VTRC Virginia Transportation Research Council

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Assessment of High RAP Surface Mixtures with Recycling Agents and/or Softer Binders in Virginia: *Towards Sustainable Paving*

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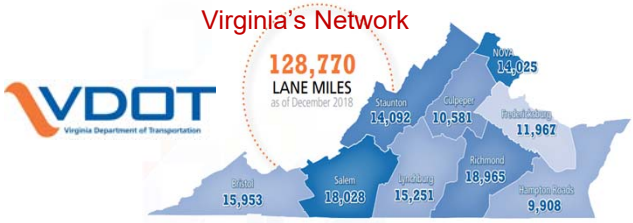
Introduction
Virginia's Network



- 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

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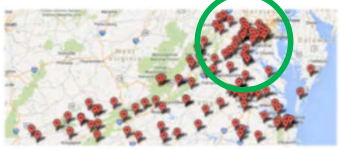
Background
RAP in Virginia

- 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



Background
VDOT Specifications – Surface Layers

- ≤ 30% RAP in unmodified dense-graded surface and intermediate courses
- ≤ 20% RAP in PG 70-22 Stone Matrix Asphalt mixtures (SMAs)
- ≤ 15% RAP in PG 76-22 (64E-22) (dense-graded and SMAs)

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Background
Motivations to Using More RAP

- Increased Interest in Recycled / Reclaimed Materials
  - Cost reduction
  - Industry factors
  - Environmental impacts
- Virginia DOT Stance
  - Encourage material recycling / reclaiming
  - Encourage cost reduction measures
  - Encourage innovation
  - ***Ensure quality materials and performance***

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Background
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

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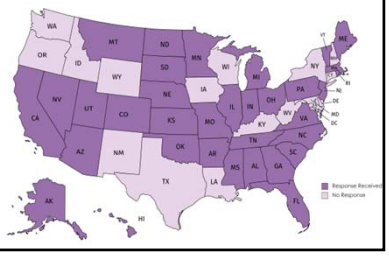
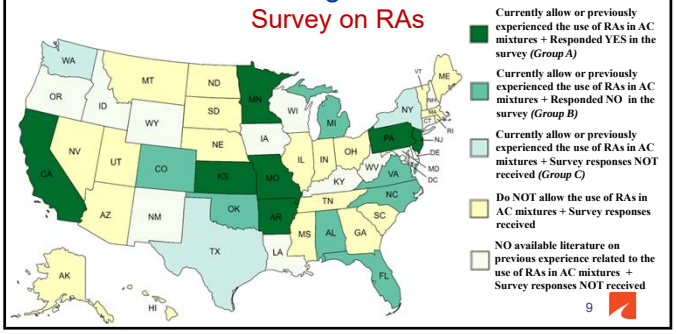
State of the Practice
Survey of Agencies – RAP/RAS/RAs

- **State DOTs**: ***70%*** Response Rate as of 12/03/2020
- Emphasis on:
  - ➢ Permissibility & Usage of RAP, RAS, & *RAs*
  - ➢ Design Methods & Performance Evaluation
  - ➢ Production & Quality Assurance
  - ➢ Best Practices & Lessons Learned



State of the Practice
High RAP Specifications

Background
Survey on RAs



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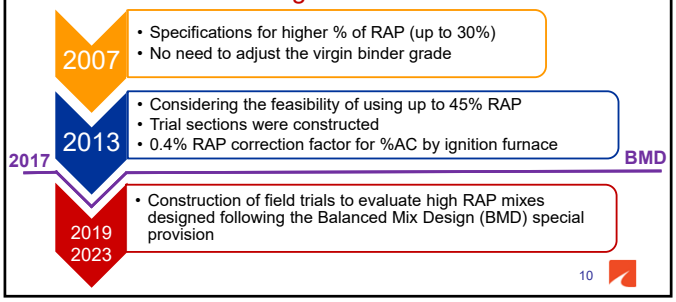
Background
Towards Higher RAP Contents



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Background
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 T 401)
CML ≤ 7.5 %

Moisture Damage
Tensile Strength Ratio Test (AASHTO T 283)
TSR ≥ 80 %

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Objective and Scope of Work
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
Meet Volumetrics + Performance

BMD Approaches
BMD P+VO

Approach D: Performance Design
Meet Performance (regardless of volumetrics)

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Pilot Projects
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**

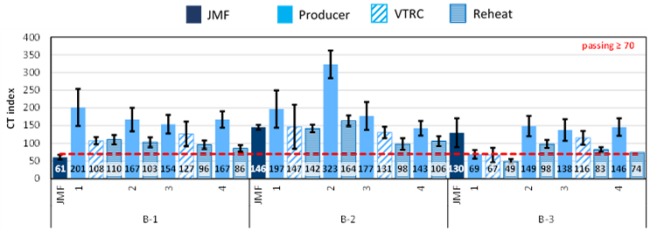
Colony Burkeville – August 2020
- SM-12.5 30% RAP PG64S-22
- **SM-12.5 35% RAP PG58-28 + RA 1**
- **SM-12.5 35% RAP PG58-28 + Fibers + RA 2**

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**

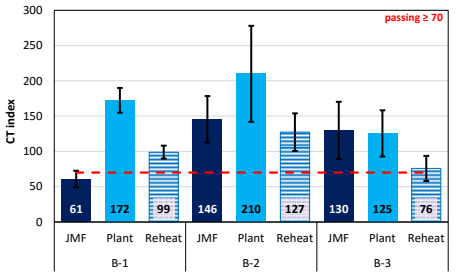
Pilot Projects
General Sampling Plan - Production

Production		Producer-Made Pills (No Reheating) Producer testing	VTRC testing	Loose Mix Sampling VTRC reheat testing	Cores (x10)
Day 1 (~1,000 tons)	Sublot A (T1)	3 Cantabro 5 IDT-CT	3 Cantabro 5 IDT-CT 4 APA	3 Cantabro 5 IDT-CT 4 APA	IDT-CT APA
	Sublot B (T2)	3 Cantabro 5 IDT-CT	4 APA	3 Cantabro 5 IDT-CT 4 APA	
Day 2 (~1,000 tons)	Sublot C (T3)	3 Cantabro 5 IDT-CT	3 Cantabro 5 IDT-CT 4 APA	3 Cantabro 5 IDT-CT 4 APA	
	Sublot D (T4)	3 Cantabro 5 IDT-CT	4 APA	3 Cantabro 5 IDT-CT 4 APA	

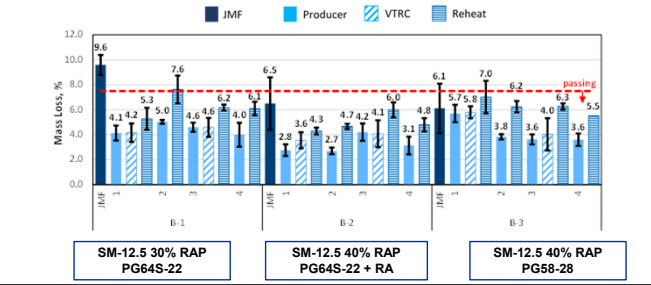
Pilot Projects – Case Study
Superior Stafford – August 2020 – CT index



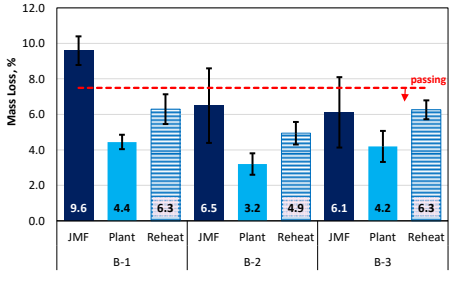
Pilot Projects – Case Study
Superior Stafford – August 2020 – CT index



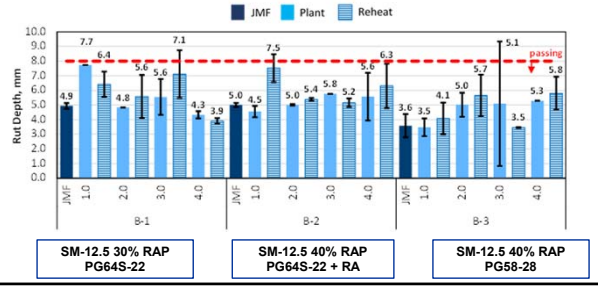
Pilot Projects – Case Study
Superior Stafford – August 2020 – Mass Loss



Pilot Projects – Case Study
Superior Stafford – August 2020 – Mass Loss

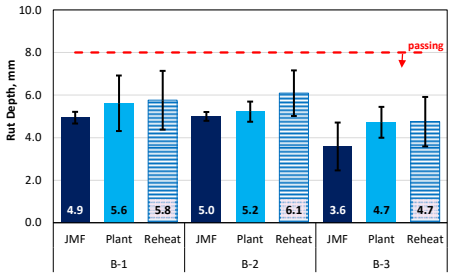


Pilot Projects – Case Study
Superior Stafford – August 2020 – APA Rut Depth



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

Pilot Projects – Case Study
Superior Stafford – August 2020 – APA Rut Depth



B1: SM-12.5 30% RAP PG64S-22

B2: SM-12.5 40% RAP PG64S-22 + RA

B3: SM-12.5 40% RAP PG58-28

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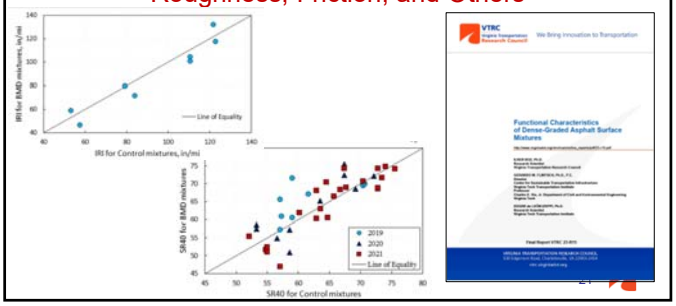
Surface Characteristics
Roughness, Friction, and Others



Balanced Mix Design
Progression of Approaches

Approach I

-Evaluate ***typical everyday mixtures*** using a suite of quick, fast, simple, but ***empirical*** tests

-Establish thresholds based on descriptive statistical parameters

Approach II

-Evaluate ***BMD Mixes*** and Correlates the selected empirical tests to fundamental tests and associated mechanistic-based performance analyses

+ Accelerated Testing

Approach III

-Uses the ***in-service performance of BMD pavement sections***.

-Considers in-service distress data, testing of cores, and in-situ testing.

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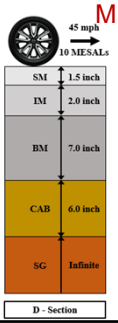
Pilot Projects – Case Study
ME Analysis – Numerical Example



Mix 6 (SM-12.5 30% RAP PG64S-22)					
Years	%Damage (Total)	%Damage (Top)	%Damage (Bottom)	Total Rutting [in.]	AC Rutting [in.]
3.08	26.49%	23.67%	27.89%	0.097	0.038
15.08	42.11%	40.79%	42.76%	0.126	0.058
30	54.84%	54.74%	54.90%	0.141	0.071

Mix 7 (SM-12.5 40% RAP PG64S-22 + RA)					
Years	%Damage (Total)	%Damage (Top)	%Damage (Bottom)	Total Rutting [in.]	AC Rutting [in.]
3.08	25.96%	22.73%	27.58%	0.093	0.034
15.08	43.00%	41.57%	43.71%	0.122	0.055
30	55.88%	55.89%	55.87%	0.138	0.068

Mix 8 (SM-12.5 40% RAP PG58-28)					
Years	%Damage (Total)	%Damage (Top)	%Damage (Bottom)	Total Rutting [in.]	AC Rutting [in.]
3.08	26.94%	24.74%	28.05%	0.119	0.057
15.08	42.41%	41.40%	42.91%	0.160	0.089
30	54.92%	54.75%	55.01%	0.182	0.109

Accelerated Pavement Testing
2020 BMD Experiment

- Six (6) mixtures
  - SM-9.5A + 30% RAP (PG 64S-22) - typical 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 64S-22 + RA)** - BMD
  - **SM-9.5A + 45% RAP (PG 58-28)** - BMD
  - **SM-9.5A + 60% RAP (PG 58-28 + RA)** - BMD
- Performance Evaluation
  - Laboratory - BMD and advanced testing
  - Site - Rutting and cracking testing experiments

Two 1.5-inch lifts over compacted aggregate base

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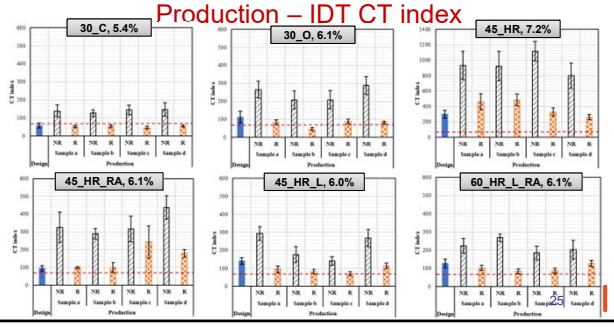
Accelerated Pavement Testing

Production – IDT CT index



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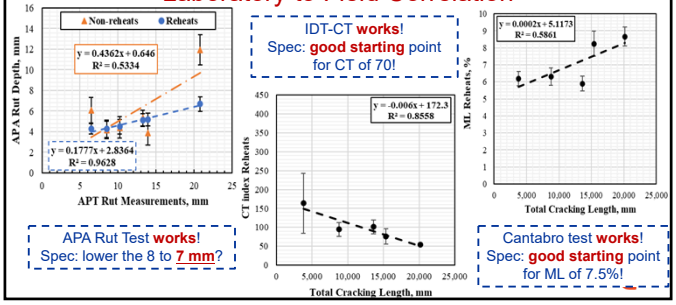
Accelerated Pavement Testing

Laboratory to Field Correlation



IDT-CT **works**!
Spec: **good starting** point for CT of 70!

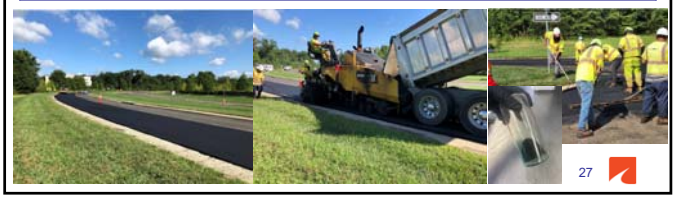
APA Rut Test **works**!
Spec: lower the 8 to **7 mm**?

Cantabro test **works**!
Spec: **good starting** point for ML of 7.5%!

More Pilot Projects

High RAP with RA – 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)



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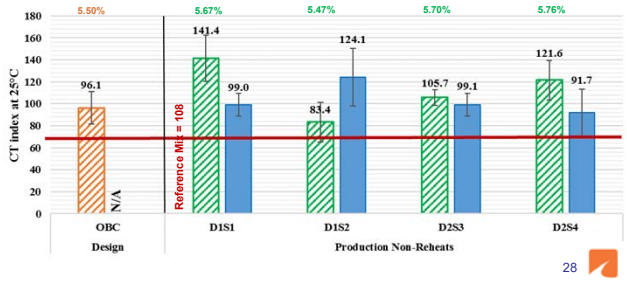
Use of Recycling Agents

Performance Data - Production



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More Pilot Projects

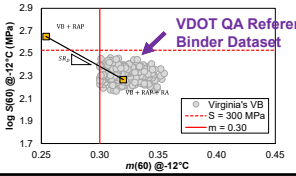
High RAP with RA – Summer 2023

Producer	Location	Mix Type
Superior Paving	Northern Virginia	SM-9.5: 40% RAP + PG 64S -22 + RA1
Branscome	Hampton Roads	SM-12.5: 40% RAP + PG 64S -22 + RA2

Recycling Agents

Two Engineered Frameworks

- Framework 1 (APL)
  - Determines the acceptability of a specific RA product for inclusion in VDOT's Approved Product List using Similarity Analysis



Recycling Agents
Two Engineered Frameworks

- Framework 2 (Mix Design)
  - Evaluates the short- and long-term effectiveness of RAs in improving the performance of surface mixtures, particularly those with high RAP contents

$$(CT_{index})^{1day\ LTOA}_{aging\ sensitivity} = \left[\frac{(CT_{index})_{STOA} - (CT_{index})_{1day\ LTOA}}{(CT_{index})_{STOA}}\right] * 100$$

→ CT index Aging Sensitivity should be < 45%.

Sustainability
Definition and Scope

- In the Context of "*Pavements*":
  - Achieve the engineering goals for which it was constructed
  - Preserve and restore surrounding ecosystems
  - Use financial, human, and environmental resources economically
  - Meet basic human needs such as health, safety, equity, employment, comfort, and happiness

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FHWA Climate Challenge Project
Scope / Tasks

1. Roadmap development
2. Develop and deliver training
3. ***Conduct LCA Case Studies and Develop EPD data***
4. Assist in developing asphalt binder EPDs based on publicly available background datasets
5. Develop standards to quantify impacts of paving practices
6. Concluding symposium

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Closing Remarks
On-Going Efforts

- Validation of Engineered RA Framework
  - Three high RAP trials with RAs in Virginia: 2022 (x1) and 2023 (x2)
  - Develop a draft Virginia Test Method + Automated Tool (e.g., excel)
- RAP Binder Availability and Activity
  - Looking at 14 representative RAP sources in Virginia
  - RA is a major element for the activity assessment
- Field Performance Assessment and Spec Validation
  - All BMD sections / mixtures in general
  - Focus on high RAP with RA sections

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Closing Remarks
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.

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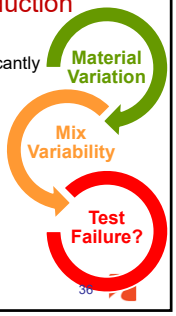
Closing Remarks
Lessons Learned – Design to Production

- 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



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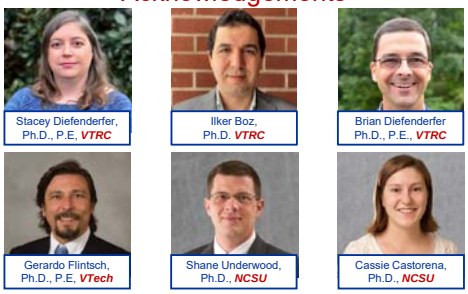
Resources and References

2019 - 2022 High RAP Field Trials & Schedules

Closing Remarks

Acknowledgements



Closing Remarks

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- Asphalt Binder Suppliers
- Recycling Agents Suppliers

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Thank You!

VTRC Virginia Transportation Research Council

VDOT Virginia Department of Transportation

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