“Four Pillars of WMA”

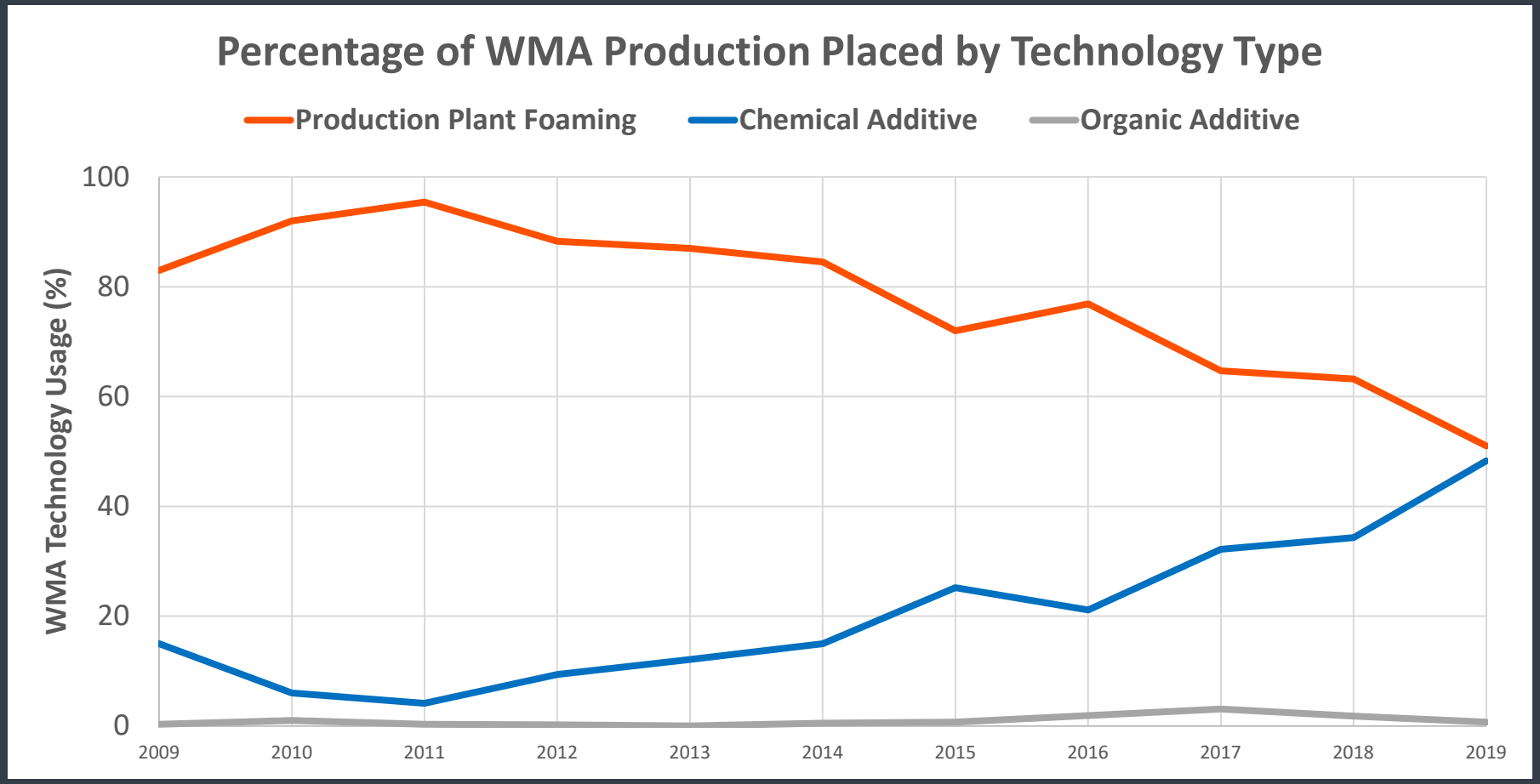
Benefits of WMA and Lower Mixture Production Temperatures

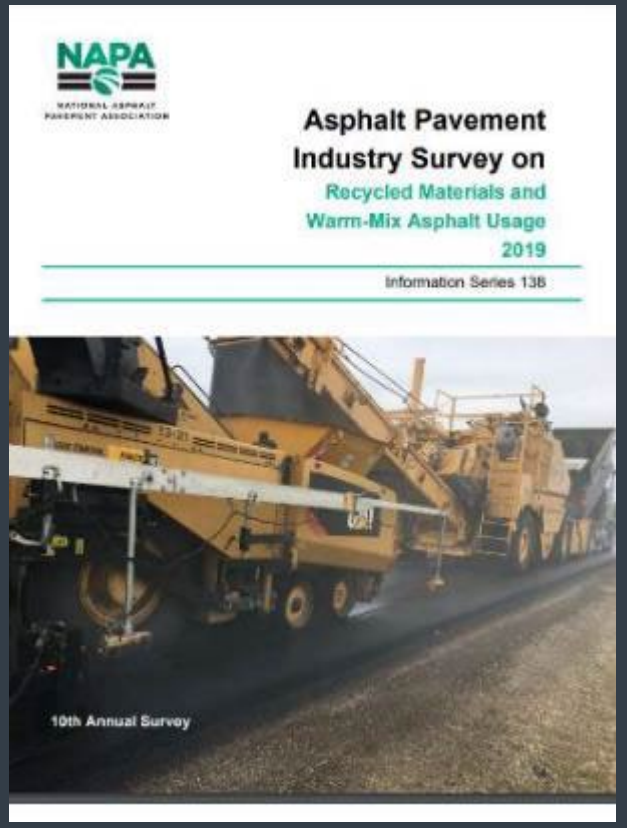
65th APAM Annual Conference

February 22, 2022

Trey Wurst, P.E.

NAPA Survey on WMA Usage





Data taken from NAPA's "Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2019"

WMA Technology	% Production										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Production Plant Foaming	83.0	92.0	95.4	88.3	87.0	84.5	72.0	76.9	64.7	63.2	51.0
Additive Foaming	2.0	1.0	0.2	2.0	0.3	0.0	2.1	0.0	0.0	0.7	0.0
Chemical Additive	15.0	6.0	4.1	9.4	12.1	15.0	25.2	21.1	32.2	34.3	48.3
Organic Additive	0.3	1.0	0.3	0.2	0.0	0.5	0.7	1.9	3.1	1.8	0.7

Ingevity


Left Lane 340-350F
Production temperature
92-93% density
Better
Binder Life
in the Field
Right Lane 265-290F
Included WMA Additive
94%+ density

The “Four Pillars Approach” to WMA

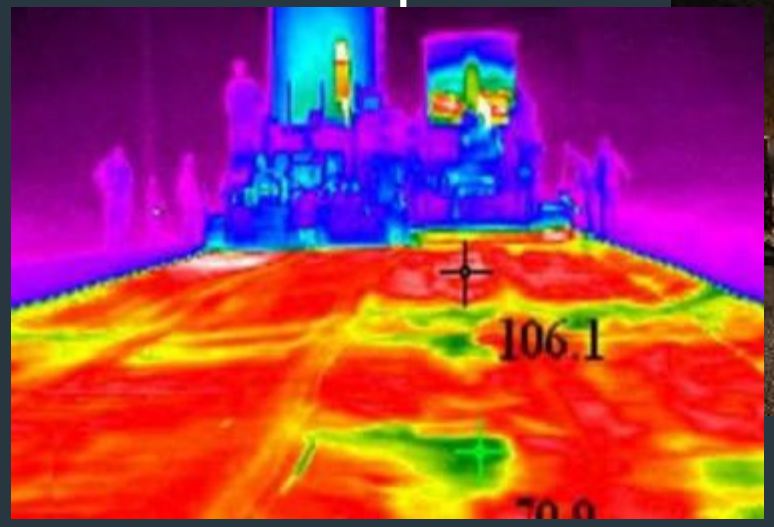
Field Performance

Binder Analysis

Pavement Design

Reduced Carbon Footprint

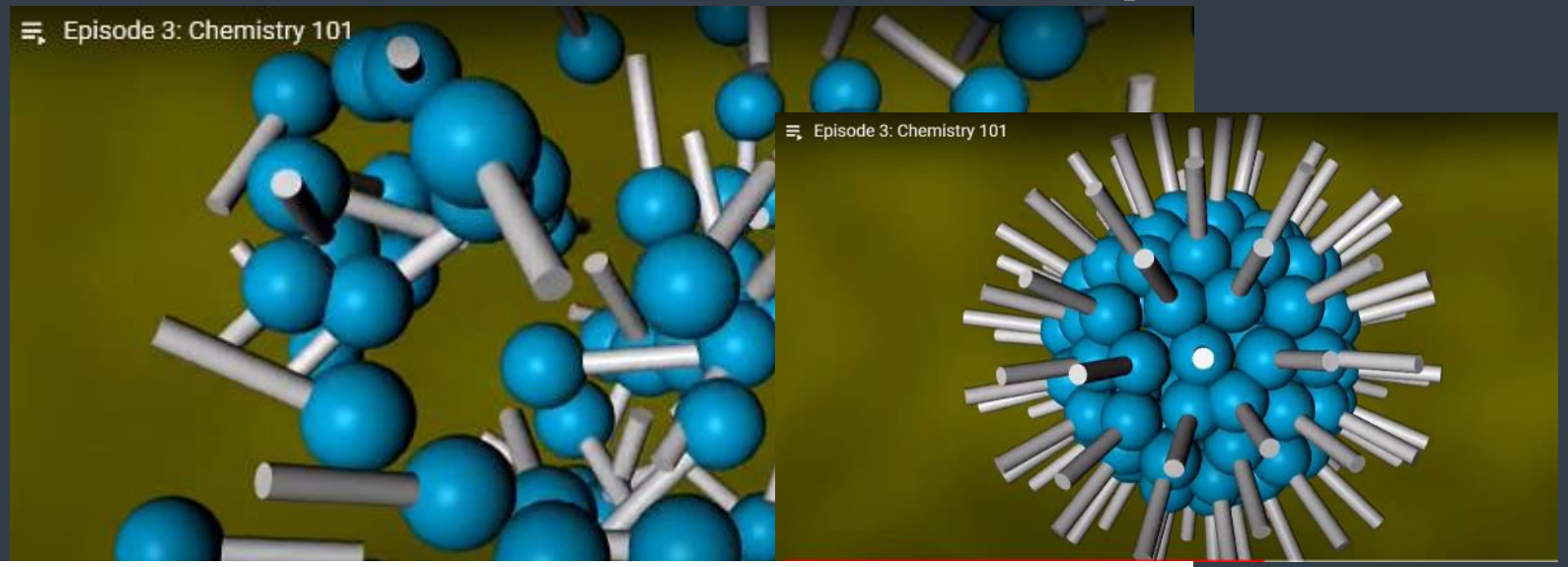
Total WMA Producers in 2018	185	100%
WMA Technologies used at WMA & HMA Temperatures	97	52.4%
WMA Technologies used at WMA Temperatures Only	52	28.1%
WMA Technologies used at HMA Temperatures Only	36	19.5%



Surfactants – How Evotherm Chemistry Works

- Surfactants form micelles which act like ball-bearing lubricants
- Same way soap works
- YouTube video series explaining Evotherm chemistry
- YouTube video link below to Video 1 of 4.

https://www.youtube.com/watch?v=Flii1fp76NY&t=99s



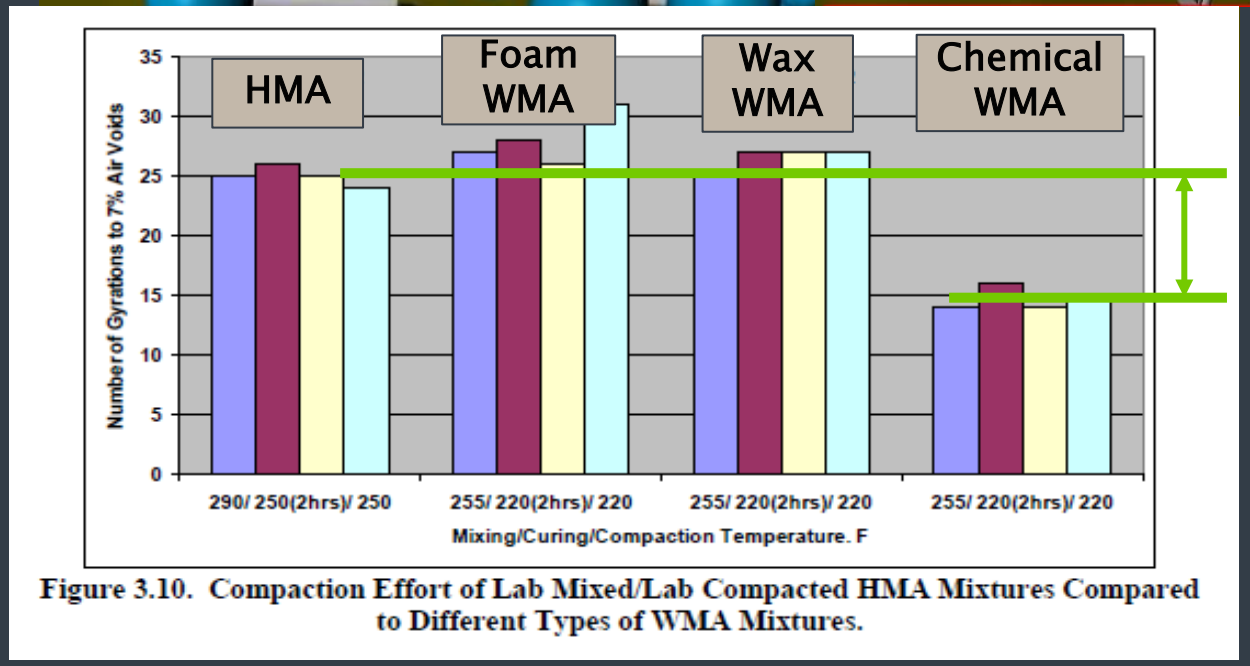


Figure 3.10. Compaction Effort of Lab Mixed/Lab Compacted HMA Mixtures Compared to Different Types of WMA Mixtures.

40% Reduction in Compaction Effort

Estakhri, Cindy. "Laboratory and Field Investigation of Warm Mix Asphalt in Texas." FHWA/TX-10/0-5597-02. July 2010

Ingevity

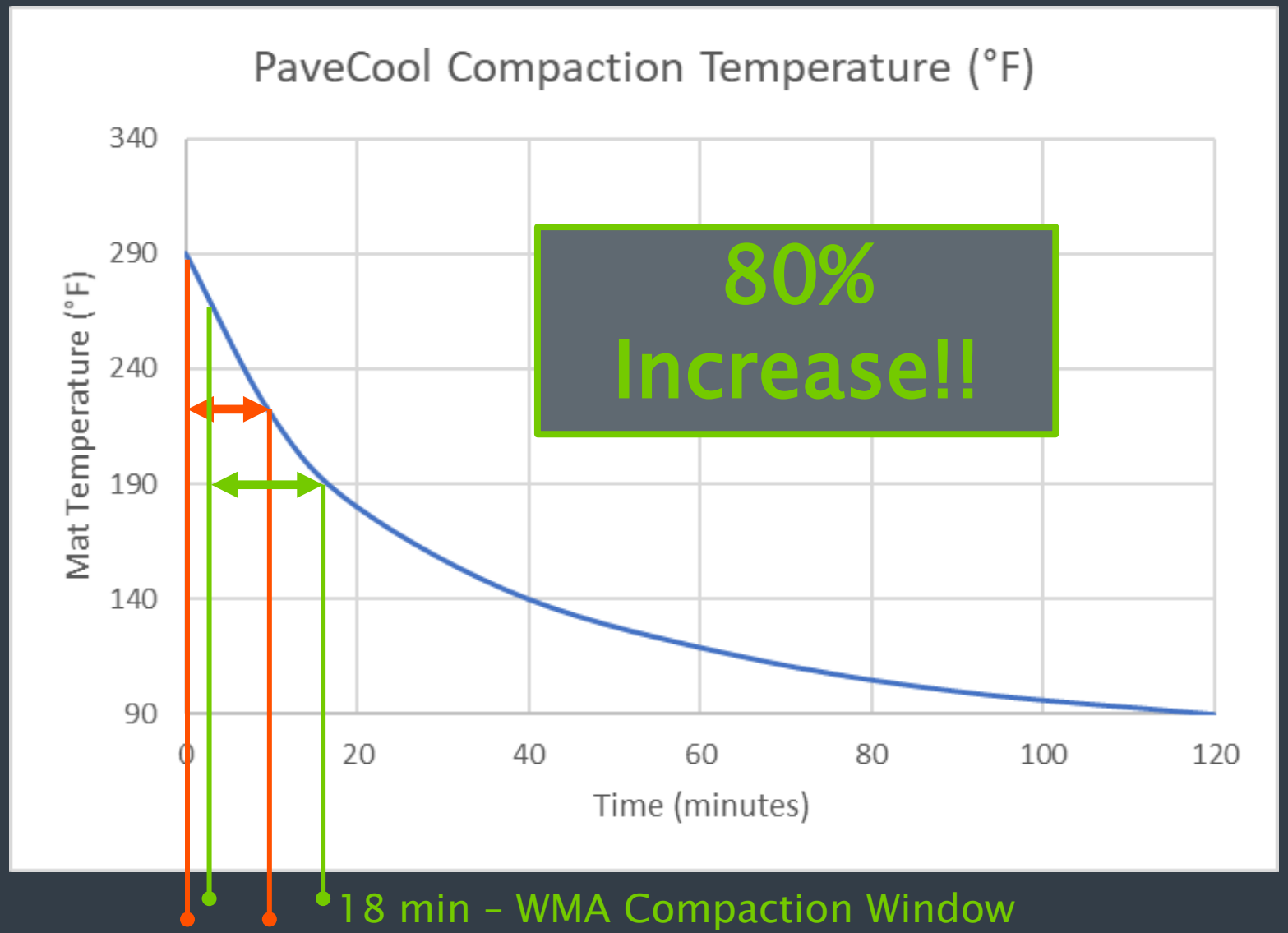
Compaction Window

Assumptions

- 2 in lift
- 50°F Ambient Temps
- 5 mph wind speed
- Dense graded mix

HMA
Mix Temp - 305°F
Compaction Temp Window 290°F - 220°F

WMA
Mix Temp - 275°F
Compaction Temp Window 260°F - 190°F



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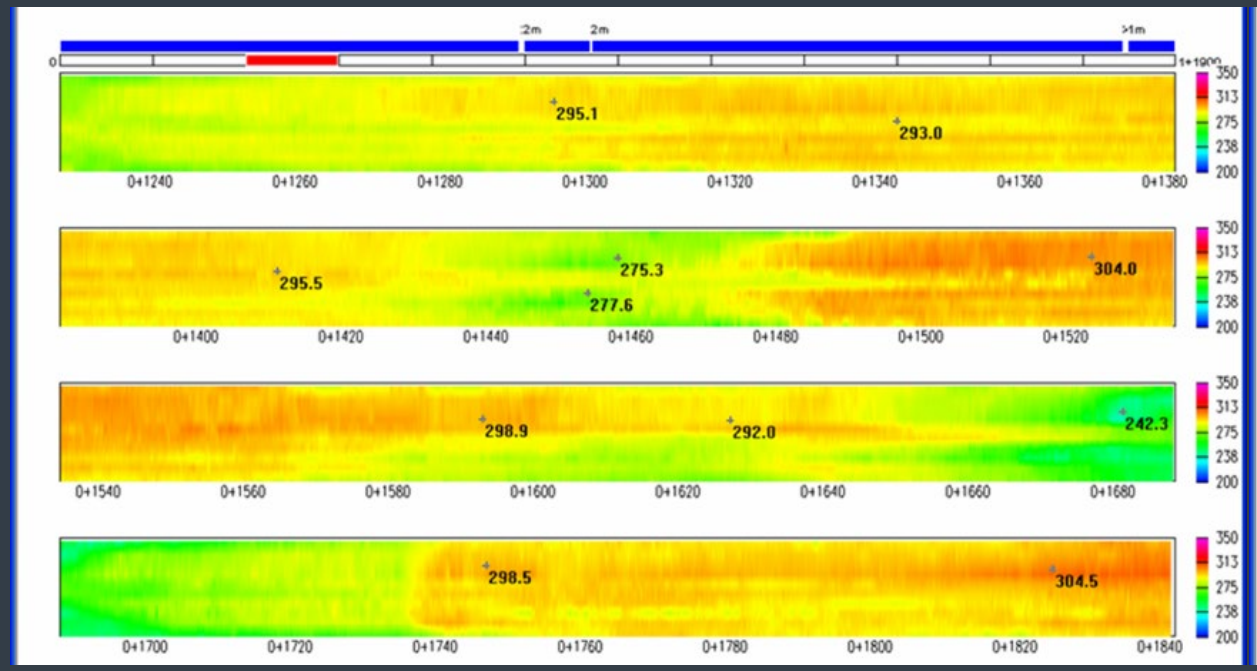
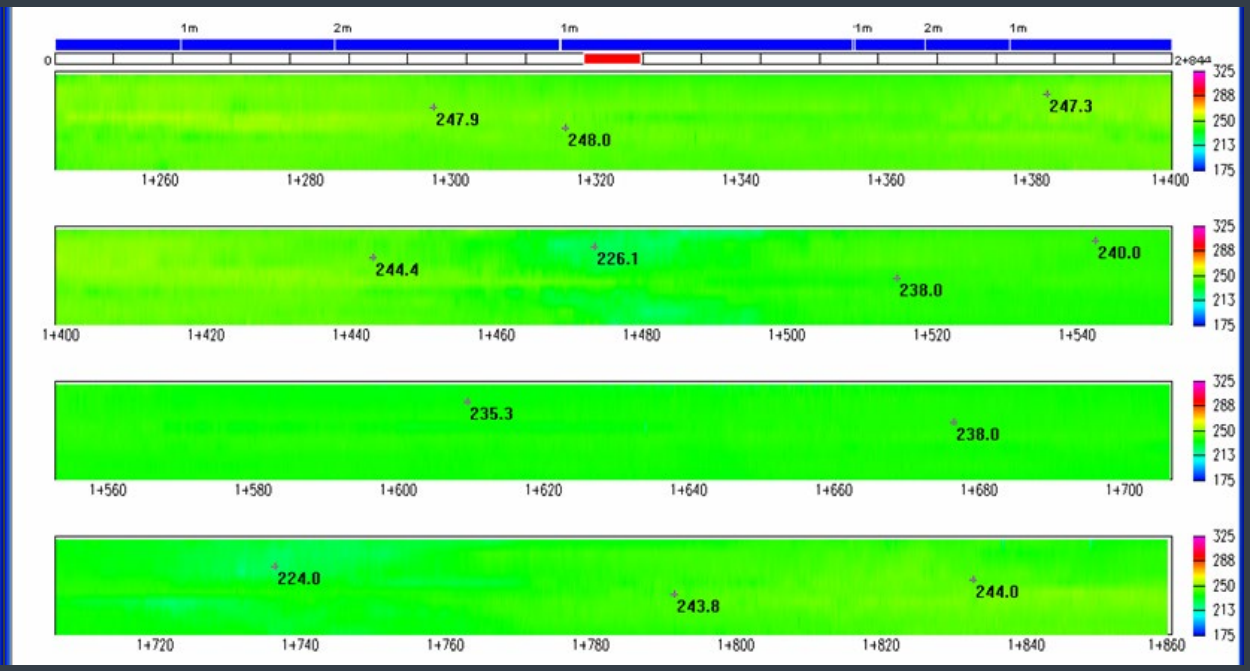
Thermal Segregation





62°F Difference

HMA

24°F Difference

WMA

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WMA – Cold Weather

- Increase Dosage
- Keep HMA Mix Temp
- Check WMA additive viscosity
- Heated Tote/Terminal Blend
- Tack Coat/Base Temp
- No Thin Lifts

Cold Weather Plant Difficulties

- Equipment Startup
  - Drag slats
  - Conveyers
  - Silo Gates
- Practice
- Watch for binding
- Calcium Chloride in the agg bins
- Improve insulation

Cold Weather Paving Difficulties

- Equipment startup
  - Hiccup while paving
- Paving train tight
- Anti-freeze in Roller tanks
- Insulated/Tarped Trucks
- Limit material transfer
  - 10-20F vs 5F
- Unload 3rd , 4th trucks first
- Keep hopper full if stop is required.
- Minimum handwork
- Utilize Multi-Cool App
- No Rubber Tire

2 | Better Binder Performance

What Influences Binder Aging?

Short-Term "Spurt" Aging

Process dependent
Controllable

In-Service Aging

Environmental dependent
Predictive

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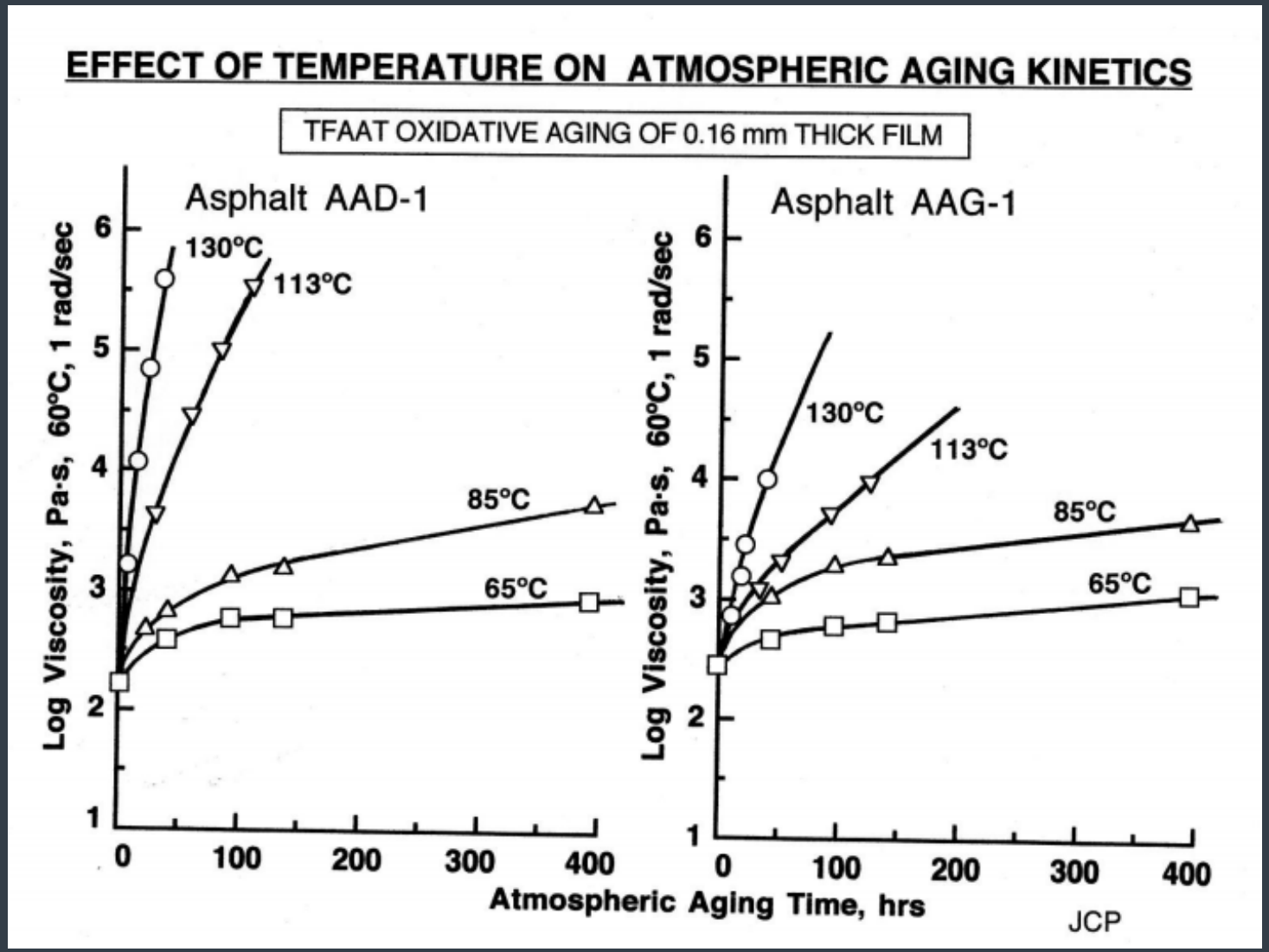
The Higher the Oxidation Temperature, the Faster the Stiffening

Work pointed to the key role that temperature plays in the rate of alteration of binder composition, alterations which manifest themselves in physical and rheological properties. The graph at right shows the rate of **change in log viscosity depends greatly on the temperature during oxidation.**



Petersen, J.C., "Oxidative Aging Model: How It Relates to the Prediction of Pavement Performance," WRI/FHWA Symposium, Laramie, WY, June **2006**.

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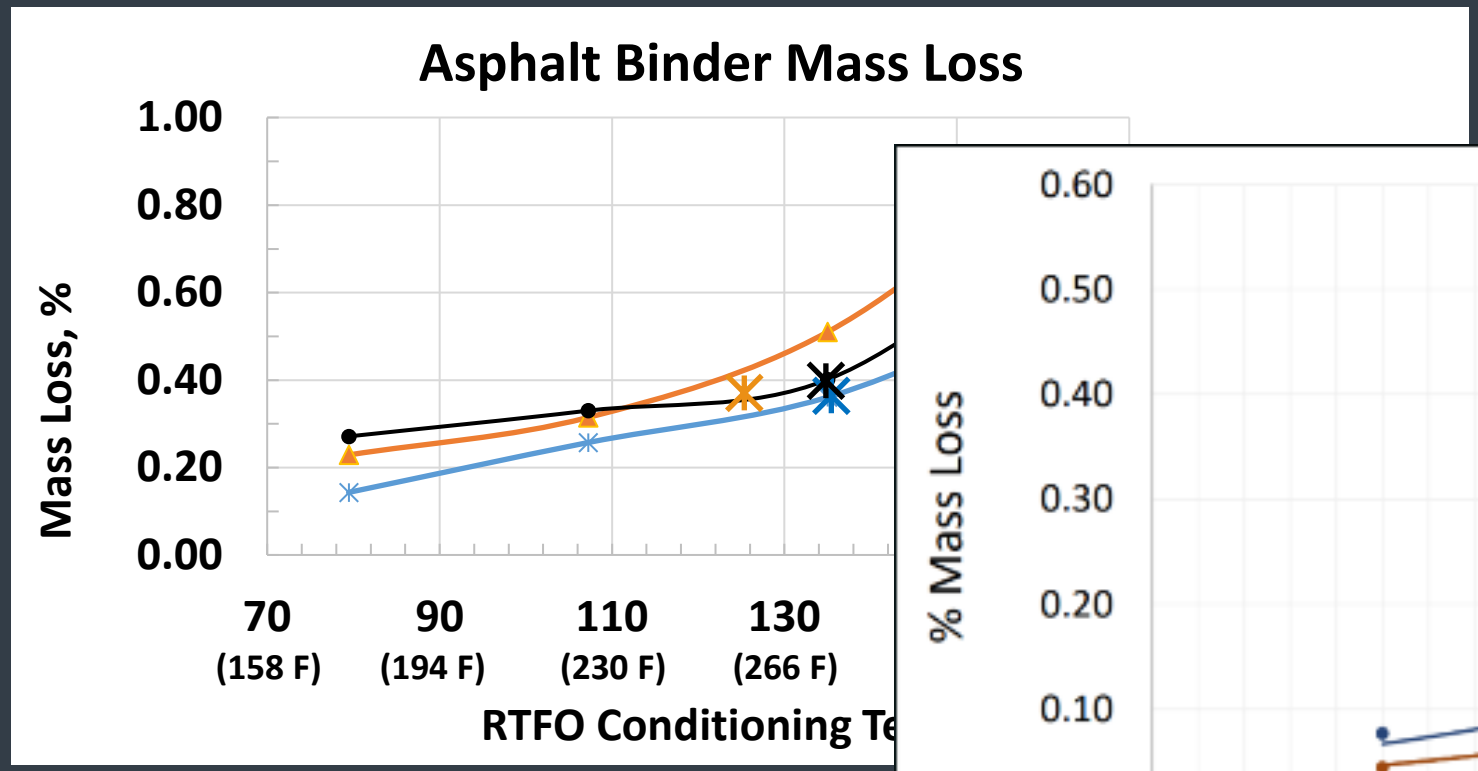
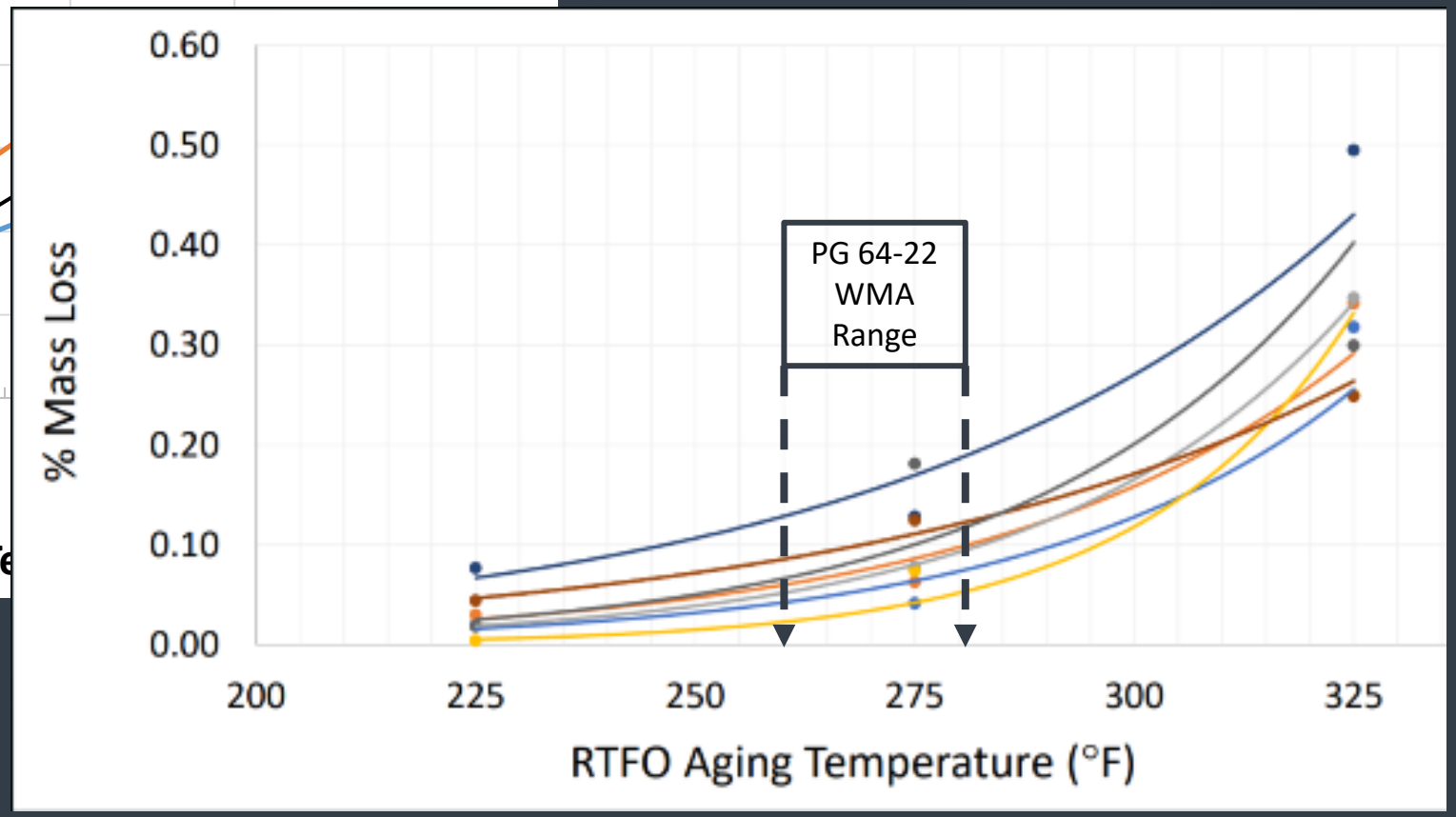
Binder Mass Loss vs RTFO Temperatures





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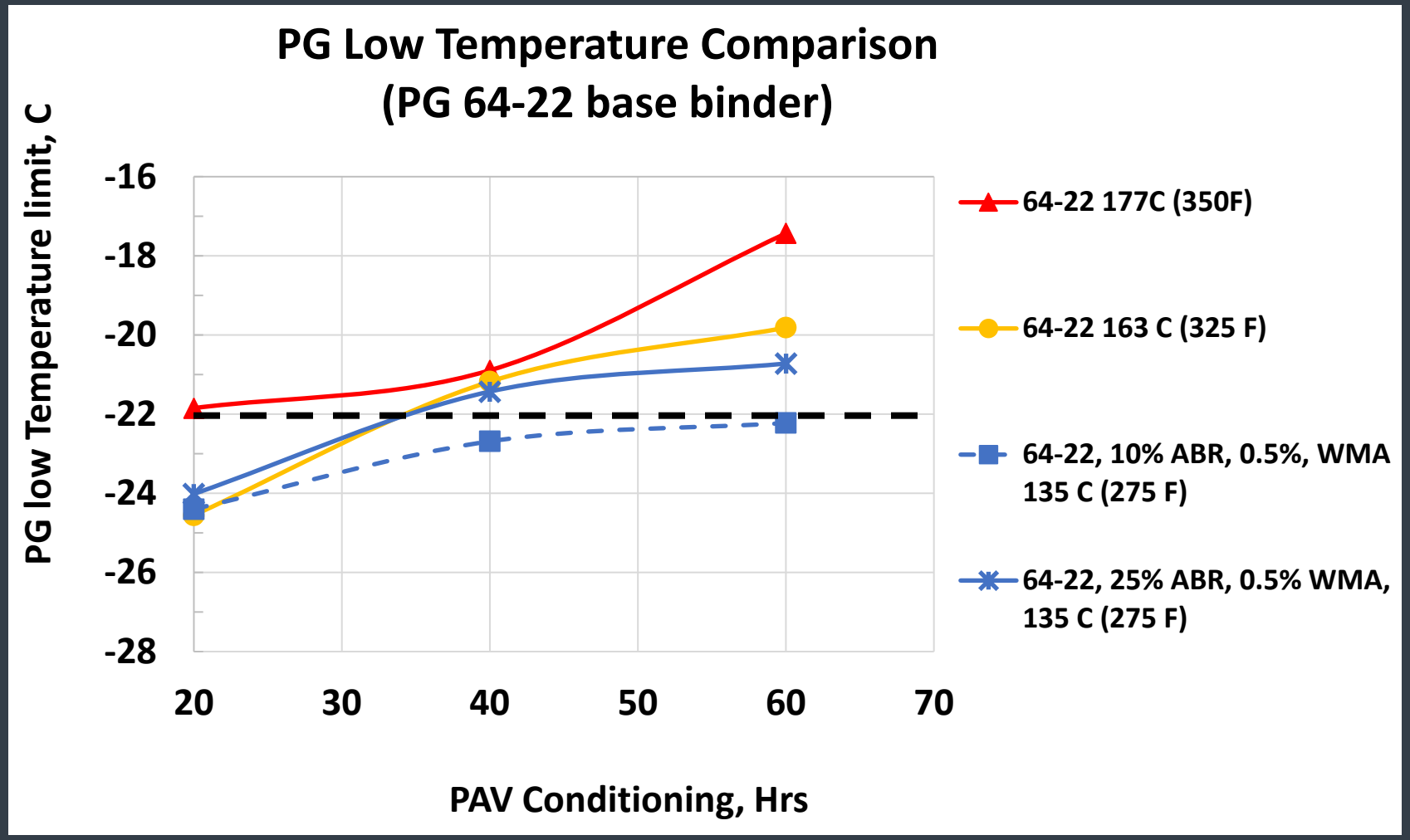
PG Low Temp After Extended Aging

- 20 Hr PAV is common aging limit for PG specifications
- PG 64-22 RTFO 350F is out of spec after 20 Hr PAV
- Reducing RTFO 50F still meets spec after 60 Hrs



5yrs	10yrs	15yrs

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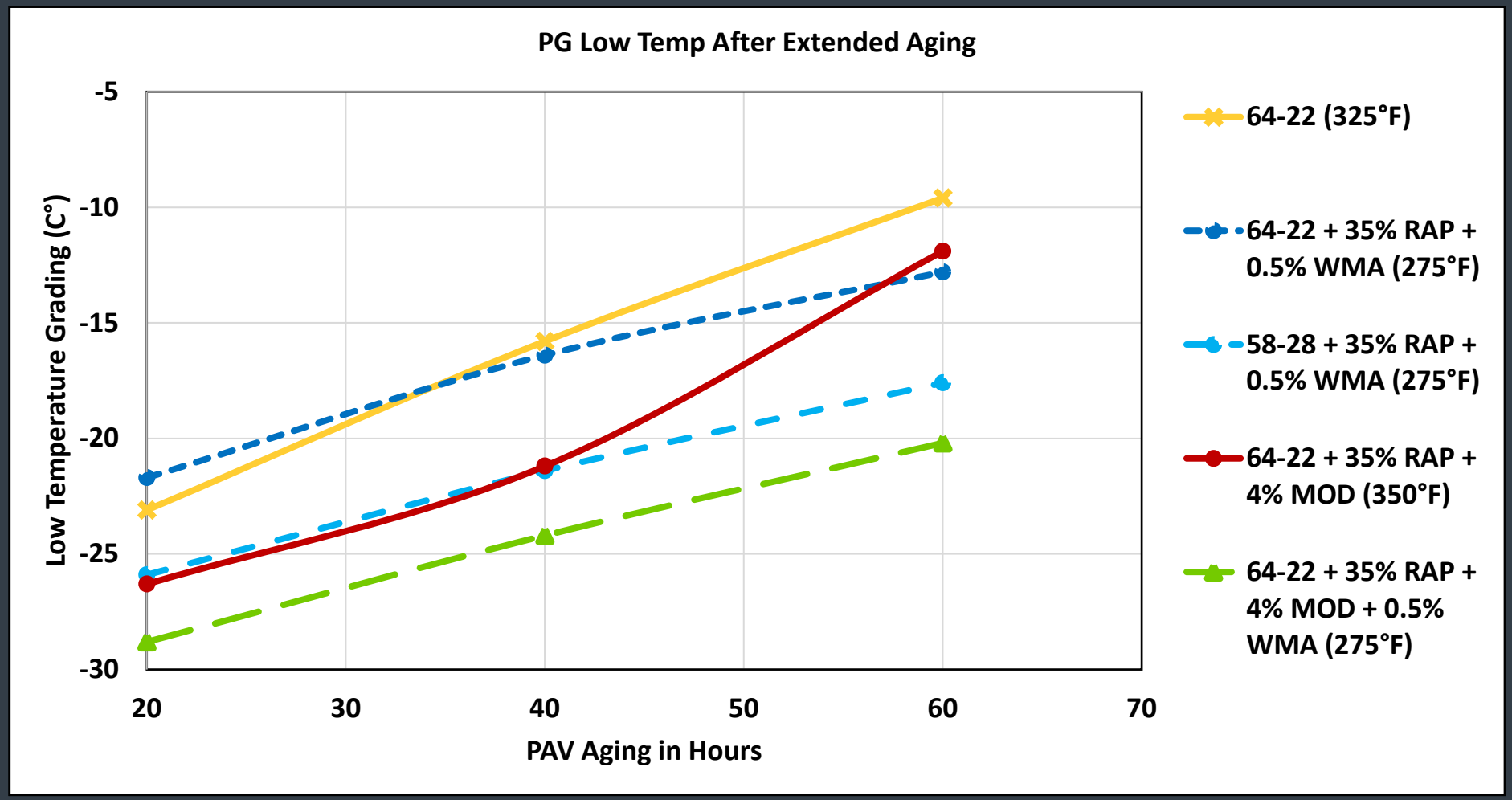
PG Low Temp After Extended Aging with Modifier Comparison

Grade bumping and Modifiers also shift graph.

WMA shift from lower mix temperature of greater significance



5yrs 10yrs 15yrs

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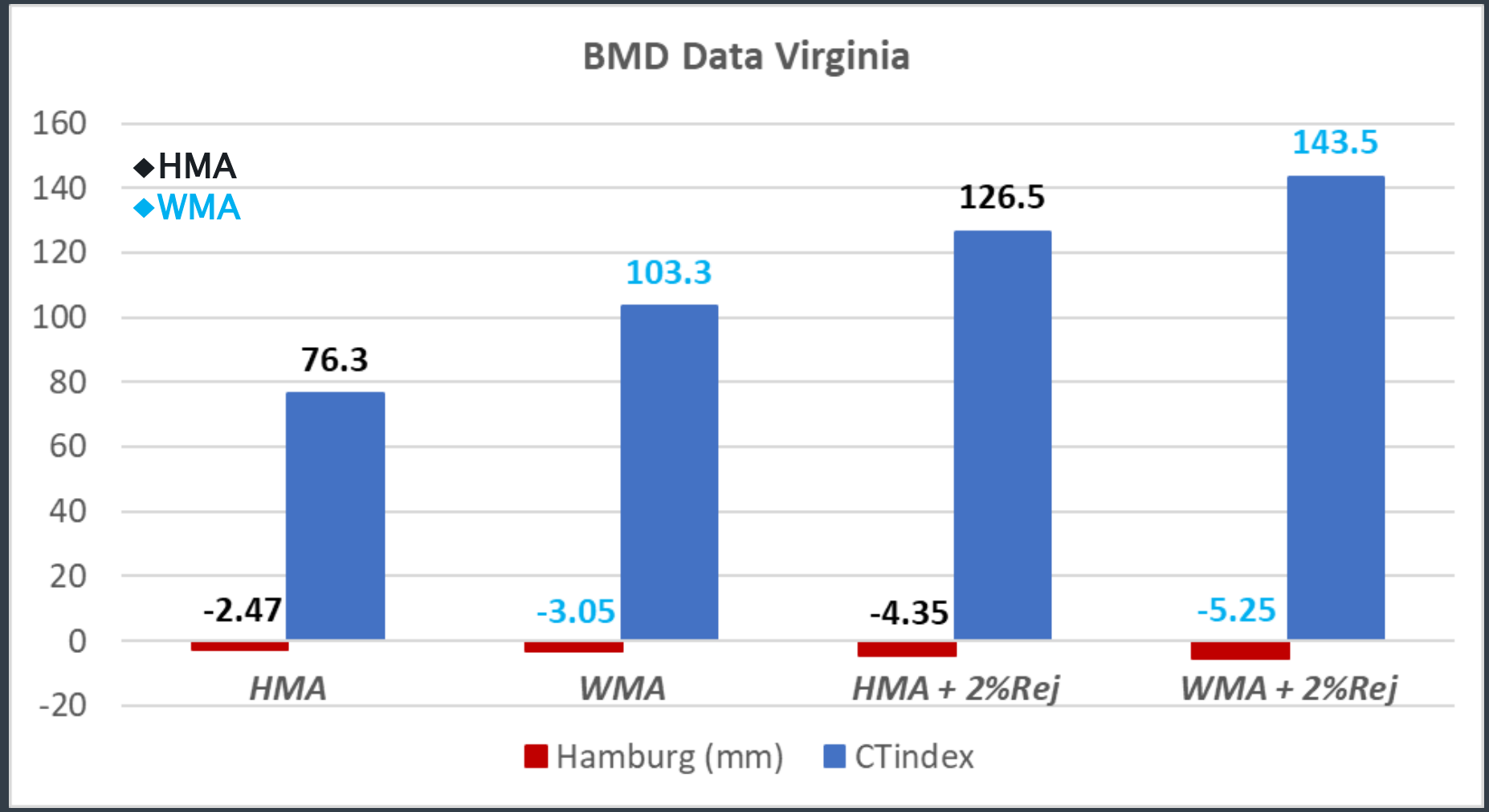
3 | Pavement Designed to Perform

Mixture Performance Testing – BMD with Rejuvenator

WMA Shift and a Rejuvenator Shift



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More effective use of asphalt binder

Evotherm @ 275˚

Hot mix control @ 325˚

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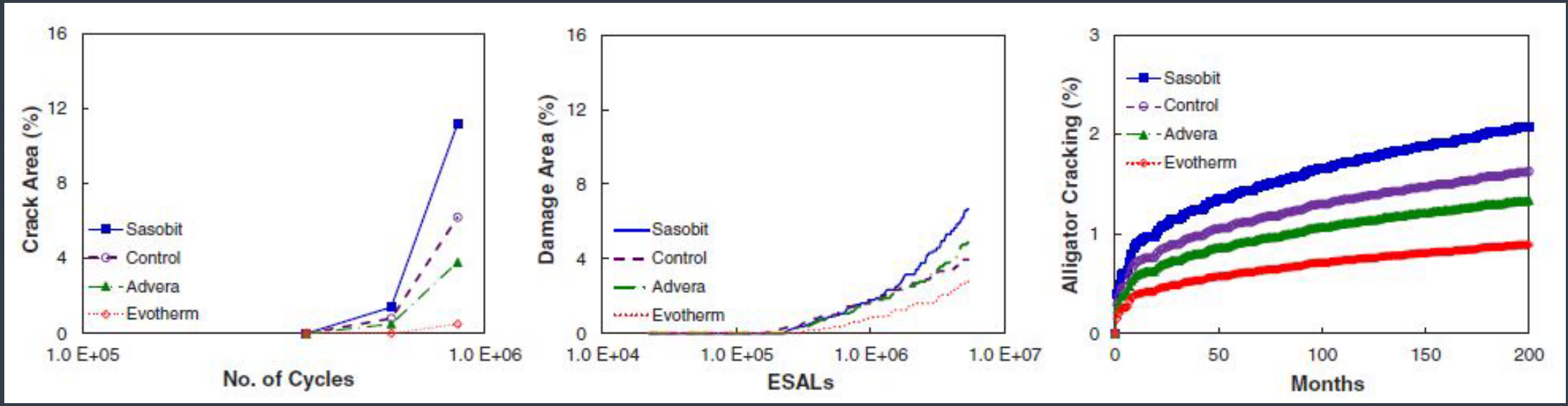
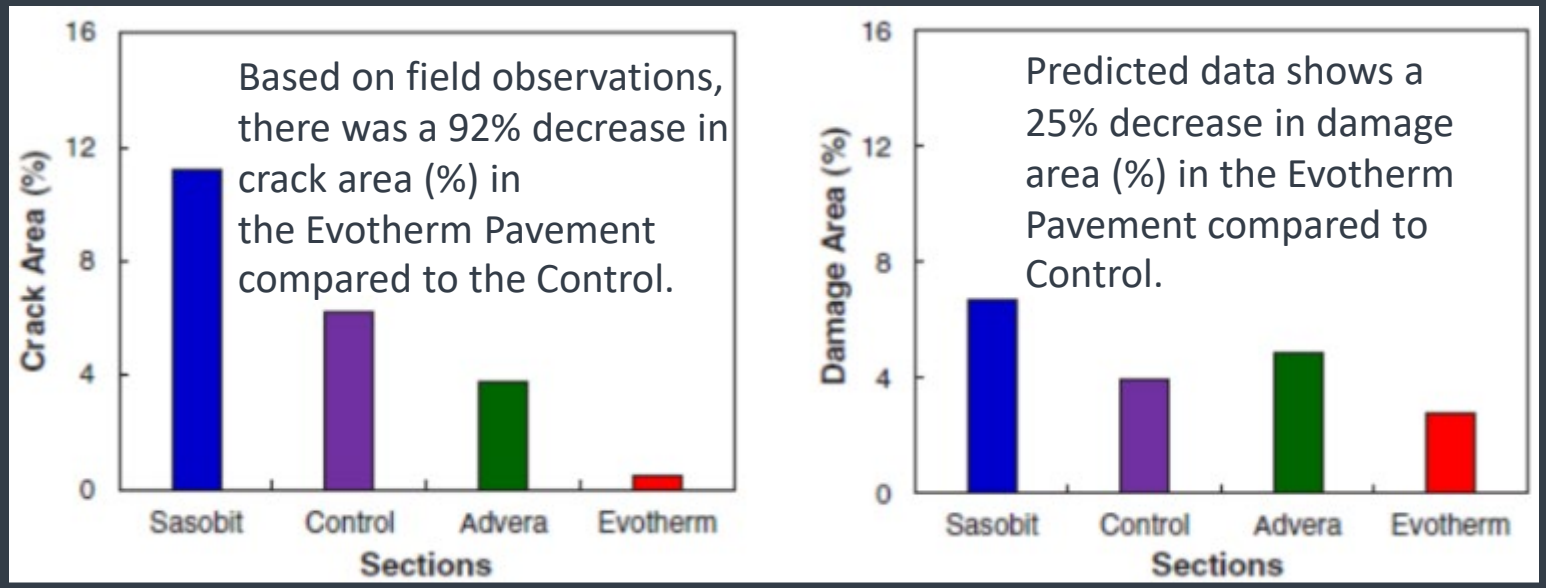
Observed vs Predicted WMA Field Performance



Observed FlexPave Pavement ME



- Wang, Yizhuang; Norouzi, Amirhossein; and Kim, Richard. Y. Comparison of Fatigue Cracking Performance of Asphalt Pavements Predicted by Pavement ME and LVECD Programs. Transportation Research Record 2590. 2016.

4

Reduced Carbon Footprint

Our Industry Needs Leaders…

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Fugitive Emissions: LOAD OUT

APT Minima Device

340°F mix
7:36-8:36
32.5% burner output

295°F mix
9:45-10:45
25% burner output

255°F mix
11:43-12:43
21% burner output

Concentration [µg/m³] (PPB)

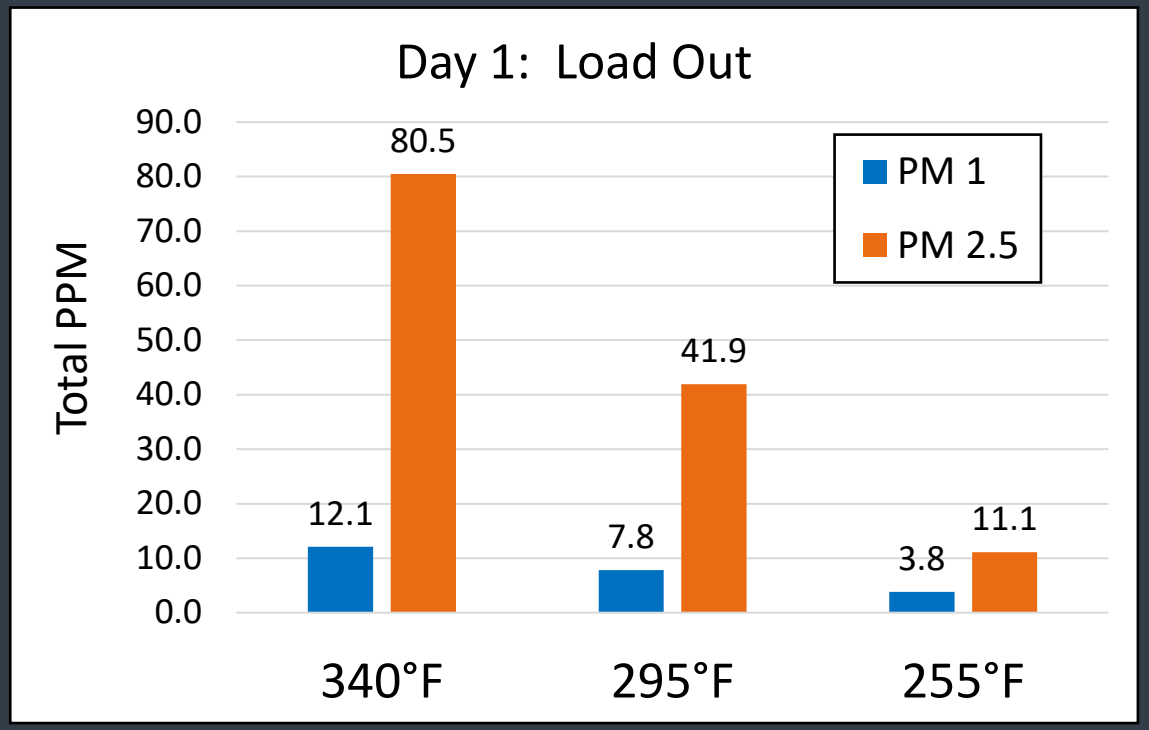
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0

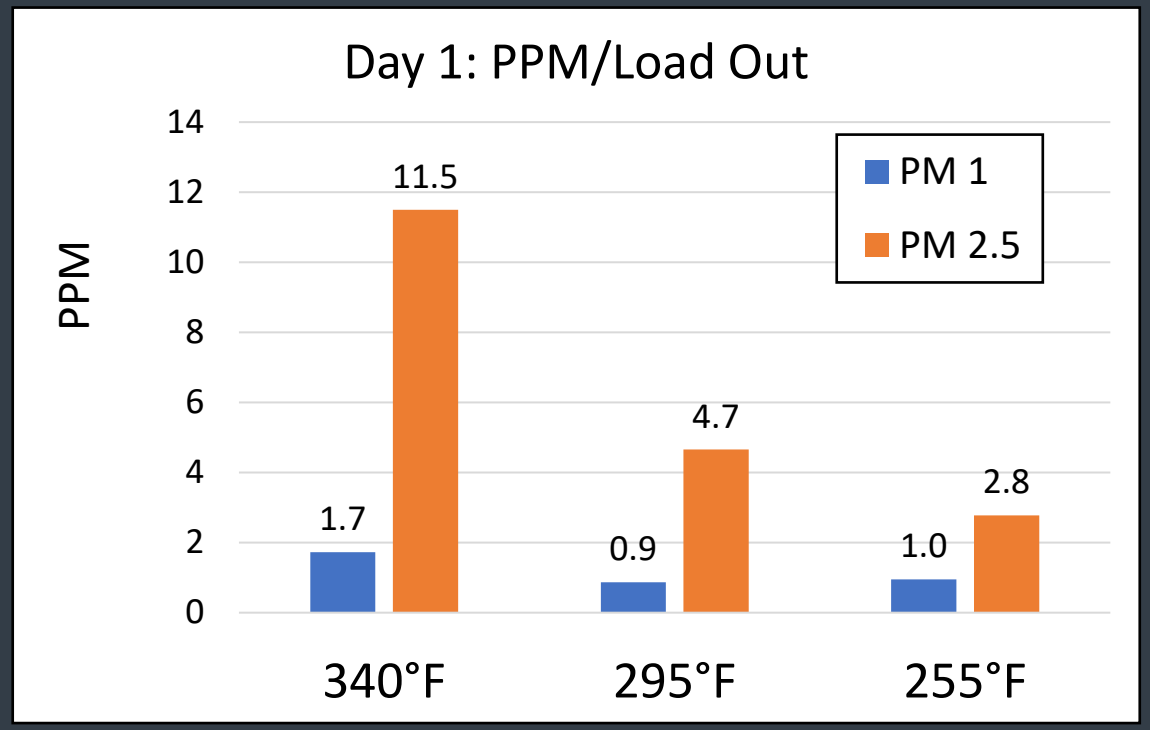
07:00 08:00 09:00 10:00 11:00 12:00 13:00

Time

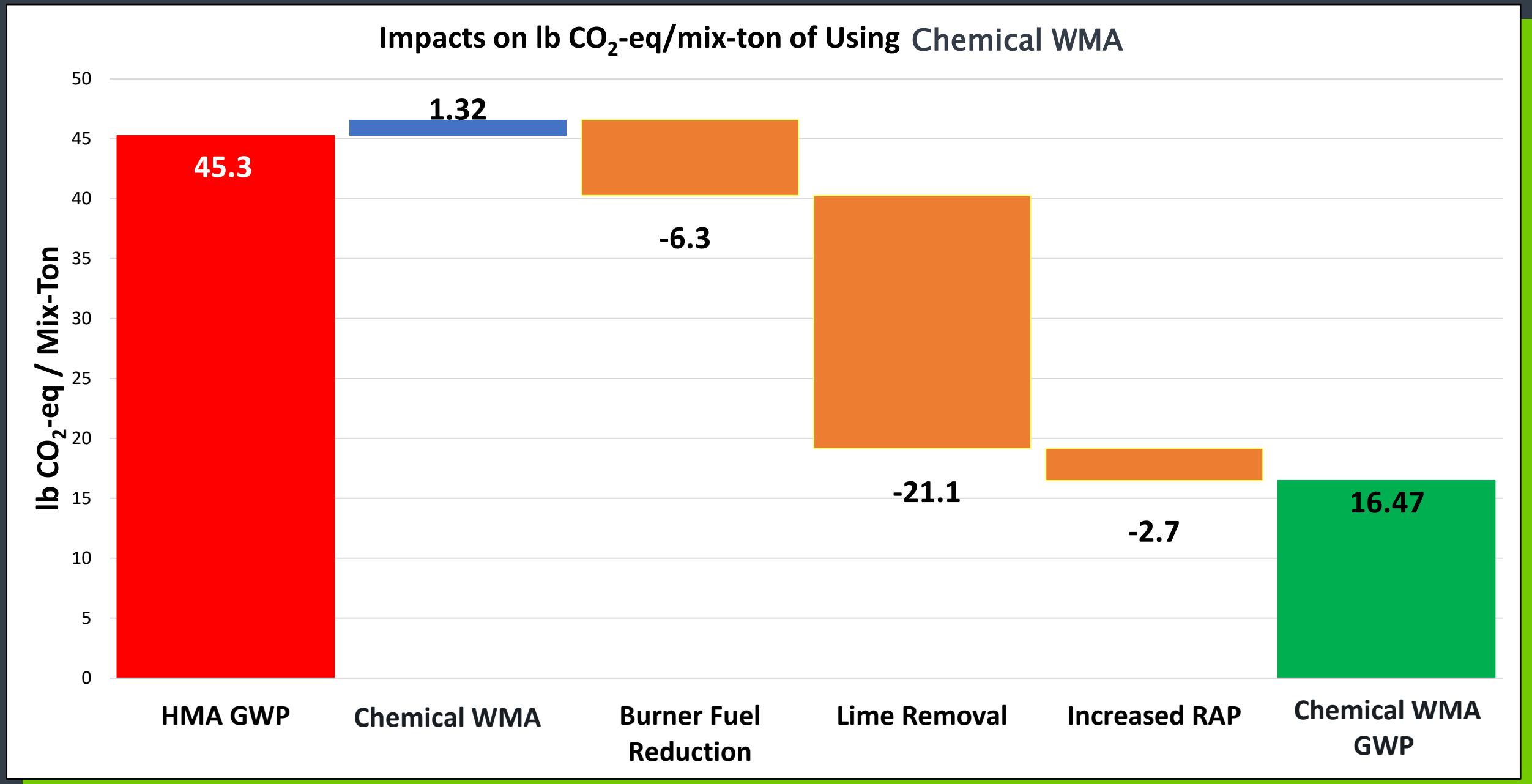
PM1 PM2.5

Fugitive Emissions: Load Out



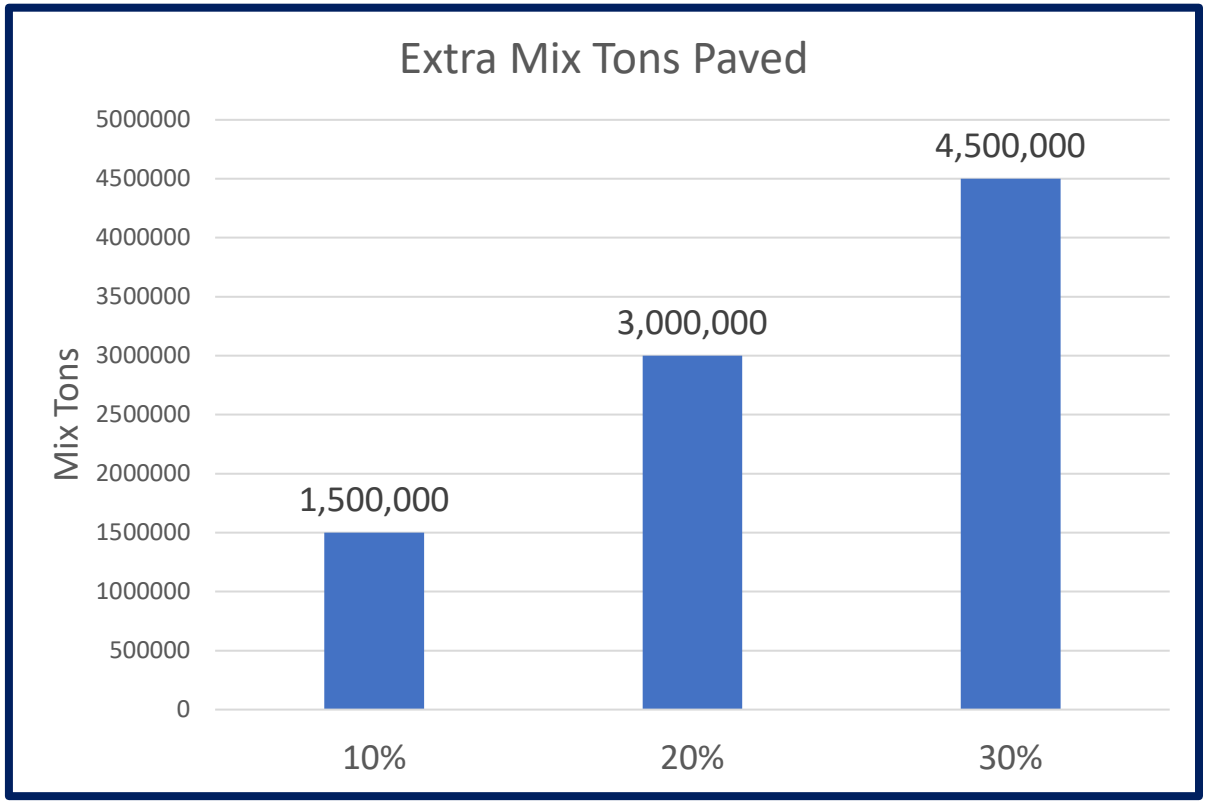


WMA Environmental Benefits



Just how Economical can Chemical WMA be for Michigan?

- Michigan lays roughly 15 Million Tons of Asphalt each year
- Assuming a $75 mix ton price on the Average
- Michigan spends roughly $1.13 billion/yr on Asphalt
- Assuming asphalt overlays last 10 years on average.
  - A 10% life extension saves MI ~$112.5 million/yr
  - A 20% life extension saves MI ~$225 million/yr
  - A 30% life extension saves MI ~$337.5 Million/yr



Chemical WMA presents an opportunity for MI to realize $100-$300 Million per year in life cycle cost savings!

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Questions – Come by the Booth

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Senior Technology Development Engineer

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Cargill Asphalt Solutions:
Unique chemistries to help you build and maintain better roads

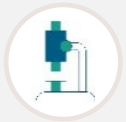
Dan Staebell
North America
Business Development Leader
Dan_Staebell@Cargill.com

Cargill Helping the world thrive

Cargill's Role in Asphalt

To be the industry leader in high-performance and sustainable asphalt additives.

- Rejuvenation
- Warm Mix
- Cold Mix
- Emulsions
- Rheology
- Stabilizers



State-of-the-art Asphalt Lab

- Customer custom formulation services
- Compositional and analytical evaluation
- Advanced rheology and thermal analysis

155,000 employees

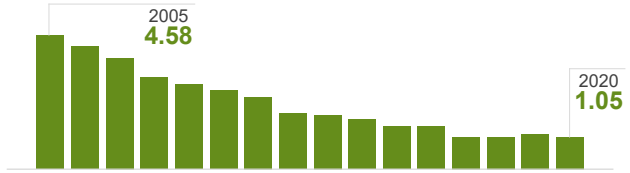
155 years of experience

Working in **70** countries

$114,6 billion in annual revenue

Our commitments

Safe
We relentlessly work to improve the safety of our people. Reduction in injuries per 200,000 hours worked over 15 years.



Responsible
We strive to strengthen the communities where we live and work.

$115 million
Total charitable contributions last year across 56 countries

Attendance at our farmer trainings for sustainable agricultural practices totaled 860,000 last year

Sustainable

- Agriculture is how we will protect the planet and our shared future.
- Climate change: Reducing supply chain emissions per ton of product 30% by 2030, and absolute operational emissions 10% by 2025
- Water resources: Achieving sustainable water management in all priority watersheds by 2030
- Land use: Eliminating deforestation in our supply chains by 2030

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Sustainable practices in the US are growing

Problem: Adoption of recycled materials and solutions is slowing down

2019 NAPA Asphalt Pavement Industry Survey on Recycled Materials Recycled Asphalt Pavement (RAP) and Recycled Asphalt Shingle (RAS):

- From 2018 to 2019, the average percentage RAP used stayed the same: 21.1%.
- 93.9% of producers report having excess RAP.
- RAP used in asphalt remains a rich opportunity.

	2018	2019
RAP use	82.2 million tons	89.2 million tons
RAS use	1.05 million tons	0.92 million tons

Source: National Asphalt Pavement Association, all data represents the US

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Rejuvenators: An Engineered Solution

“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 asphalt, to restore performance, and durability.

A good rejuvenator reverses the impact of aging:

- Restores cracking resistance, maintains rutting performance
- Improves workability, compaction, and appearance
- Improves aging susceptibility of the pavement
- Provides predictable and reliable results

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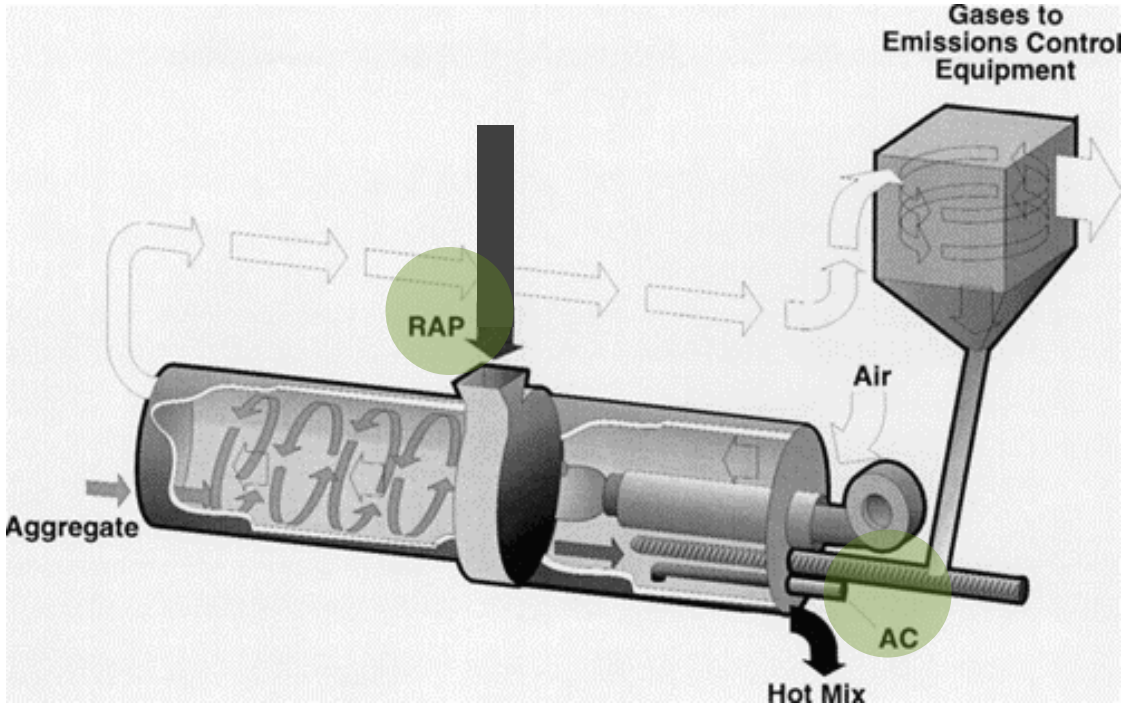
How are Rejuvenators Used?

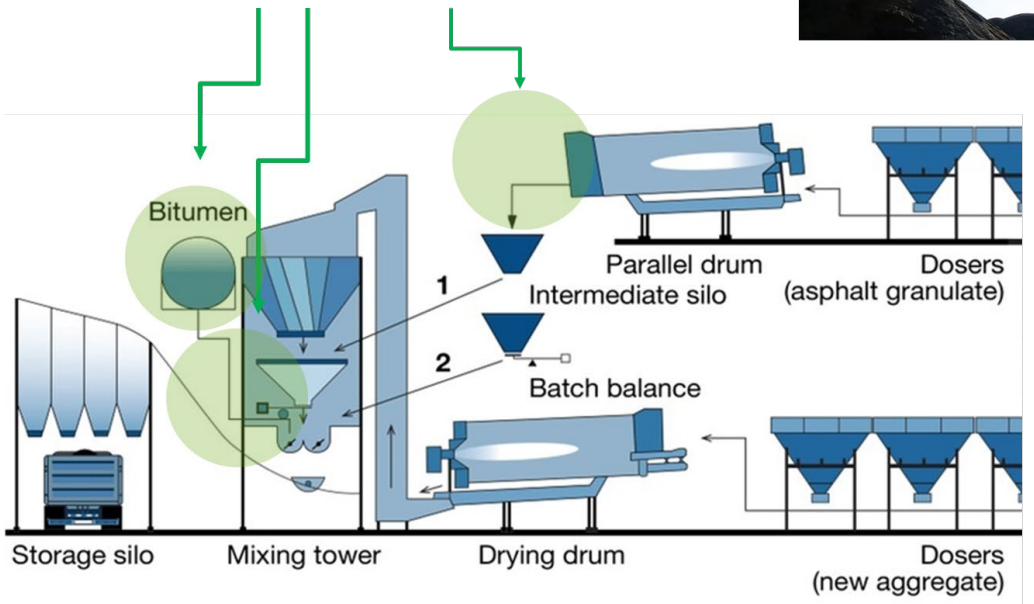
Typically, **1-3% wt. of the binder or 0.05-0.15% wt. of the mix**, added via:

1. In-line into virgin binder using additive pump
2. Treatment of RAP (at collar or during processing)
3. Injection into pugmill or mixing drum
4. Pre-blended into virgin binder (least common)

Drum Plant Example



Batch Plant Example



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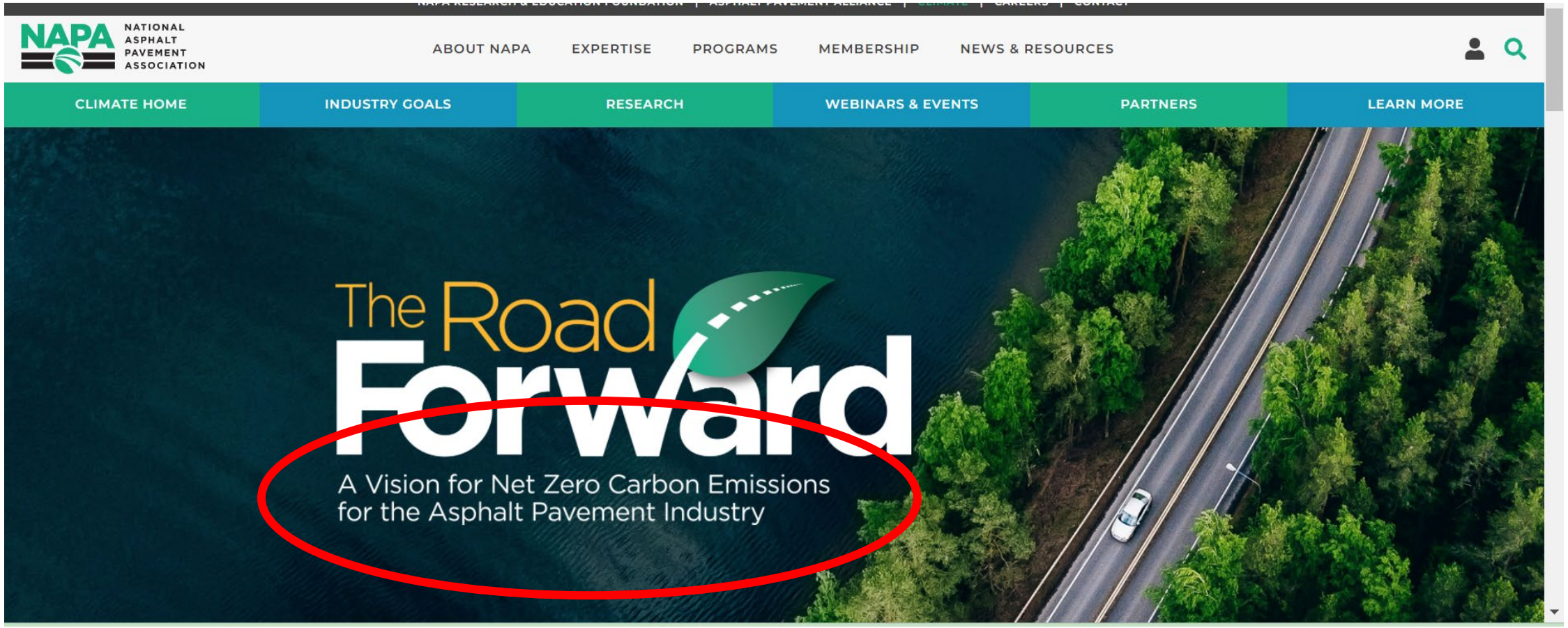
Why this Matters!

https://www.asphaltpavement.org/climate



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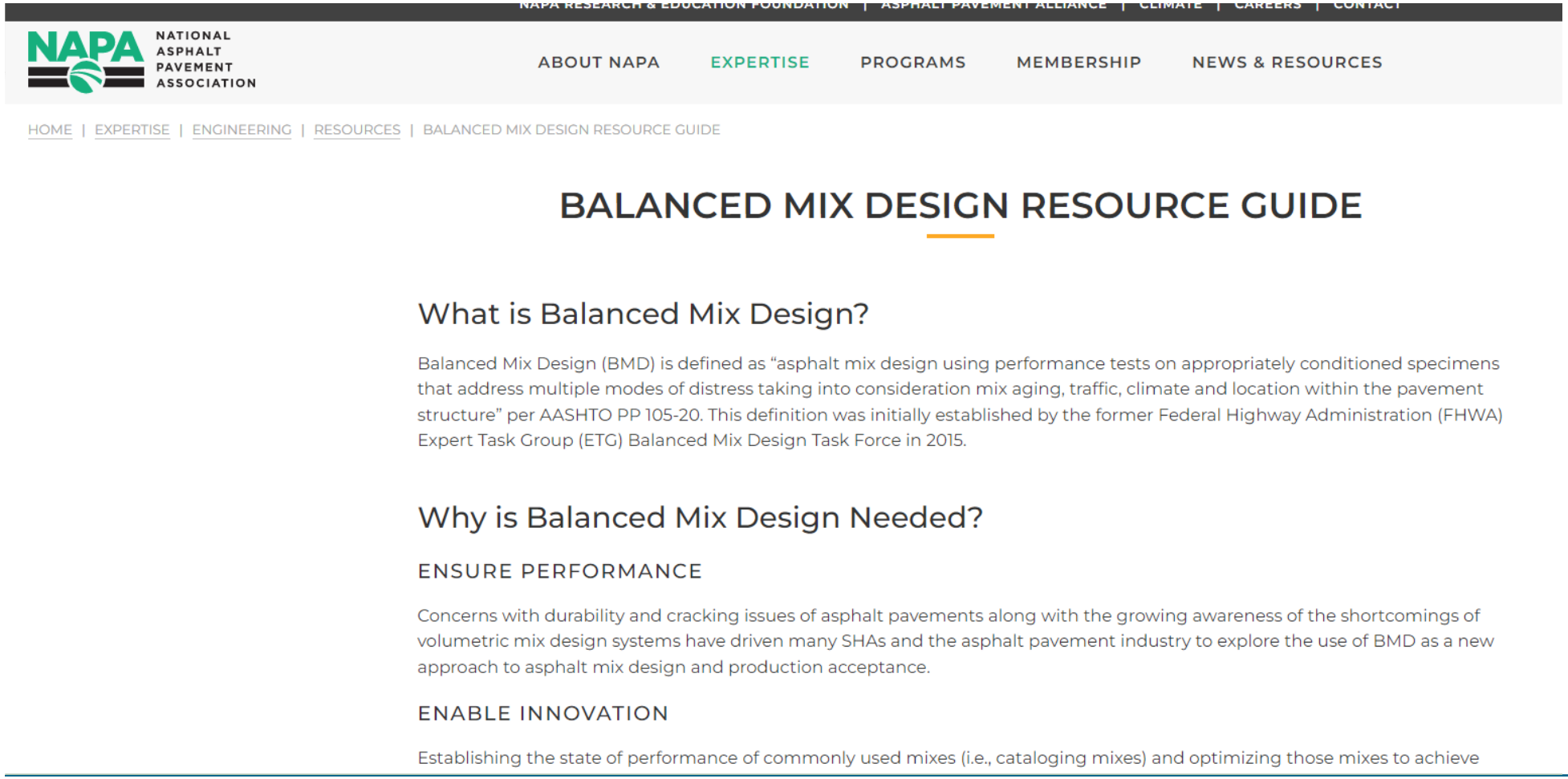
Why this Matters!

https://www.asphaltpavement.org/expertise/engineering/resources/bmd-resource-guide



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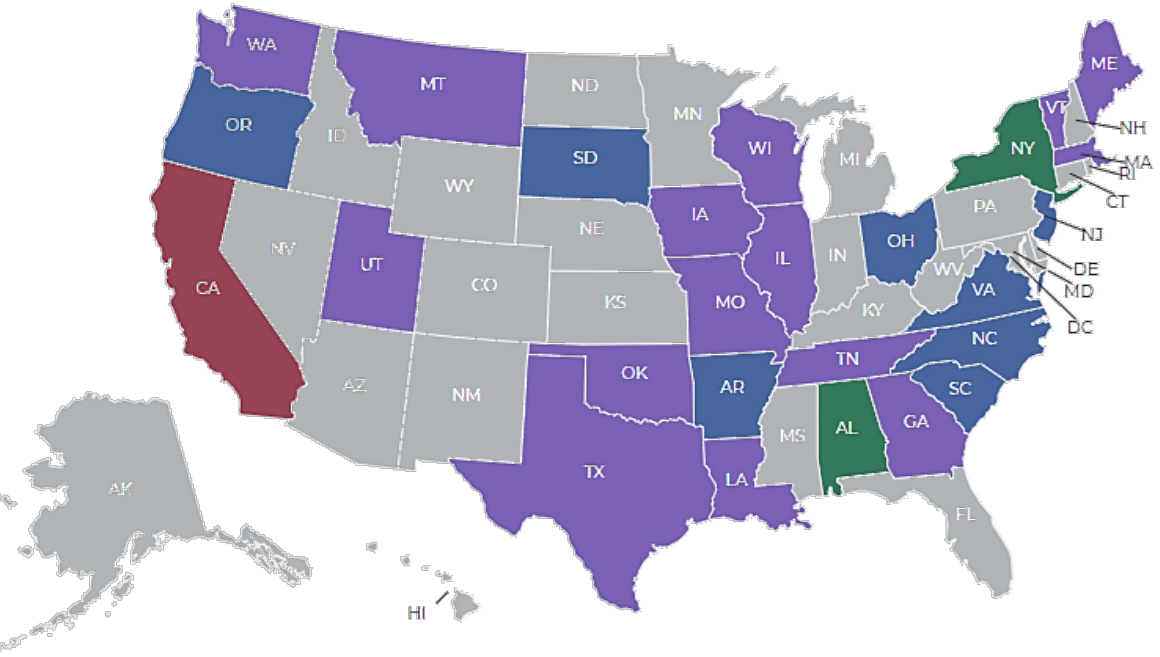
Where BMD tests are being used?



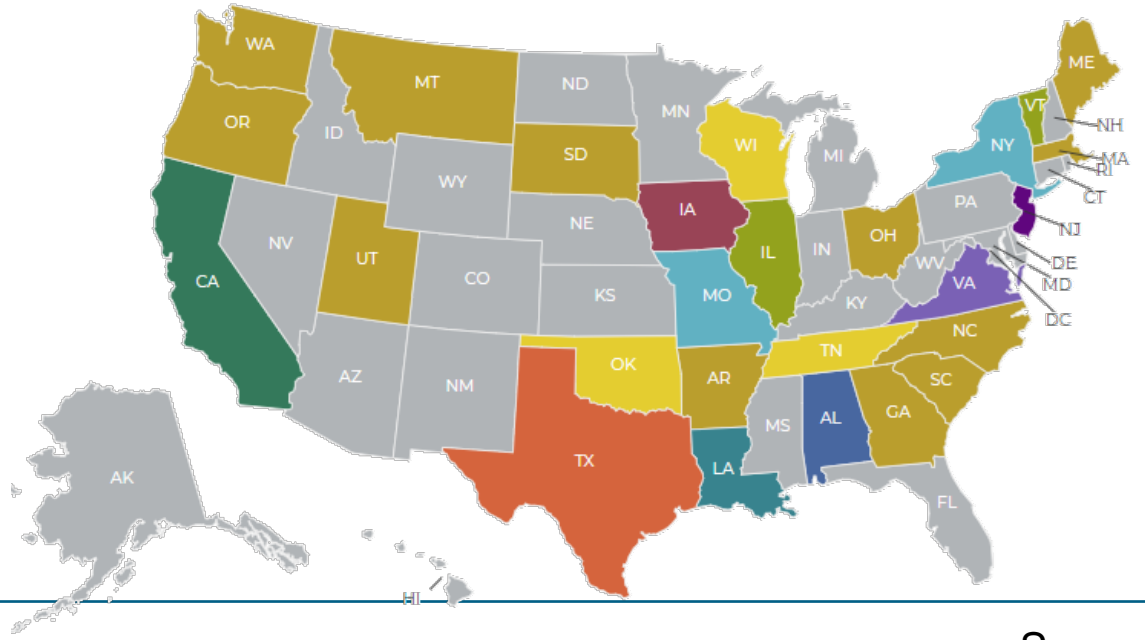
APA
FN, HWTT
HT-IDT
HWTT

Rutting Tests:

- Most common is Hamburg Wheel Tracking
- Not much hesitancy over adoption of rutting tests

Cracking Tests:

- Not much consensus
- Tendency toward simpler tests
- Some concerns over performance correlations for simpler tests



AL-CT
BBF, DCT
BBF, I-FIT
CANTABRO, IDEAL-CT
DL, IDEAL-CT
I-FIT
I-FIT, IDEAL-CT
IDEAL-CT
N/A
OT, BBF
SCB-JC

Source: NAPA

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Role of Recycling Agents in BMD

- Recycling agents have been used to modify performance attributes in a mix.
- The following general impact trends can be expected:

Mix Parameter	Expected RA Impact
Cracking Resistance	Improve
High Temperature Stiffness	Decrease
Moisture Resistance	Typically, None
Compactability	May improve
RAP / RAS Content	May be increased
Asphalt Content (P_b)	May offset P_b increase
Virgin Binder Grade	May eliminate “Grade Dump”

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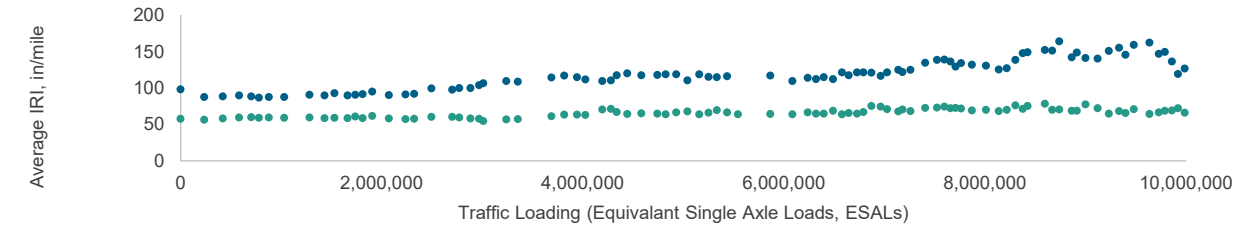
Proven performance. With Anova® Rejuvenator.

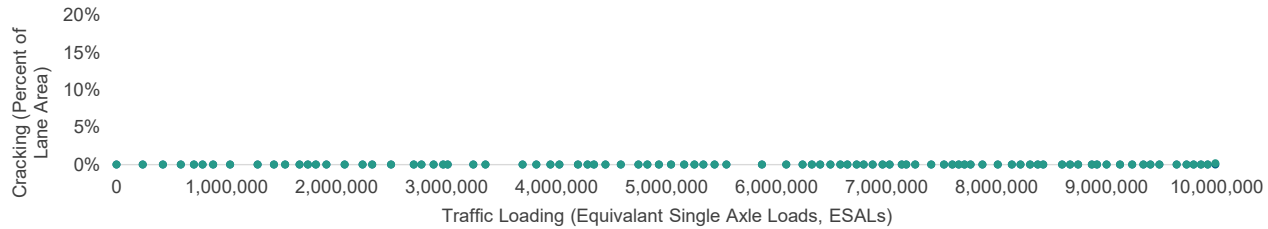
To demonstrate performance against the typical 30% RAP mix, Cargill built a test section on the NCAT track using 45% RAP and Anova Rejuvenator.

After 10 million loadings, zero cracks appeared in the test section.

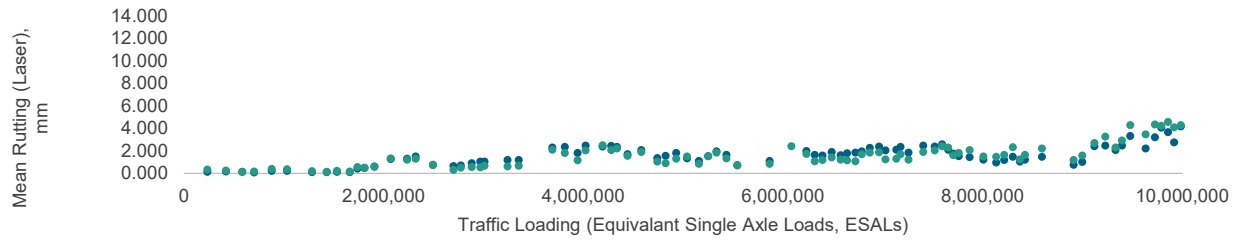
Maintaining Smooth Ride



0 Cracking



No Rutting



● 30% RAP Control ● 45% RAP + Anova™

* Data provided and measured by NCAT using plant produced mix.

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Proven performance. With Anova® Rejuvenator.

To demonstrate performance against the typical 30% RAP mix, Cargill built a test section on the NCAT track using 45% RAP and Anova Rejuvenator.

After 10 million loadings, zero cracks appeared in the test section.

Table 1 – Properties and performance test results for plant produced, lab compacted mixes.

	Control/ Standard Mix	Anova Mix
Virgin Binder grade	64-22	64-22
RAP Percentage	30%	45%
Extracted mixture binder grade	76.7-14.6	76.9-22
Rutting test result (APA @ 64°C)	2.51mm	2.55mm
Cracking test result (IDEAL CT) Target >70	124	100
Cracking test result (IFIT, flexibility index)	6.1	8.0
Cracking test result (DCT @ 12°C, J/m2)	520	565
Cracking test result (Overlay NJDOT)	296	325

● 30% RAP Control ● 45% RAP + Anova™

* Data provided and measured by NCAT using plant produced mix.

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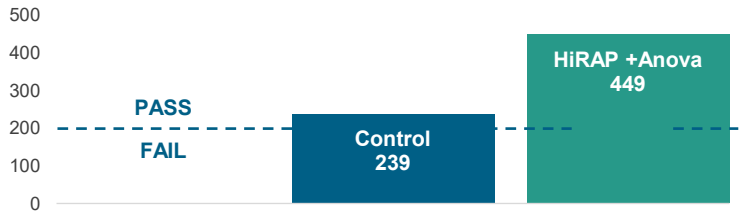
Proven performance. With Anova® Rejuvenator.

- To demonstrate performance against the typical 25% RAP mix, Cargill built a test section on MnRoad, using 45% RAP and Anova Rejuvenator.

The test section maintained great cracking performance through 2.5 MM ESALs and 3 winters.

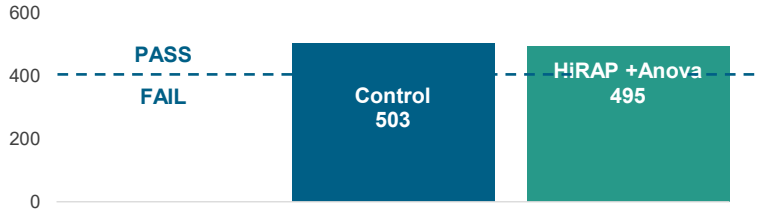
Increased reflective cracking resistance

Cycles to failure, overlay tester*



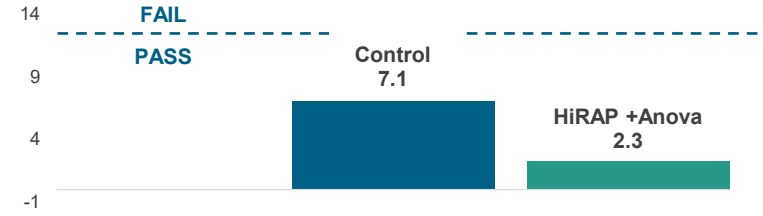
Improved thermal cracking resistance

Fracture energy (J/m2), DCT*



Maintaining rutting resistance

Rutting depth (mm), Hamburg wheel*



Target specification

* Data provided and measured by MnDOT using plant produced mix.

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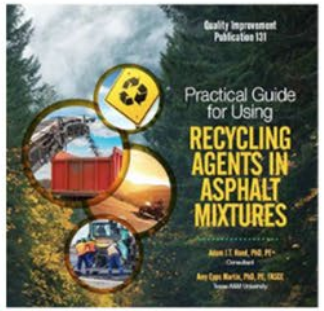
Conclusions and Summary

- Implementation of high RAP + Rejuvenator by BMD is highly practical today, with millions of tons produced every year.
- Process requires a framework that provides **transparency and reliability for all stakeholders**:
  - Step 1: Recycling Agent Property Certification (e.g. through ASTM D4552-20) - by supplier
  - Step 2: Initial dosage determination based on rheology, led by supplier
  - Step 3: Balanced Mix Design (BMD) process, led by producers
  - Step 4: Robust quality management practices by all parties

- Great resource for industry adopters of RA:

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION



- NAPA's Quality Improvement Publication (QIP) 131, Practical Guide for Using Recycling Agents in Asphalt Mixtures, provides a tiered set of step-by-step approaches to:
  - facilitate the use of recycling agents
  - produce asphalt pavements with good performance, and
  - promote sustainability

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Thank You

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Reversing the impact of aging.

Dan Staebell
North America
Business Development Leader
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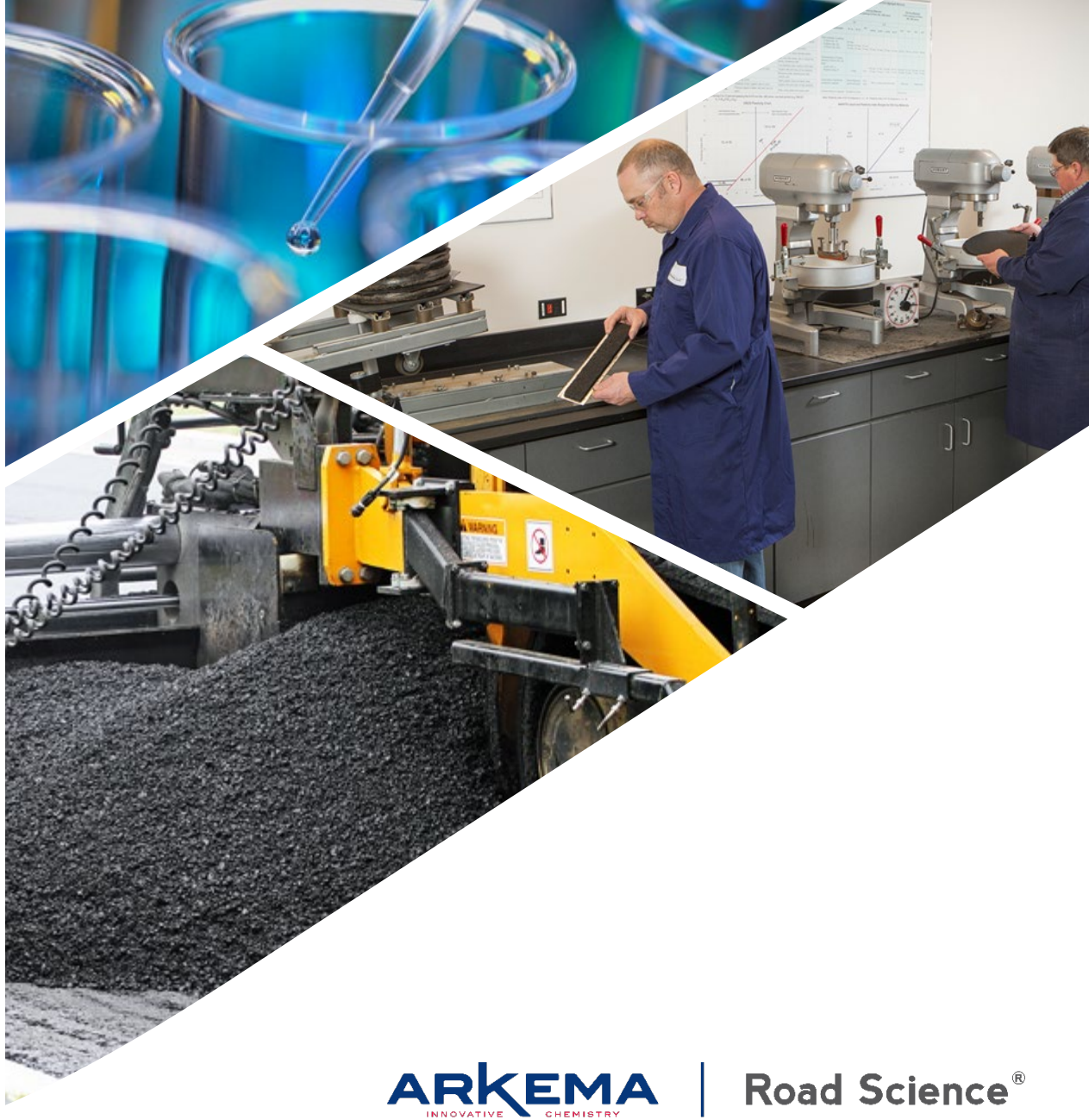
Cargill® Helping the world thrive

WARM MIX PAVING: A FIELD ENGINEER'S PERSPECTIVE

PRESENTED BY:
MIKE LONGSHAW, FIELD ENGINEER

FEBRUARY 22, 2022

ASPHALT PAVEMENT ASSOCIATION OF MICHIGAN



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BUILDING A NEW LEADER IN SPECIALTY SURFACTANTS

A bit about me…

- **21 years working with the Kansas Department of Transportation**
  - Construction engineer
  - Area engineer
  - District construction and materials engineer
- **4 years working as a materials engineer with a highway contractor**
  - Developed asphalt and concrete mix designs
  - Supervised QC testing
  - Bid construction projects
- **9 years working with Arkema-Road Science as a field engineer**
  - Project support
  - Lab work

Mike Longshaw,
Field Engineer Arkema-Road Science

Today, DOTs are facing many challenges

Aging infrastructure

Tight budget constraints

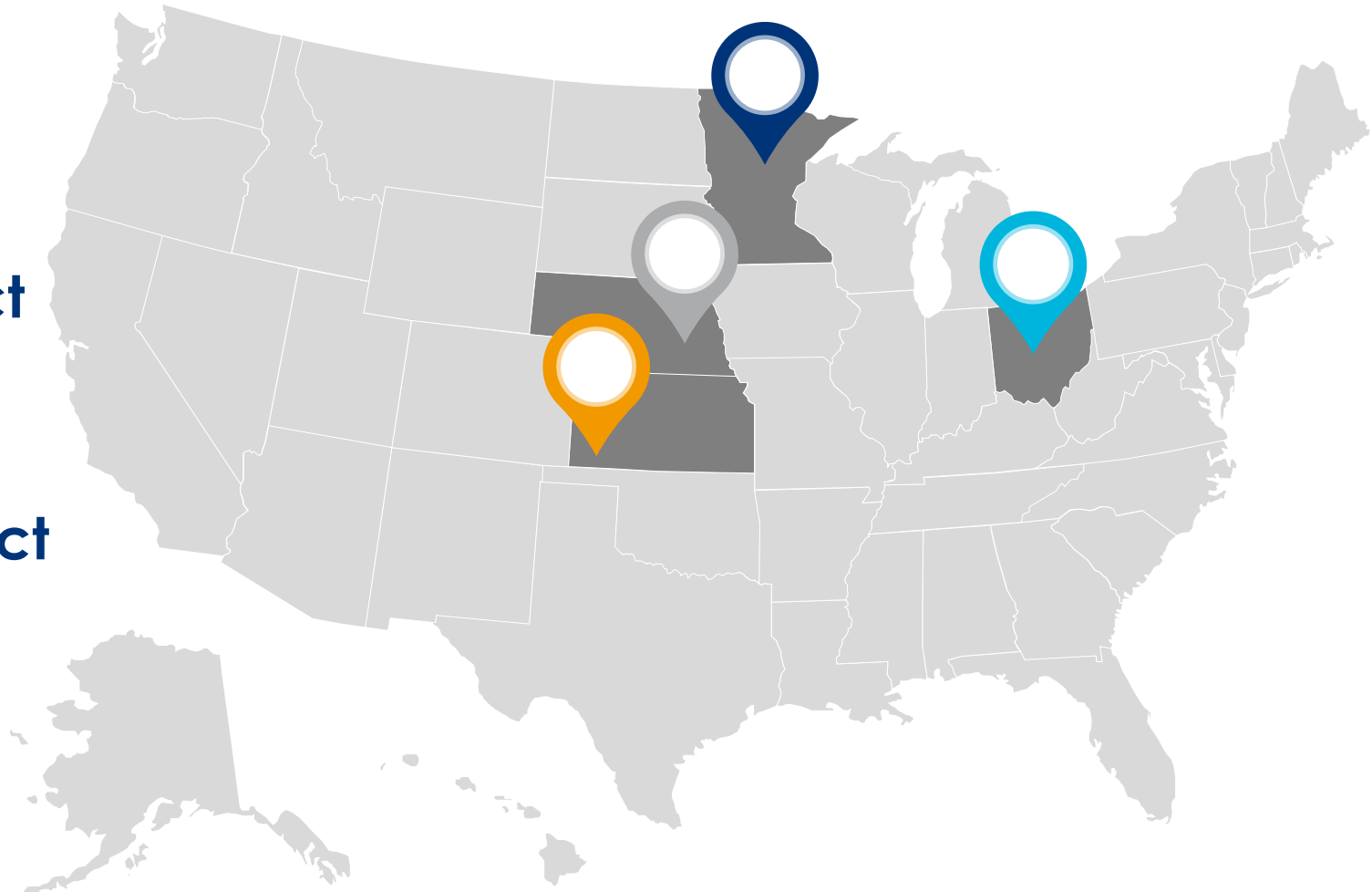
Heavier than anticipated traffic loads

Prematurely cracking pavements

Warm mix paving reduces costs and improves performance

Let’s explore four warm mix paving projects

- Kansas Warm Mix Project
- Nebraska Warm Mix Project
- Minnesota Warm Mix Project
- Ohio Warm Mix Project



Ohio Warm Mix Project: Challenges

- Partial depth asphalt patches
- Labor intensive
- Very slow work
- Material near end of truck load was very difficult to work with as it cools
- Current situation
  - PG 64-28 binder
  - PPA modified

Tacked patch hole ready for hot mix asphalt

Dumping asphalt into patch hole

Ohio Warm Mix Project: 1st day, no warm mix additive

- Temperature of asphalt mix at plant 300 °F
- Complaints about unworkable mixture
- Last mix out of truck very stiff and almost impossible to shovel and rake

Construction crew shoveling and raking asphalt throughout patch

Small roller compacting asphalt in patch hole

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Ohio Warm Mix Project: 2nd day, with warm mix additive

- Non-amine warm mix asphalt due to PPA modification of binder
- Dropped plant temperature to 270 °F
- Easier to rake
- Mix at end of truck much more workable

Final raking before compaction

Roller compaction

Ohio Warm Mix Project: Results

- Better workability
- Longer workability
- Lab work:
  - Indirect Tensile Asphalt Cracking Test (IDEAL-CT) Index increased by 33% by lowering temperature from 300 °F to 270 °F

Completed patch

IDEAL CT testing machine

Nebraska Warm Mix Project: Challenges

- State Highway 21 near Broken Bow, NE
- Very late in construction season (November 7)
- Work had to be completed this season
- Decent haul from plant to project location (45+ min)
- Belly dump paving
- Lots of things working against success
- Temperature not ideal
- 32 °F with strong north wind

Paving train on State Highway 21

Nebraska Warm Mix Project: Results

- Kept rollers close to paver
- Obtained density bonus with warm mix additive
- Tensile strength ratio of 94%

Paver, pick up device and truck

Minnesota Warm Mix Project: Challenges

- Crow Wing County specified maximum asphalt plant temperature of 230 °F after warm up
- Required chemical warm mix additive by spec
- Rain the night before
- Placed on granular subgrade

Paving on granular subgrade

Minnesota Warm Mix Project: Current Situation

- Asphalt plant lowered temperature after slat conveyor warmed up
- Asphalt plant mixing temperature 222 °F
- Asphalt plant very close to project

Nuclear density gauge

First lift on granular subgrade

Minnesota Warm Mix Project: Results

- Utilized a combination of rollers
- Found a tender zone where compaction was difficult
- Backed off secondary roller and reached compaction requirement
- Very little cracking after a few years

Pneumatic roller

Finish roller

Kansas Warm Mix Project: Challenges

- Very high polymer binder
- Two mixes: one virgin and the other with 15% recycled asphalt pavement (RAP)
- Had effective binder requirement
- Contractor wanted to reduce temperature in order to limit absorbed asphalt

Mixture behind paver

Steel face roller

Kansas Warm Mix Project: Results

- Obtained maximum density bonus on both mixes although different rolling patterns
- Could not reduce temperature as much on 15% RAP mix due to clumping of the RAP at lower temperature

Density checked with nuclear meter

Finished pavement

Warm mix paving is the solution to today's DOT challenges

- Allows for paving in non-ideal conditions when necessary
- Extends the compaction time to obtain maximum density
- Can lower the plant temperature to reduce aging, maintain the good parts of the binder and reduce cracking
- Potentially improve IDEAL CT Index and help meet Balanced Mix Design requirements
- Saves contractors money by reducing absorbed asphalt and reducing energy costs

Another beautiful road in Kansas

Chemical Additives is your fix

Contact Arkema-Road Science for your chemical additive needs

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WARM MIX ASPHALT A FIELD ENGINEER'S PERSPECTIVE

THANK YOU – QUESTIONS?
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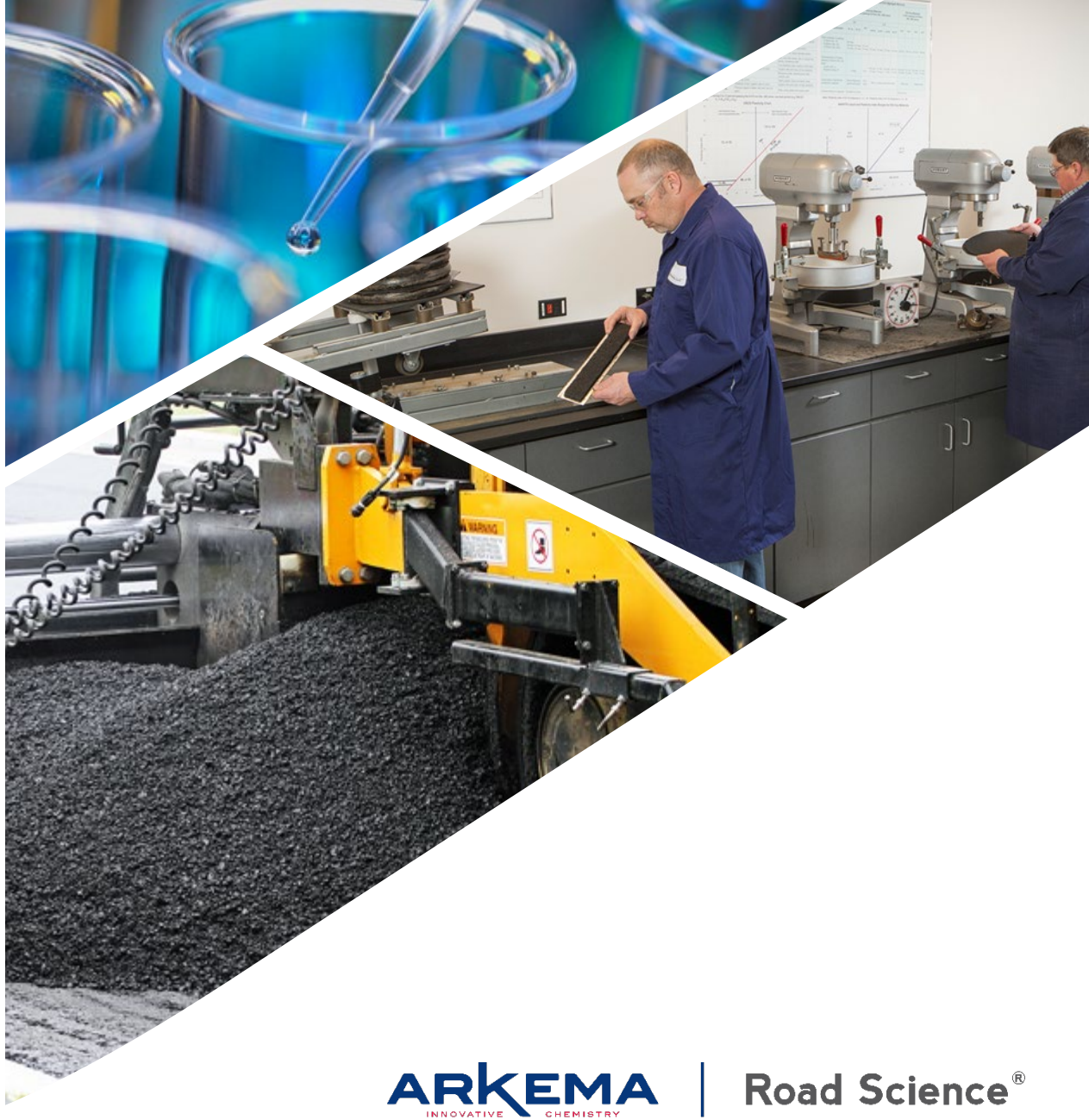

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