HP): 7 – 8 % polymer content.***

Highly Polymer Modified Mixtures

Survey of US and Canadian Provincial Agencies



- Currently uses and/or previously experienced HP material + Survey Responses Received
- Currently uses and/or previously experienced HP material + Survey Responses Not Received
- No previous experience with HP material + Survey Responses Received
- No available literature on previous experience with HP material + Survey Responses Not Received

Habbouche et al. ***State of the Practice for High Polymer-Modified Asphalt Binders and Mixtures***. TRR, 2020, https://doi.org/10.1177/0361198121995190

Definitions and Specifications

- Definition and acceptance of HP binders **is not** related to SBS polymer content.
- ***Performance-oriented viewpoint***: definition related to specific binder rheology-related parameters and characteristics.

Agency	Standard / Test Method	Properties / Comments
Virginia	AASHTO T 332 AASHTO T 350	PG 76E-28 $J_{nr,\,3.2} \leq 0.1\ kPa^{-1}$ and $R_{3.2} \geq 90\%$ at 76 ºC

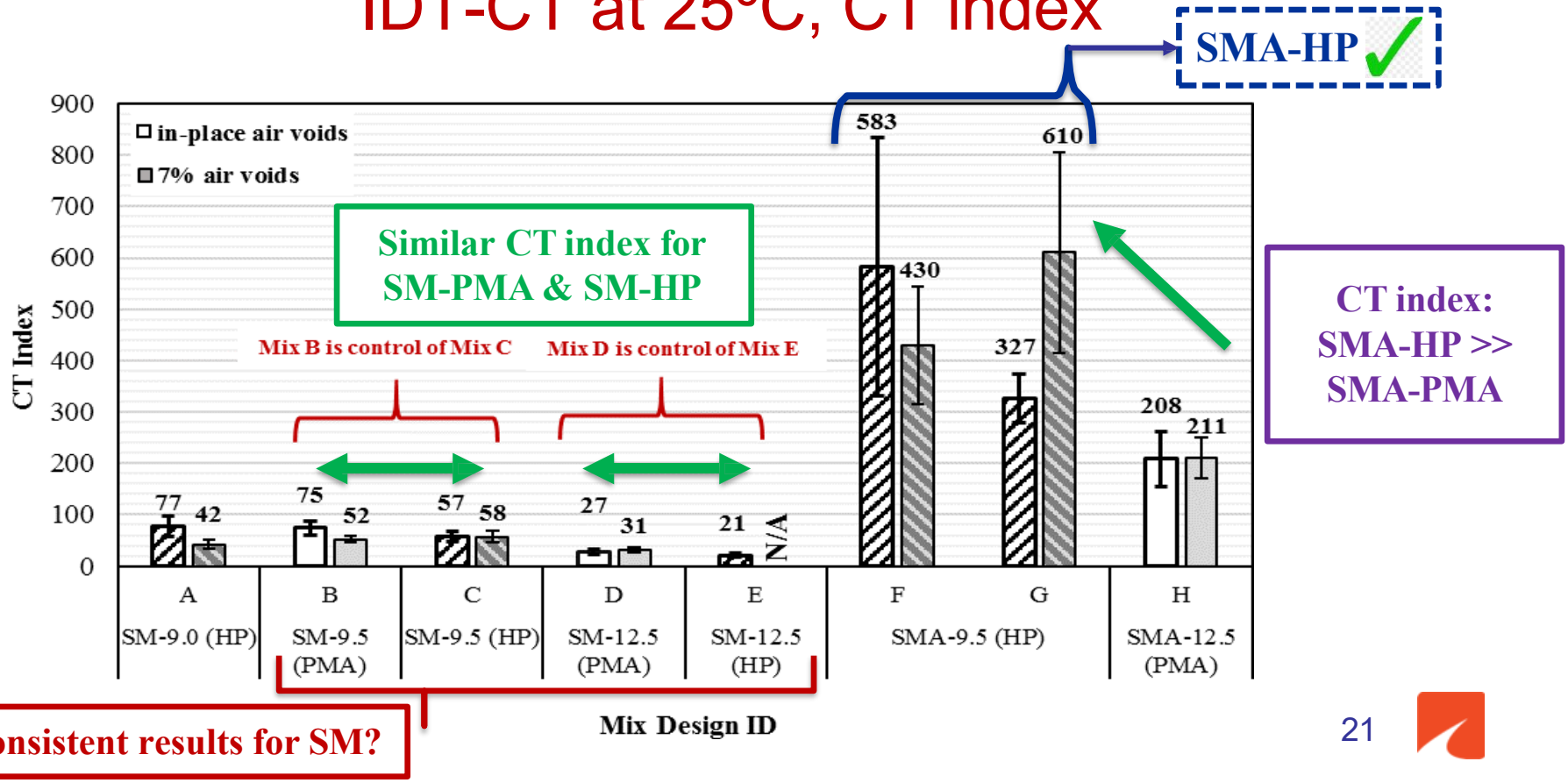
Background

HP AC Mixtures in Virginia: Types & Quantities

Year	Comments: Mix Type / District	Quantity of HP AC Mixes Produced (tons)	
		Specific per Mix Type & District	Total
2014	SM-9.5 / NOVA (trial section)	--	--
2015	SM-9.0 / NOVA	4,808	**44,084**
	SM-12.5 / NOVA	31,972	
	SMA-9.5 / NOVA	7,304	
2016	SM-12.5 / NOVA	5,643	**11,848**
	SMA-9.5 / Richmond	6,205	
2017	SM-12.5 / Hampton Roads	11,726	**69,744**
	SMA-12.5 / Hampton Roads	24,005	
	SM-9.5 / NOVA	3,904	
	SM-12.5 / NOVA	25,954	
	SM-12.5 / Richmond	4,155	
2018	SM-9.5 / NOVA	974	**12,635**
	SM-12.5 / NOVA	11,661	
2019	SM-9.0 / NOVA	17,724	**65,923**
	SM-9.5 / NOVA	6,598	
	SMA-9.5 / NOVA	41,601	

Cracking Performance Evaluation

IDT-CT at 25ºC, CT index



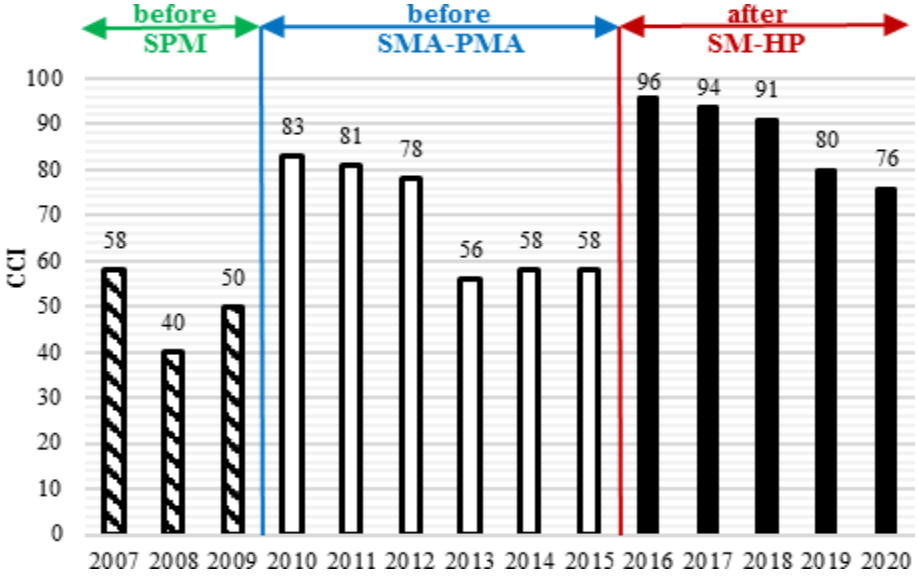
In-Service Field Performance

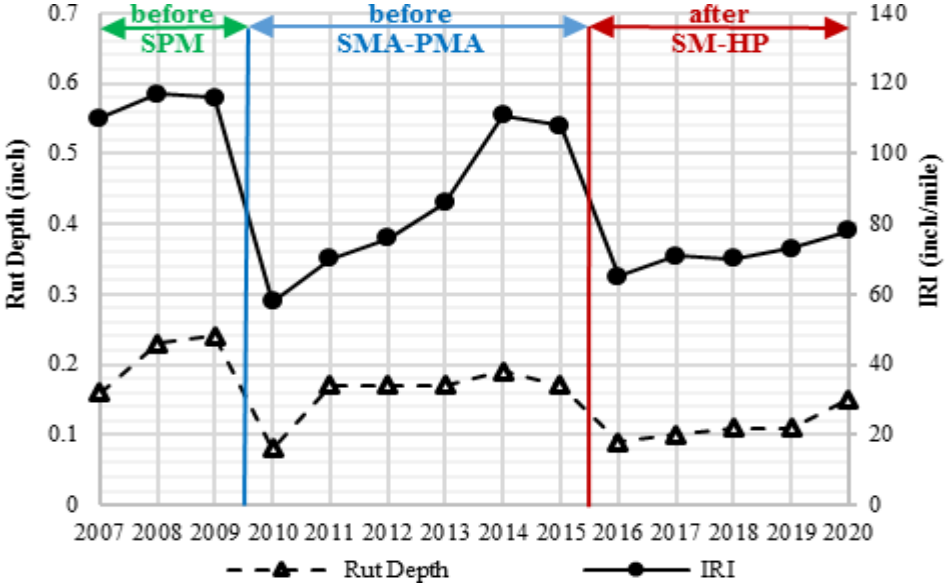
HP and PMA Selected Routes

No.	Route	County / County Mileposts	Pavement Type	Activity		Year of Prior Rehabilitation
				Details	Year	
1	I-95SB	Prince William, 0.02-3.89	BOJ	SM-12.5 E(HP) 2.0 in	2015	2009
2	I-95SB	Prince William, 10.98-13.12	BOJ	SMA-9.5 E(HP) 1.5 in SMA-9.0 E(HP) 1.0 in	2015	2007
3	I-95NB	Prince William, 0.07-3.92	BOJ	SM-12.5 E(HP) 2.0 in	2015	2008
4	I-495NB	Fairfax, 5.56-6.63	BOJ	SM-12.5 E(HP) 2.0 in	2016	2012
5	I-95SB	Hanover, 2.76-5.63	BOJ	SMA-19.0 E 2.0 in SMA-12.5 E(HP) 1.5 in	2016	2002
C6	I-95NB	Henrico, 7.33-9.55	BOJ	SMA-9.5 E 1.5 in SMA-19.0 E 2.0 in	2015	2004
7	I-64EB	York, 14.81-20.55	BOJ	THMACO 0.75 in SMA-12.5 E(HP) 2.0 in	2017	New Construction
8	I-64WB	York, 14.98-20.33	BOJ	THMACO 0.75 in SMA-12.5 E(HP) 2.0 in	2017	New Construction
9	I-95NB	Fairfax, 3.41-4.45	BIT	SM-12.5 E(HP) 2.0 in	2017	2010
10	I-495NB	Fairfax, 1.194-3.66	BOJ	SM-9.0 E(HP) 1.0 in SMA-9.5 E(HP) 1.5 in	2018	2014
11	I-95NB	Prince William, 11.121-12.64	BOJ	SM-12.5 E(HP) 2.0 in	2018	2011

In-Service Field Performance

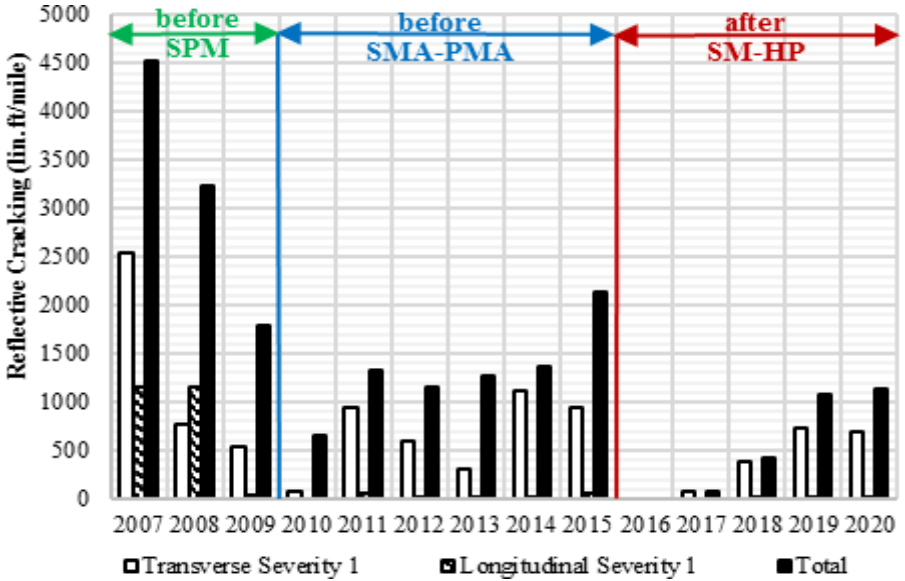
e.g., BOJ Section No.1

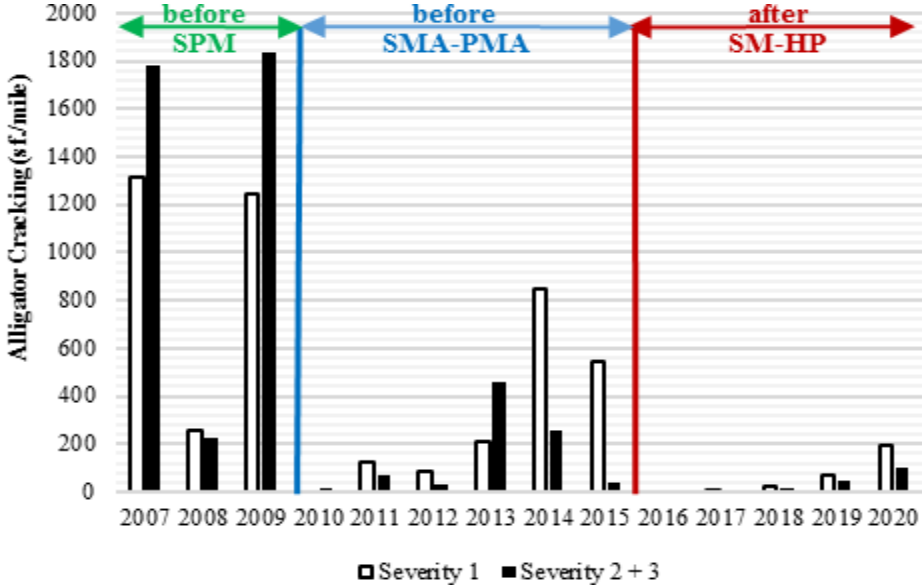




In-Service Field Performance

e.g., BOJ Section No.1, *Cont'd*

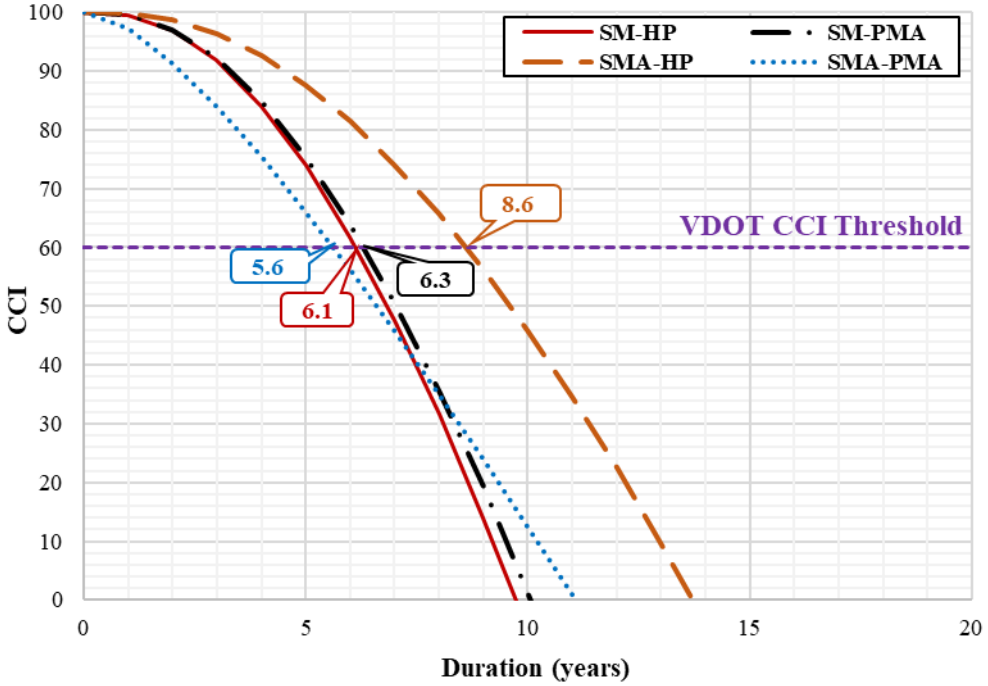




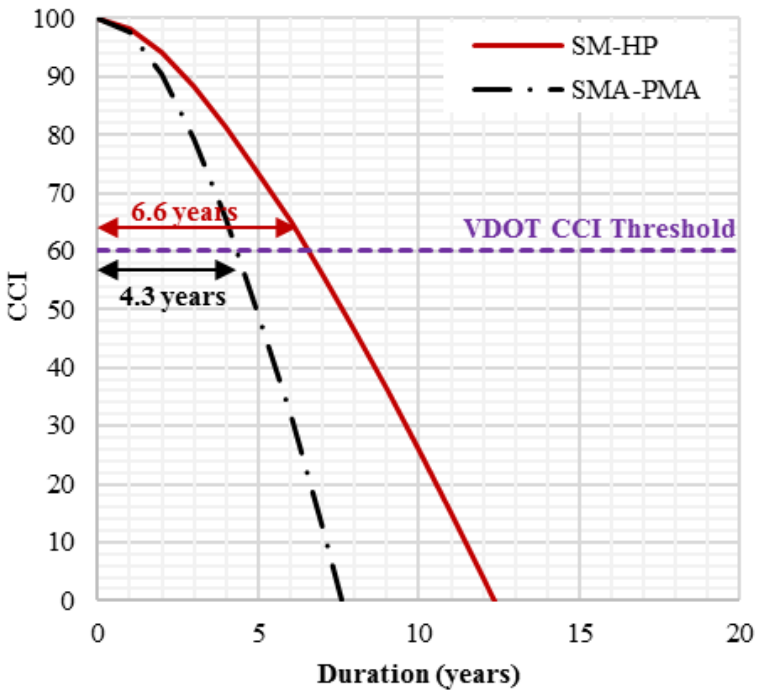
In-Service Performance Life

Analysis (ii) vs. (iii), Approach I

SM-PMA vs. SM-HP vs. SMA-PMA vs. SMA-HP



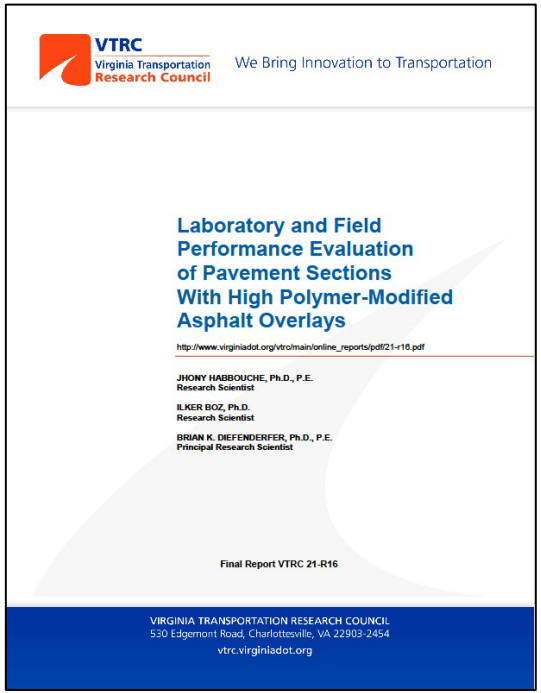
PMA vs. HP Mixtures



Resources and References

Virginia's HP Binders and Mixtures

- State of the Practice or Using HP Asphalt Binders and Mixtures in Northern America: https://tinyurl.com/2p8kyy9b
- Lab and Field Performance Evaluation of HP Asphalt Overlays: https://tinyurl.com/bdzmavby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Laboratory and Field Performance Evaluation of Pavement Sections With High Polymer-Modified Asphalt Overlays

http://www.virginiadot.org/vtrc/main/online_reports/pdf/21-r16.pdf

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Final Report VTRC 21-R16

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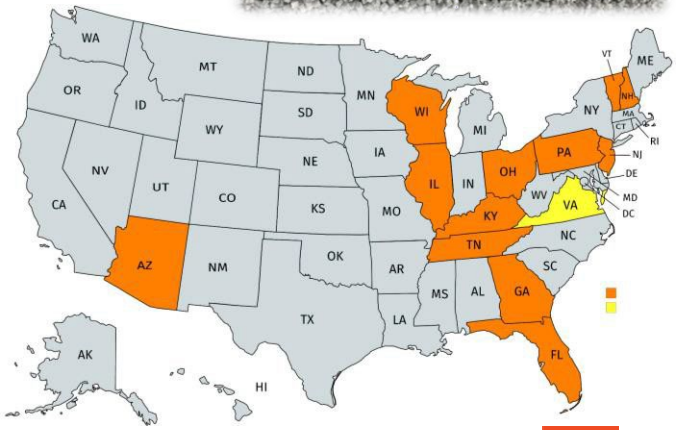
Engineered Additives in Binders

Hybrid Rubber Modified Asphalt

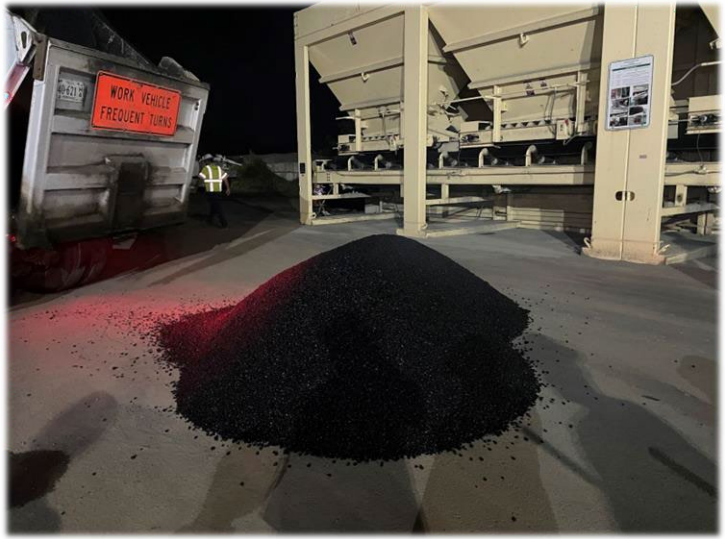
- What is in it for VDOT?
  - **Identify other alternatives for asphalt binder modification with promising performance**
- HRMA
  - 75% GTR + 20% SBS + 5% Chemistry
- Modification
  - Terminal or Plant
  - Very high solubility
  - Very high elastic recovery (~85%)
  - High workability and effective compactibility

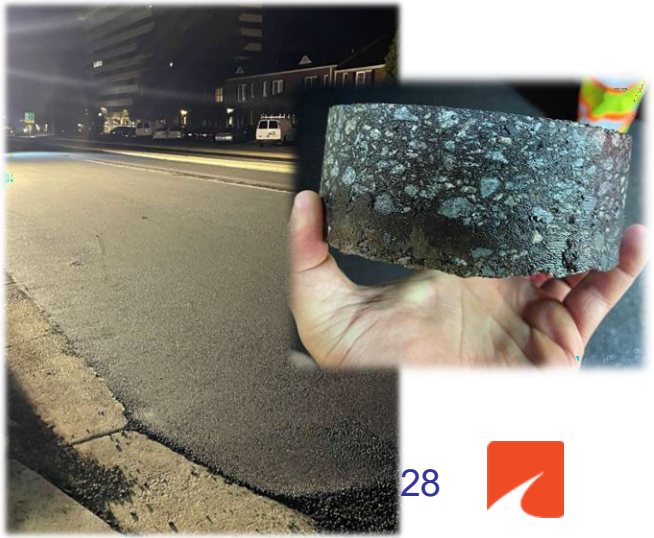


HRMA Binders & Mixtures

Field Trials – Summer 2021

Producer	Location	Mixture Type
Superior Paving	Rte 625 / Waxpool	**SM-12.5 E:** 15% RAP + PG64E-22
		SM-12.5 HRMA: 15% RAP + HRMA binder
Virginia Paving	Rte 120 / Glebe Rd	**SM-9.5 E:** 15% RAP + PG64E-22
		SM-9.5 HRMA: 15% RAP + HRMA binder





HRMA Binders & Mixtures

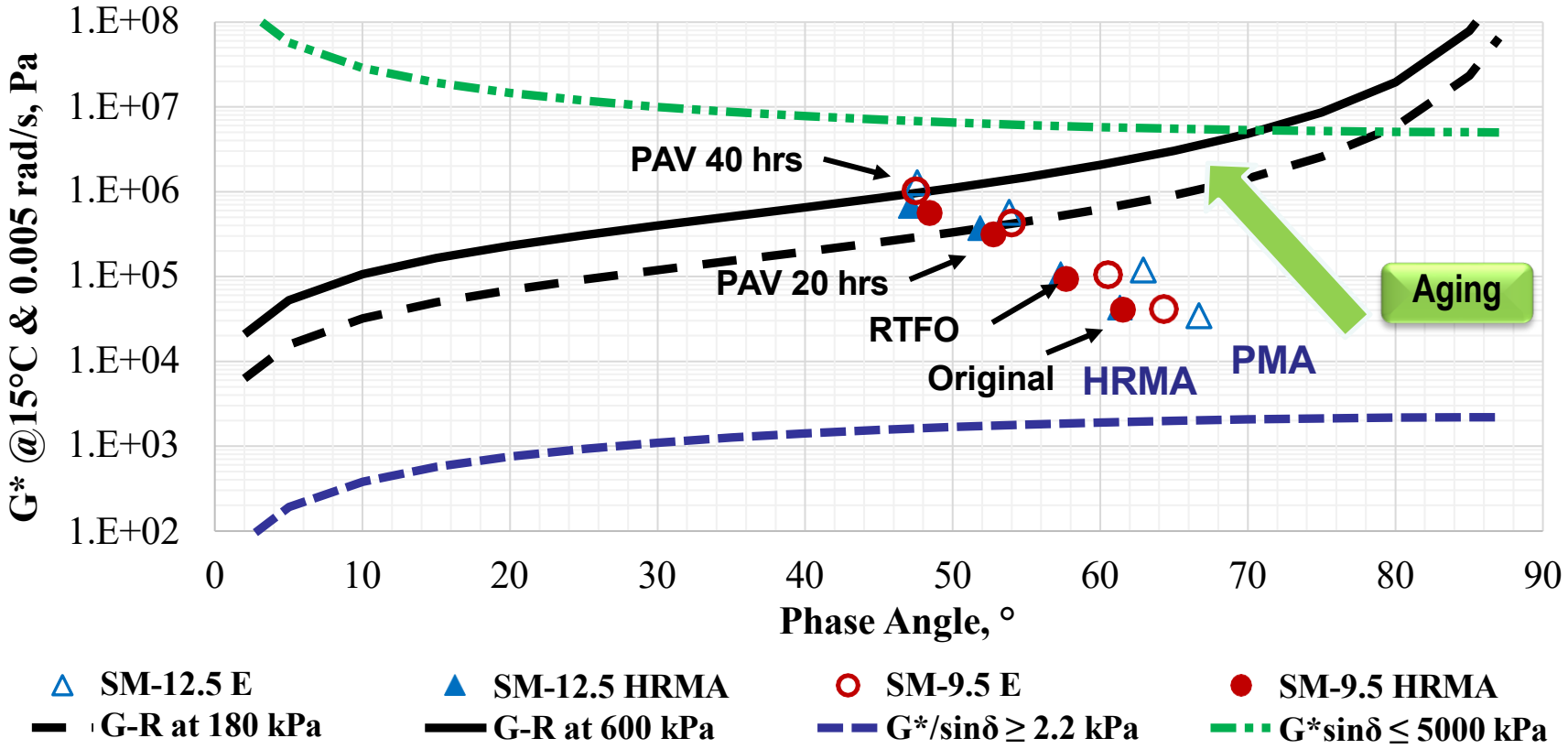
Asphalt Binders – Performance Grade

Mix / Binder ID	PGH	MSCR @ 64°C		after 20 hrs PAV			after 40 hrs PAV		
		Jnr@3.2 Max 0.5	%R@3.2	PGI	PGL	ΔTc Min -5	PGI	PGL	ΔTc Min -5
SM-12.5 E	79.1	0.19	67.6	**23.8**	**-24.1**	-1.9	**25.9**	**-20.1**	**-4.7**
SM-12.5 E (E&R)	79.5	**0.31**	**50.4**	23.3	-22.5	-5.8	xx	xx	xx
SM-12.5 HRMA	79.6	0.19	62.8	**19.5**	**-27.7**	-1.8	**22.0**	**-25.0**	**-3.2**
SM-12.5 HRMA (E&R)	84.4	**0.21**	**53.3**	21.1	-24.5	-6.0	xx	xx	xx

➔ ***Was able to design a binder with a performance equal or better to the conventional E binder !!***

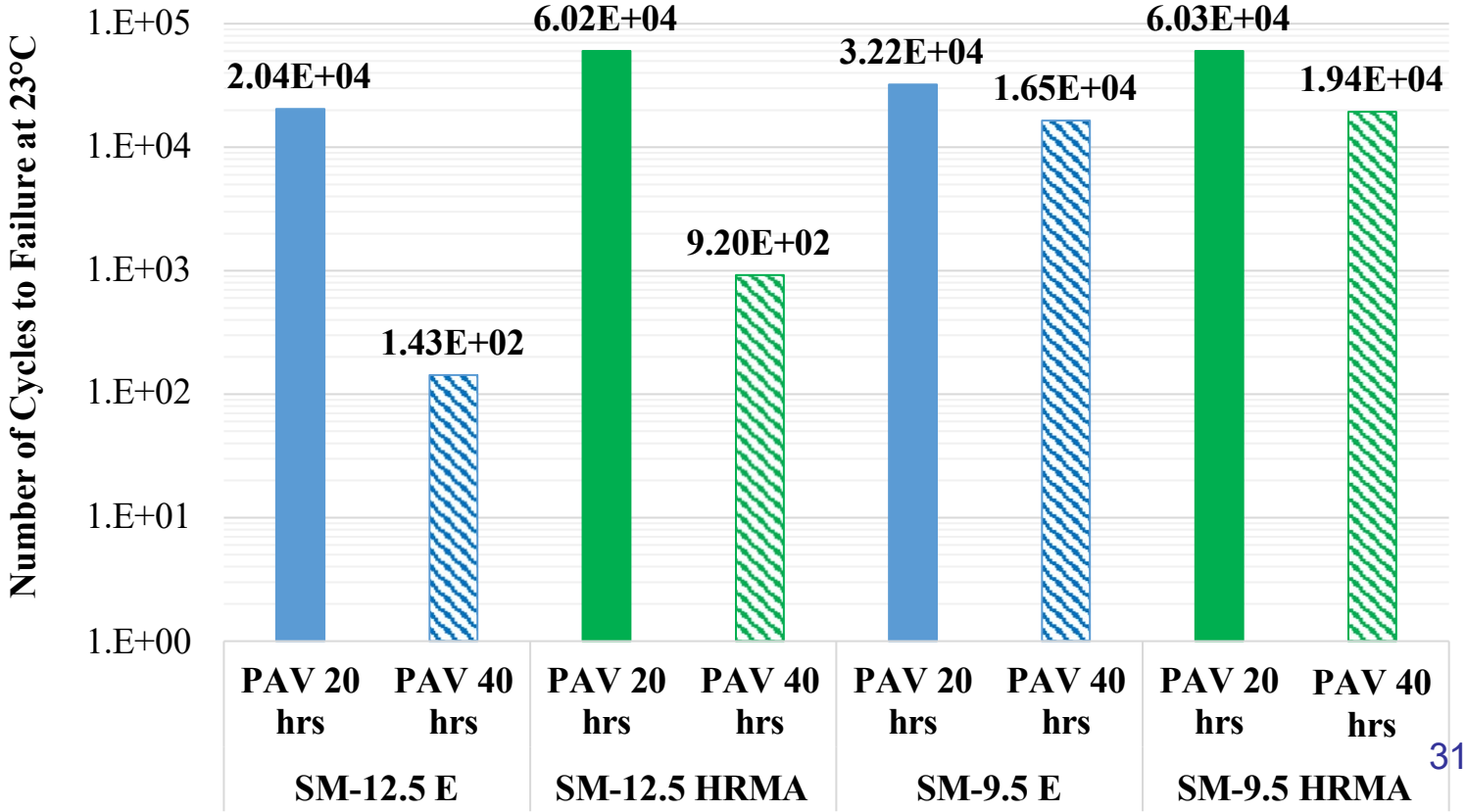
HRMA Binders & Mixtures

Asphalt Binder Aging Susceptibility



HRMA Binders & Mixtures

Fatigue Resistance – LAS Testing



Resources and References

Rubber and Hybrid Rubber Modified Mixtures

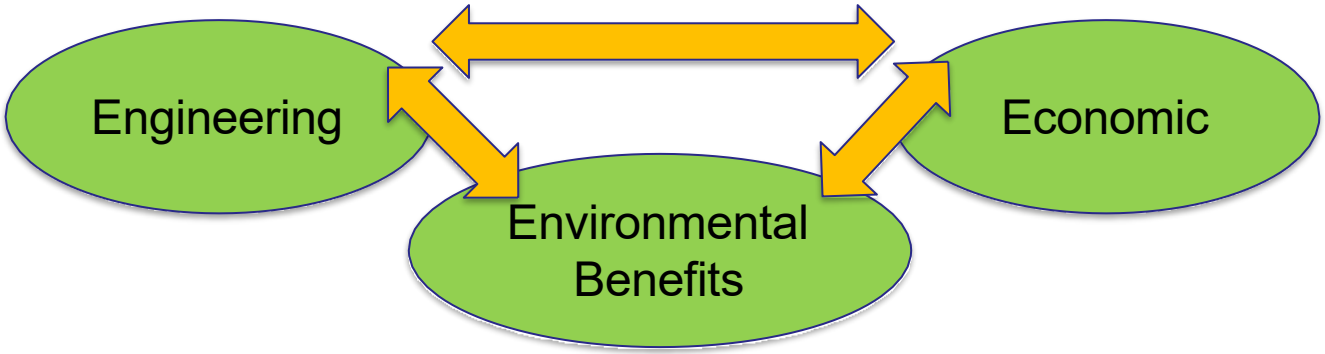
- Ground Tire Rubber (GTR) Modified Asphalt Surface Course: https://tinyurl.com/bp73k33a
- Asphalt Rubber Gap Graded Surface Mixture (AR-GGM): https://tinyurl.com/y5r9uw8e
- Engineered Additives (HRMA) to Enhance Properties of Asphalt Binders and Mixtures: https://tinyurl.com/529k3ceh

Recycled Plastic Waste

Introduction

- In 2017, 35.4 million tons of plastic waste in US:
  - 26.8 million tons ***(76%)*** stacked and landfilled
  - 5.6 million tons ***(16%)*** undergoing combustion
  - 3.0 million tons ***(8%)*** recycled

- FHWA's policy on recycled materials states:



Recycled Plastic Waste

Vision, Benefits, and Implementation

- Assess the feasibility of using RPM mixtures
  - Improve pavement performance as a ***sustainable*** solution
  - Help divert plastic waste from being placed in a landfill
  - Utilize plastic waste as commodity replacement for other raw materials
- Develop material property database for RPM mixtures
  - Gain gradual knowledge with regards to the types of plastic that may be compatible with locally available raw materials
  - Provide VDOT with additional alternatives to modify binders and mixtures
- Provide a better understanding of the potential environmental impacts

Recycled Plastic Waste

RPM Field Trials – Summer 2021

Year	Contractor	Mixture Type / Description	Locations
2021	Colony Construction	**SM12.5-D1**: 30% RAP + PG64**S**-22	--
		SM12.5-E1: 15% RAP + PG64**E**-22 **(~3.5% SBS, wet)**	Old Stage Road, Chester
		SM12.5-P1: 15% RAP + PG64**S**-22 + **P1** **(5%, dry)**	
		SM12.5-P2: 15% RAP + PG64**S**-22 + **P2** **(3%, dry)**	

700 T of asphalt / night
Binder content of ~6.5%

➔**Save the equivalent weight of plastic going to landfill as 606,667 single use plastic bags**

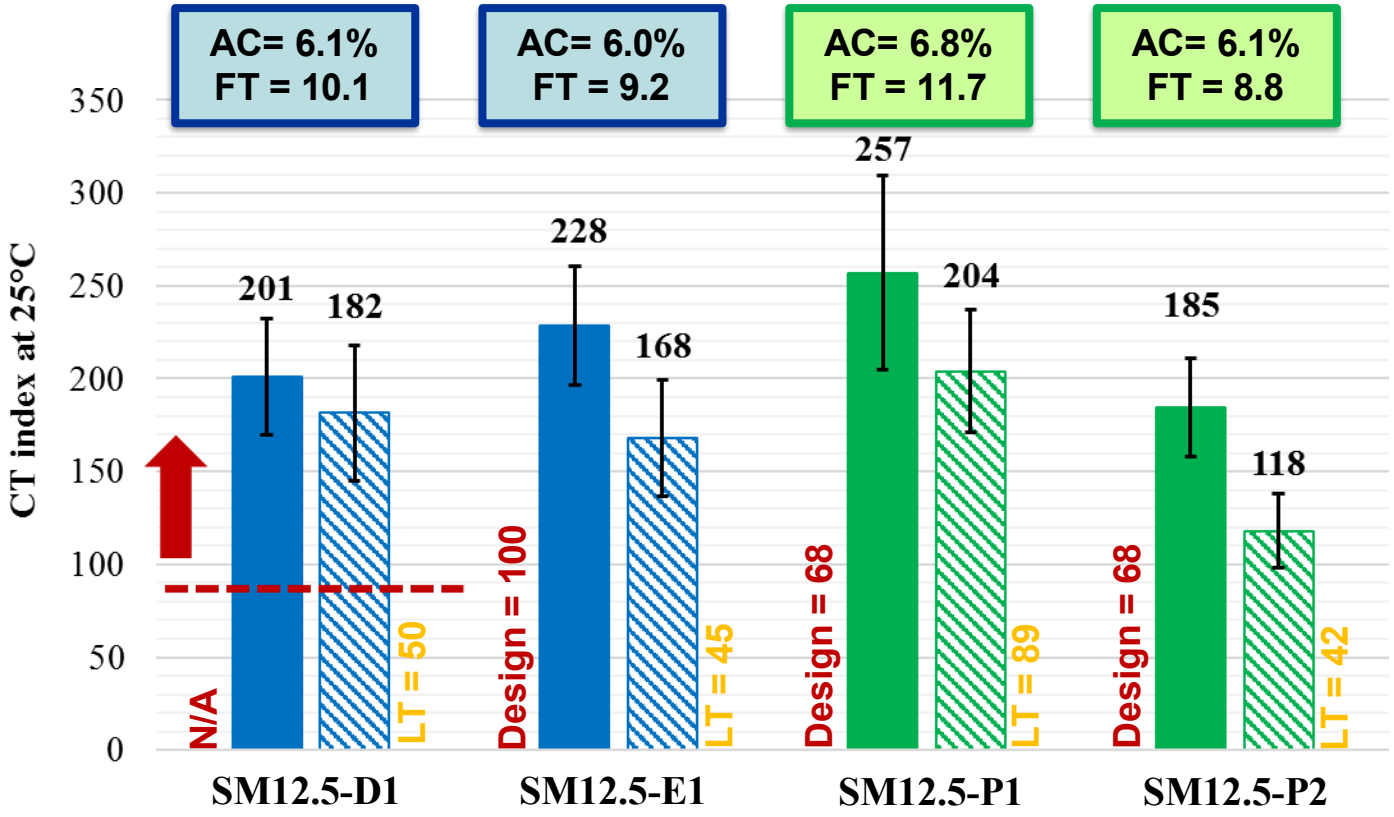
➔**Offset 10,292 KG of CO2**

Recycled Plastic Waste
Experimental Program

- Laboratory Evaluation
  - Non-reheated / reheated specimens (BMD testing)
  - Three levels of testing complexity
  - Field cores (thickness, density, permeability, & cracking testing)
  - Evaluation of virgin and extracted & recovered binders
- Structural Assessment via NDT
  - Run FWD, GPR, and Profilometer (IRI)
- Surface Condition Survey
  - Initial, 12-month, and 24-month (+ periodical visits)

Recycled Plastic Waste

Cracking – IDT-CT at 25ºC



Recycled Plastic Waste

Asphalt Binders – Performance Grade

Mix / Binder ID	PGH	MSCR @ 64°C		after 20 hrs PAV			after 40 hrs PAV		
		Jnr@3.2 Max 0.5	%R@3.2	PGI	PGL	ΔTc Min -5	PGI	PGL	ΔTc Min -5
SM12.5-D1	65.7	0.56	9.8	27.0	-20.8	-2.7	--	-18.0	-4.1
SM12.5-E1	81.2	0.22	48.3	24.4	-23.4	-2.5	--	-19.1	-5.4
SM12.5-P1	74.1	1.02	5.5	23.9	-24.4	-1.7	--	-16.6	-7.8
SM12.5-P2	75.0	0.87	5.3	25.5	-22.3	-1.9	--	-18.3	-4.7

➔ ***Question:*** ***Were we able to extract ALL plastic particles with the binder?***

Recycled Plastic Waste

RPM Field Trials – Summer 2022

Year	Contractor	Mix Type / Description	Location
2022	Colony Construction	**SM9.5-D2:** 30% RAP + PG64S-22	--
		SM9.5-P1: 15% RAP + PG64S-22 + **P1** **(5%, dry)**	SR 645, Prince George
		SM9.5-P3: **40% RAP** + PG64S-22 + **P3** **(8%, dry)**	SR 630, Prince George

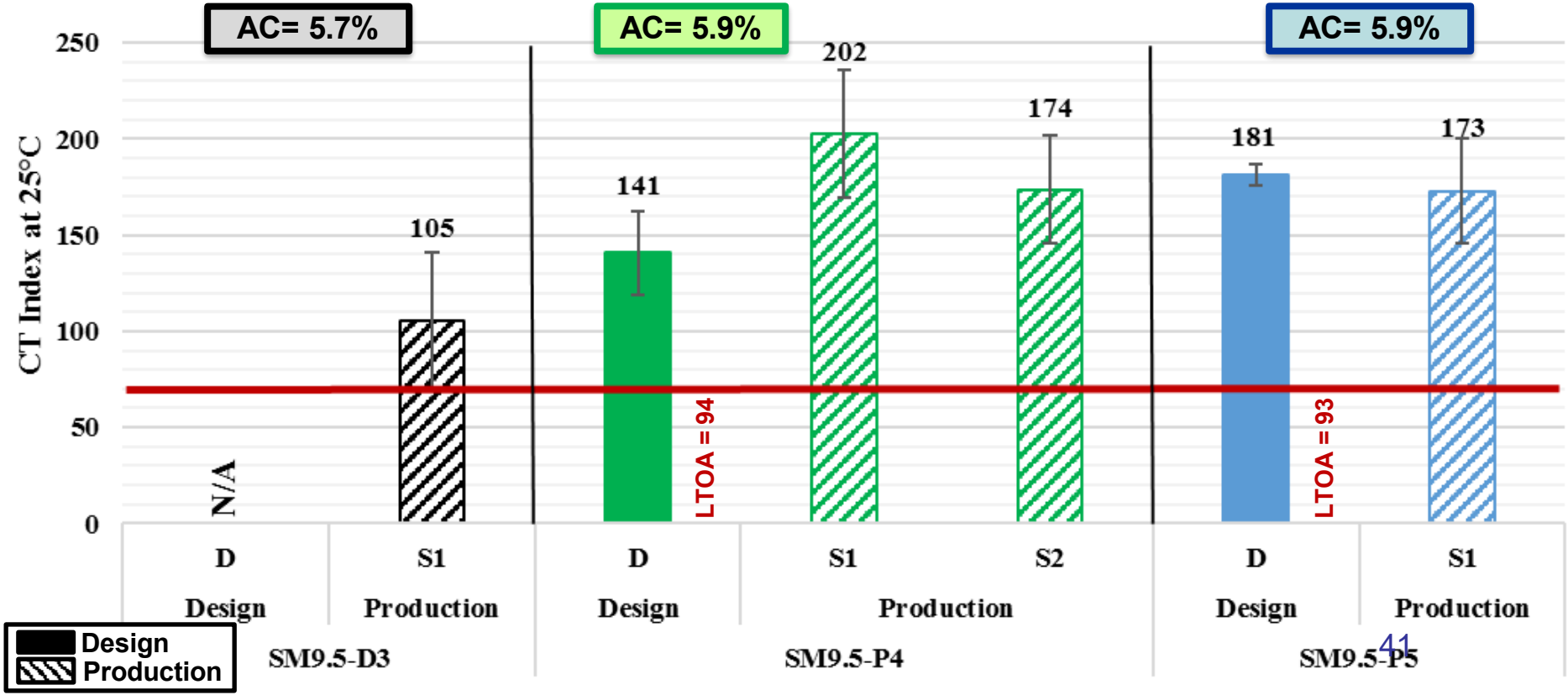
Recycled Plastic Waste

RPM Field Trials – Summer 2022

Year	Contractor	Mix Type / Description	Location
2022	Allan Myers	**SM9.5-D3:** 30% RAP + PG64S-22	--
		SM9.5-P4: 15% RAP + PG64S-22 + **P4** (2%, dry)	SR 622, Dorset Rd
		SM9.5-P5: 15% RAP + PG64S-22 + **P5** (3%, wet)	SR 622, Dorset Rd

Recycled Plastic Waste

Design vs. Production / Non-Reheats



Recycled Plastic Waste

Ongoing Efforts

- Develop analysis methods to determine if microplastics are present in wear related particles
- Additional evaluation of mid- and long-term aged RPM mixes
- Recycling process of RPM mixes
  - Impact on material design and performance properties
  - Evaluation of fumes and emissions generated from RPM mixes
- Recycled plastic waste (types, source, processing) in VA
- Potential development of a Roadmap / Implementation plan
- Environmental impacts NOT quantified yet ➔ LCA case studies as part of the FHWA Climate Challenge Project for VA

Additives in Binders and Mixtures

Closing Remarks

- Providing durable materials and pavements
- Research efforts support all components of VDOT's pavement program:
  - Materials and Maintenance
  - Pavement Design and Construction
- Continuous ongoing effort to find better performing, sustainable, and more economical / cost-effective solutions.

Acknowledgments

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- Polymers / Additives Suppliers: Kraton Polymers and Ingevity
- Plastic-Based Additive Suppliers
  - MacRebur Ltd, KAO Chemicals, Advanced Materials Group, GreenMantra Technologies
- Machines Supplier: Hi-Tech Asphalt Solutions, Inc.

VTRC
Virginia Transportation
Research Council

Thank You!

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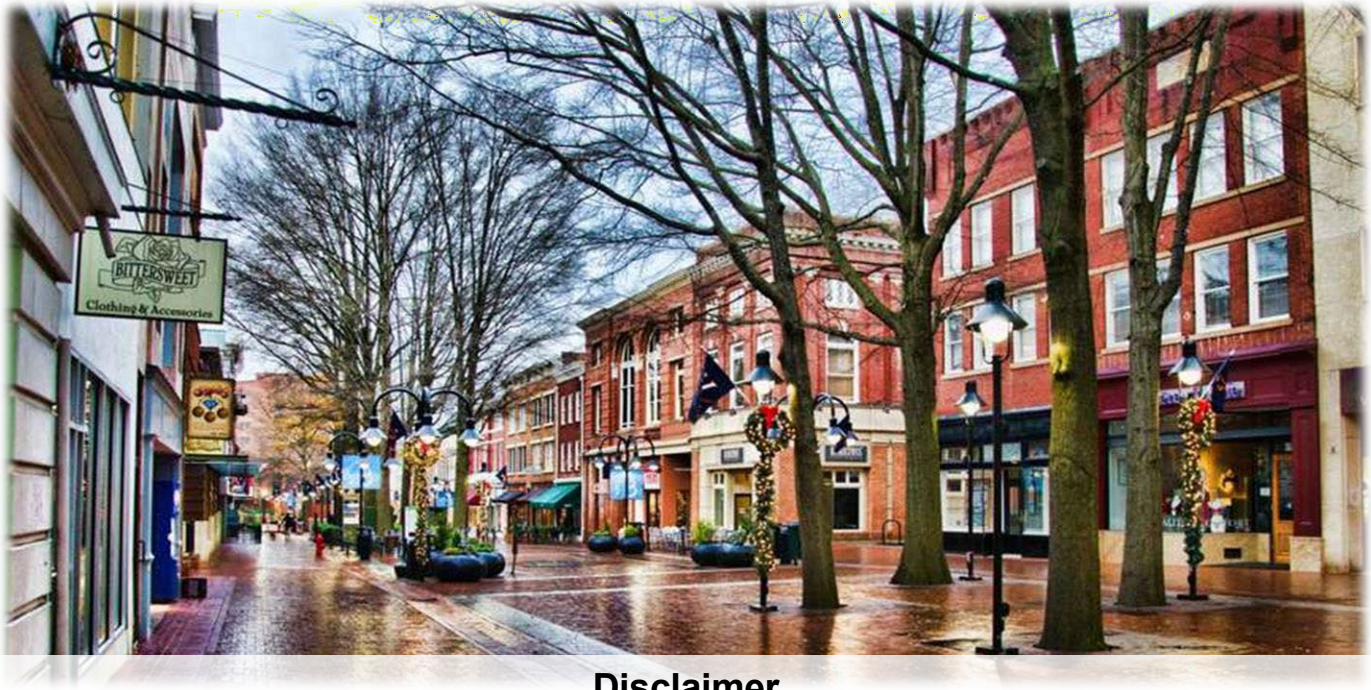
MAP
Association of Modified Asphalt Producers



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