Path towards Reliable Implementation of Rejuvenated High-Recycled HMA

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Cargill

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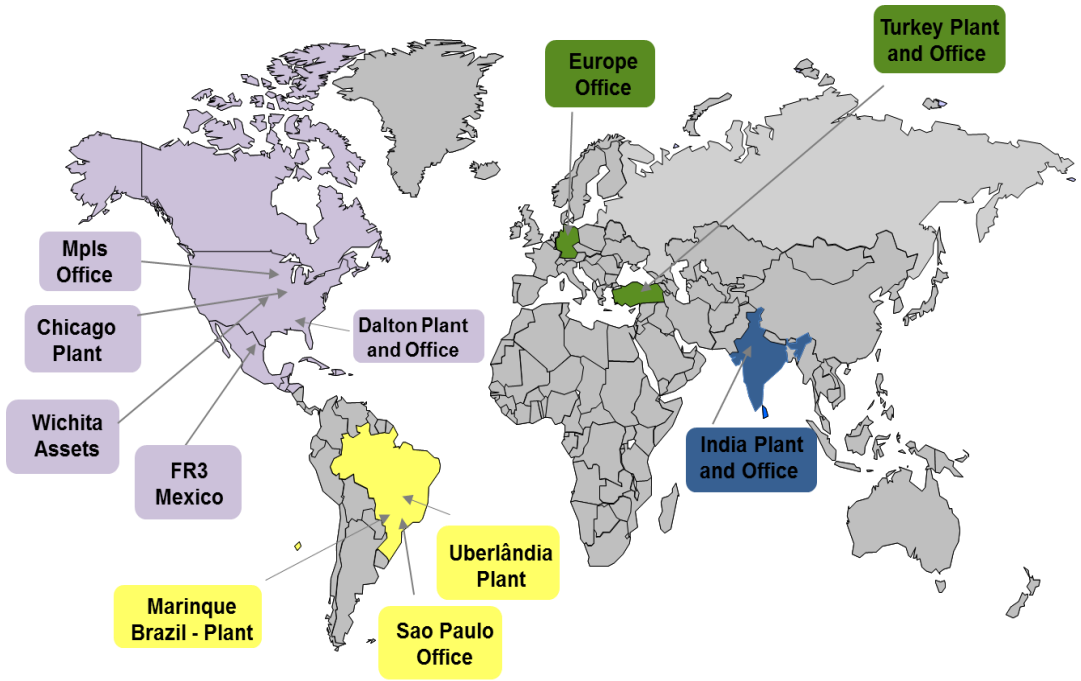
Cargill's Role in Asphalt

- Cargill is a developer and producer of bio-Industrial additives and sustainable performance industrial solutions.

1. Cargill Anova™ Rheology Modifiers
2. Cargill Anova™ Rejuvenators
3. Cargill Anova™ Cold Mix Solutions
4. Cargill Anova™ Anti-strips
5. Cargill Anova™ WMA
6. Cargill Anova™ Emulsifiers



Asphalt R&D Center located in Plymouth MN.

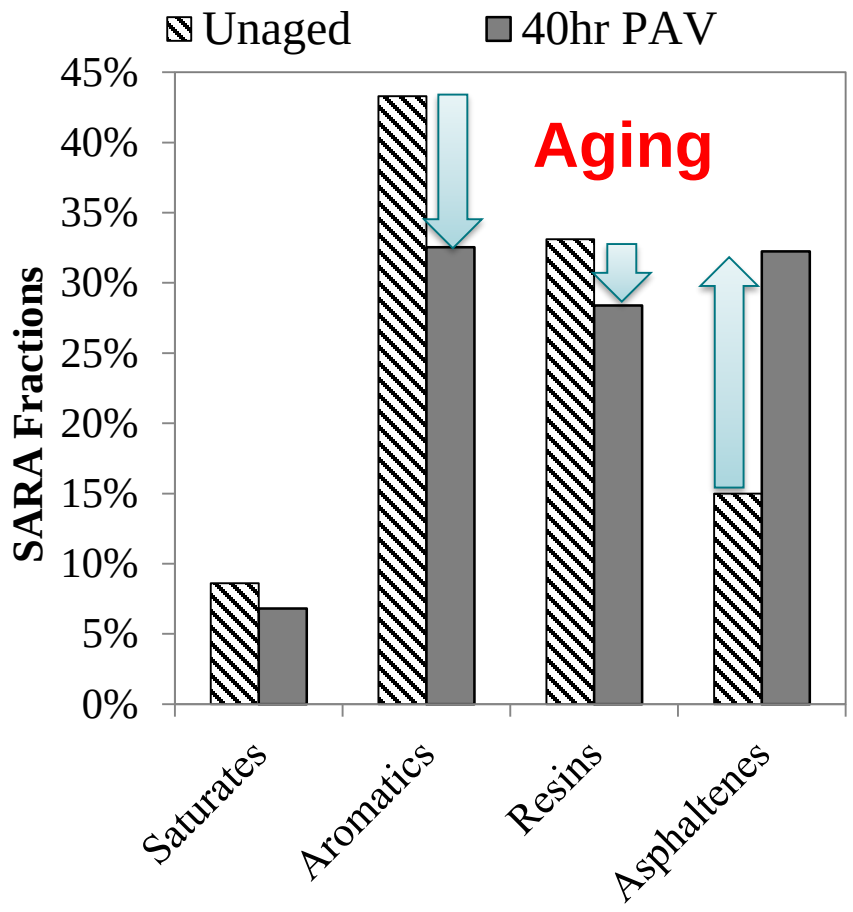
The Potential of high RAP Rejuvenation…

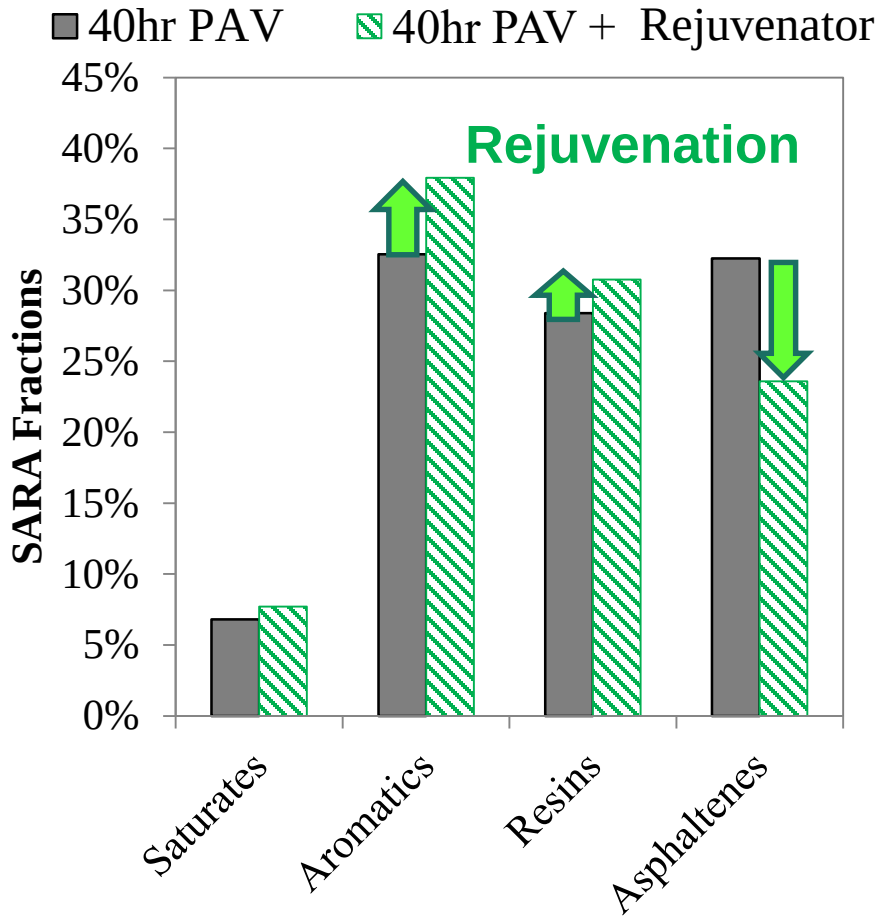
Introduction: Asphalt Aging

- Pavements age from the surface, downwards
- Aging is affected by rate of air permeability (porosity), climate conditions, UV, etc.
- Aged bitumen is more brittle and less durable.
  - Flaws can quickly become crack initiation points, and eventually water penetration points.
  - Excessive use of aged reclaimed asphalt pavement (RAP) can impart same properties to new pavements.
  - **An engineered solution is needed…**

- **“Rejuvenation” is an inaccurate, but popular term.**
  - Rejuvenators do not undo oxidative aging!!!
- **A good rejuvenator** reverses the impact of aging on asphalt, reactivating the bitumen, to restore performance, and durability.

Re-Balancing Bitumen Fractions





Thin Layer Chromatography (TLC) using an Iatroscan

Plant Incorporation Process

Many options for dosing:

- In virgin bitumen using antistrip pump
- Pre-blended into virgin bitumen
- Pre-treatment of RAP
- Injection into pugmill
- …

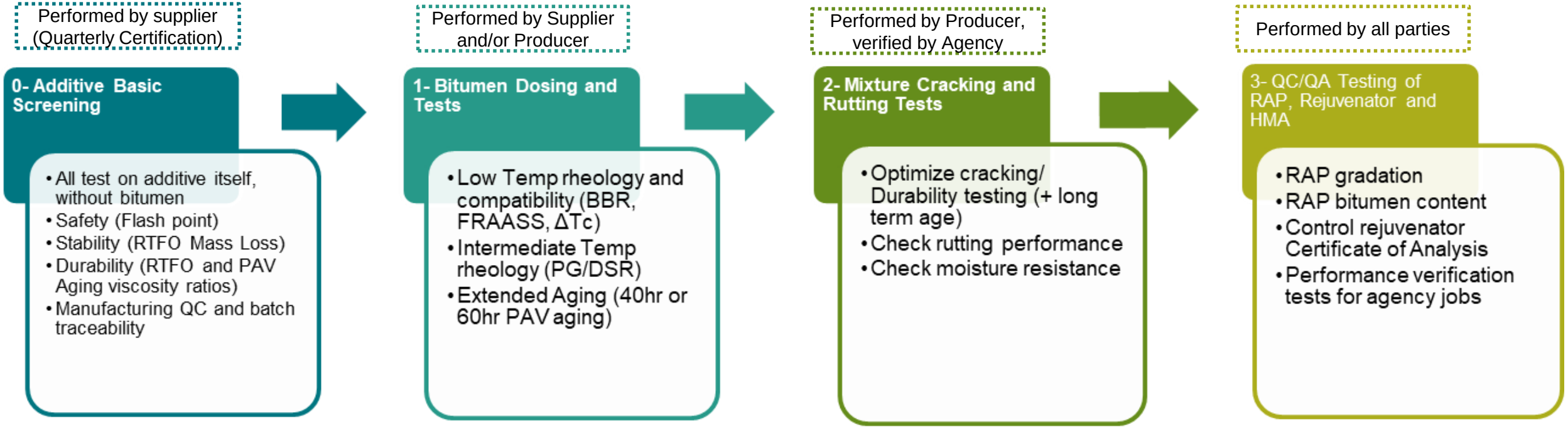
- Additive injected in-line to the bitumen line connecting bitumen tank to asphalt drum. Dosing system is similar to that utilized for liquid antistrip additives.

What is the process for producing high-RAP mixes?

1. **Check and meet the fundamentals:**
   - Can the plant reliably handle more RAP? (Capacity, belts, flights, dryers, etc.)
   - Do I have a way to introduce rejuvenators into my mix at the plant? (e.g. a liquid antistrip system or similar additive setups)
   - Do I have enough RAP?

2. **Implementation:**
   A. For implementation in “non-spec” commercial mixes: Work with rejuvenator supplier on the appropriate dosage to produce higher RAP mixes with quality consistent with normally supplied mix designs. Step up RAP QC frequency.
   B. For implementation in agency “spec” mixes: Fundamentally the same, but also requires a framework that provides **transparency and reliability for all stakeholders**.

High Level Typical Process Flowchart



- All Test Methods listed below are just possible examples
- It is not anticipated that all tests on every list would be necessary.
- Level of rigor should be proportionate to job type and service level.

Example of Step 0: Rejuvenator Screening/Selection
(Expansion of tests listed in ASTM D4552, not standardized)

- This step insures that rejuvenator meets basic requirements for safety, thermal stability, storage stability, and compatibility to be used in Hot Mix Asphalt production.

Rejuvenator Properties	Potential Limits (Internal specifications)	Anova 1815 Rejuvenator
Homogeneity (Storage Stability)	Stable, Homogenous	Stable, Homogenous
Density @ 25 °C, g/ml	Asphalt ±10% (0.90-1.10)	0.94
Pour point (pumpability) Temperature	Max 32°F (0°C)	-5°C
Flash Point °C, Open Cup	Min 240°C (as in Asphalt)	>290°C
N-Heptane Insoluble Content	Max 1.0% (No Asphaltenes)	0.1%
RTFO Aging Viscosity Index	Max 3.0 (Similar to asphalt)	1.05
RTFO Mass Loss	<1.0% (as in asphalt)	<0.5%
PAV Aging Viscosity Index	Max 3.0 (to be verified)	1.10

So: What is the typical process for Agency high-RAP mixes?

Design Methods:

Option 1: Performance-modified Volumetric Design: AC content based on voids, determine rejuvenator content to meet performance

Option 2: "Full" Balanced Mix Design (BMD): Determine AC and rejuvenator directly based on performance test instead of voids.

- Designing a high performance HMA with rejuvenation is a 3+1 step process:
  - Step 0: Rejuvenator characterization and Quality Control (performed by **Rejuvenator supplier**)
  - Step 1: Initial dosage determination based on rheology (performed by **Rejuvenator Supplier,** based on **HMA Producer's** Volumetric mix design)
  - Step 2: Performance-modified mix design (**HMA Producer**, supported by **Rejuvenator Supplier**)
  - Step 3: Robust QC/QA protocol to be followed for all material. (**All Parties Involved**)

Examples of Current BMD Systems adopted by agencies

Agency:	New Jersey DOT	Chicago DOT	Illinois Tollway	Illinois DOT	Virginia DOT
Durability Test	Overlay Tester	DCT	DCT + IFIT	IFIT	IDEAL-CT, Contabro
Rutting Test	APA	Hamburg	Hamburg	Hamburg	APA
Binder Specification	None	Extracted pass PG XX-22, ΔTc > 5	None	None	None
High-RAM Approval Process	Mix Design Approval	Mix Design approval and trial	Mix Design approval and trial	Meet Spec Limits	Meet Spec Limits
State of Implementation	Active as of 2018	Active as of 2018	Active as of 2018	Active as of 2019	Trial spec as of 2019

Balanced Mix Design for Minnesota:
MnDOT Approved Mix for I-94 Freeway

Approval Process

1. Lab samples were prepared based on rejuvenator supplier dosage recommendations and HMA producer's mix design.
2. Laboratory performance tests were conducted to determine reasonable equivalence to control.
3. Binder extraction tests were conducted on lab samples to determine reasonable equivalence to control.

45% RAP + Anova™ Rejuvenator vs. Control: 25% RAP

"Performance-modified" Volumetric Mix Design:

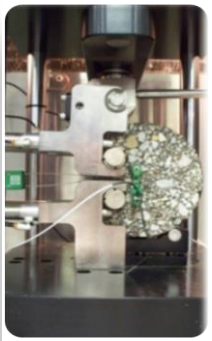
- AC% optimized by VMD, standard densities
- Performance checked with DCT and Hamburg

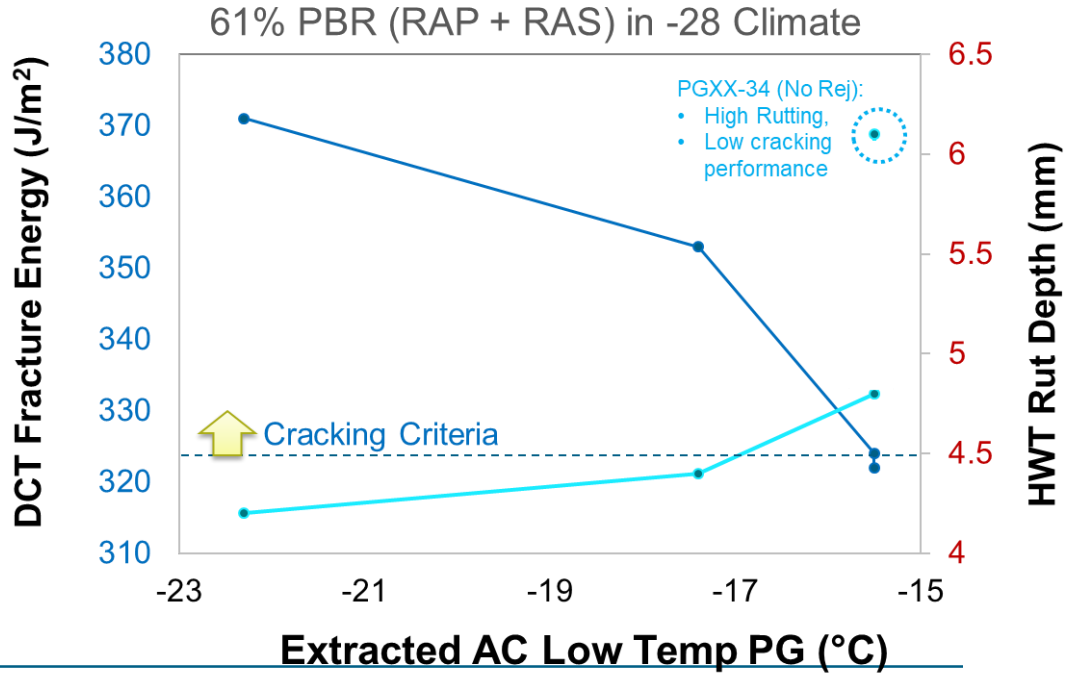
Description	Extract AC %	HT PG	LT S PG	LT m PG	ΔTc	DCT -20°C (J/m^2)	HWT at 50°C n=5K
25%RAP Control	5.19%	65.1	-29.6	-24.3	-5.2	502.8	7.95mm
45%RAP Rejuvenator	4.51%	66.5	-28.7	-27.2	-1.5	495.0	2.35mm

Balanced Mix Design for City of Chicago:
Chicago DOT Approved Mix

55% FRAP, 5% RAS, Surface Course

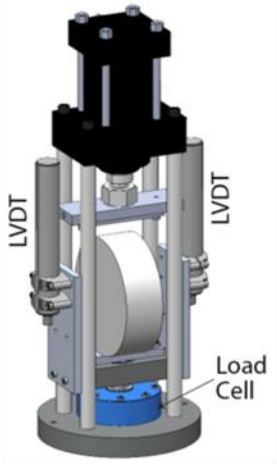
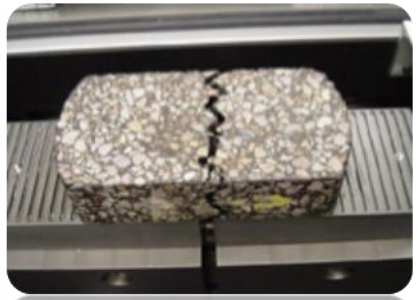
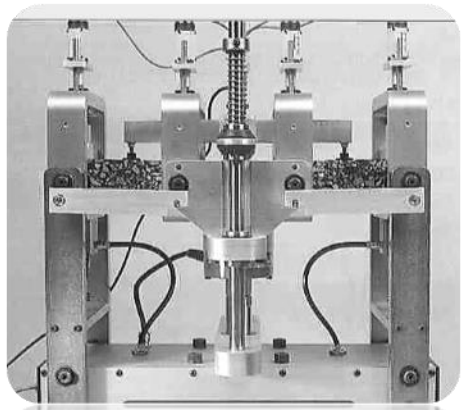
1. Lab samples were prepared based on supplier's dosage recommendations and HMA producer's mix design.
2. Laboratory performance tests were conducted to determine reasonable equivalence to control.
3. Binder extraction tests were conducted on lab samples to confirm reasonable equivalence to control.
4. After lab approval a plant trial was carried out verifying design performance.
5. Mixture has been approved and in use since 2017.





More Rejuvenator

But do we have enough tests?

DCT	IDEAL-CT	IFIT / SCB	Overlay Tester	Beam Fatigue
				
Disc Compact Tension	Indirect Tensile Asphalt Cracking Test	Illinois Flexibility Index Test / Semi-circular Bend	a.k.a. Texas Overlay Tester	4-point Beam Fatigue
Low Temp PG + 10	25°C or room	Generally 25°C or room	25°C (or 15°C)	Varies 4-25°C
Cut and notched sample	Sample only compacted to height	Cut and notched sample	Cut sample	Cut sample after Slab compaction

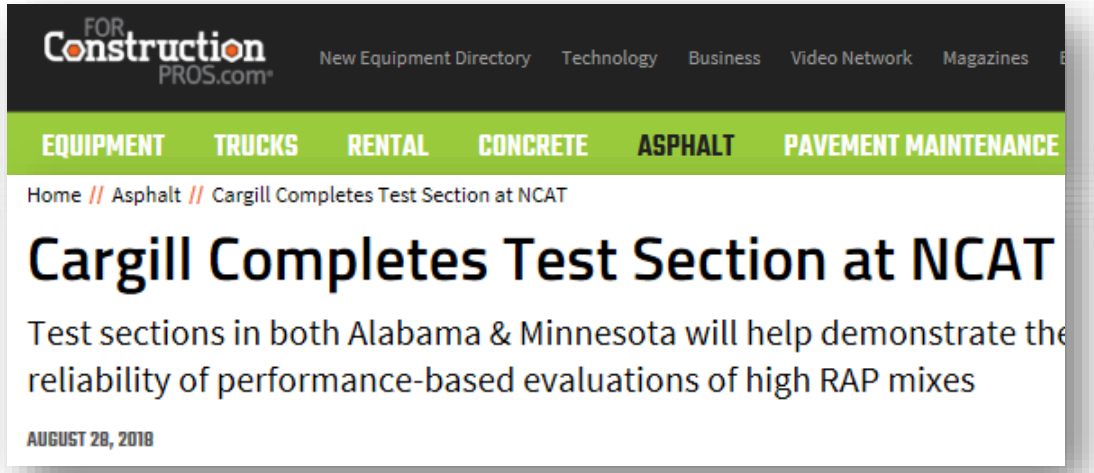
NCAT + MnROAD + Cargill Partnership:

Objective: Answer critical questions needed for Implementation of Hi-RAM BMD


EQUIPMENT WORLD'S
BETTER ROADS
EQUIPMENT BETTER ROADS

Cargill, NCAT, MnROAD launch project to give states 'real-world data' on new design principles

Joy Powell | August 30, 2018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Cargill Completes Test Section at NCAT

Test sections in both Alabama & Minnesota will help demonstrate the reliability of performance-based evaluations of high RAP mixes

AUGUST 28, 2018

- 5 main mixes with varying RAP content, Rejuvenator content, Virgin Binder types (good and bad ΔTc)
- Cold climate and warm climate comparisons
- All mixtures to be tested using DCT, Overlay, IFIT, IDEAL-CT, Hamburg, APA, Contabro, and TSR.
- Cracking tests after short term and long term aging.
- Outcomes:
  - Establish equivalency levels, and long term aging impacts across all test types.
  - Potential QC/QA methods

NCAT + MnROAD + Cargill Partnership

NCAT Trial (Auburn, AL with VDOT)

- 45% RAP + Anova™ Rejuvenator
- Control: 30% RAP
- Balanced Mix Design
  - AC% optimized by IDEAL-CT and APA
  - Air voids allowed to vary (higher density)

Description	HT PG	LT m PG	ΔTc	IFIT FI	DCT -12°C (J/m²)	IDEAL-CT	Overlay NJDOT	APA at 64°C
30%RAP Control	76.7	-14.6	-9.2	6.1	520	124	296	2.51mm
45%RAP Rejuvenator	75.9	-22.0	-2.0	8.0	565	100	325	2.55mm

MnROAD Trial (Minneapolis, MN with MNDOT)

- 45% RAP + Anova™ Rejuvenator
- Control: 25% RAP
- “Performance-modified” Volumetric Mix Design
  - AC% optimized by VMD, standard densities
  - Performance checked with DCT and Hamburg

Description	Extract AC %	HT PG	LT S PG	LT m PG	ΔTc	DCT -20°C (J/m²)	HWT at 50°C n=5K
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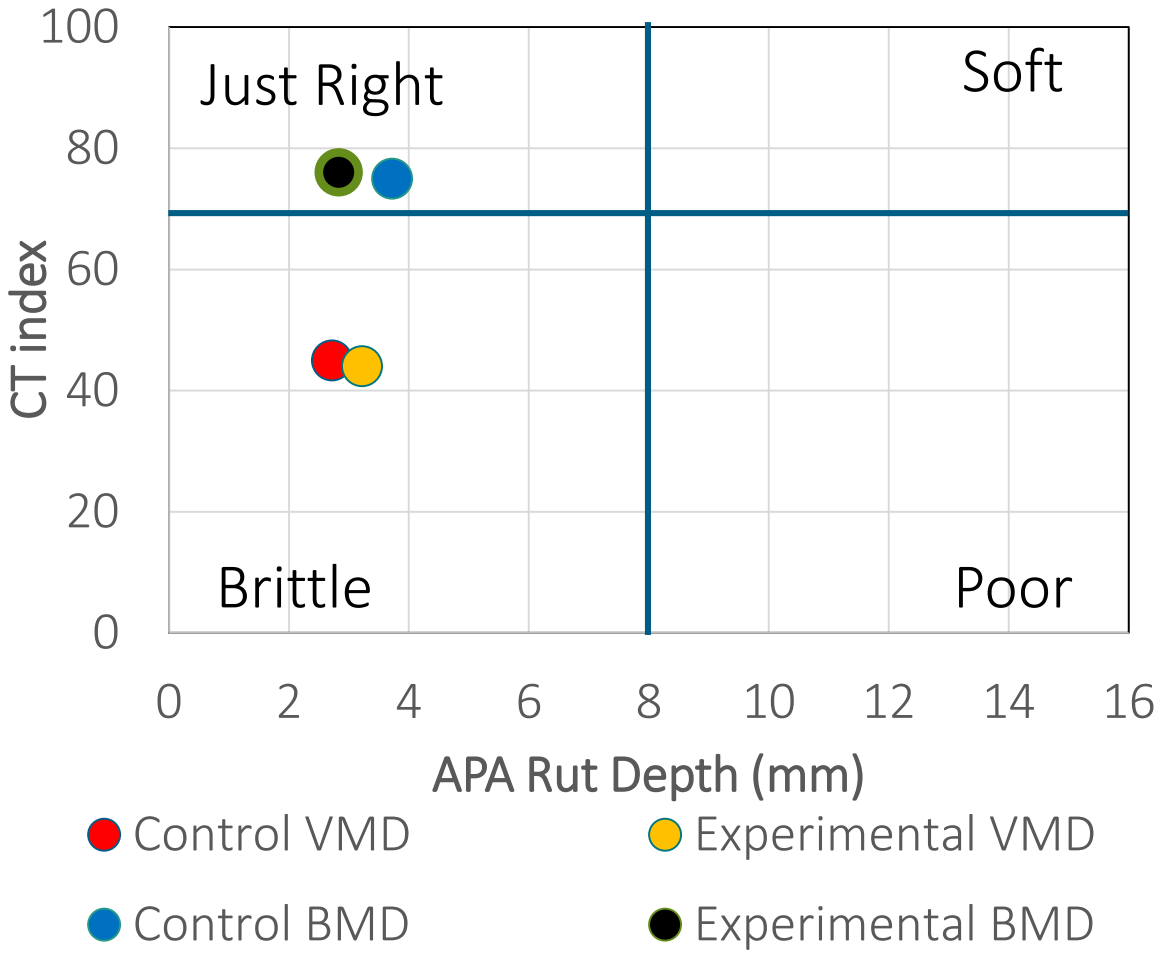
VDOT Specification: From VMD to BMD



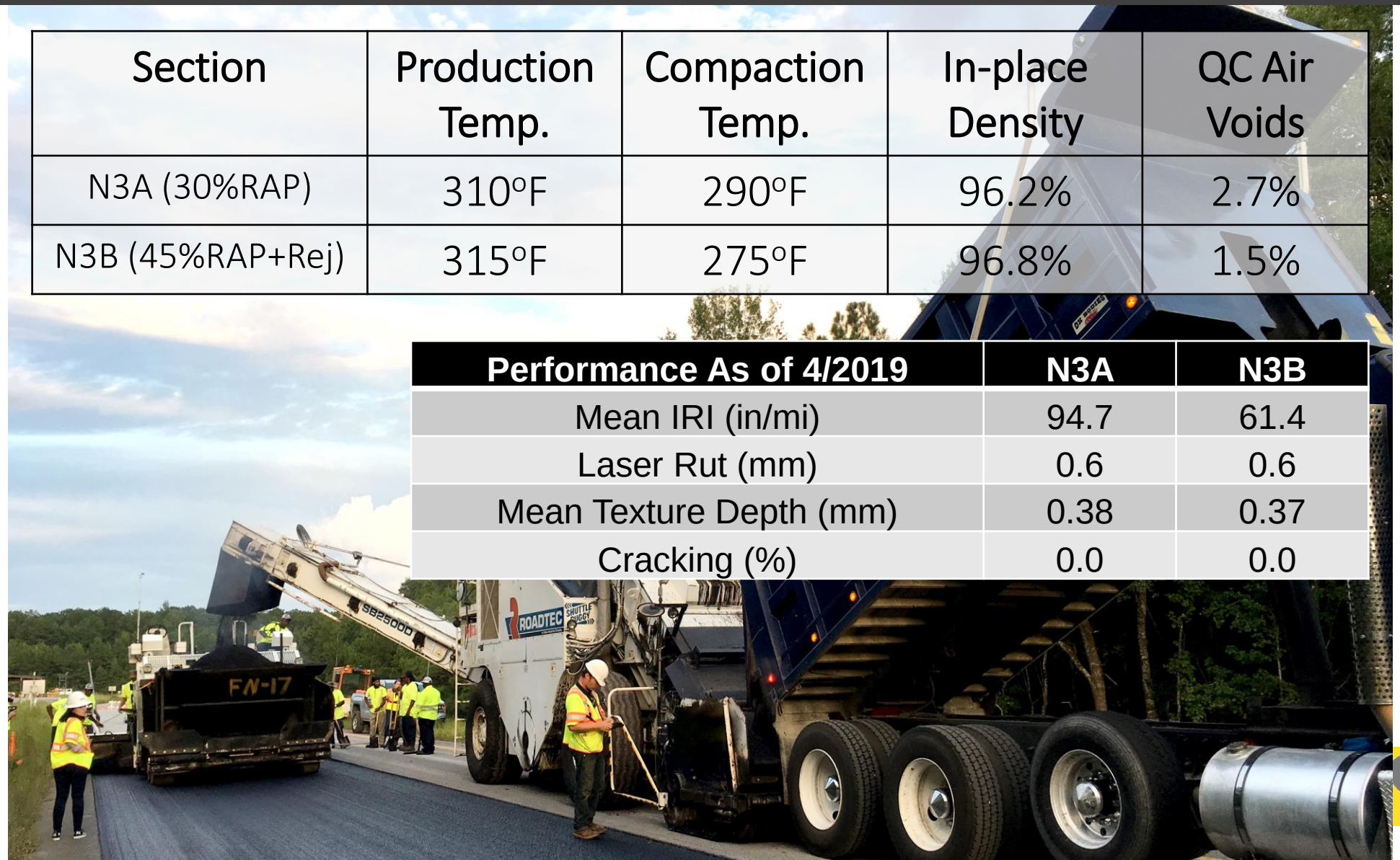
Parameter	VMD Control (30% RAP)	BMD Control (30% RAP)	BMD Experimental (45% RAP)	VDOT Specification
Total AC%	5.19	5.50	5.80	
% Virgin binder	3.86	4.17	3.59	
RAP ABR	0.26	0.24	0.38	
Va (%)	4.0	2.9	2.3	4.0
VMA (%)	16.3	15.8	16.2	Min. 16.0
VFA (%)	75.9	82.4	85.8	70 – 85
DP	1.07	1.00	1.07	0.7-1.3
TSR	0.89			
APA Rut (7% Va)	2.72 mm	3.72 mm	2.83 mm	≤ 8.0mm
Cantabro Loss	3.5%			
CT_{index}	45	75	76	≥ 70

- Meeting VDOT BMD required higher AC content at low RAP and use of a Rejuvenator at high RAP.
- With adoption of BMD, some VMD specification become superfluous and can be loosened.

Construction (Sep. 6, 2018)

Section	Production Temp.	Compaction Temp.	In-place Density	QC Air Voids
N3A (30%RAP)	310°F	290°F	96.2%	2.7%
N3B (45%RAP+Rej)	315°F	275°F	96.8%	1.5%

Performance As of 4/2019	N3A	N3B
Mean IRI (in/mi)	94.7	61.4
Laser Rut (mm)	0.6	0.6
Mean Texture Depth (mm)	0.38	0.37
Cracking (%)	0.0	0.0



National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Conclusions and Summary

- Implementation of high RAP + Rejuvenators in “non-spec” commercial mixes can be highly practical and feasible today:
  - Work with rejuvenator supplier on the appropriate dosage to produce higher RAP mixes with quality consistent with normally supplied mix designs.
  - Step up RAP QC frequency.
- Implementation of high RAP + Rejuvenator in agency “spec” mixes requires a framework that provides **transparency and reliability for all stakeholders**.
- Designing a high performance HMA with rejuvenation is a 4-step process:
  - Step 0: Rejuvenator characterization and quality control (supported by supplier)
  - Step 1: Bitumen Design: Initial dosage determination based on rheology
  - Step 2: Balanced Mix Design (BMD) using performance-related tests to optimize and select design parameters.
  - Step 3: Robust QC/QA protocol to be followed for all material.

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