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The Future of Roadways: Green, Equitable, Intelligent & Integrated
6TH ANNUAL IRF GLOBAL R2T CONFERENCE

Optimization of high-RAP mixes using Balanced Mix Design and Accelerated Pavement Testing

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VIRGINIA TECH

FM Consultants

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Acknowledgement

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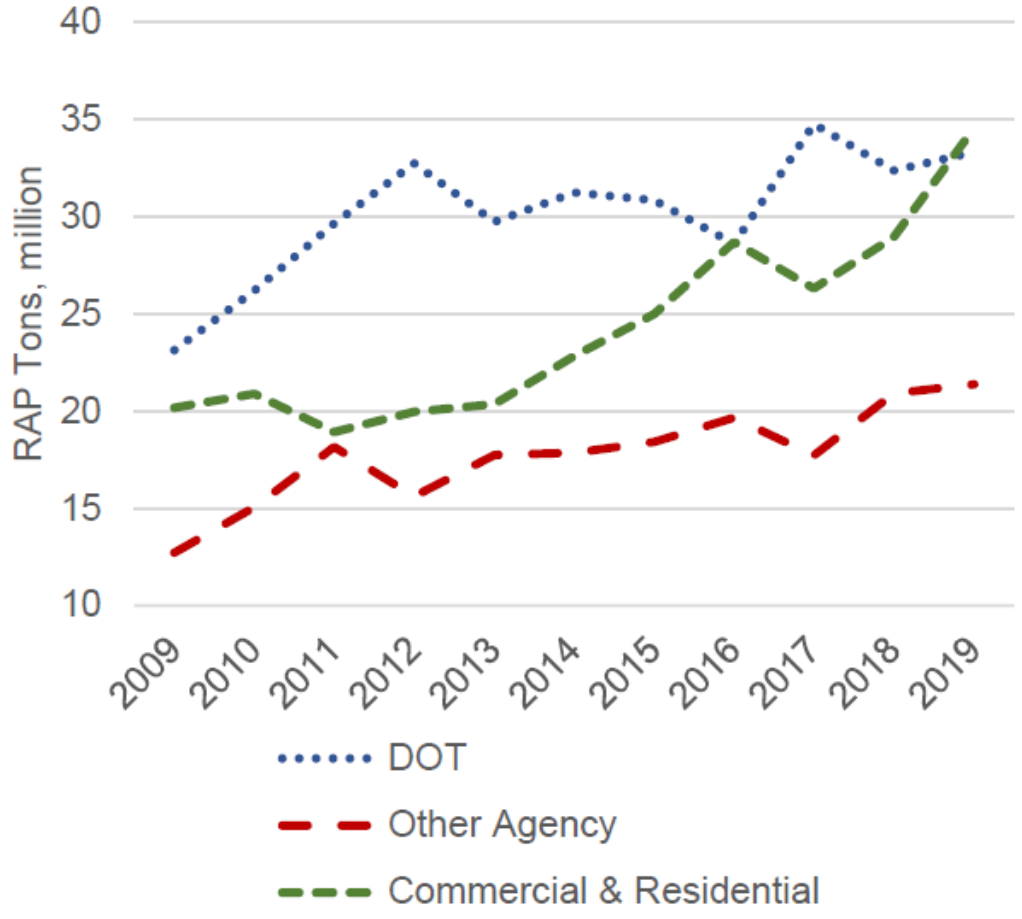
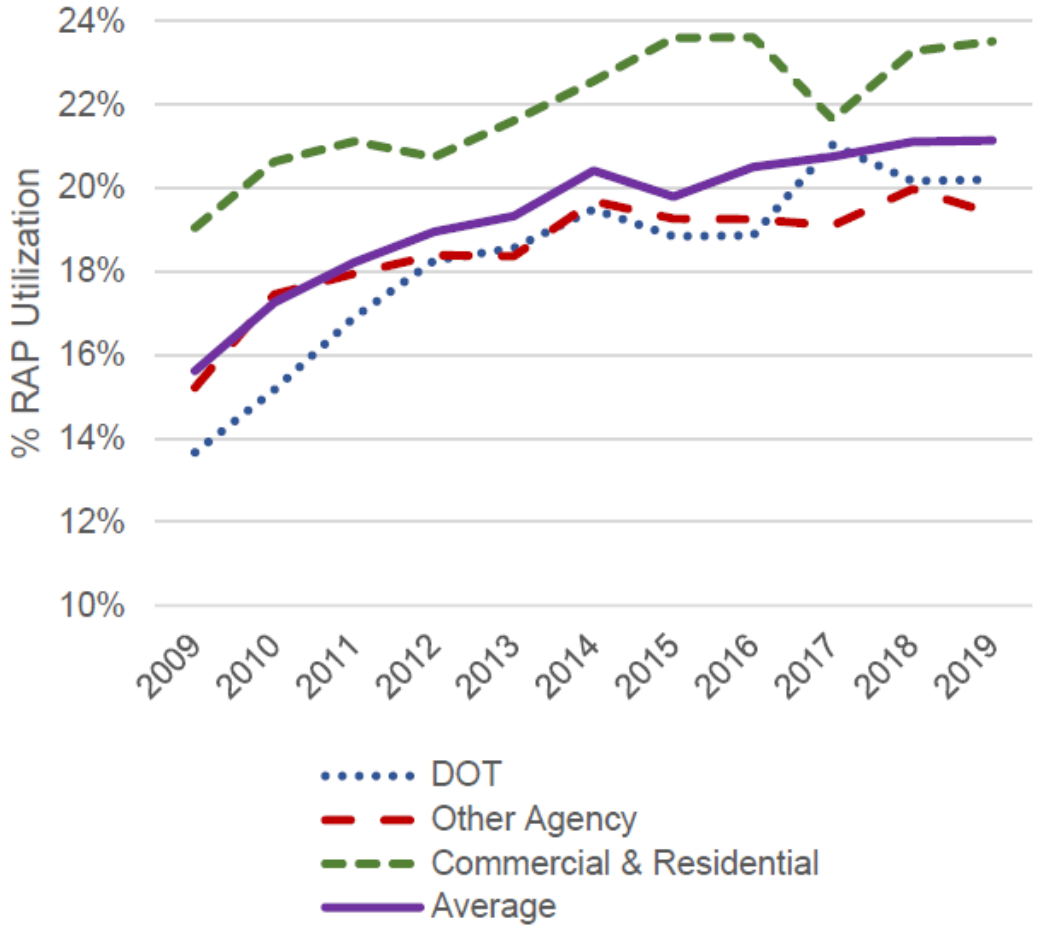
- ✓ Ingevity

Introduction

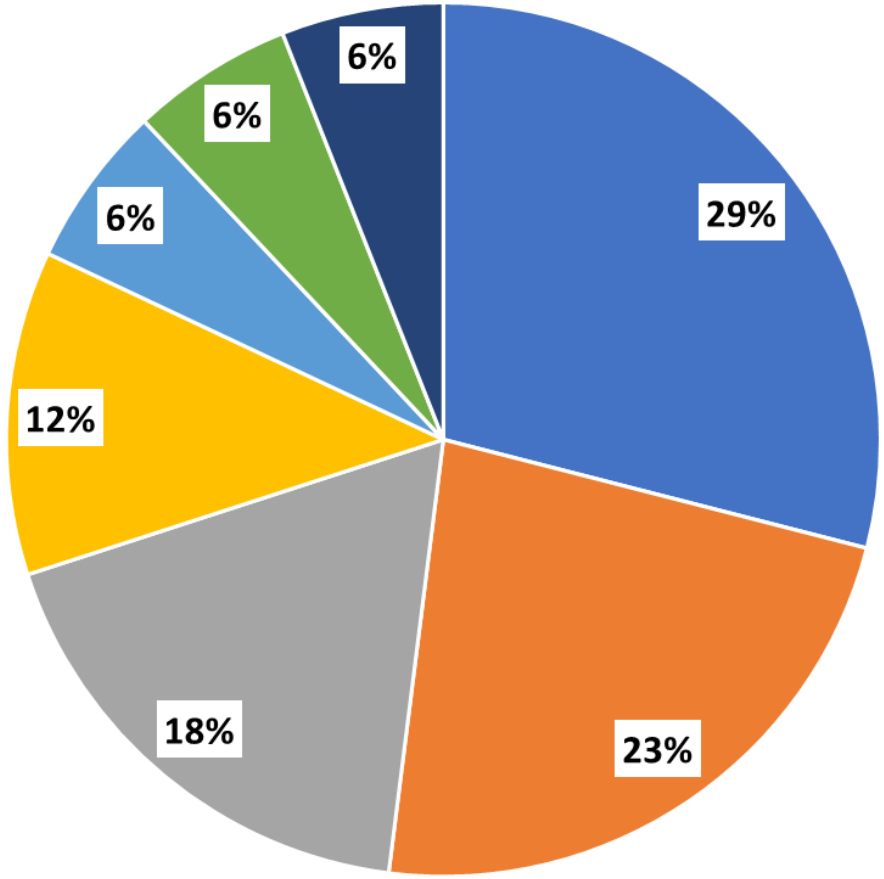
Background - Pavement Recycling





Williams, B. A., Willis, J. R., & Shacat, J. (2020). *Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2019.*

How to increase RAP use?



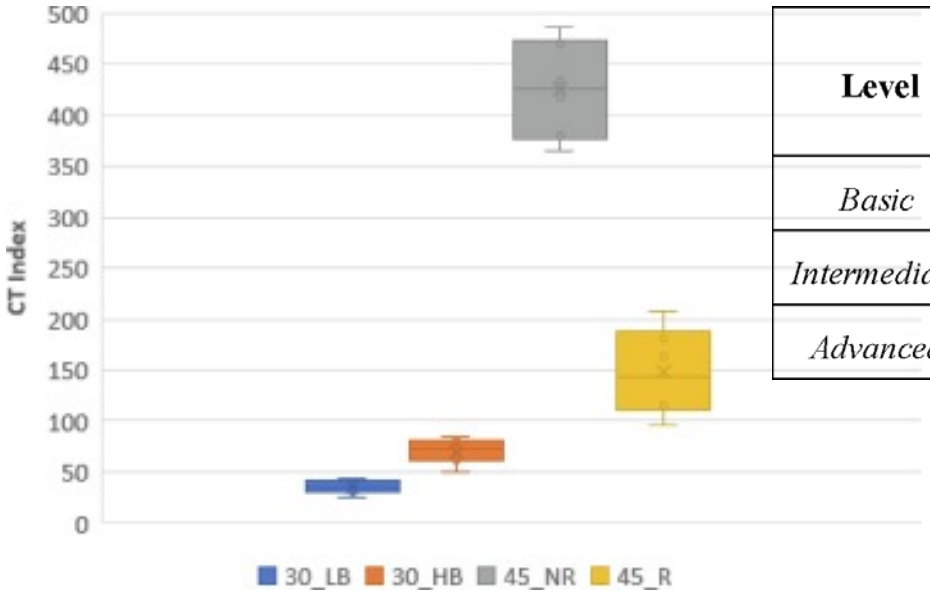
- Balanced Mix Design/Mixture Performance Testing
- Increase Utilization in Lower Layers/Layered Design
- Fractionating RAP
- Work with DOT on Specification
- Increased/Excellent QC of Recycled Materials
- Binder Grade Bumping
- High RAP Specification for Low Volume Roads

Williams, B. A., Willis, J. R., & Ross, T. C. (2019). *Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2018.*

Recent Dissertation Proposed a Three-Tier System

Level	Cracking	Rutting	
Basic	CT_{Index}	HT-IDT	
Intermédiate	I-FIT	APA	
Avanzad	S-VECD	CFN	SSR

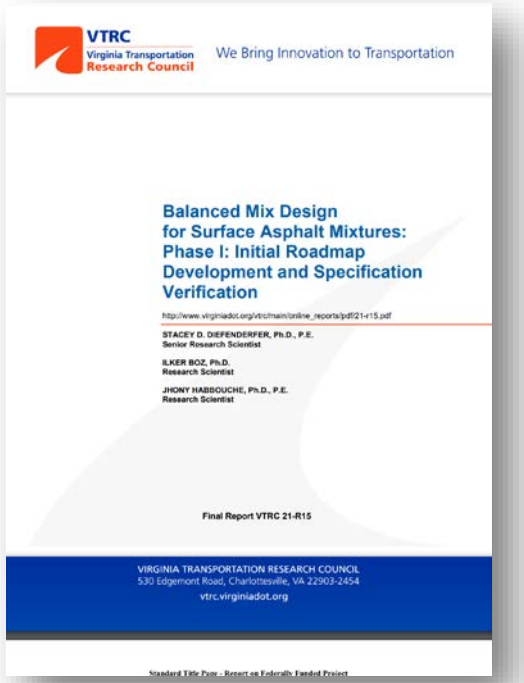
- ✓ Good performing blends with 30 and 45% RAP.



Level	Test	30_LB		30_HB		45_NR		45_R		Test Avg. COV
		Average	COV	Average	COV	Average	COV	Average	COV	
Basic	CT	35.52	17%	69.96	17%	425.39	11%	147.54	29%	19%
Intermediate	I-FIT	1.96	31%	6.85	17%	22.85	25%	7.27	25%	25%
Advanced	S_{app}	17.45	N/A	15.77	N/A	21.92	N/A	17.03	N/A	N/A

Meroni, F., Flintsch, G.W., Habbouche, J., Diefenderfer, B.K., Giustozzi, F., "Three-level performance evaluation of high RAP asphalt surface mixes, *Construction and Building Materials*, vol. 309, 2021.

Virginia BMD Journey



- ✓ VDOT is interested in ways to facilitate the increased durability of asphalt mixtures in an effort to make its roadway network more sustainable, longer lasting, and more economical
- ✓ Committed to the implementation of the BMD method in an effort to improve asphalt mixture performance
  - Laboratory experiment
  - APT experiment
  - Pilots with in-service monitoring
  - Full implementation

https://vtrc.virginia.gov/media/vtrc/vtrc-pdf/vtrc-pdf/21-R15.pdf

Three-Tier BMD Implementation

Step I

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

-Establish thresholds based on average, max or min ± study

Step II

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

Step III

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

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

Current VDOT BMD Special Provision

- ✓ AASHTO TP 108: Standard Method of Test for Determining the Abrasion Loss of Asphalt Mixture Specimens (Cantabro)
  - Mass loss ≤ 7.5%
- ✓ AASHTO T 340: Method of Test for Determining Rutting Susceptibility of HMA Using the Asphalt Pavement Analyzer (APA)
  - Rutting ≤ 8.0 mm
- ✓ ASTM D 8225: Determination of Cracking Tolerance Index of Asphalt Mixture Using the Indirect Tensile Cracking Test at Intermediate Temperature (CTindex)
  - CTindex ≥ 70

Accelerated Pavement Testing Experiment

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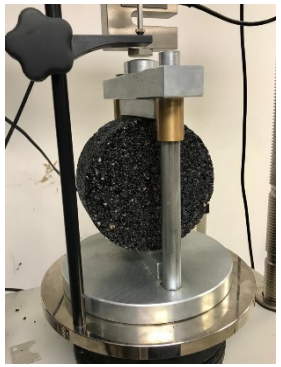
VDOT Accelerated Pavement Testing

- ✓Purpose of the APT program
  - Support VDOT pavement research to better understand response to traffic loading in a manner that is more rapid, better controlled, and less risky to the public

APT BMD Experiment Objective

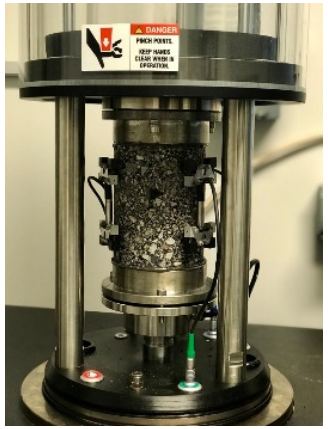
Primary:

- ✓ Can we design mixes with high RAP contents using Balanced Mix Design (BMD)?



Secondary:

- ✓ Verify the validity of the simple tests and limits set for the pilot projects
- ✓ Do we need to have the three tiers?



Asphalt Surface Mixtures Evaluated

- ✓ 6 SM-9.5A Mixes (1 Control and 5 BMD)
  - **Mix I:** 30% RAP + PG64S-22 ***(typical production)***
  - **Mix II:** 30% RAP + PG64S-22 ***(BMD)***
  - **Mix III:** 45% RAP + PG64S-22 ***(BMD)***
  - **Mix IV:** 45% RAP + PG64S-22 + RA ***(BMD)***
  - **Mix V:** 45% RAP + PG58-28 ***(BMD)***
  - **Mix VI:** 60% RAP + PG58-28 + RA ***(BMD)***

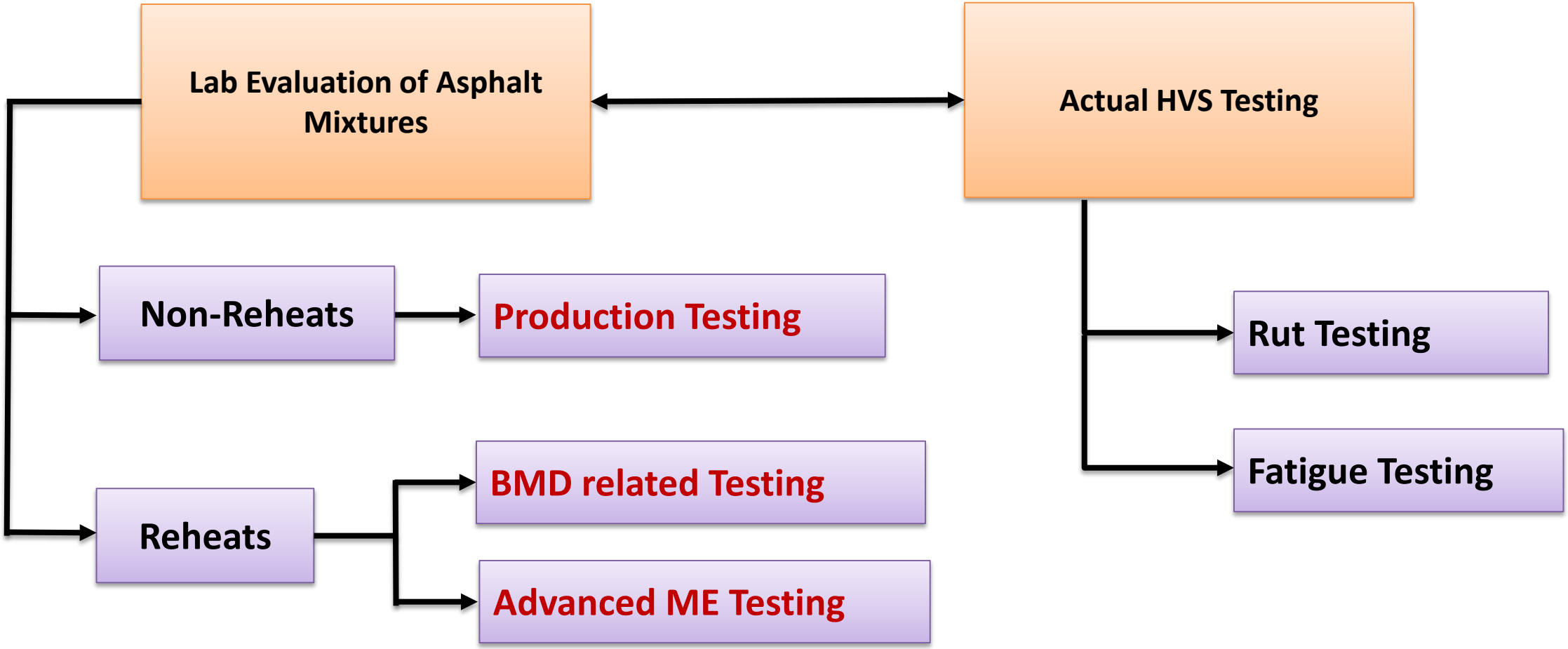
Production (VDOT)

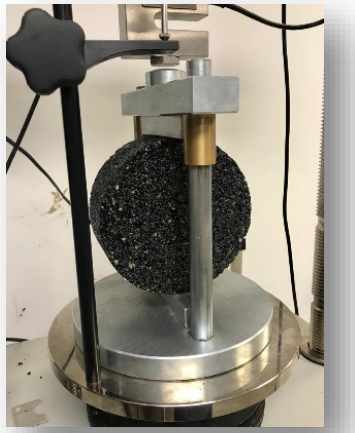
Volumetric Properties

Mix ID	Mix I	Mix II	Mix III	Mix IV	Mix V	Mix VI
Composition	30% RAP + PG64-22	30% RAP + PG64-22	45% RAP + PG64-22	45% RAP + PG64-22 + RA	45% RAP + PG58-28	60% RAP + PG58-28 + RA
AC Content, %	5.6	6.1	6.8	6.2	6.1	5.9
VTM, %	4.1	6.2	0.6	2.3	2.7	1.4
VMA, %	16.9	19.8	16.4	16.7	16.9	14.9
VFA, %	75.8	69.0	96.5	86.3	84.3	91.0
FA Ratio, %	1.1	1.1	1.2	1.3	1.3	1.5
Pbe	5.4	5.9	6.5	6.0	5.9	5.6
Gmm, Rice	2.542	2.522	2.508	2.539	2.535	2.539

- Volumetric Properties on Production: ***by VTRC***

Experimental Program





Supporting Laboratory Testing

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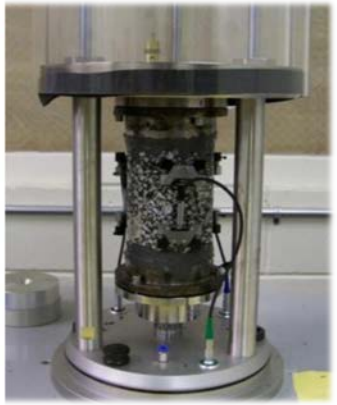
“Basic” BMD Testing Program

Daily Production	Producer-made pills (no reheating)		Loose mix sampling
	Producer testing	VTRC testing	VTRC reheat testing
Sublot 1 (T1) **(lift 1, sample 1)**	3 Cantabro 5 Ideal-CT	4 APA	3 Cantabro 5 Ideal-CT 4 APA
Sublot 2 (T2) **(lift 1, sample 2)**	3 Cantabro 5 Ideal-CT	3 Cantabro 5 Ideal-CT 4 APA	3 Cantabro 5 Ideal-CT 4 APA
Sublot 3 (T3) **(lift 2, sample 1)**	3 Cantabro 5 Ideal-CT	4 APA	3 Cantabro 5 Ideal-CT 4 APA
Sublot 4 (T4) **(lift 2, sample 2)**	3 Cantabro 5 Ideal-CT	3 Cantabro 5 Ideal-CT 4 APA	3 Cantabro 5 Ideal-CT 4 APA

Advanced ME based Testing on Reheated Material

Asphalt Mixture Performance Tester

- **Dynamic Modulus |E*|**
- **Cyclic Fatigue test using S-VECD Model**
- **Stress Sweep Rutting (SSR)**
- **Confined Flow Number**
- **Texas Overlay**



Accelerated Pavement Testing Results

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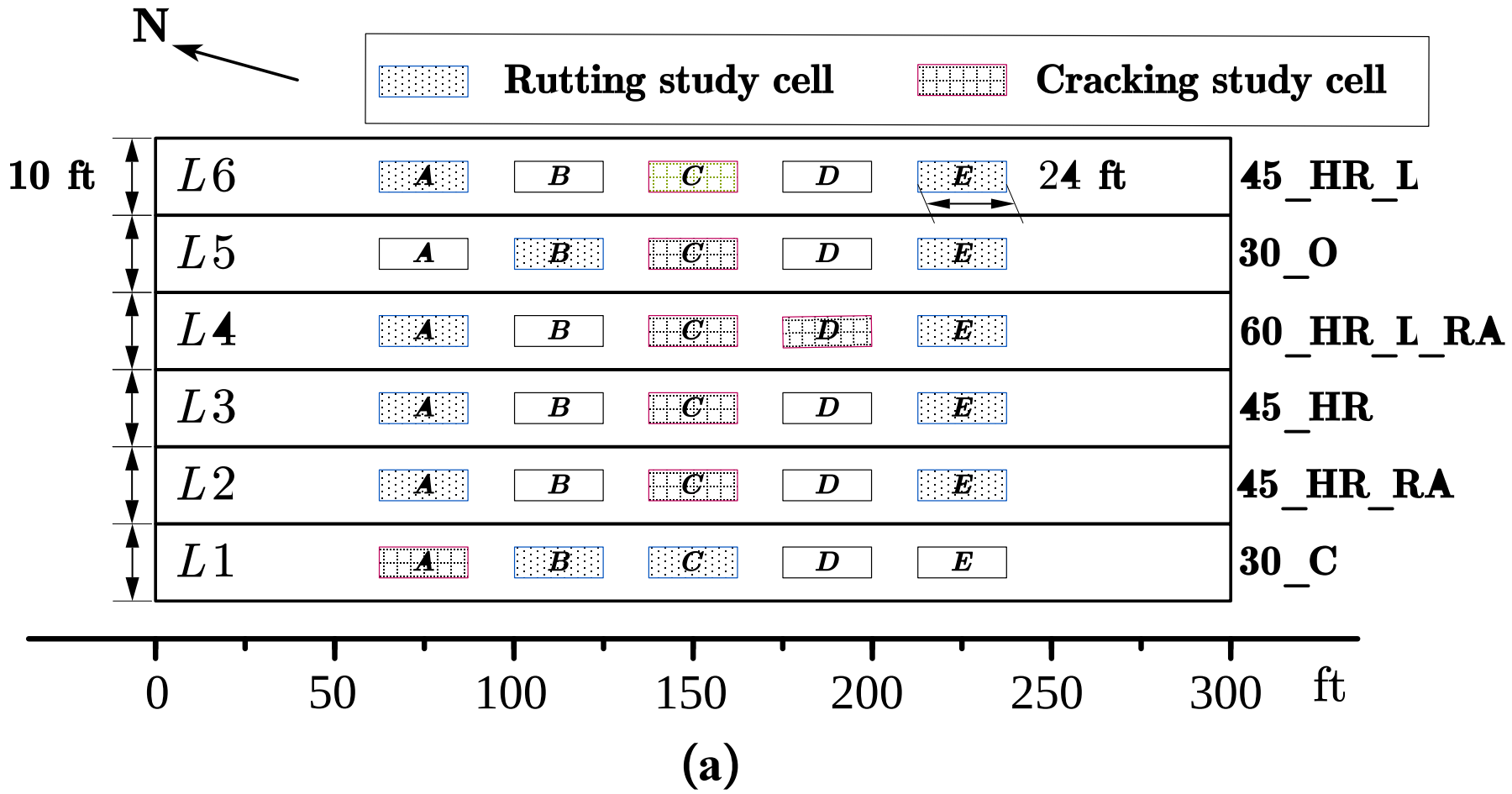
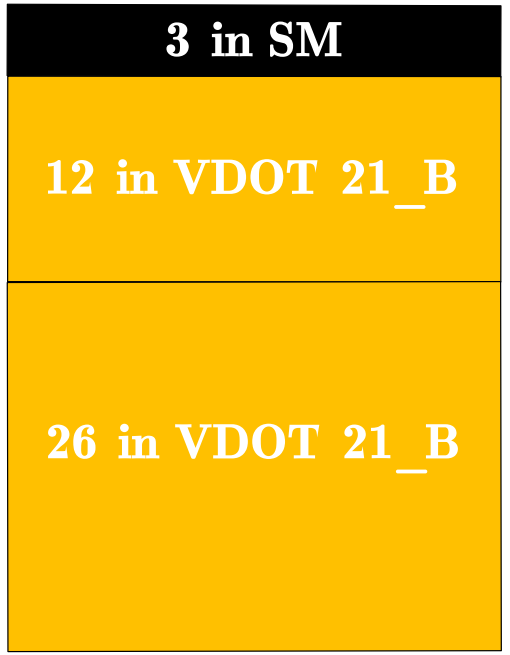
APT Cycle 2 Experiment Layout



(a)



(b)

Testing Conditions

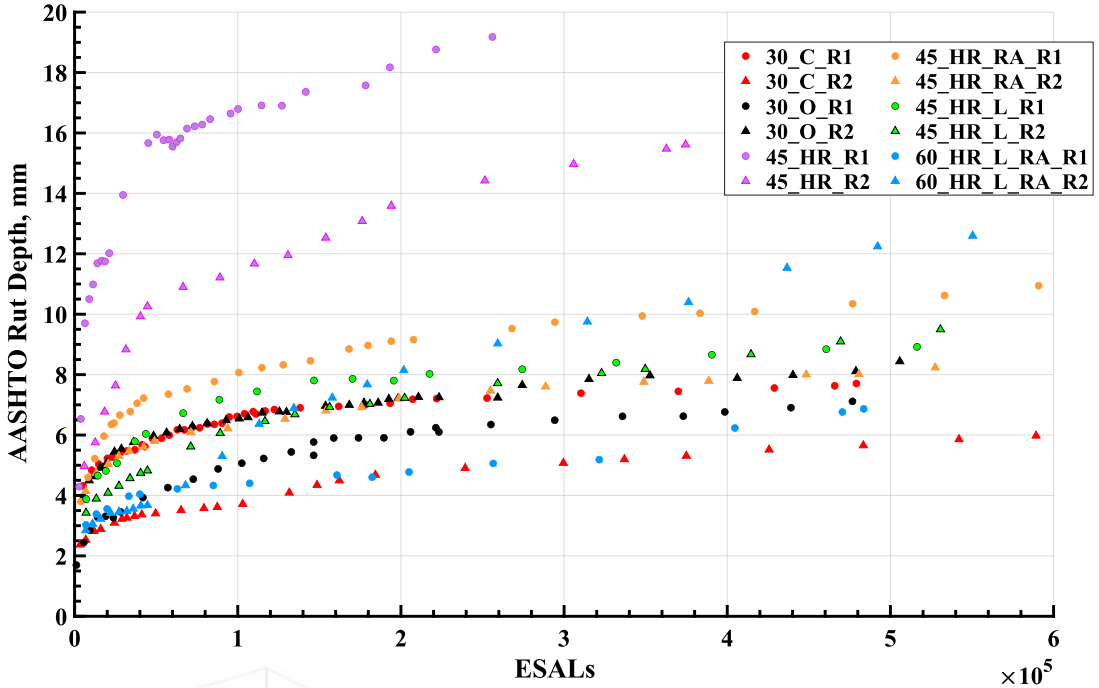
Rutting

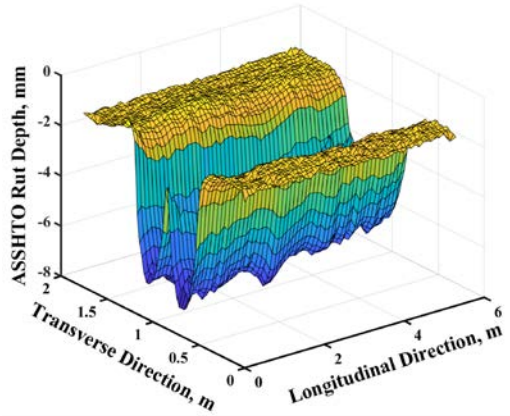
- ✓ Same as in previous experiments
- ✓ Unidirectional
- ✓ 9,000 lb → 12,000 lb → 15,000 lb
- ✓ 40^{o} C
- ✓ Narrow wander (uniform)
- ✓ 4 mph (2020)
- ✓ 6 mph (2021)

Cracking

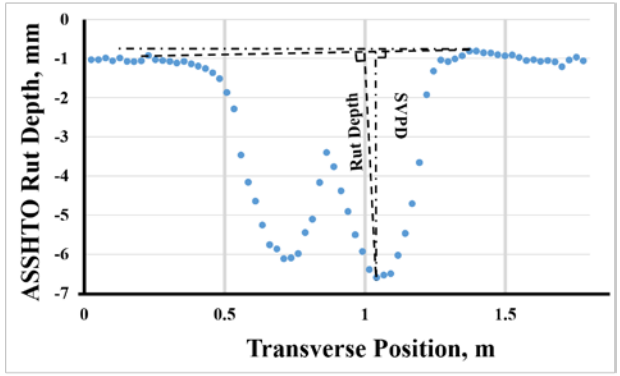
- ✓ Used similar experimental conditions to FHWA ALF
- ✓ Bidirectional
- ✓ 15,000 lb
- ✓ 20^{o} C
- ✓ Wider wander (~Normal, s = 5-10in)
- ✓ 4 mph → 6 mph

Rutting Results



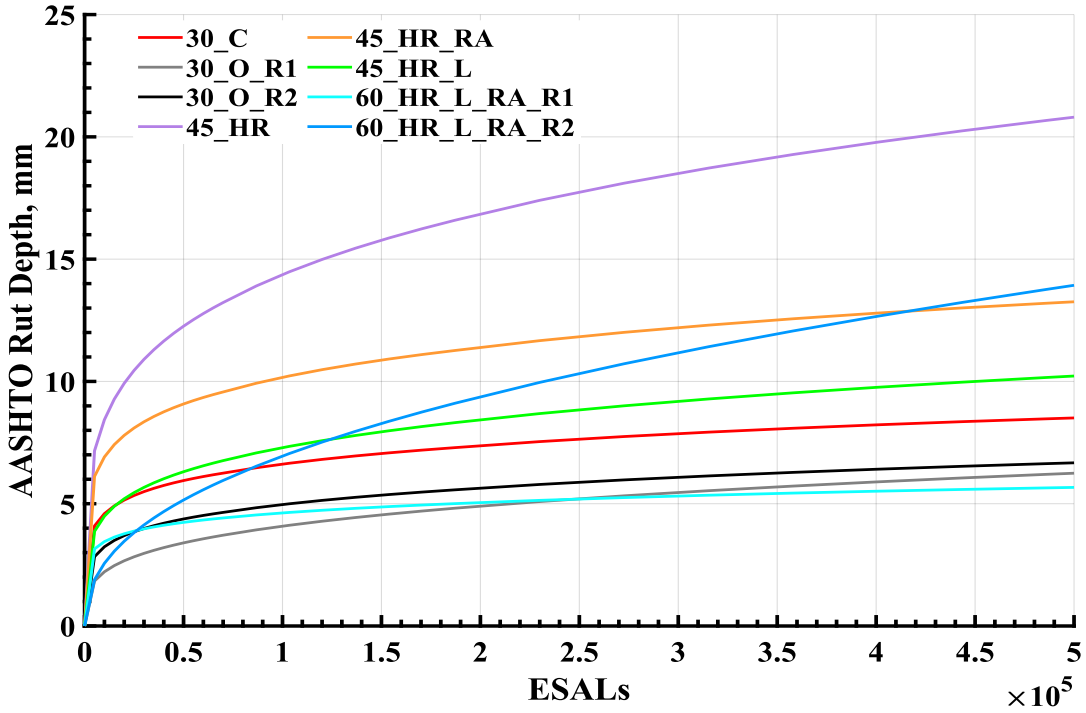


(a)

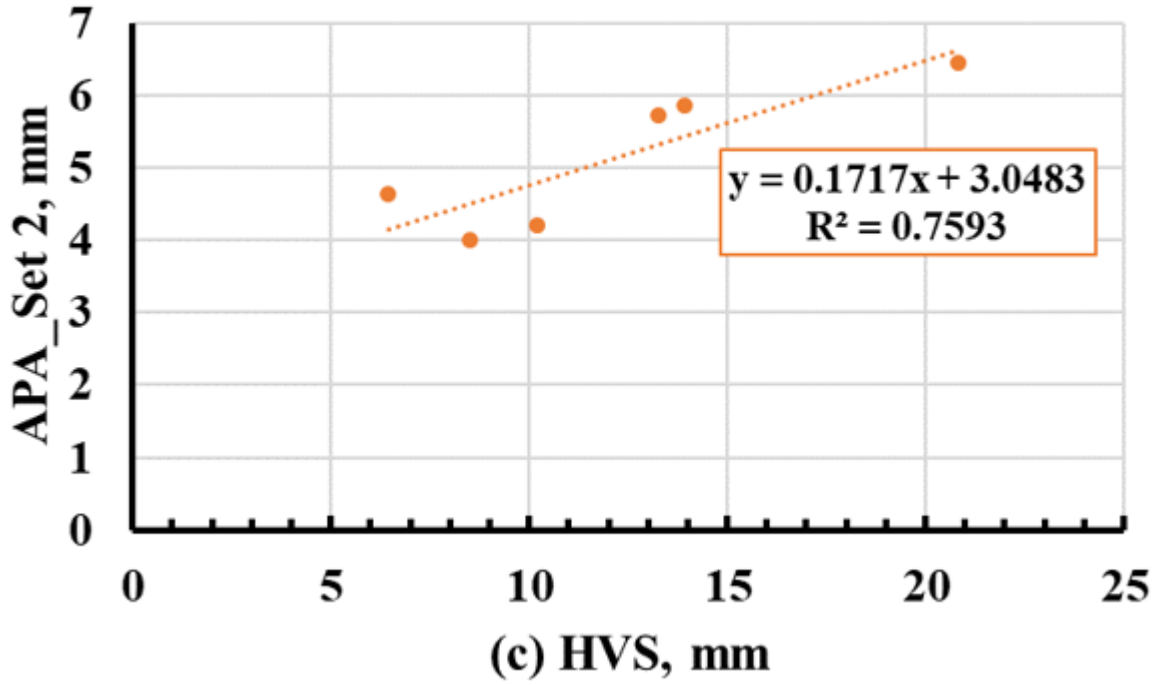


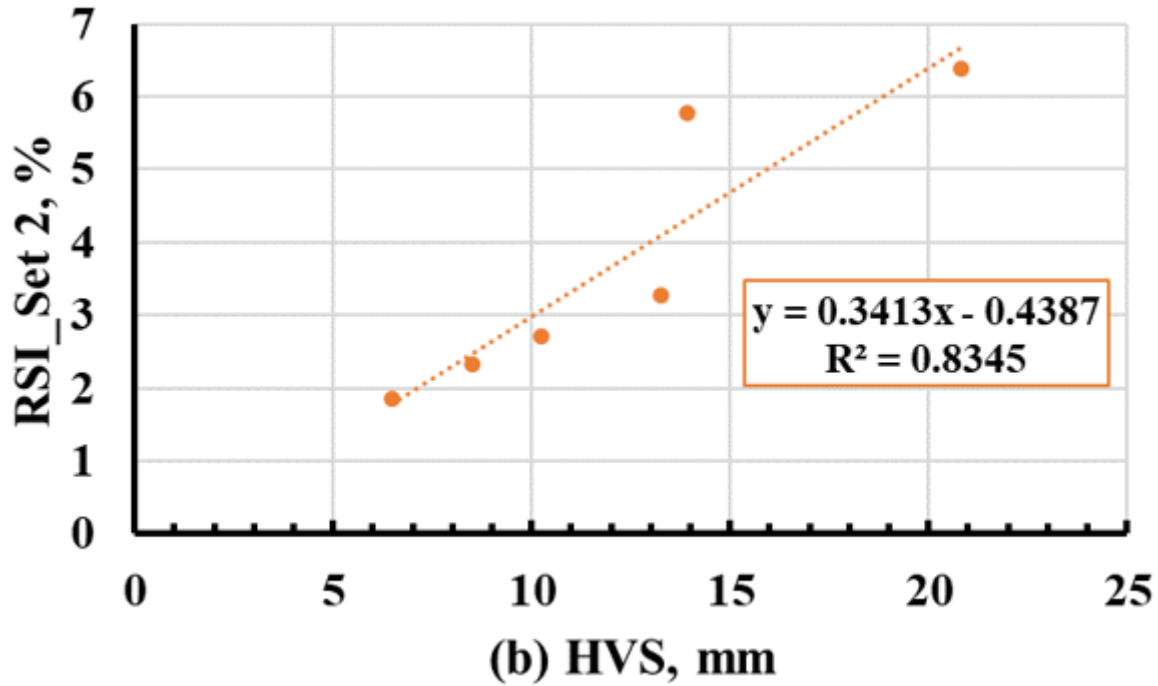
(b)

$$RD = \alpha \cdot ESAL^{\beta_1} \cdot Age^{\beta_2}$$

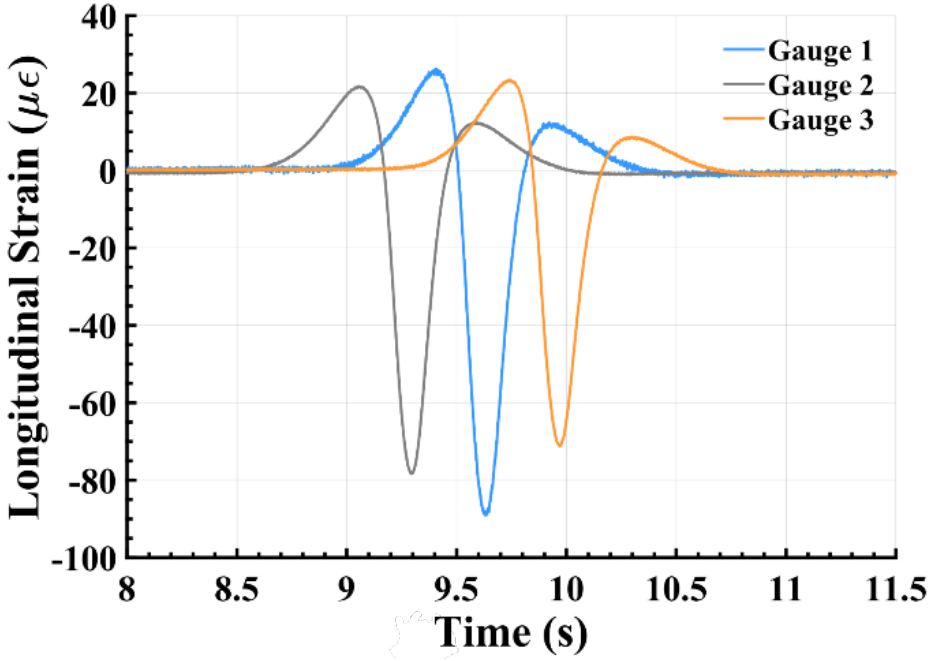


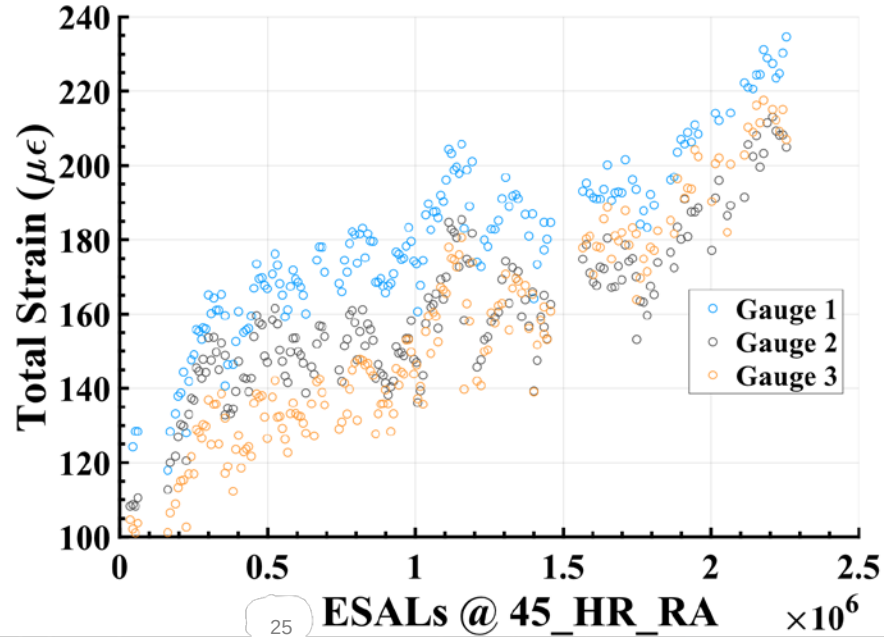
Preliminary Rutting Comparisons

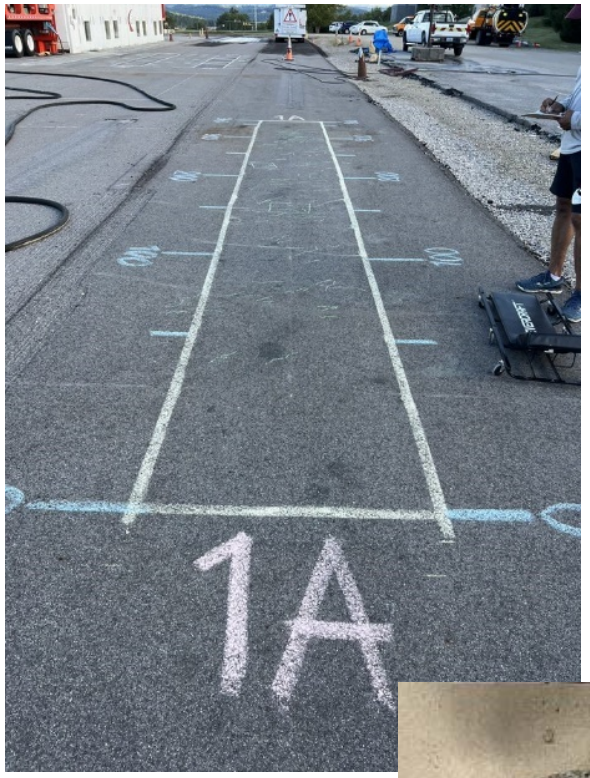




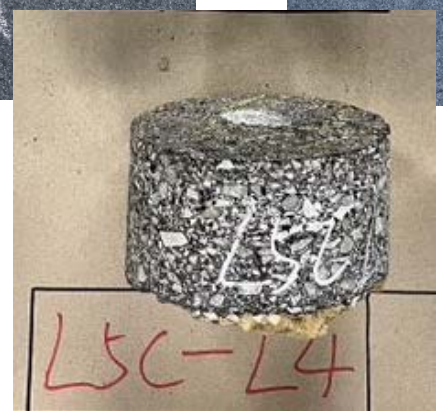
Cracking


Gauge 1
Gauge 2
Gauge 3
Longitudinal Strain (με)
Time (s)

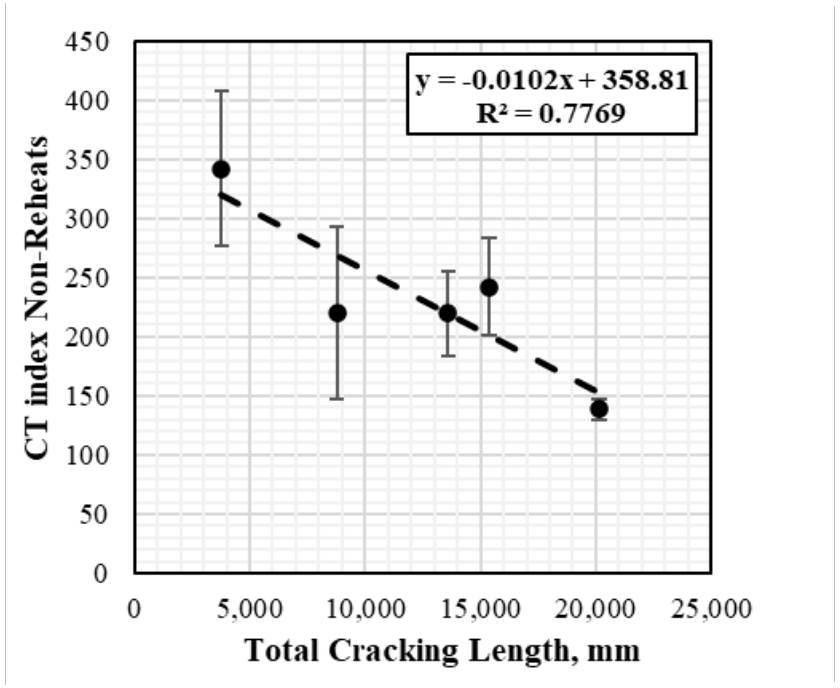

Gauge 1
Gauge 2
Gauge 3
Total Strain (με)
ESALs @ 45_HR_RA
×10^6

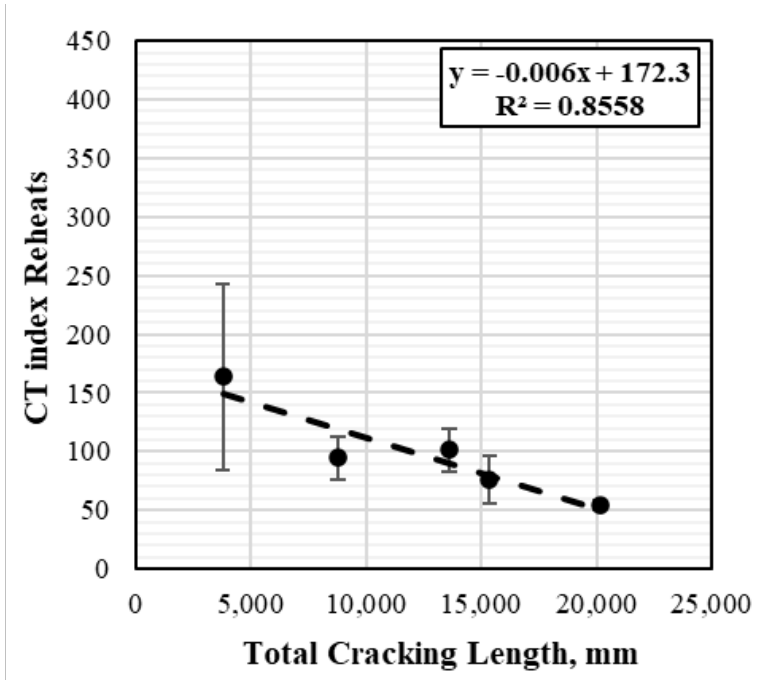

1A

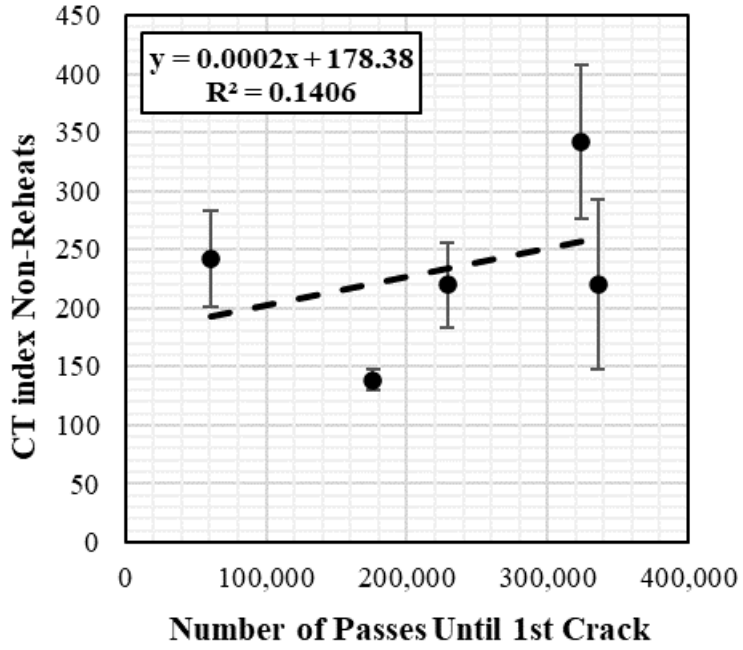

5C

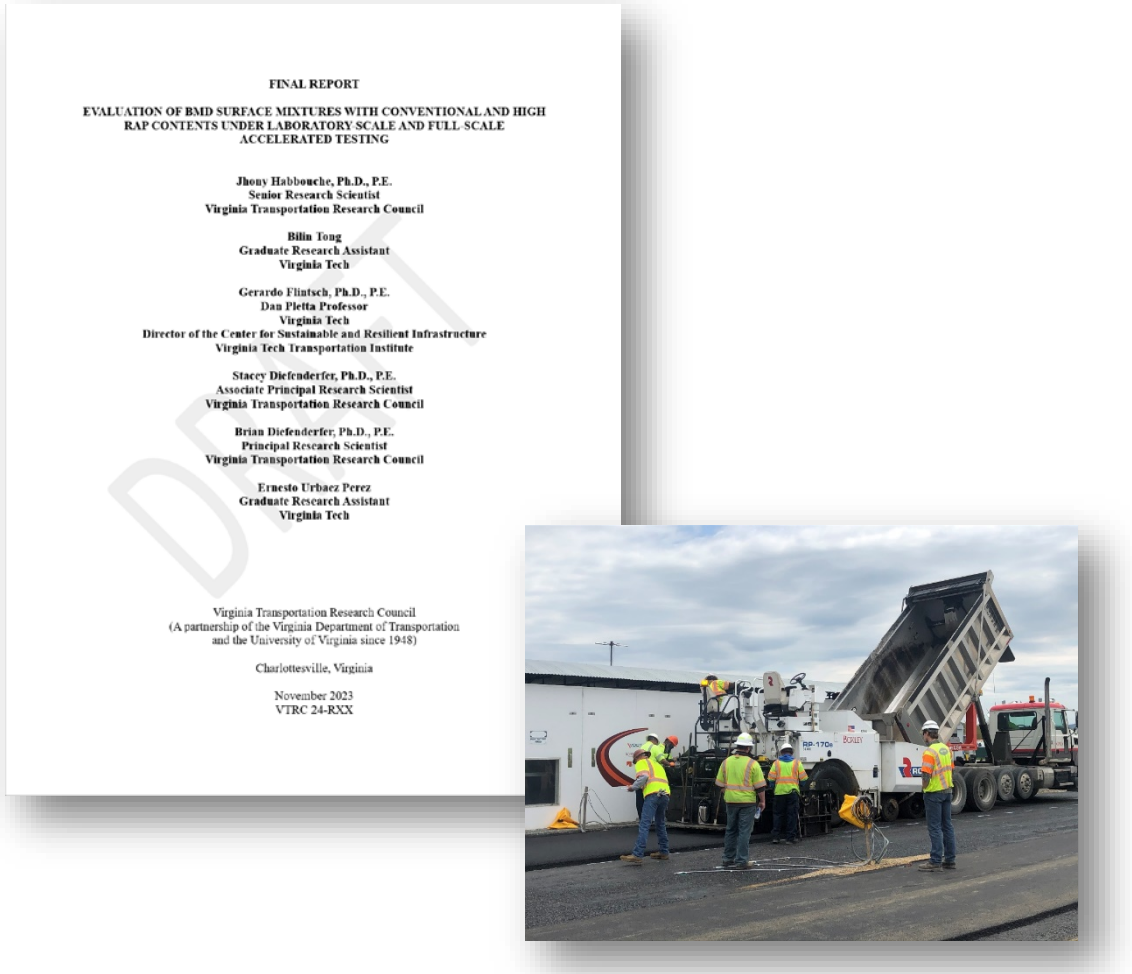

L5C-L4

Preliminary Cracking Comparisons









FINAL REPORT

EVALUATION OF BMD SURFACE MIXTURES WITH CONVENTIONAL AND HIGH RAP CONTENTS UNDER LABORATORY SCALE AND FULL SCALE ACCELERATED TESTING

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Charlottesville, Virginia

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VTRC 24-RXX

Preliminary Conclusions

Center for Sustainable & Resilient Infrastructure

Preliminary Conclusions (i)

- ✓ Surface Mixes with high RAP contents (45% or 60% by total weight of mixture), exceeding the conventional upper limit 30% set by the current specifications, can be designed using the current VDOT BMD special provision and can be successfully produced in the field.
- ✓ Recycling agents and/or a softer binder seem to be needed to be used when designing HRAP surface mixtures in Virginia.
- ✓ HRAP mixtures can be produced in the field with no significant alterations in aggregate gradations and asphalt binder content when compared to the gradations and binder content specified in the design.

Preliminary Conclusions (ii)

- ✓ Rutting
  - Strong agreement was observed between the APT rut depth measurements and the APA test results collected in the laboratory. APA rut test is expected to reflect the true rutting performance.
  - The current BMD APA rut depth threshold of 8 mm appears to be high and may need revision. Waiting for HARP real-world field performance data of pilots.
- ✓ Cracking
  - Strong linear relationships between cracking and CT index were observed. Additional data from other field trials needed to reach final conlcusions.
  - The CT index threshold of 70 and the ML threshold of 7.5% appears to be an acceptable starting point to design mixtures that perform similarly or even better than the conventional ones in Virginia.

Preliminary Conclusions (ii)

- ✓ APT can serve as a valuable bridge between laboratory testing and long-term pavement performance monitoring, offering accelerated insights through deliberate, intensified loading conditions and varied environmental factors.

Optimization of high-RAP mixes using Balanced Mix Design and Accelerated Pavement Testing

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