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Benefits of WMA

Extending Pavement Service Life by Reducing Production Temperatures Using WMA

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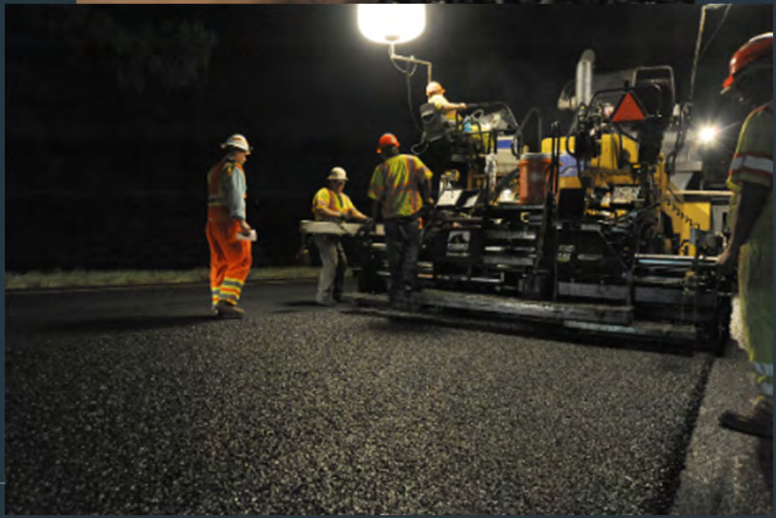
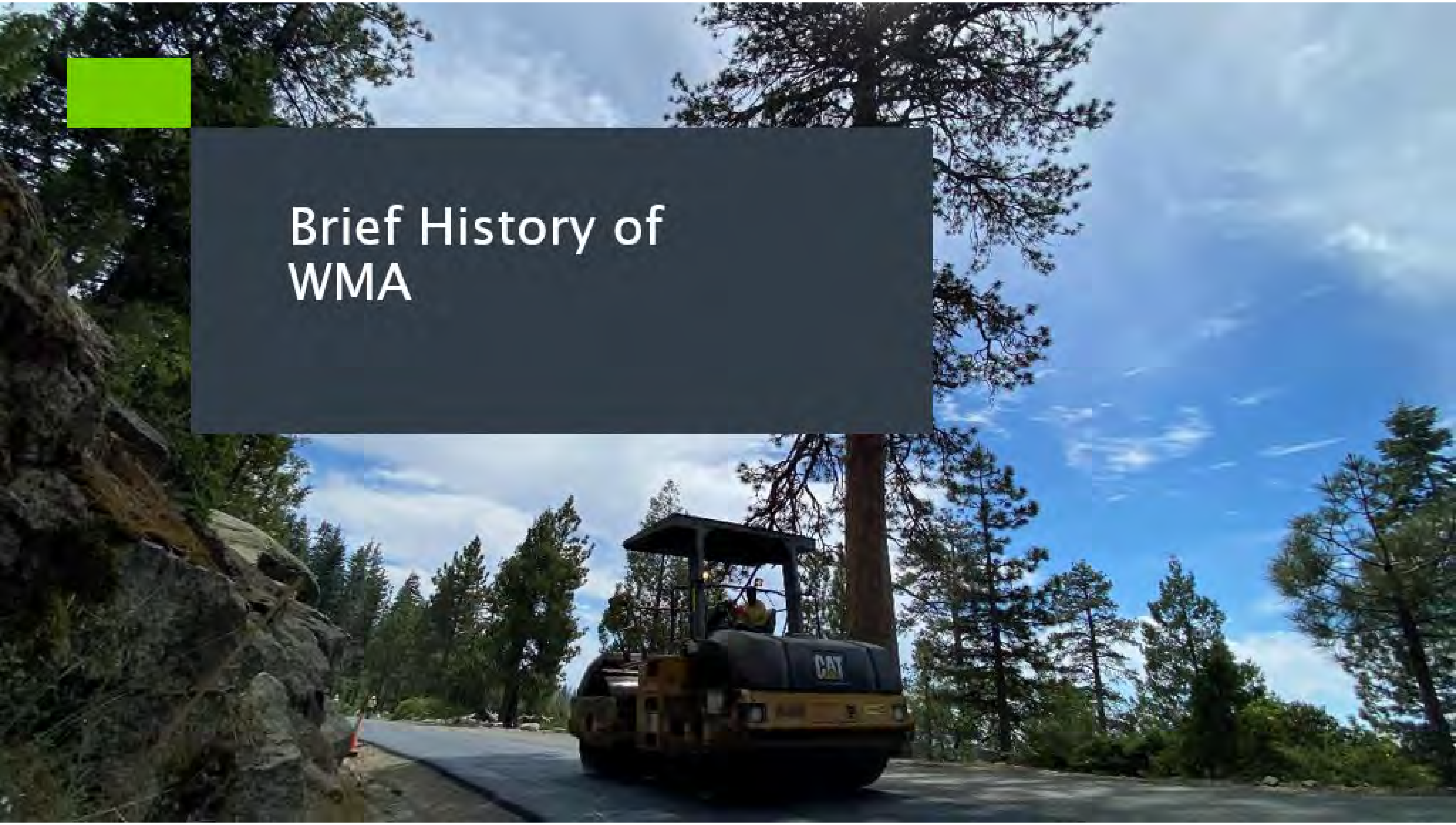
Technical Marketing Manager
December 7, 2023

Agenda

- Brief History of WMA
- What's Out There – Field Data
- Why? – Reduced Binder Oxidation
- Mixture Performance Improvement?
- Designing Longer Lasting Pavements



Brief History of WMA



History of WMA

2002
- NAPA led study tour to Europe

2004
- WMA demonstration at World of Asphalt
- First field trials in FL and NC

2005
- WMA TWG formed
- First WMA on NCAT Test Track
- Field trials in FL, IN, MD, NH, OH, TX and Canada

2007
- FHWA/AASHTO European Scan Tour
- NCHRP 9-43 on WMA Mix Design initiated

2008
- WMA trials in 32 states
- 1st International WMA Conference

2009
- Full-Depth WMA Test Sections at NCAT
- NCHRP 9-47 on Eng. Props, emissions, field performance completed

2010
- WMA trials in 45 states / 10 Canadian Providences
- Over 20 WMA technologies in the US

2011
- NCHRP 9-43 completed
- 2nd International WMA Conference

2013
- NCHRP 9-49 on WMA Moisture Susceptibility completed

2014
- NCHRP 9-47A on WMA Properties and Performance completed

2015
- NCHRP 9-53 on Foamed Asphalt completed

2016
- NCHRP 9-49A on Long-Term Field Performance completed

2018
- NCHRP 9-55 on RAS + WMA completed

2020
- NCHRP 9-61 on binder aging to accurately reflect mix aging to be completed

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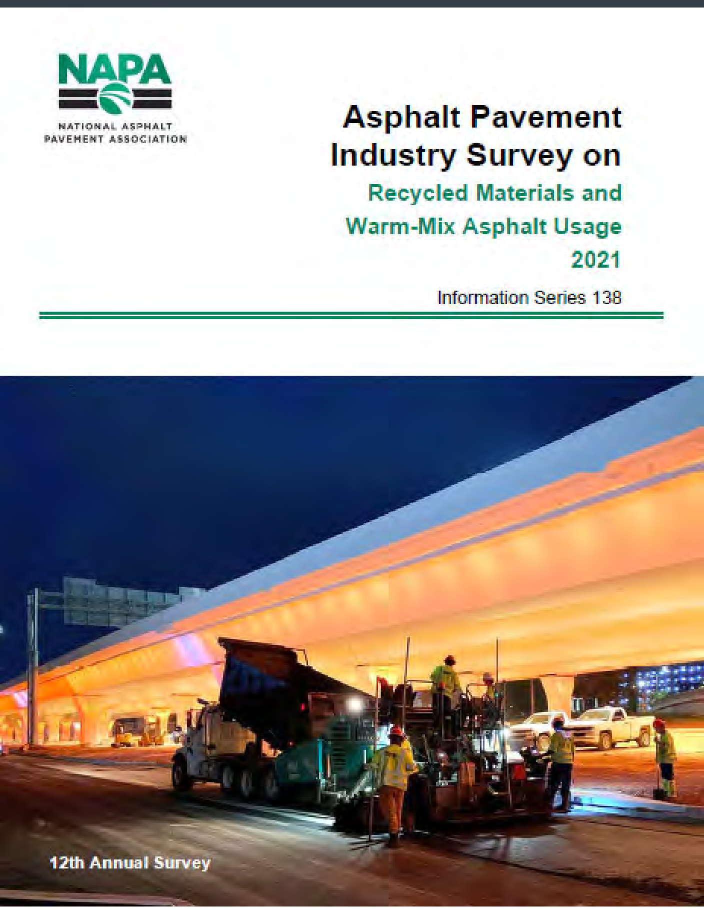
WMA TECHNOLOGIES

- Foam (either mechanical or additive)
  - Uses volume expansion of asphalt, when water converts from liquid to gas, to allow better mixing/coating
- Chemical additives
  - Surfactants use a variety of chemical mechanisms to allow better mixing/coating and compaction
- Wax additives
  - Decrease asphalt viscosity to allow better mixing/coating

NAPA's WMA Usage Survey – 2021

The National Asphalt Paving Association (NAPA) has conducted a systematic survey of asphalt mixture producers across the United States to quantify the use of recycled materials and the production of WMA from 2009 until 2021.


NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage 2021

Information Series 138

12th Annual Survey

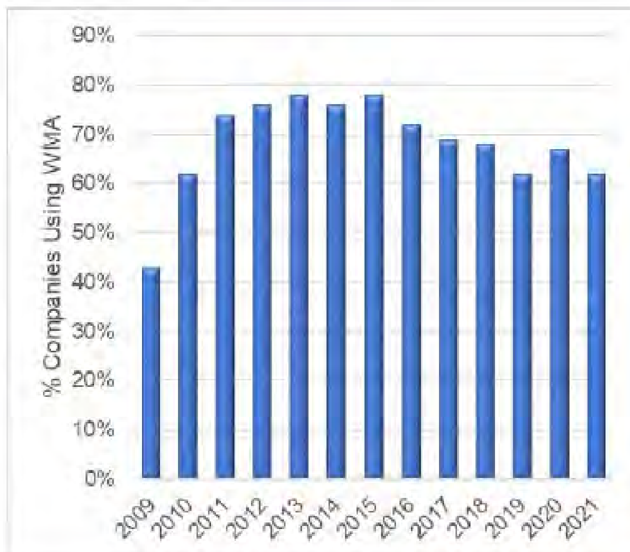


Figure 14: Percent of Companies Using WMA Technologies

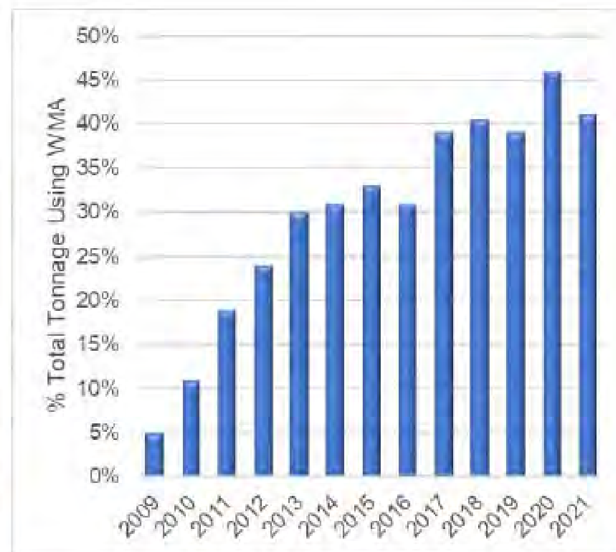


Figure 15: Percent Total Tonnage Produced Using WMA Technologies

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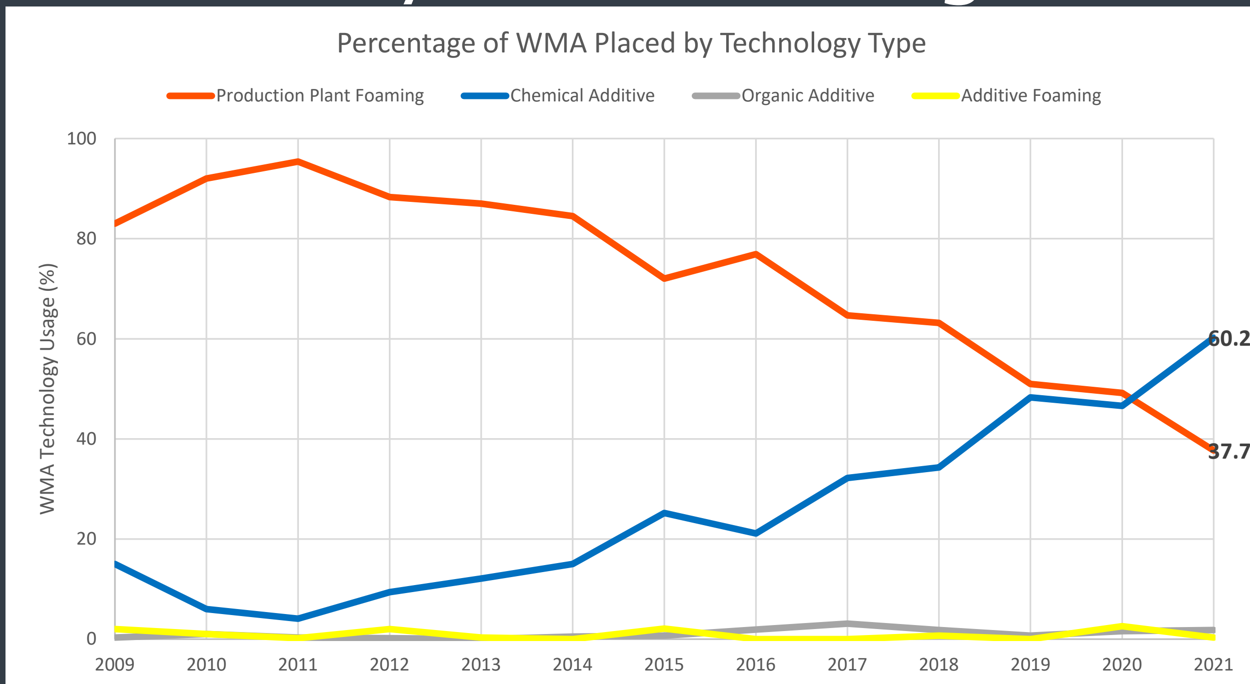
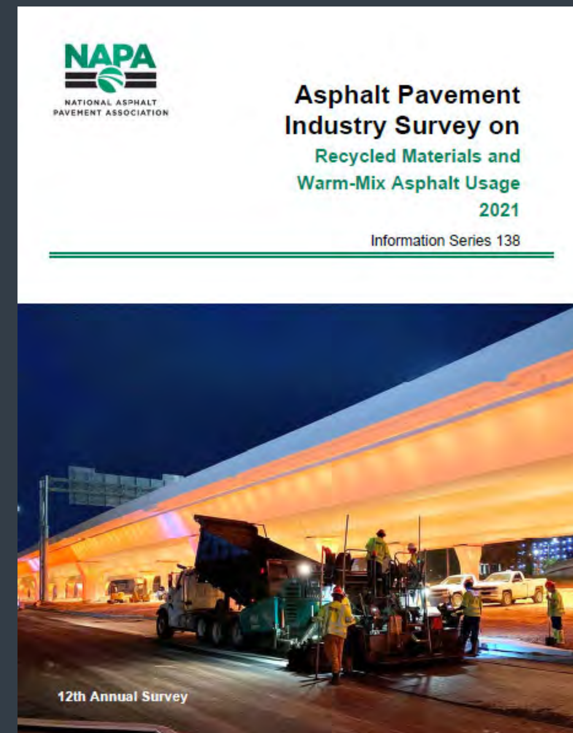
NAPA Survey on WMA Usage



WMA Technology	% Production												
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Production Plant Foaming	83	92	95.4	88.3	87	84.5	72	76.9	64.7	63.2	51	49.2	37.7
Additive Foaming	2	1	0.2	2	0.3	0	2.1	0	0	0.7	0	2.6	0.3
Chemical Additive	15	6	4.1	9.4	12.1	15	25.2	21.1	32.2	34.3	48.3	46.6	60.2
Organic Additive	0.3	1	0.3	0.2	0	0.5	0.7	1.9	3.1	1.8	0.7	1.6	1.8



Data taken from NAPA's "Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2021"

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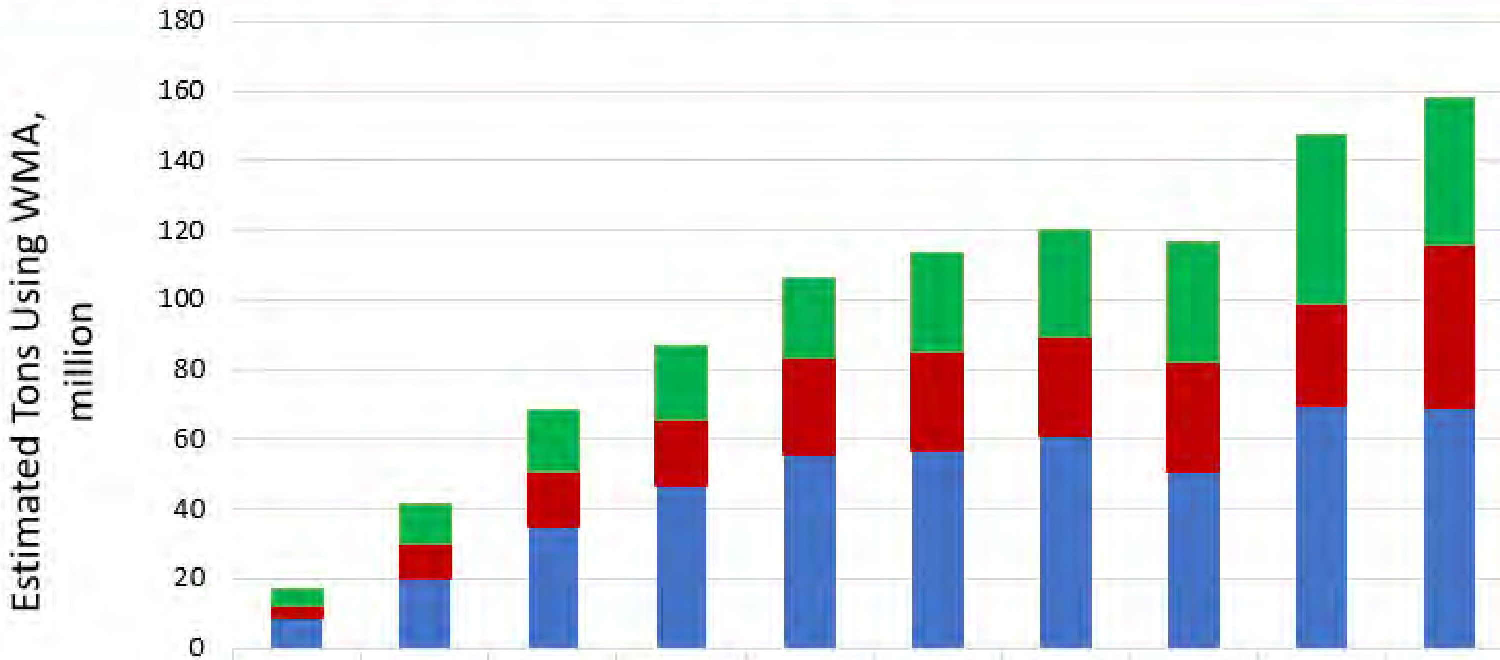
NAPA SURVEY ON WMA USAGE



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Commercial & Residential	4.6	11.3	17.8	21.4	22.8	28.5	30.4	34.6	48.4	42
Other Agency	3.6	9.8	16.3	18.9	27.9	28.4	28.5	31.5	29.4	46.5
DOT	8.6	20	34.6	46.4	55.7	56.9	60.9	50.7	69.6	69.3

Graphs are from NAPA's "Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2018"

NAPA'S WMA USAGE SURVEYS

In previous surveys, producers were asked to estimate tonnage produced using WMA technologies with a temperature reduction of 10F to 100F.

New in 2018, an additional question was asked about tonnage produced using WMA technology but without reducing temperatures.

Results indicated that prior surveys have better captured the use of WMA technologies than the use of warm mix at reduced temperatures.

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%

Data are from NAPA's "Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2018"

LESS BINDER OXIDATION

COLD WEATHER PAVING

FIBER-FREE SMA

MIX TYPES: OGFC PMB GTR …

MAT DENSITY

MORE UNIFORM

SEGREGATION =

LESS THERMAL

HIGHER RECYCLED MATERIAL CONTENT

LONGER HAUL DISTANCES

BETTER COMPACTION

DENSITY = BONUS PAY

LIME REPLACEMENT

REDUCED AGGREGATE ABSORPTION

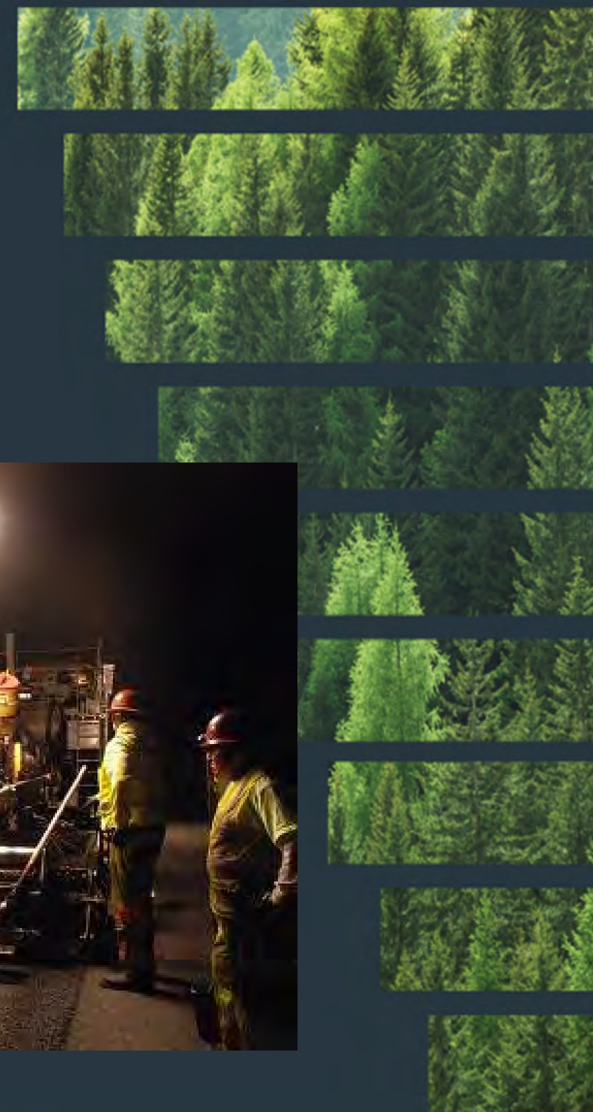
Ingevity "Four Pillars Approach" to WMA

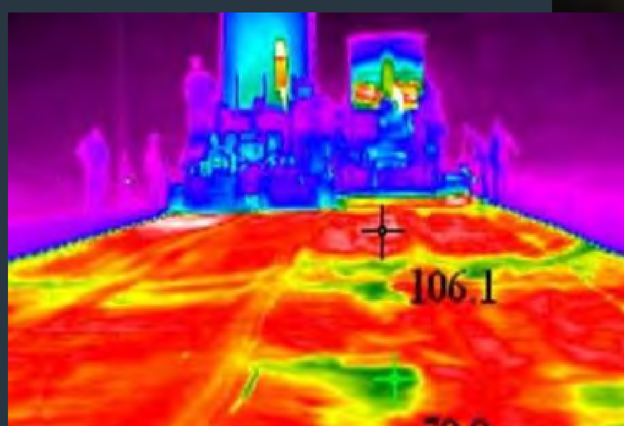
Field Performance

Binder Analysis

Mixture Performance

Pavement Design





1 | Binder Performance

100 Years Ago Technologists Spoke of "Aging" as "Weathering"

By at least 1925, oxidation studies had revealed evidence that **air exposure** converted **resins to asphaltenes** and that different bitumen components adsorbed (reacted with oxygen differently) (Ref. Hoibert).

As early as the 1930's, oxygen uptake, light, solar radiant energy, and heat were among the well recognized causes of binder stiffening. (Ref. Hoibert)

By 1956, when W.P. van Oort published his seminal work on oxygen adsorption, "weathering" was called "aging."

Hoibert, A.J., Editor, "Bituminous Materials: Asphalts, Tars, & Pitches," Vol. II, John Wiley & Sons, **1965**, p. 98.

Durability of Asphalt

Its Aging in the Dark

W. P. VAN OORT

N. V. De Bataafsche Petroleum Maatschappij, Koninklijke-Shell Laboratorium, Amsterdam, The Netherlands

ONE of the important factors determining the lifetime of constructions in which asphalt has been used is the influence exerted on the asphalt by the weather. The entire complex of changes in the properties of asphalt by atmospheric influences, to the detriment of the construction concerned, is called aging. The degree to which asphalt resists these influences is called its durability.

Literature (*1*, *3*) on the aging phenomena of asphalt is extensive. However, most of the published studies describe only the phenomena observed. Frequently, correlations between aging phenomena and properties of the asphalt are sought by purely empirical methods. Many methods described aim at obtaining direct information by short-time tests on asphalt behavior after long exposure.

According to the literature, the action of oxygen is one of the principal factors responsible for the occurrence of aging phenomena. When asphalt is exposed to atmospheric oxygen, a slow autoxidation occurs, the chemical nature of which depends to a very large extent upon the temperature. At temperatures above 100° C. dehydrogenation takes place, as is evident from the water produced. Some carbon dioxide is also formed (*5*). At lower temperatures—e.g., 25° or 50° C.—the oxygen involved in the oxidation is quantitatively bound in the bitumen and no water or carbon dioxide is formed.

The rate of the oxidation may be followed by means of oxygen absorption measurements. The over-all rate of oxygen absorption was found to be not only determined by the chemical nature of the asphalt, but also by the physical transport of the oxygen from the surrounding atmosphere to the interior of the material. Therefore, it is also a physical problem, one of diffusion in particular.

A study of the time-absorption curve for oxygen is presented. Both experimental and theoretical investigations are included to acquire an understanding of phenomena involved by the transfer of oxygen and related factors determining the velocity of the entire process.

In order not to complicate this fundamental study, aging in the absence of light was investigated. Such an investigation is very important, as most of the asphalt is employed in road carpets and similar constructions, where the greater part of the asphalt is subjected to slow oxidation in the dark, owing to the porous structure of the mixture that usually exists. Some practical data on the change in mechanical properties as a result of aging are given to substantiate this theoretical investigation. A microviscometer developed by Labout and van Oort (*2*) was used to collect these data.

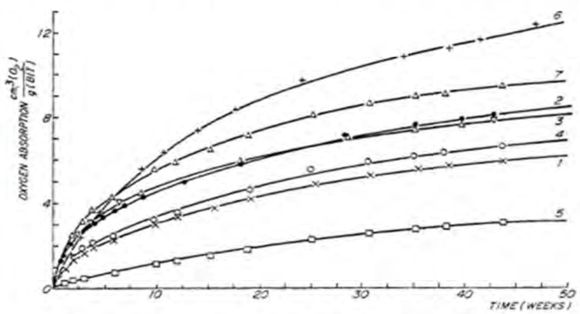


Figure 1. Absorption of oxygen by different asphalts in the dark

In 7-micron layers at 22° C. and 1-atm. pressure

		Pen 25° C.	Softening point R and B ° C.
1.	Middle East	24	56
2.	Middle East	46	52
3.	Middle East	57	52
4.	Venezuelan	55	52
5.	Venezuelan	27	84
6.	Indonesian	21	52
7.	Residue of Dubbs plant	109	45

RESULTS OF MEASUREMENTS

Oxygen Absorption. The conditions under which the absorption of oxygen was measured were chosen so as to accord as closely as possible with conditions of actual service. Measurements were made on asphalt in thin films at temperatures between 20° and 70° C. The procedure used for measuring absorption was based on the conventional

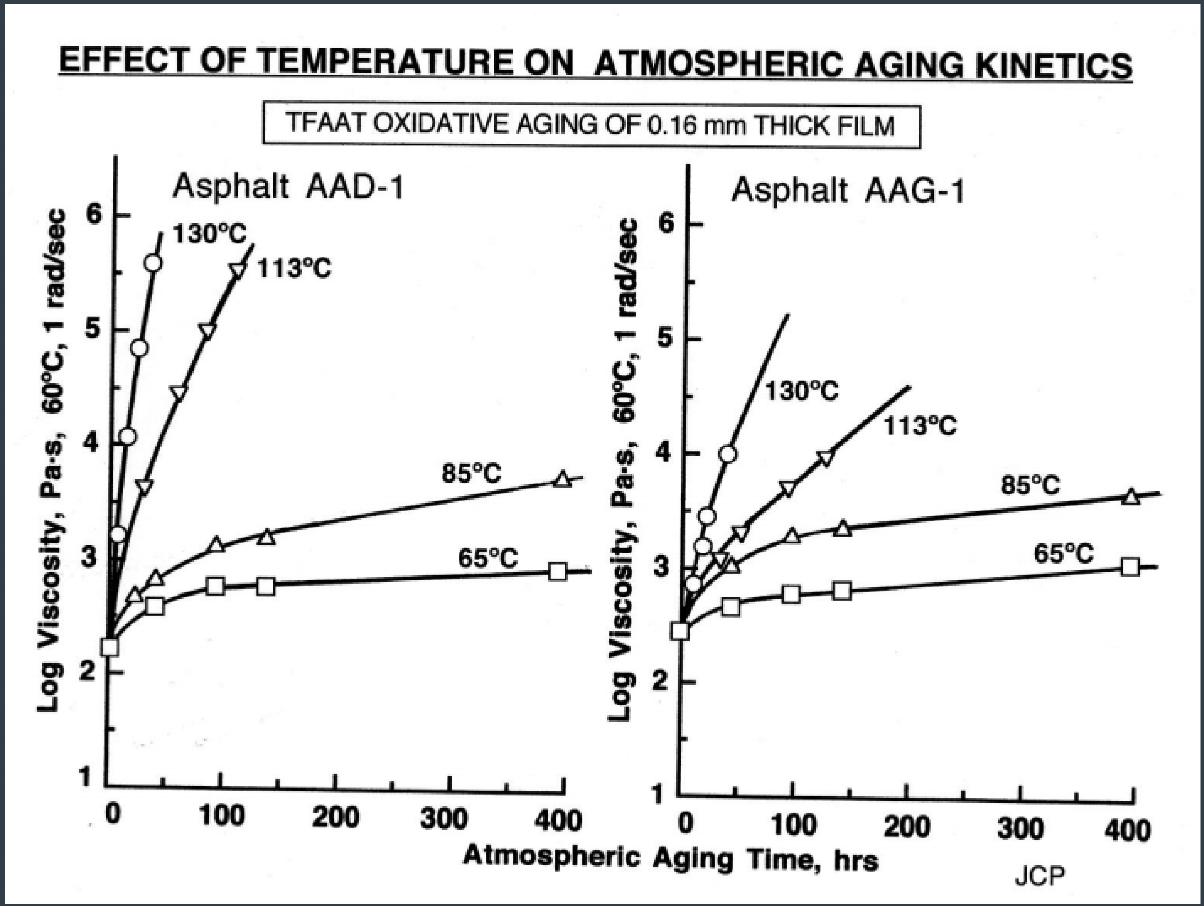
4. Venezuelan 55 52
5. Venezuelan 27 84
6. Indonesian 21 52
7. Residue of Dubbs plant 109 45

tures between 20° and 70° C. The procedure used for measuring absorption was based on the conventional

1196

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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How Our Industry Lab Ages Binder

Short-term Aging
Rolling Thin Film Oven

PG 64

In-service Aging
Pressure Aging Vessel

-22

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What Influences Binder Aging?

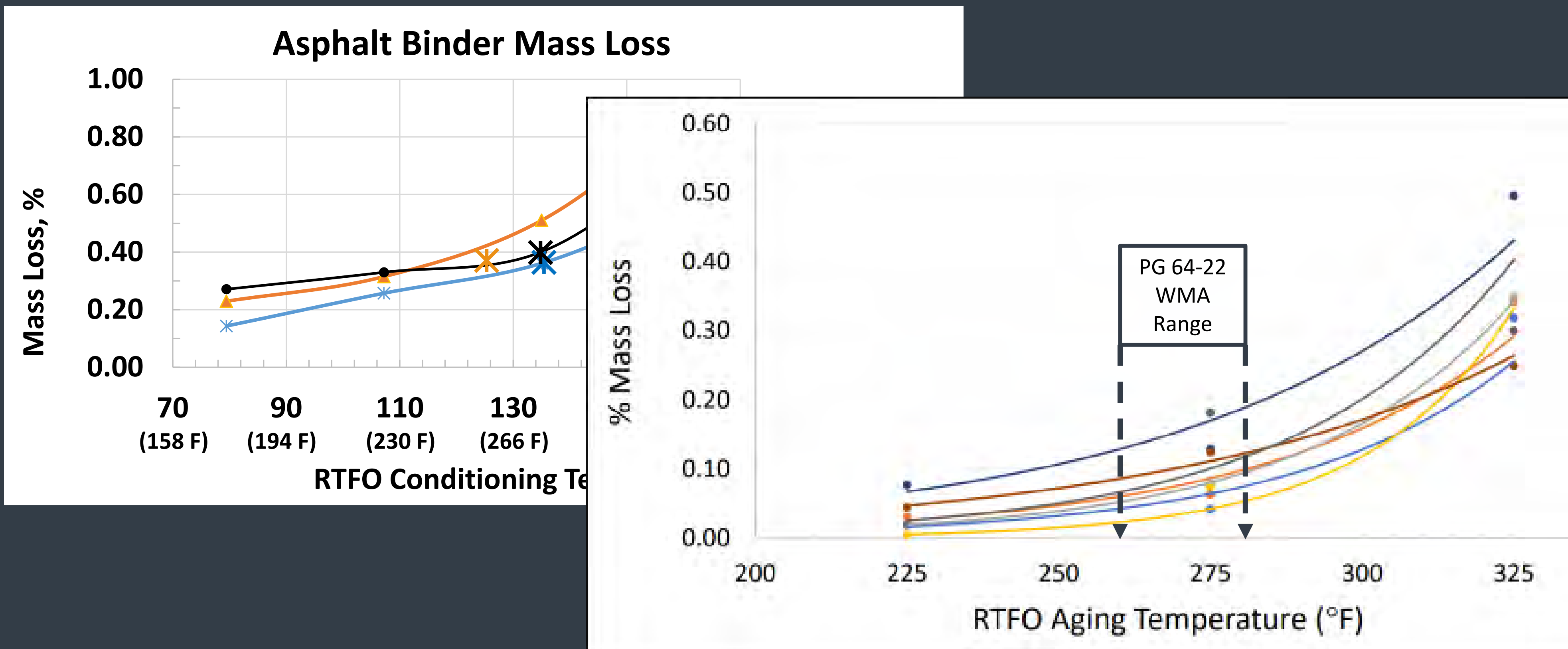
Short-Term "Spurt" Aging

Process dependent
Controllable

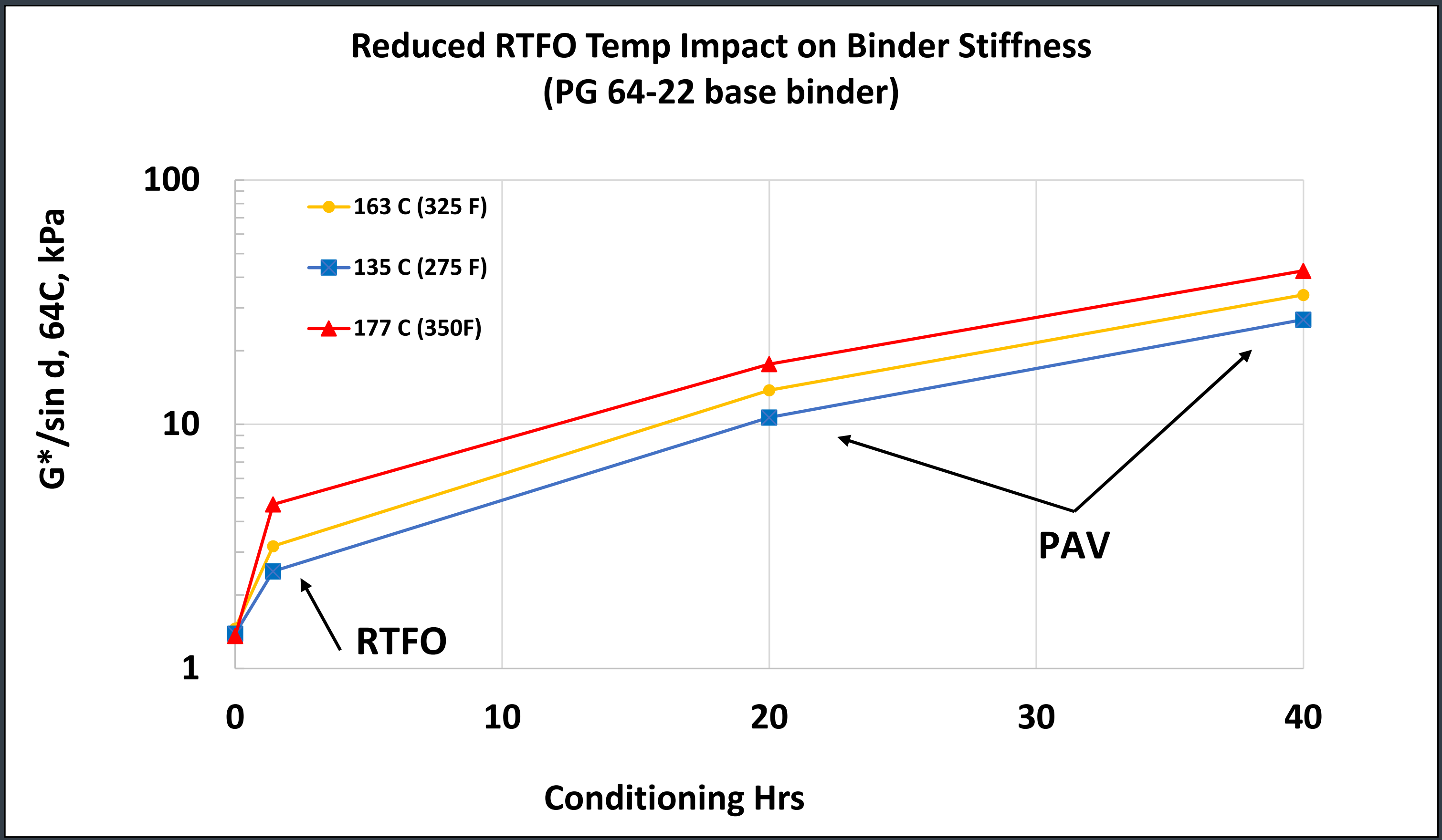
In-Service Aging

Environmental dependent
Predictive

Binder Mass Loss vs RTFO Temperatures



Binder Stiffness vs RTFO Temperatures



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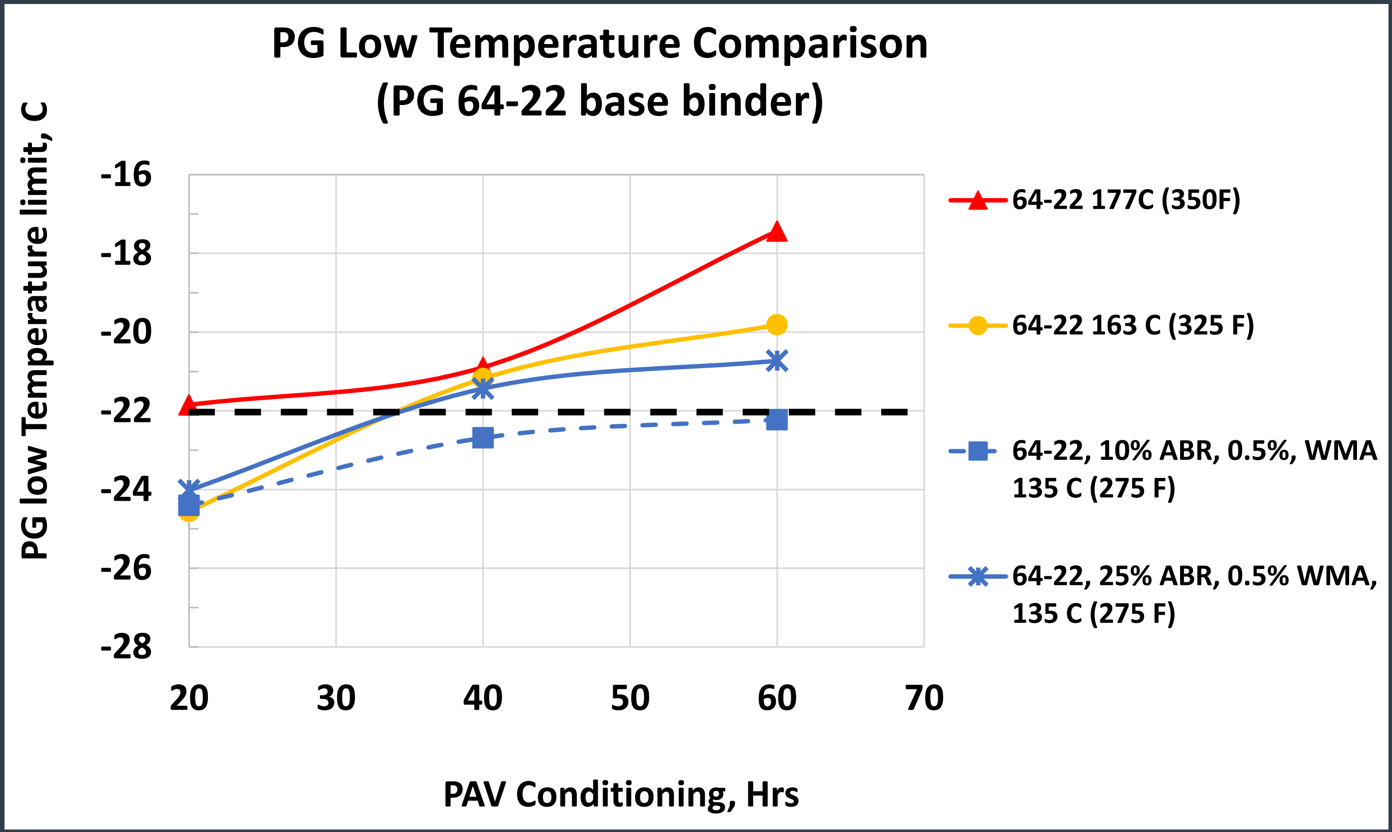
PG Low Temp After Extended Aging

- 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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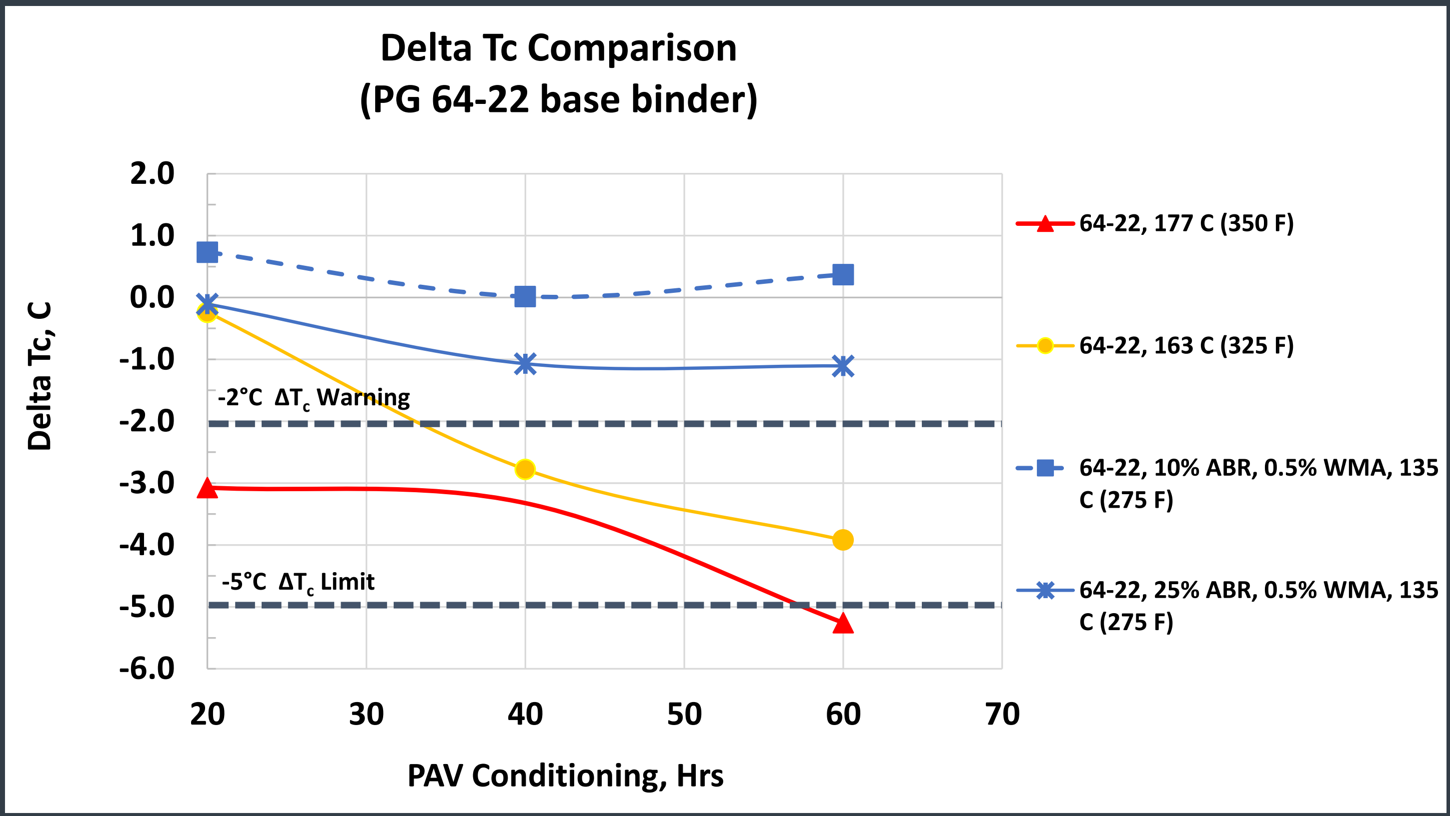
Lowering Temperature Improves Long-Term ΔTc



5yrs	10yrs	15yrs

$\Delta Tc = T_{cont}\,S - T_{cont}\,m$

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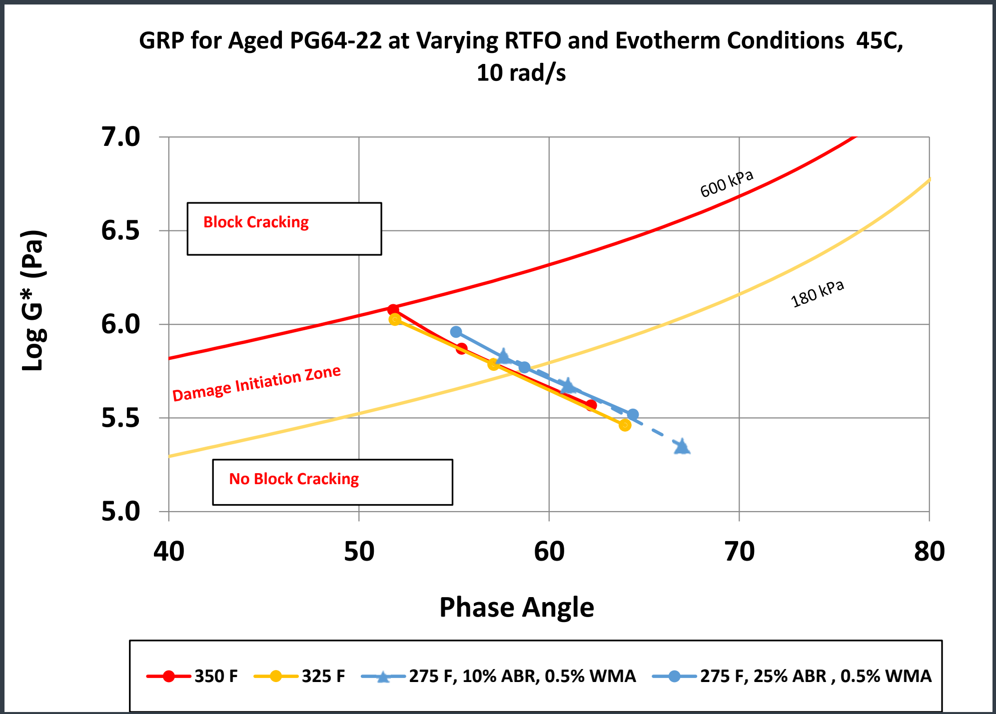
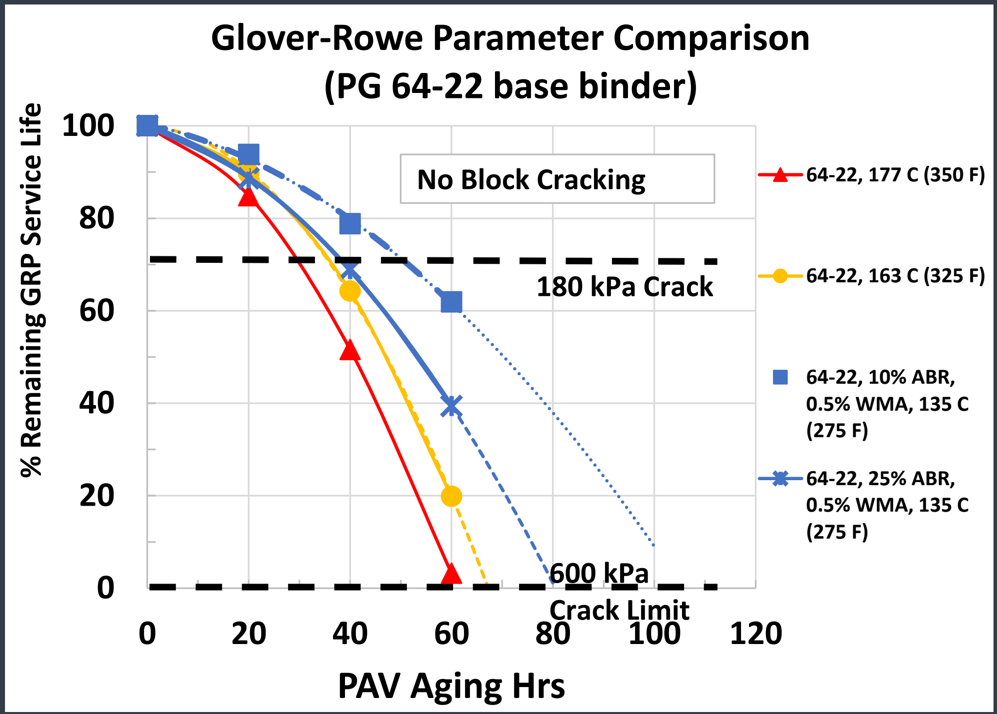
Glover-Rowe Parameter with Low Temperature

Black Space Diagram



GRP Values



$$GRP = \frac{G^*(\cos \delta)^2}{\sin \delta}$$

% remaining life =

$(GRP_{limit} - GRP)/GRP_{limit} * 100$

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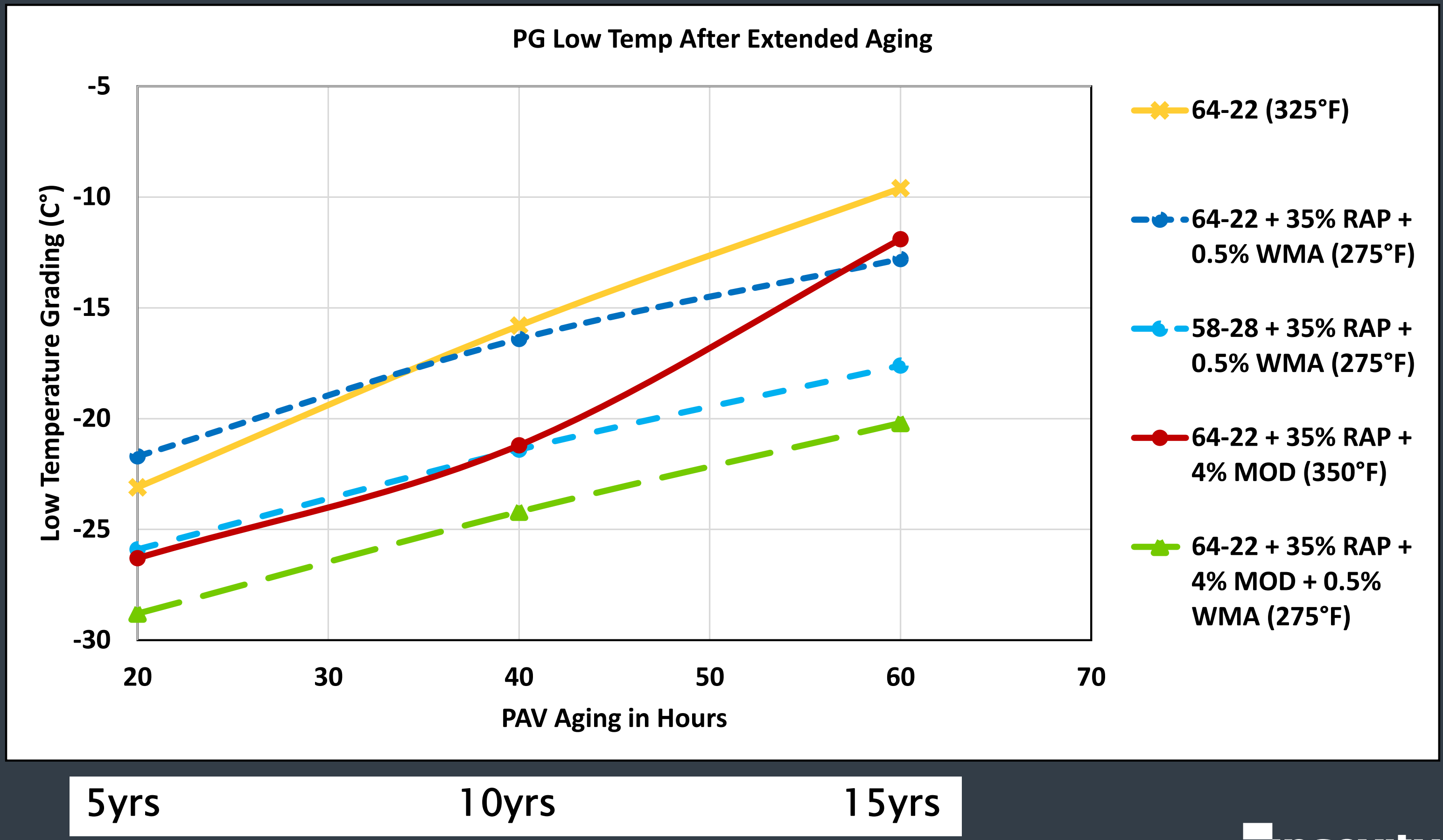
PG Low Temp After Extended Aging with Modifier Comparison

Grade bumping and Modifiers also shift graph.

WMA shift from lower mix temperature of greater significance



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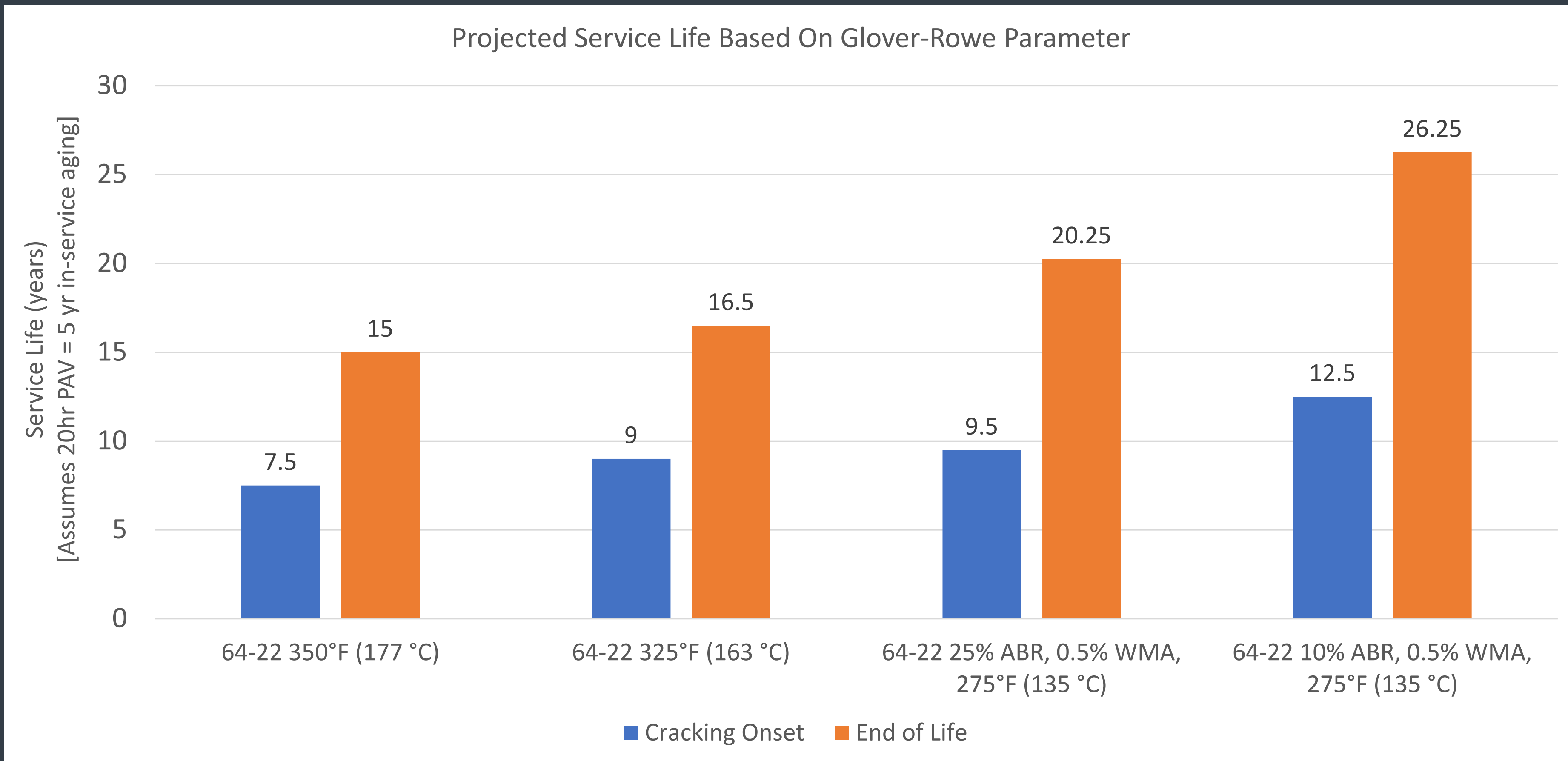
Lower Production Temps = Longer Pavement Life



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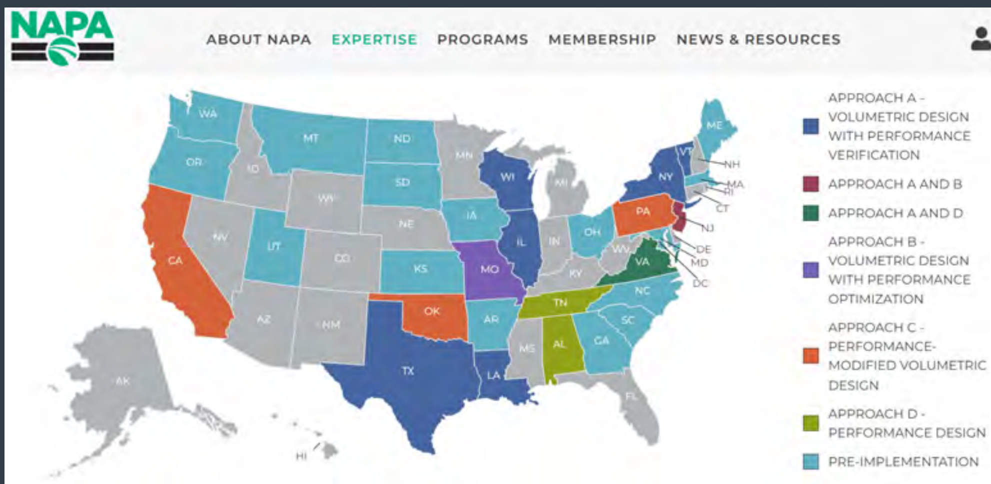
2 | Mixture Performance – BMD

BMD – NCAT Guide



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

Table 1. Summary of State-of-the-Practice on BMD Implementation

BMD Approach	State	Applicable Mixture Type	Rutting Test	Cracking Test	Performance Testing for Production Acceptance?
Approach A	Illinois	High ESAL mixtures	HWTT	I-FIT	Yes, HWTT for "Pass/Fail"
	Louisiana	Wearing and binder course mixtures	HWTT	SCB-Jc	Yes, "Pass/Fail"
	New Jersey	Specialty mixtures	APA	OT, BBF	Yes, "Pass/Fail" or Pay Adjustment
	Texas	Surface mixtures	HWTT	OT, IDEAL-CT	Yes, "Pass/Fail"
	Vermont	Superpave Type IVS mixtures	HWTT	I-FIT	Yes, PWL
Approach A and D	Virginia	Surface mixtures	APA	Cantabro, IDEAL-CT	Yes, "Pass/Fail"
Approach C	California	Long-life pavement mixtures	FN, HWTT	BBF, I-FIT	Yes, HWTT for "Pass/Fail"
	Missouri	Mainline pavement mixtures	HWTT	I-FIT, IDEAL-CT	Yes, HWTT for "Pass/Fail", I-FIT & IDEAL-CT for Pay Adjustment
	Oklahoma	Superpave mixtures	HWTT	IDEAL-CT	No
Approach D	Alabama	Superpave mixtures	HT-IDT	AL-CT	Yes, "Pass/Fail"
	Tennessee	All mixtures	HWTT	IDEAL-CT	To be determined

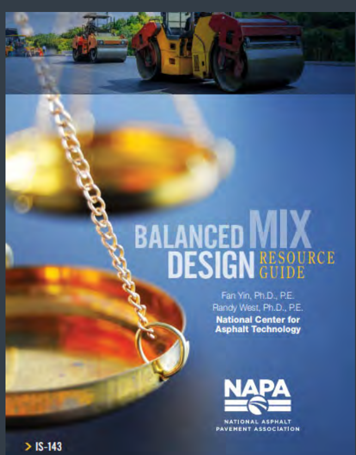
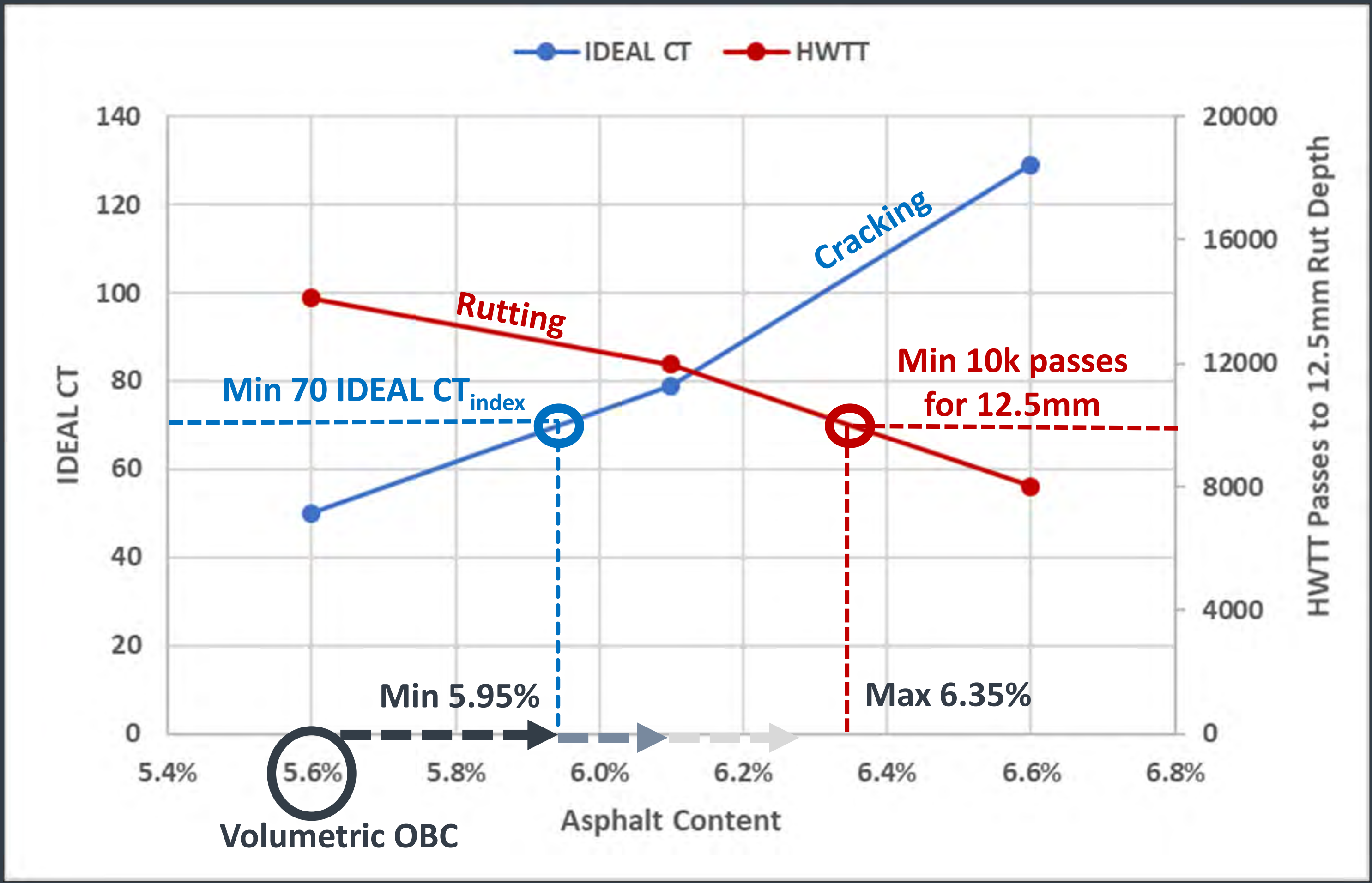


Table 14 Summary of Statistical Measures of Top-Down Cracking Tests

Test and Parameter	Average COV	Games Howell Groups	Range of R^2
Energy Ratio, ER	Not available	Not applicable	0.03 to 0.28
Texas Overlay Test, β	17%	5	0.76 to 0.91
NCAT Overlay Test, β	10%	4	0.79 to 0.97
Louisiana SCB, J_c	20%	Not applicable	0.13 to 0.78
Illinois Flexibility Index Test, FI	34%	3	0.76 to 0.89
IDEAL Cracking Test, CT_{index}	18%	4	0.87 to 0.94
AMPT Cyclic Fatigue, S_{app}	16%	5	0.89 to 0.90

NCAT Report 20-21 Validation of Top-Down Cracking Tests for BMD https://eng.auburn.edu/research/centers/ncat/files/NCAT-Cracking-Group-20210706-final.pdf

BMD Trends– Typical Approach



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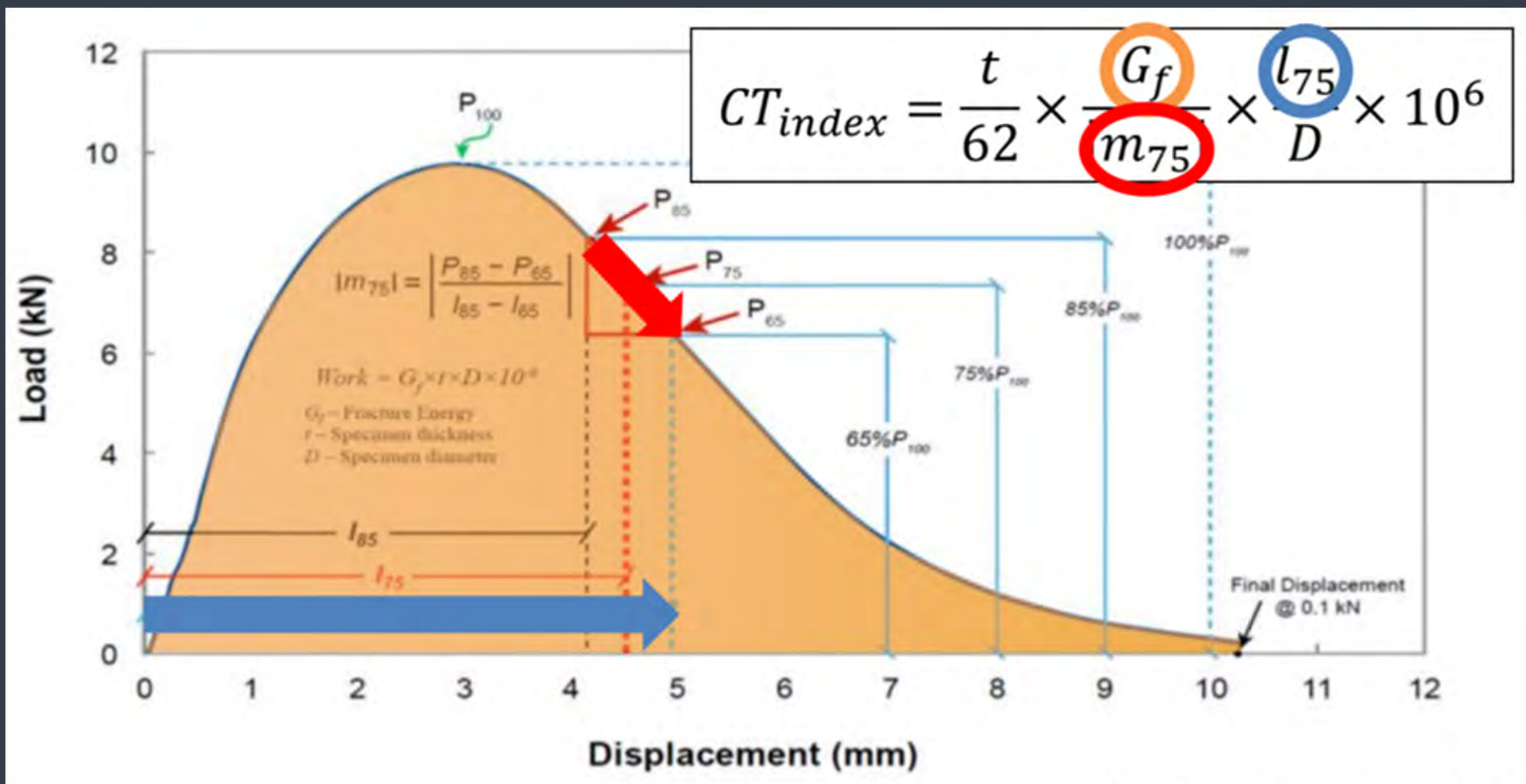
BMD – How Does IdealCT Work?



(Road and Materials, 2019)

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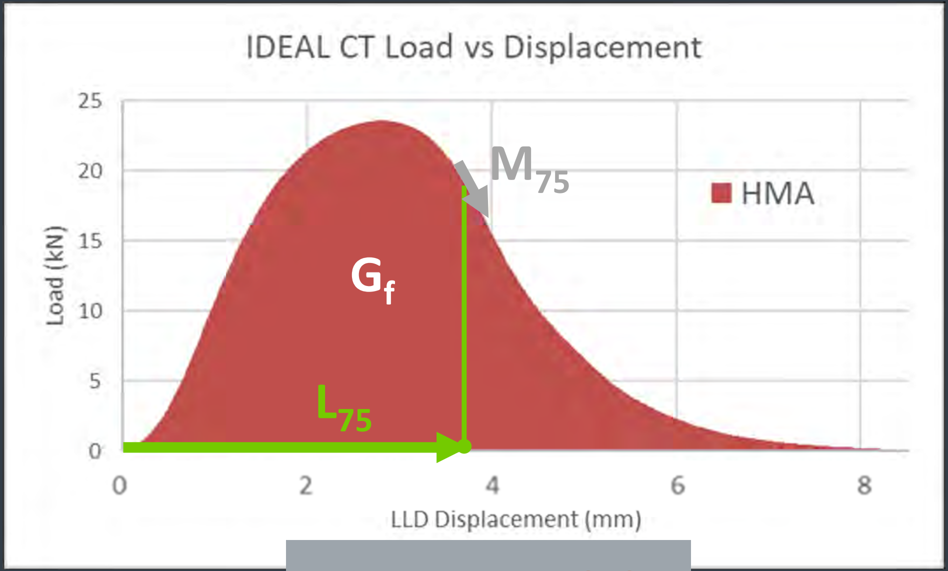
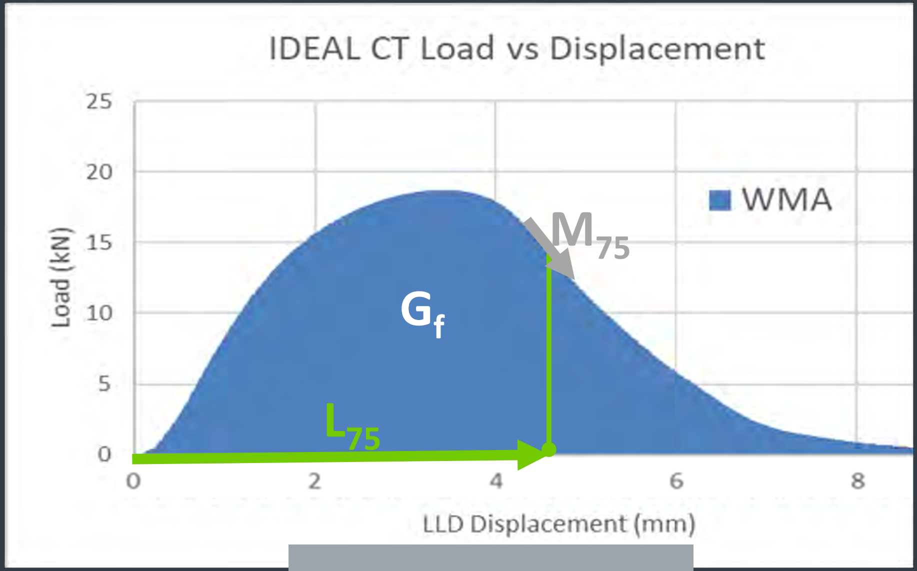
BMD – How WMA Impacts IDEAL CT

$$CT_{index} = \frac{t}{62} \times \frac{G_f}{M_{75}} \times \frac{l_{75}}{D} \times 10^6$$



CT$_{index}$=20

G_f = 9319 J/m^2
L_{75} = 3.76 mm
M_{75} = 11.64 N/m



CT$_{index}$=42

G_f = 9485 J/m^2
L_{75} = 4.69 mm
M_{75} = 7.06 N/m

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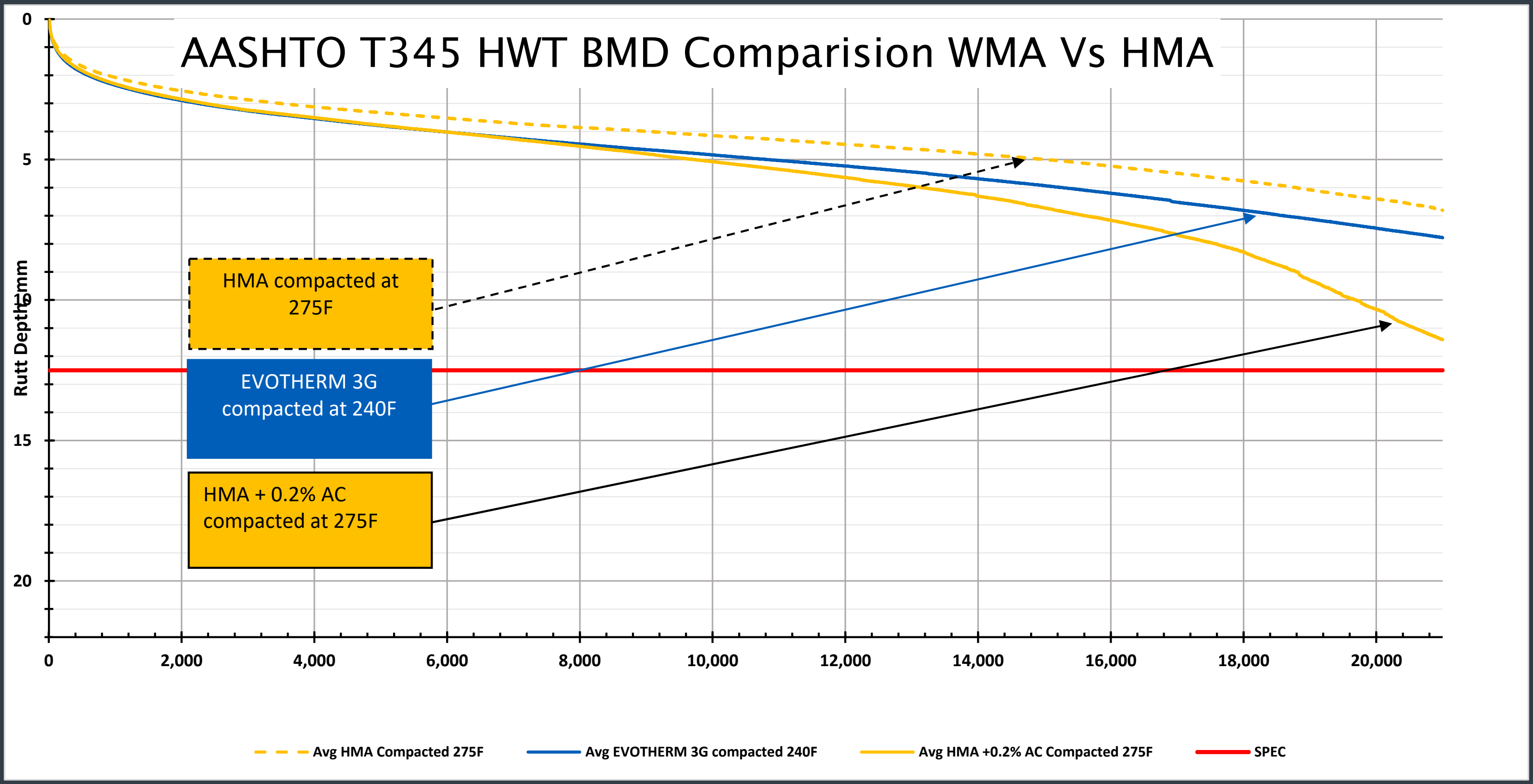
BMD – WMA vs Increased AC Content



No significant change in WMA rutting performance as compared HMA; increased AC% shows more potential to rut.

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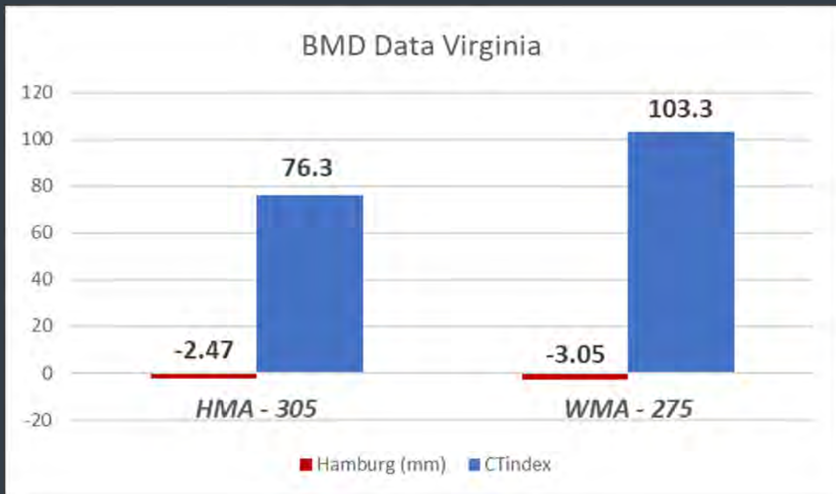
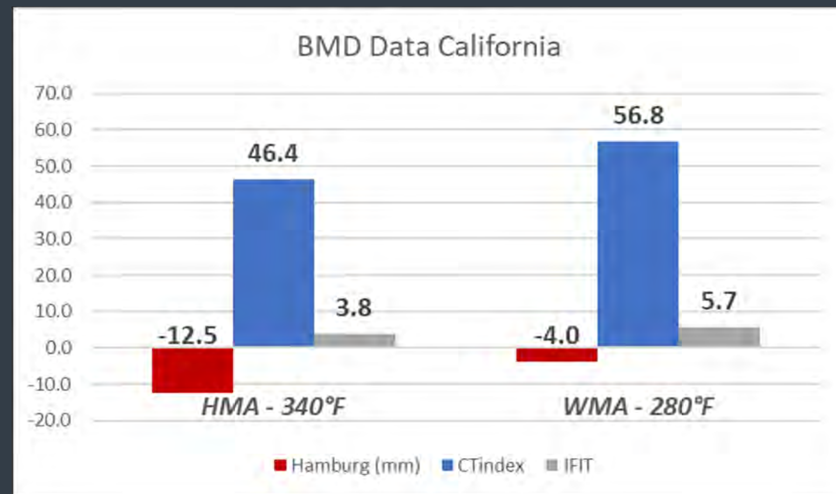
Mixture Performance Testing – BMD





- Virginia California BMD work with WMA.
- WMA improves IDEAL CT by temperature reduction
- Rutting is not affected by temperature reduction

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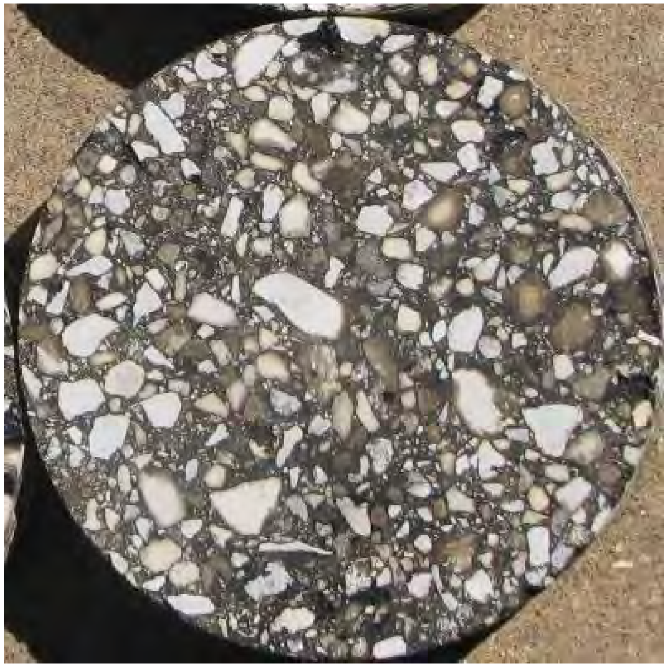
More effective use of asphalt binder

Evotherm @ 275˚

Hot mix control @ 325˚



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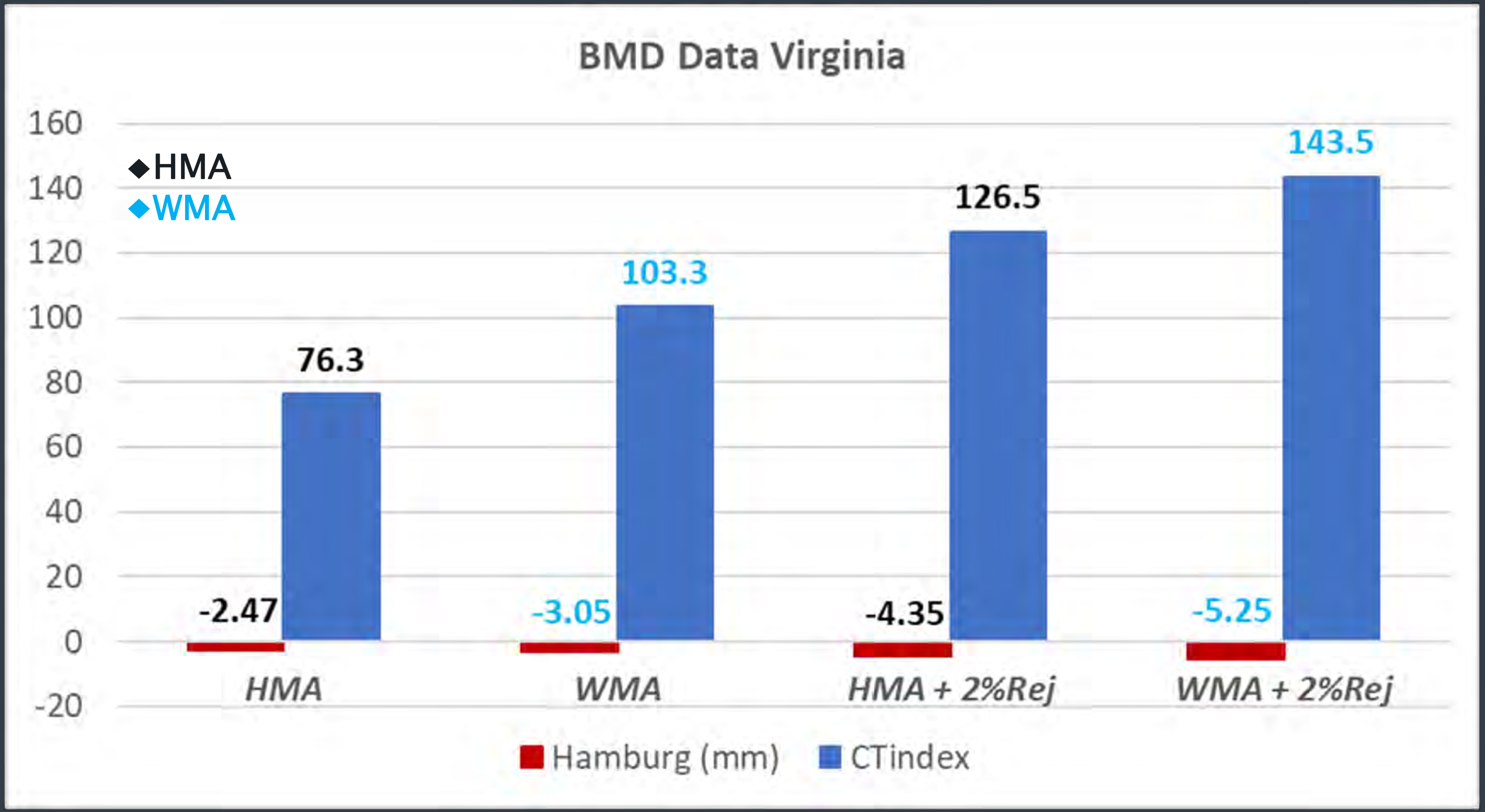
Mixture Performance Testing – BMD with Rejuvenator

WMA Shift and a Rejuvenator Shift



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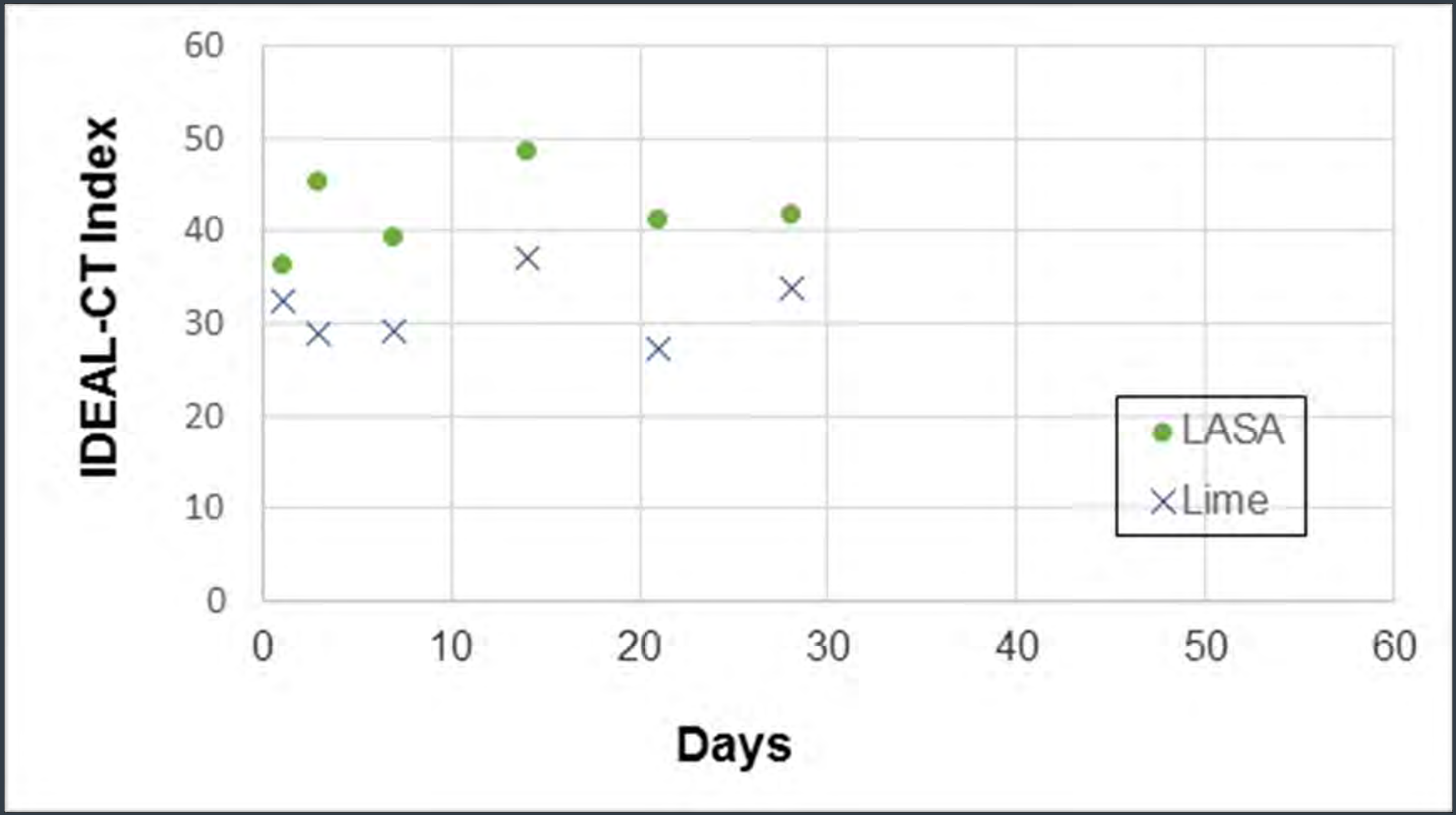
SCDOT Initial Cracking Test Benchmarking



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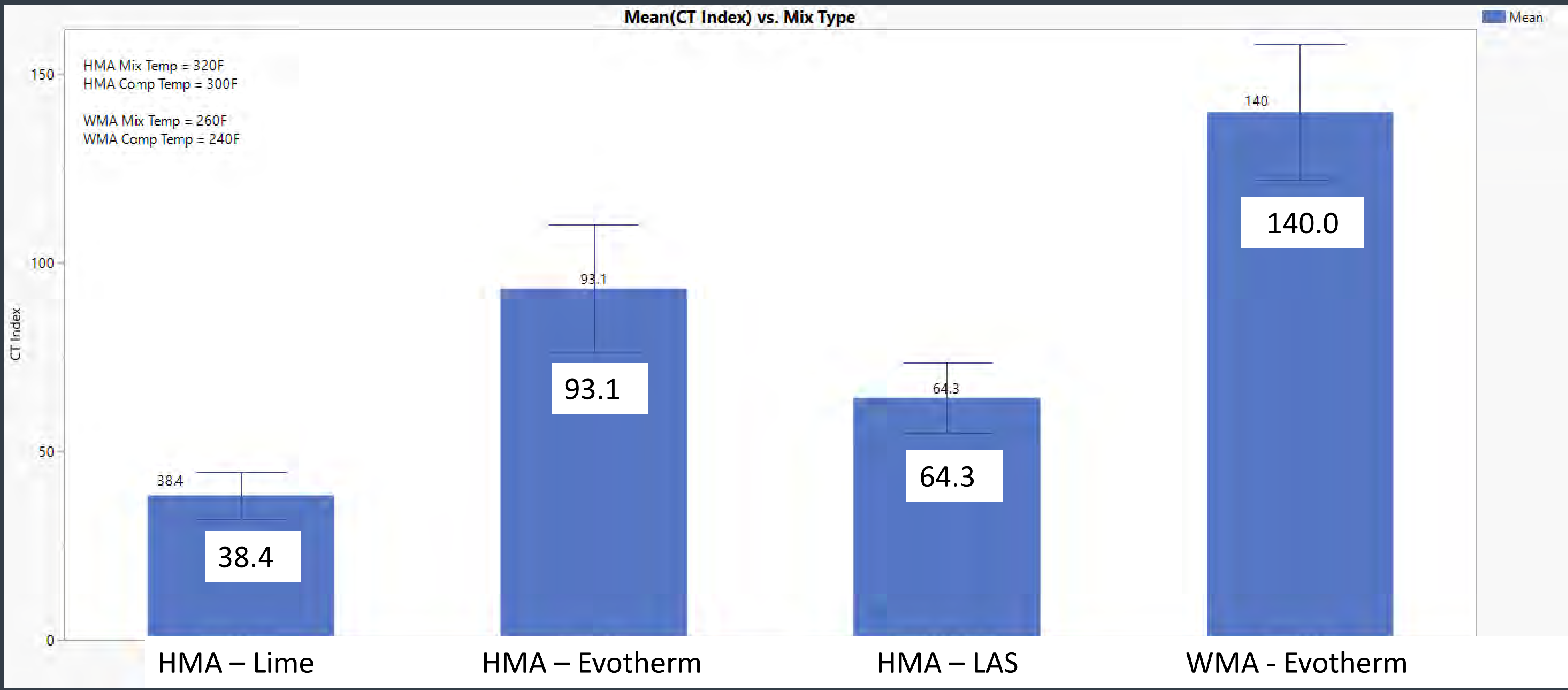
IdealCT Results –SC



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3 | Better Field Performance


Left Lane 340-350F
Production temperature
92-93% density
Better
Binder Life
in the Field
TXDOT US84 – 4 years after construction
Right Lane 265-290F
Included WMA Additive
94%+ density

How is this improvement achieved?

- Reducing production temperatures
- South Carolina I-26 2011

Independent Validation – National Level

Experimental Ranges of Evotherm WMA (NCHRP Report 843)

- Lift thickness ranges from 1.25 inches to 3.75 inches. NMAS range rom 9.5 to 19-mm.
- Unmodified binders (PG 58-28, PG 64-22, PG 52-34).
- Modified Binders (PG 64-28, PG 70-22, PG 70-28, PG 76-28, PG 76-22).
- RAP ranges from 0 to 30%.
- With 1% lime and without lime.
- With additional LAS and without.
- Aggregate type – limestone, gravel, quartzite, granite, siliceous, crushed river rock, slag, etc.
- Binder content from 4.2 to 7%.
- Traffic from 650 to 160,000 AADT.

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“Network” Level Analysis – Long Term Performance (NCHRP 843)

Mix Type	Average WP Longitudinal Cracking (ft/200 ft)	Average Transverse Cracking (ft/200 ft)	Average Rutting (in)
HMA	59.1	80.4	0.10
Evotherm WMA	47.6	64.0	0.09
% Improvement	24.2%	25.6%	~0%

Mix Type	Average WP Longitudinal Cracking (ft/200 ft)	Average Transverse Cracking (ft/200 ft)	Average Rutting (in)
HMA	5.6	31.6	0.04
Foam WMA	11.5	32.2	0.04
% Improvement	-105.9%	-2.1%	~0%

15 Projects in 11 States
Average distress after average pavement life of 6 years.
Mixture Production $\Delta T = 40°F$

10 Projects in 9 States
Average distress after average pavement life of 5.2 years.
Mixture Production $\Delta T = 45.9°F$

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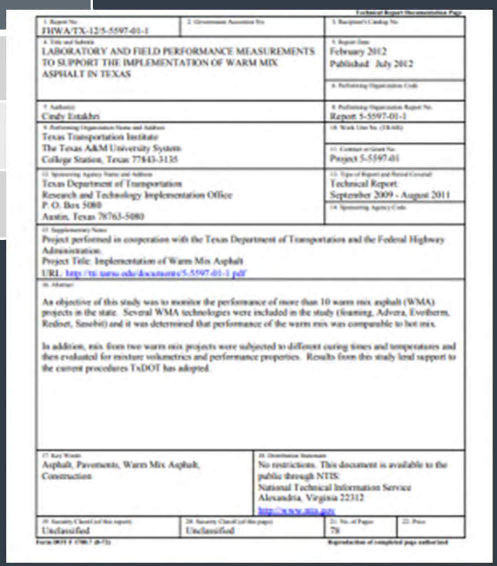
Texas Field Performance

Mix Type	Transverse Cracking (linear ft)	Longitudinal Cracking (linear ft)	Wheel Path Fatigue Cracking (linear ft)
HMA	24	296.7	33.3
Evotherm WMA	20	73.3	6.7
% Improvement	20.0%	304.5%	400.0%

3 Projects
Average distress after <u>average pavement life of 3.7 years</u>.
$\Delta T = 73°F$

Estakhri, Cindy. "Laboratory and Field Performance Measurements to Support the Implementation of Warm Mix Asphalt in Texas." FHWA/TX-12/5-5597-01-1. July 2012


FHWA/TX-12/5-5597-01-1

LABORATORY AND FIELD PERFORMANCE MEASUREMENTS TO SUPPORT THE IMPLEMENTATION OF WARM MIX ASPHALT IN TEXAS

February 2012
Published: July 2012

Cindy Estakhri

Report 5-5597-01-1

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

Project 5-5597-01

Texas Department of Transportation
Research and Technology Implementation Office
P. O. Box 5080
Austin, Texas 78763-5080

Technical Report:
September 2009 - August 2011

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Implementation of Warm Mix Asphalt
URL: http://tti.tamu.edu/documents/5-5597-01-1.pdf

An objective of this study was to monitor the performance of more than 10 warm mix asphalt (WMA) projects in the state. Several WMA technologies were included in the study (foaming, Advera, Evotherm, Rediset, Sasobit) and it was determined that performance of the warm mix was comparable to hot mix.

In addition, mix from two warm mix projects were subjected to different curing times and temperatures and then evaluated for mixture volumetrics and performance properties. Results from this study lend support to the current procedures TxDOT has adopted.

Asphalt, Pavements, Warm Mix Asphalt, Construction

No restrictions. This document is available to the public through NTIS:
National Technical Information Service
Alexandria, Virginia 22312

Unclassified | Unclassified | 78

Density Matters – We all know this

- 1% increase in field density increases pavement service life up to 10+%
- Annual Savings of $1.75 to $8.75 billion with a "B"
- FHWA Demonstration Project for Enhanced Durability of Asphalt Pavements through Increased In-place Pavement Density showcased that chemical WMA improved in place density or reduced effort needed to achieve required density.

Aschenbrener, T., ETG Presentation, April 27, 2016

FHWA Demonstration Project for Enhanced Durability of Asphalt Pavements through Increased In-place Pavement Density, Phase 3 FHWA-HIF-20-003

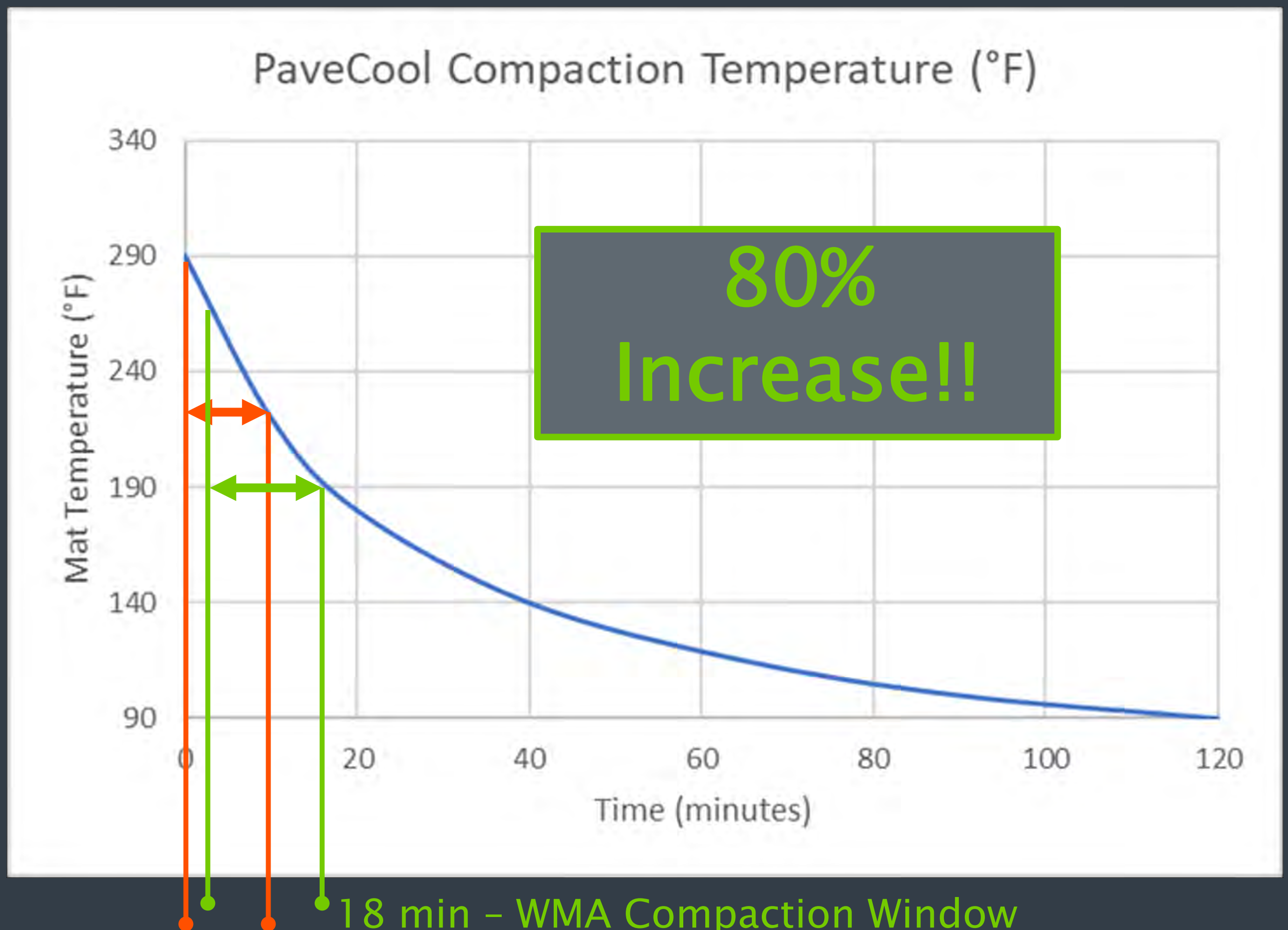
Compaction Window

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

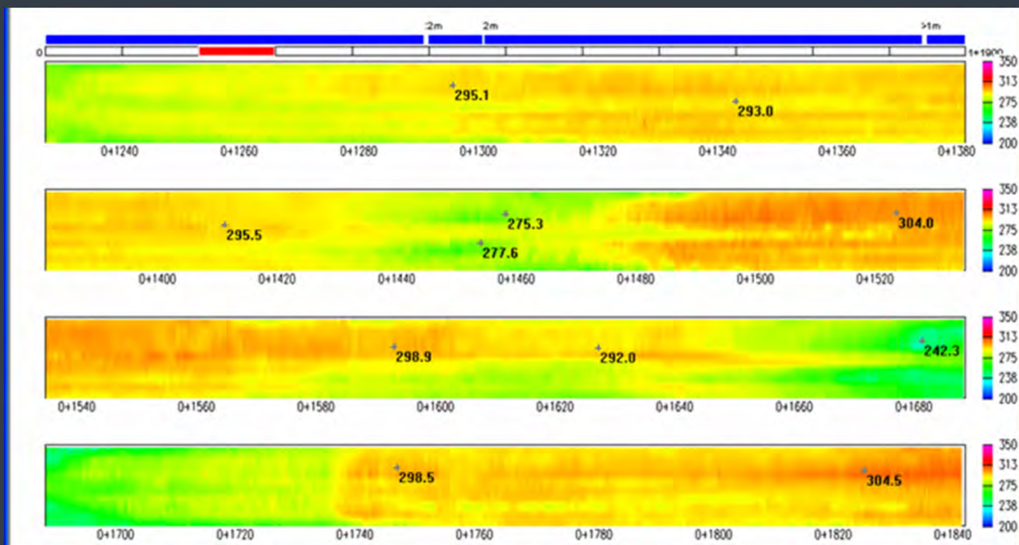
WMA
Mix Temp - 275°F
Compaction Temp
Window 260°F - 190°F

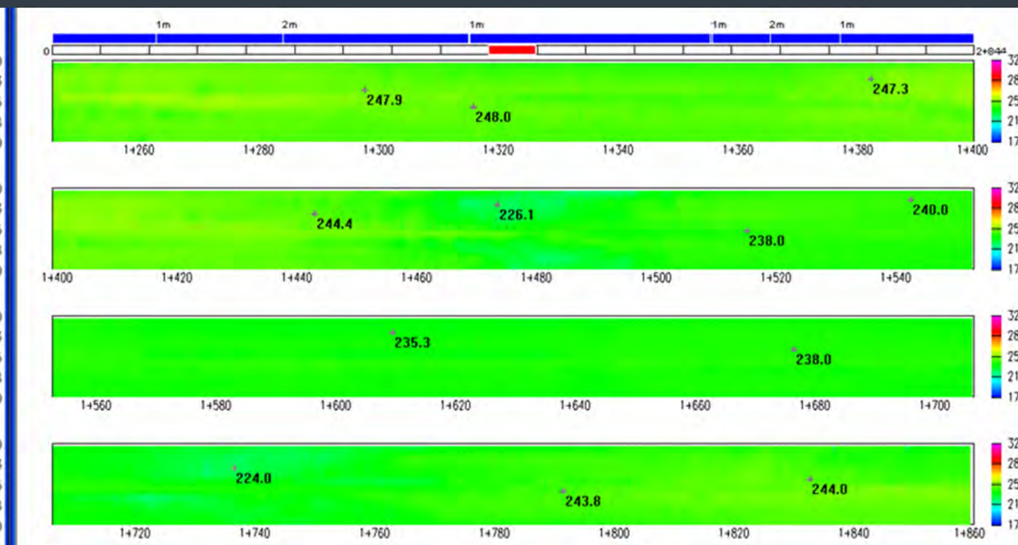


18 min – WMA Compaction Window

10 min – HMA Compaction Window

Thermal Segregation





62°F Difference

24°F Difference

HMA

WMA

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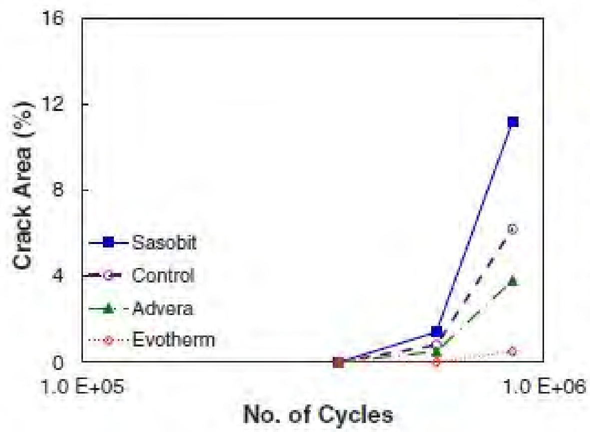
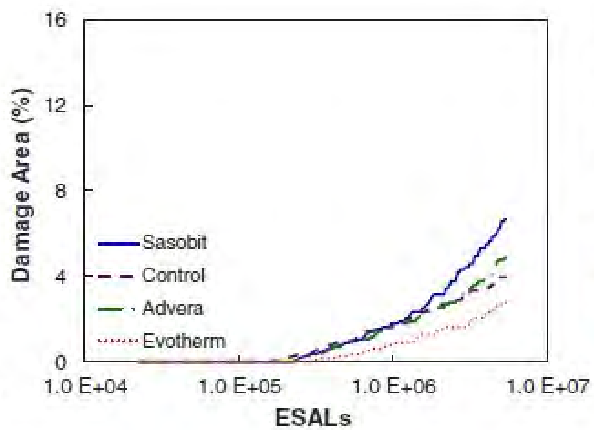
4 | Pavement Designed to Perform

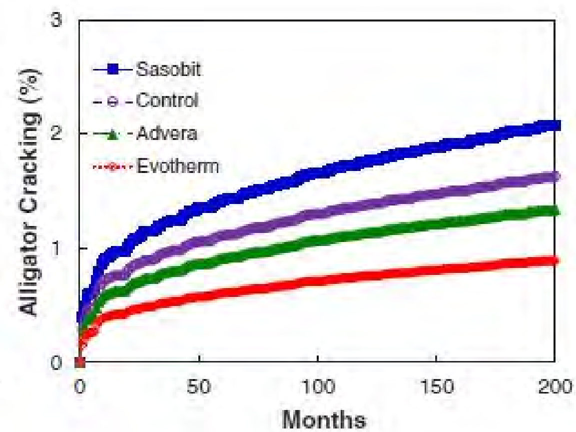
Observed vs Predicted WMA Field Performance



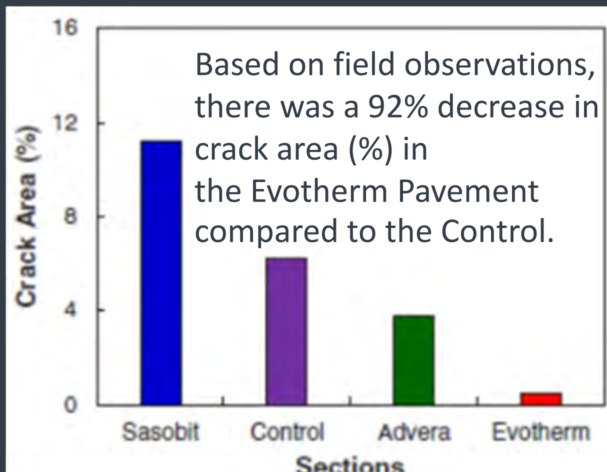
Observed

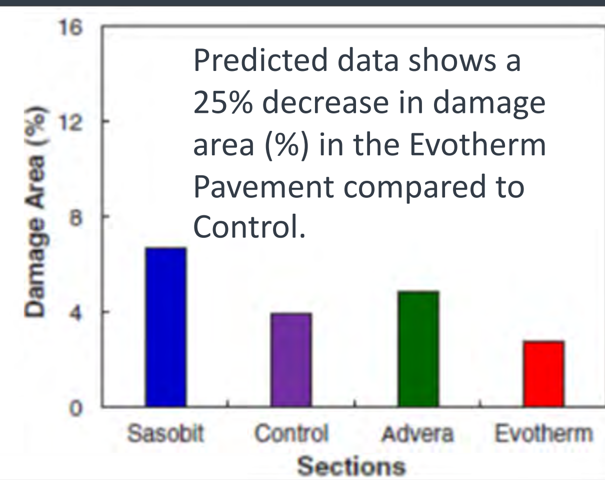


FlexPave



Pavement ME





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- 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.

Pavement Modeling – FWHA Mechanistic Empirical Pavement Design Guide

Fatigue Life Prediction – MEPDG Fatigue Model with 9-kip Axle Load

Project	Aggregate	Mix Type	Nf	Expected Life Difference
SD	Quartzite	HMA	4,601,736	41%
SD	Quartzite	Evotherm WMA	6,480,221	
SD	Limestone	HMA	1,100,550	33%
SD	Limestone	Evotherm WMA	1,460,450	
NV		HMA	1,918,621	18%
NV		Evotherm WMA	2,255,292	
CA	Granite	HMA	1,248,664	12%
CA	Granite	Evotherm WMA	1,403,296	

26% Average Life Improvement With Chemical WMA

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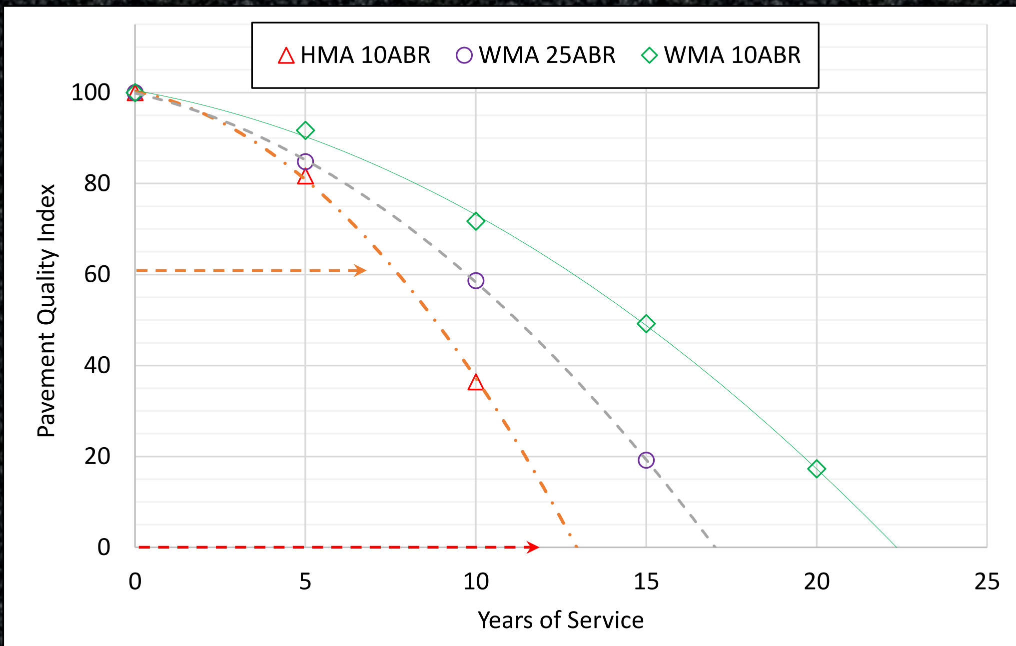
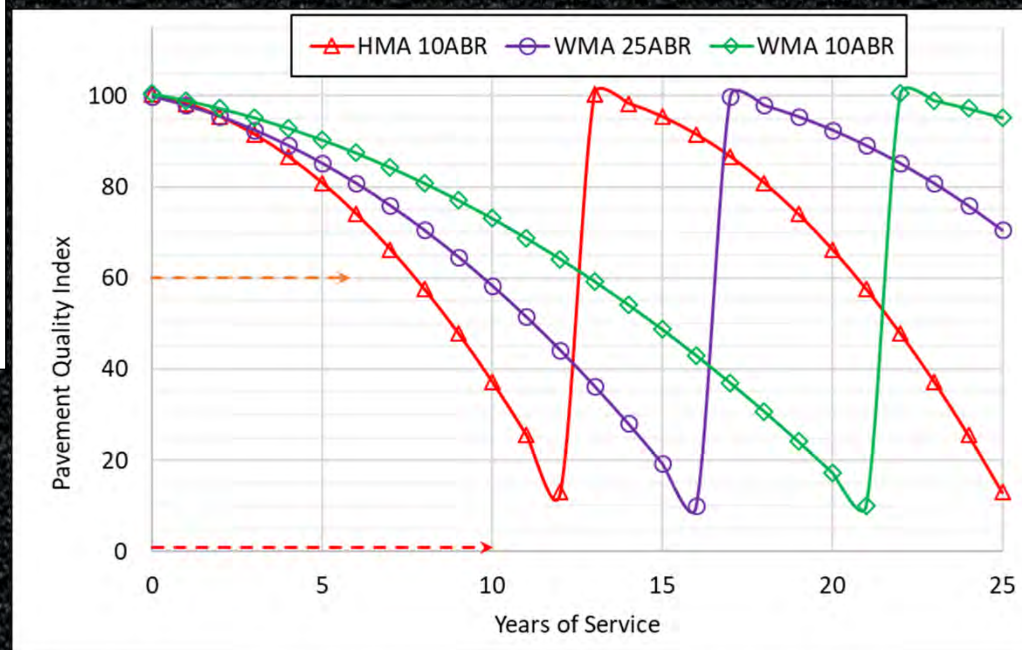
Considering Maintenance Scenarios Over a Design Life

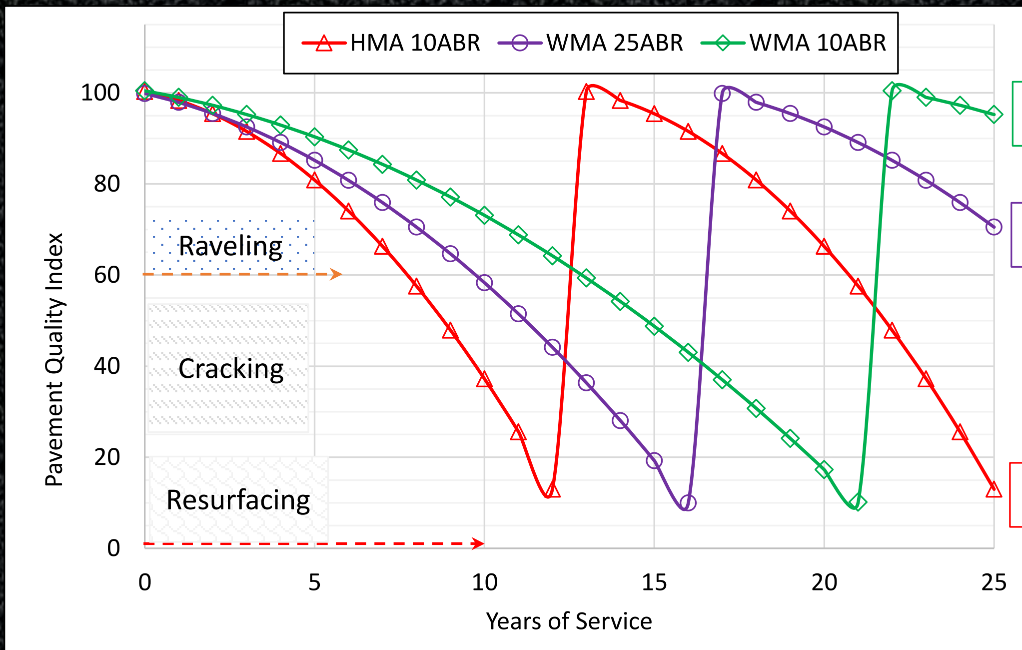


We assume that the same paving mixtures are reapplied during resurfacing and that the pavement is restored to a Pavement Quality Index of 100%. At that point, the aging cycle begins again according to the GRP's.



When each pavement reaches about 10-13% remaining binder life, the aged pavement is resurfaced. That is, the aged pavement is milled off and a new paving mixture is applied.

The Comparative Cost of the Maintenance Program Can Be Estimated



$56.5K

$68.1K

$91.0K

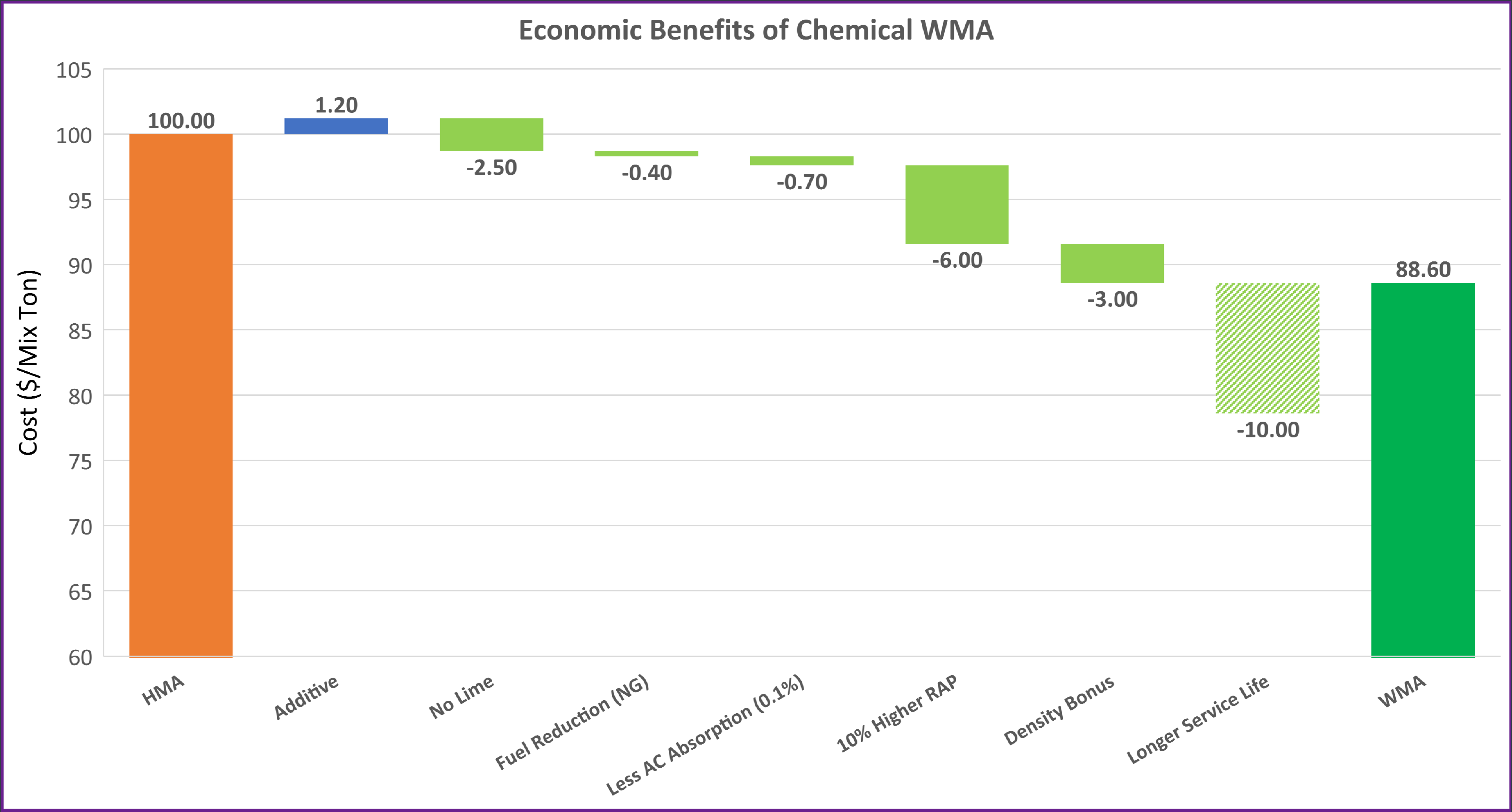
If we arbitrarily stop the analysis at 25 years of service, we can calculate the cost of each pavement over that 25-year period.

Over the 25-year period, the per lane-mile cost of each pavement:

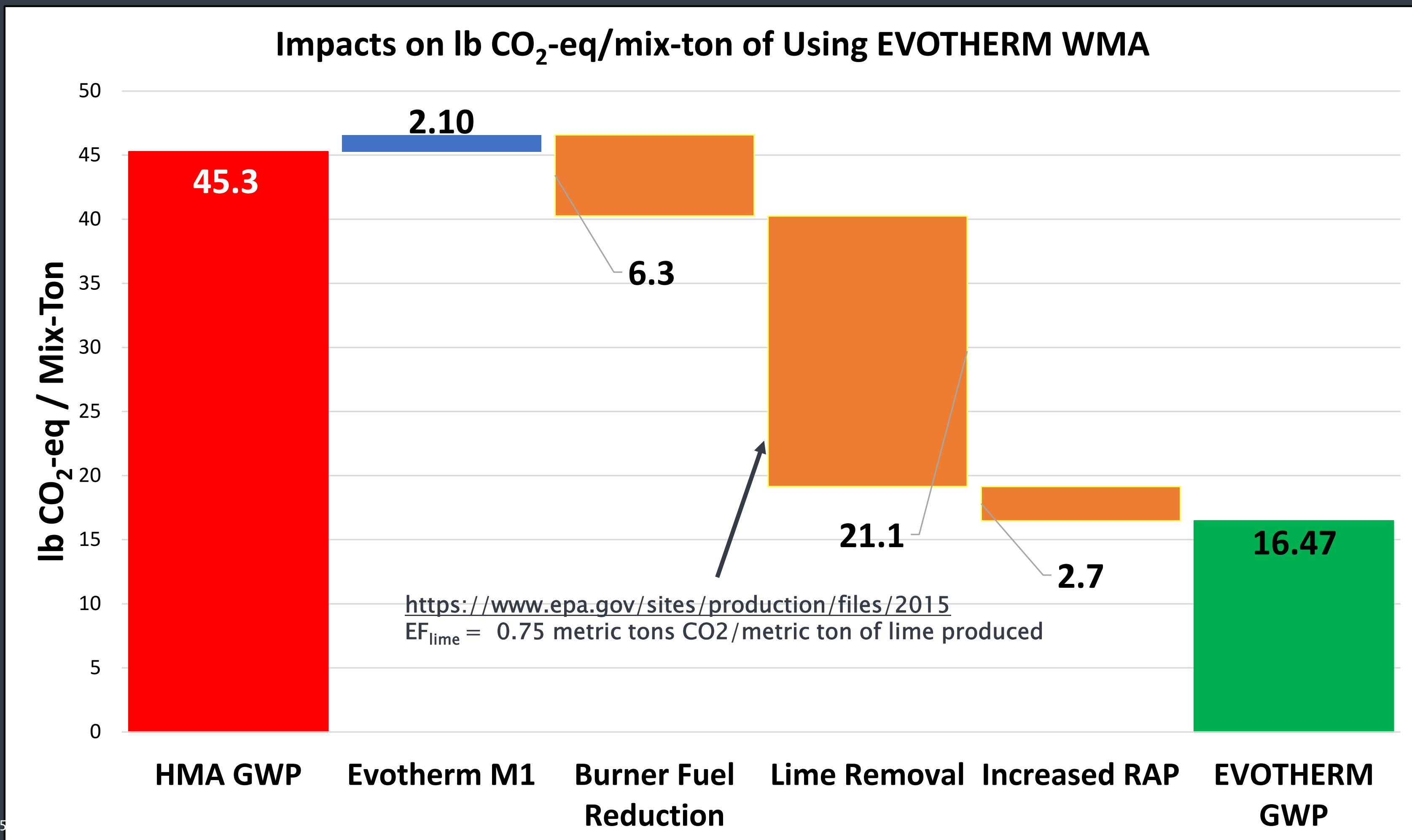
- **HMA with 10% RAP made at 325°F: $90,978.46**
- **WMA with 25% RAP made at 275°F $68,101.65 (↓25%)**
- **WMA with 10%RAP made at 275°F $56,480.00 (↓38%)**

Years	PQI	Year	Mill & Fill	PQI	Year	Mill & Fill	PQI	Year	Mill & Fill
0	100		100	100		100	100		100
1	98		98	98		98	99		99
2	95		95	95		95	97		97
3	92		92	93		93	95		95
4	87		87	89		89	93		93
5	81		81	85		85	90		90
6	74		74	81		81	87		87
7	66		66	76		76	84		84
8	58		58	71		71	81		81
9	48		48	65		65	77		77
10	37		37	58		58	73		73
11	26		26	51		51	69		69
12	13		13	44		44	64		64
13	-0.6	0	100	36		36	59		59
14		1	98	28		28	54		54
15		2	95	19		19	49		49
16		3	92	10		10	43		43
17		4	87	0	0	100	37		37
18		5	81		1	98	31		31
19		6	74		2	95	24		24
20		7	66		3	93	17		17
21		8	58		4	89	10		10
22		9	48		5	85	3	0	100
23		10	37		6	81		1	99
24		11	26		7	76		2	97
25		12	13		8	71		3	95
Sq.Yd Cost, $	6.72		6.72	6.45			6.85		6.45
Cost per Lane-Mile, $	47309		47309	45408		48224	48224		45408
Residual Life, $			3639			25530			37152
Total Cost/Lane-Mile	**$**		**90,978.46**	**$**		**68,101.65**	**$**		**56,480.00**

WMA Economic Benefits



WMA Environmental Benefits



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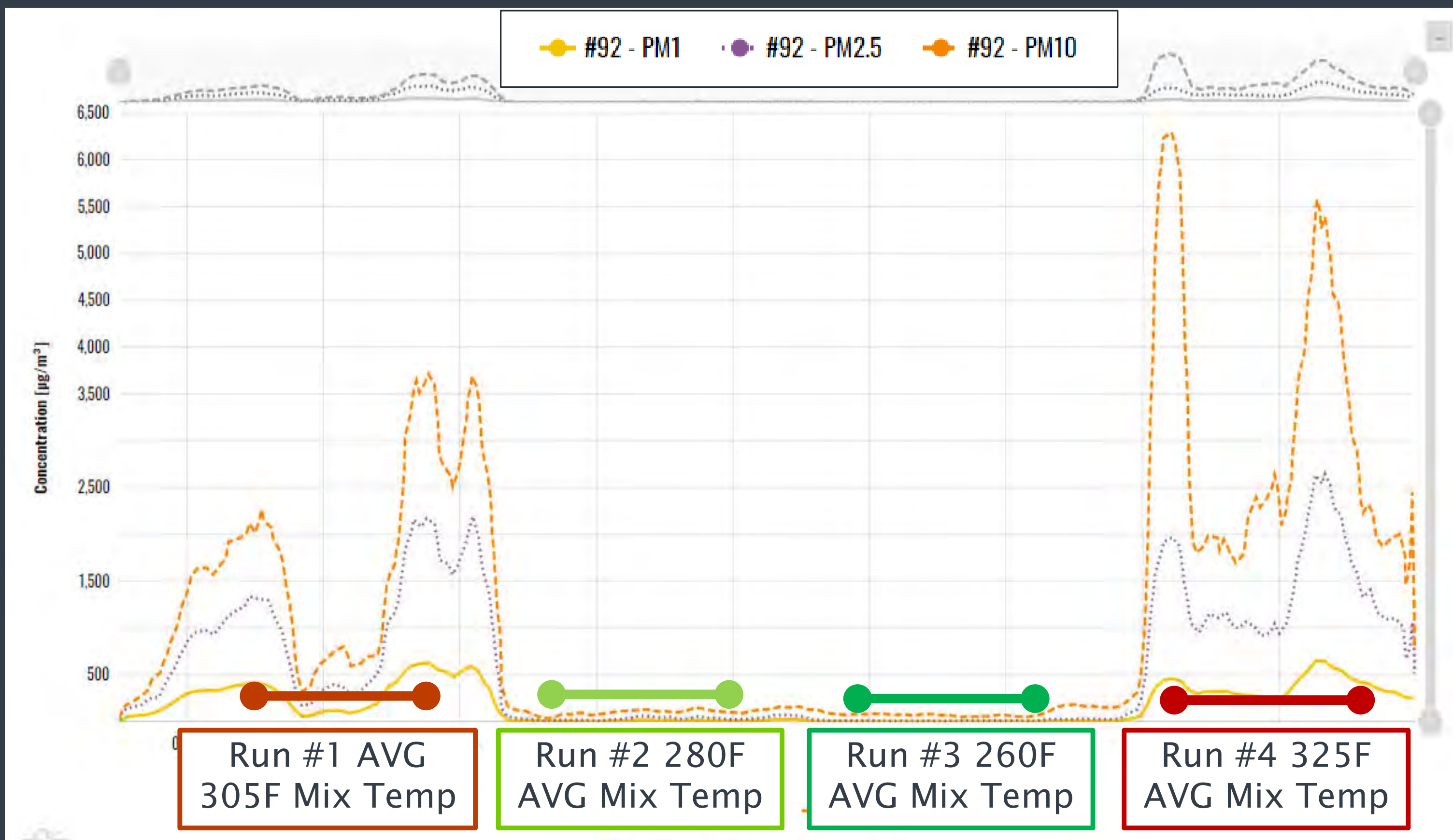
Quantifying Emissions Reductions with True WMA



APT Device

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WMA Plant Fugitive Emissions Data 2022

Project details from Contractor (Utah)

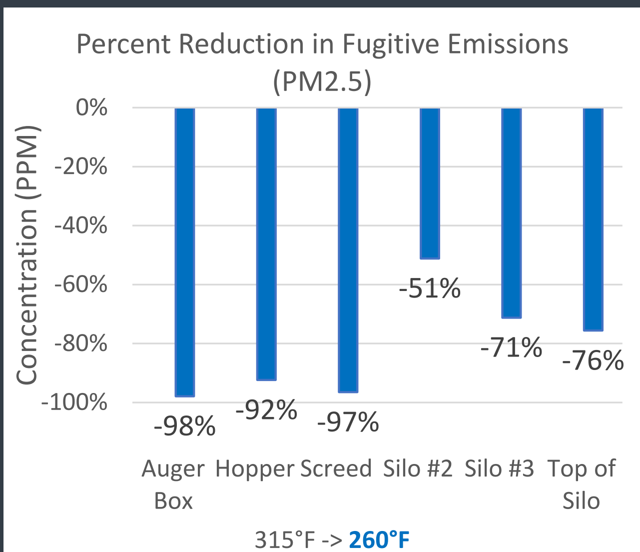
- 360 Tons/hr run rate
- Gencor Counter Flow Drum
- 15% RAP Content

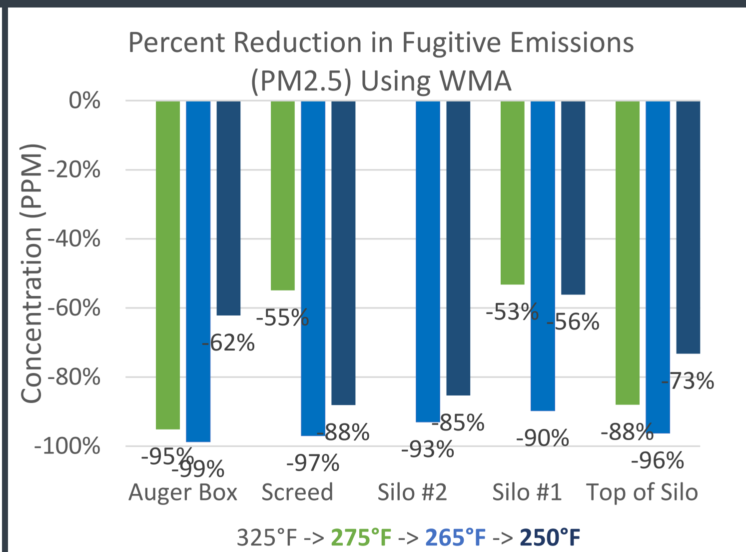
Project Details from Contractor (Florida)

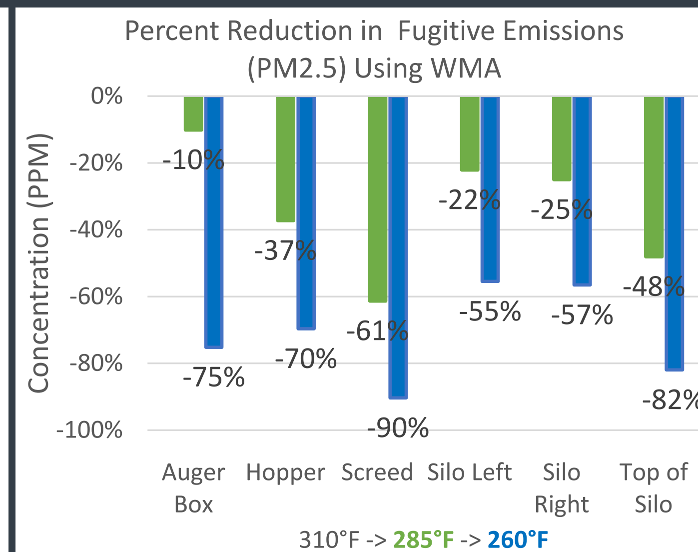
- 200 Tons/hr run rate
- Astec Double Barrel Green
- 40% RAP Content

Project Details from Contractor (Virginia)

- 290 Tons/hr run rate
- Astec Double Barrel Green
- 30% RAP Content







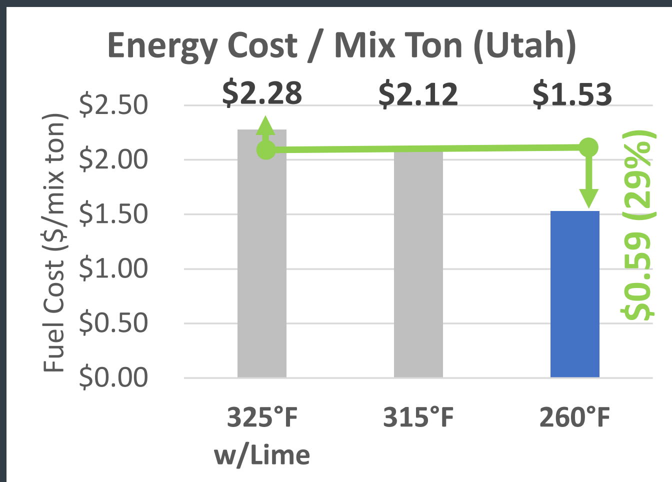
WMA Plant Fuel Consumption Data 2022

Note: Natural gas fuel $9.00/MMBtu assumption

Utah Contractor

- 360 Tons/hr
- Gencor Counter Flow
- 15% RAP
- 250k Mix Tons/yr
- $147.5k Savings (single plant at 260°F)

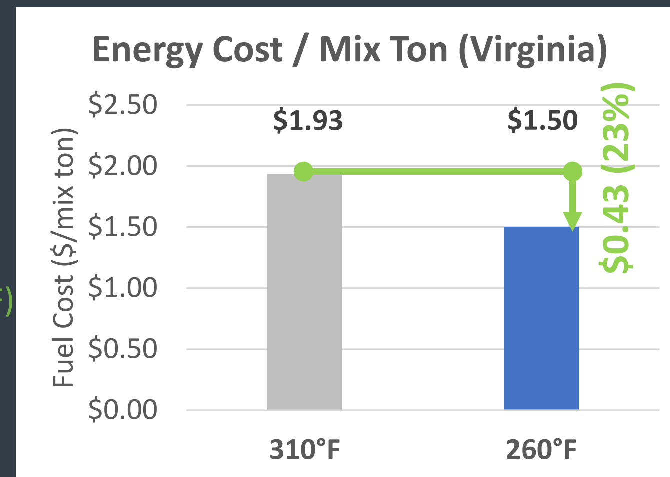
CO_2 Reduction 24.6%



Virginia Contractor

- 290 Tons/hr
- Astec Double Barrel
- 30% RAP Content
- 250k Mix Tons/yr
- $107.5k Savings (single plant at 260°F)

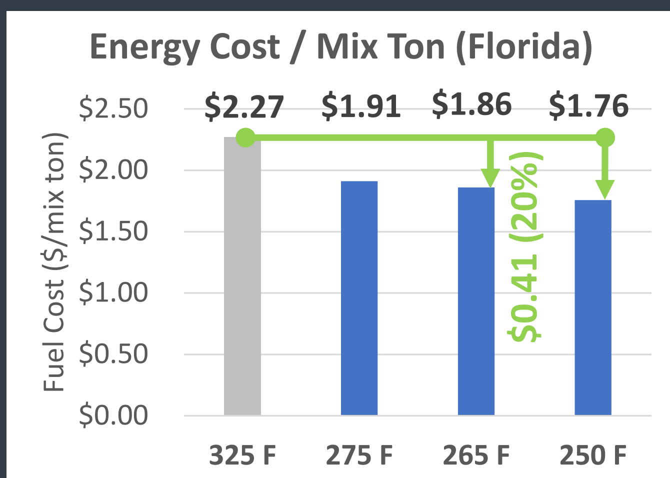
CO_2 Reduction 21.8%



Florida Contractor

- 200 Tons/hr
- Astec Double Barrel
- 40% RAP
- 150k Mix Tons/yr
- $61.5k Savings (single plant at 265°F)

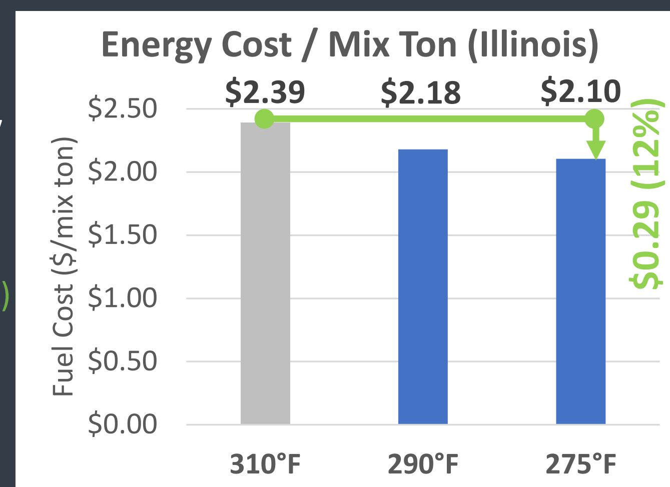
CO_2 Reduction 25.1%



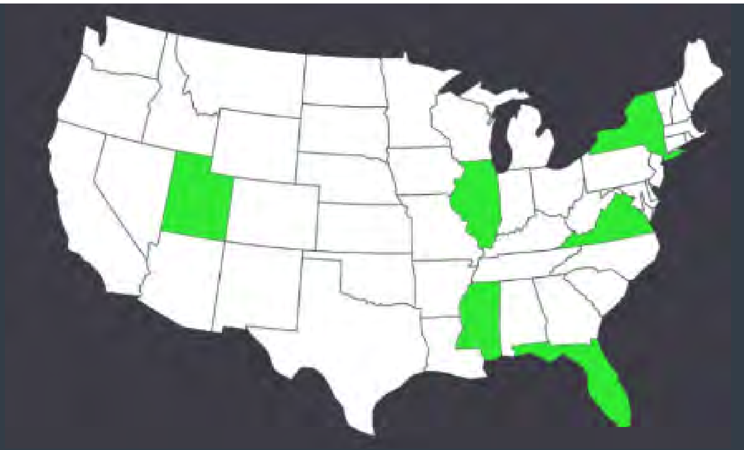
Illinois Contractor

- 300 Tons/hr
- Gencor Counter Flow
- 40% RAP Content
- 350k Mix Tons/yr
- $101.5k Savings (single plant at 275°F)

CO_2 Reduction 14.0%



2022 Low Temperature WMA



Six Projects in Six States: “By the Numbers”

Temperature

55°F

Fuel

20%

CO_2

23%

Fugitive Emissions

Top of Silo (PM10)

92%

Note: Average Reduction across the projects

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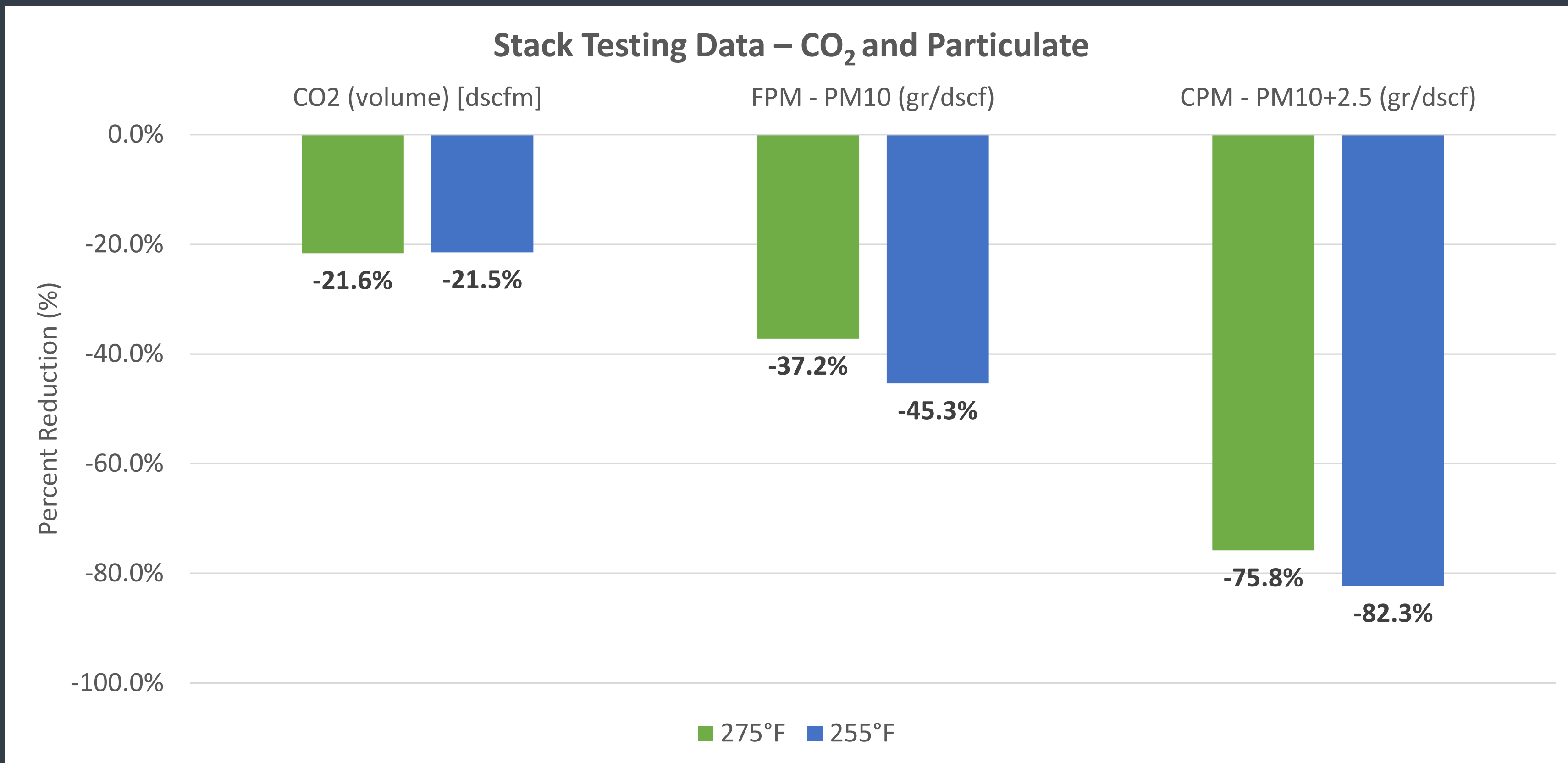
Stack Data – New York



Note: Temperature Reduced from 325°F

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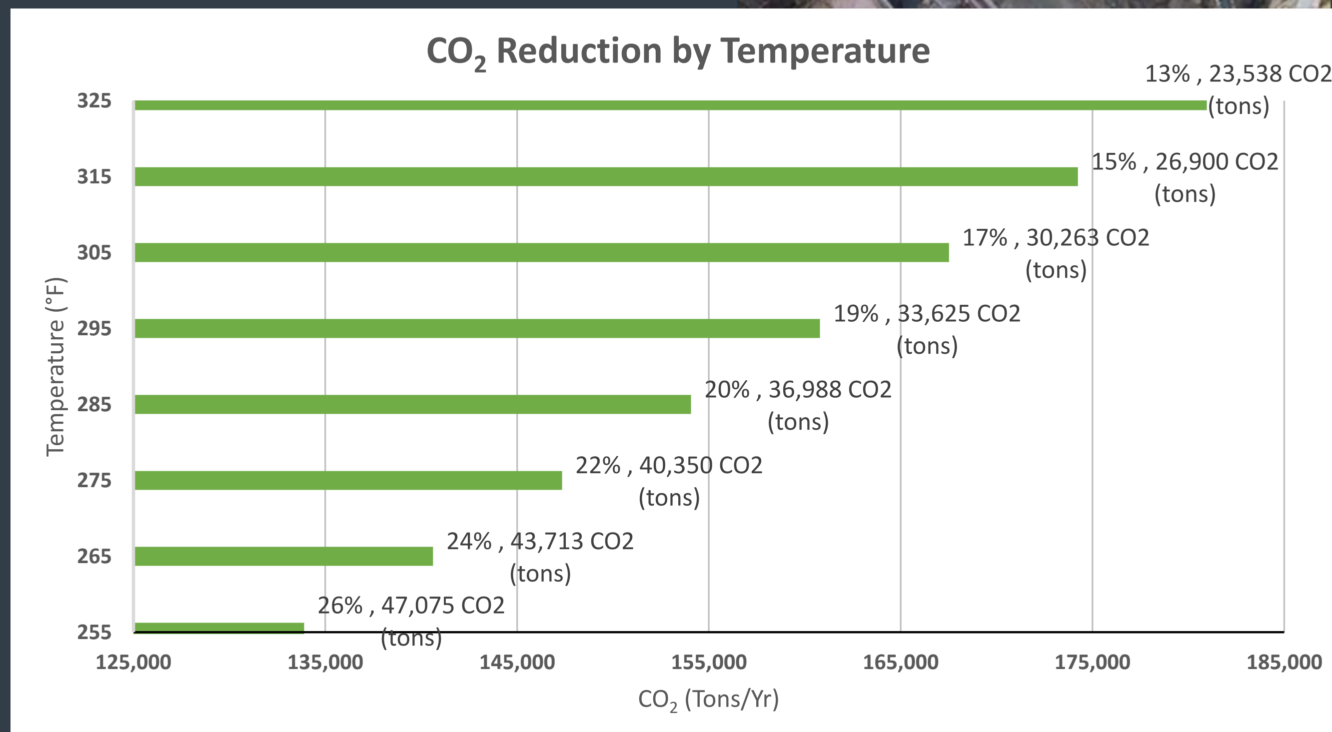
CO_2 Reduction Calculations

Six Projects in 2022 across USA

Average Temperature Reduction: **55°F**
Average Fuel Usage Reduction: **20%**
Average CO_2 Reduction (Stack): **23%**

IL Scenario Estimate

- IL produces 15 MM Tons Asphalt Mix/year (NAPA Annual Survey)
- CO2e estimated at 116.65 lbs/MMBTU Nat Gas C02e Value from EIA
- Temperature Range for data collection 255 °F to 325°F
- Total CO_2 saved if all IL mix produced at 275 °F reduced from 325°F would be >33,000 tons of CO_2
-



Agency Options

Incentive Specifications

$1/ton Bonus < 290° Production Temperature

$2/ton Bonus < 270° Production Temperature

WMA Temperature Specifications

Road Owner Specifies Max Production Temperature

Line Item Pay

DOT pays for WMA as a separate line item.

Similar model to asphalt binder in SC or LAS in TN

Ingevity EPDs for Chemical WMA Additives

Environmental Product
Declaration

Ingevity
Warm Mix Asphalt Additive, Warm Mix Asphalt Chemical Additive, Warm Mix Asphalt Chemical Package, Liquid Anti-Strip, Compaction Aid

Product
Evotherm P25

Self-declared core EPD based on the EN15804:2012 + A2

Issue Date	7/11/2022
Valid until	7/10/2027
Collection period	2021

Company
Ingevity Corporation
5255 Virginia Avenue
North Charleston, SC 29406 U.S.A.
www.ingevity.com
+1 800-458-4034

DEMONSTRATION OF VERIFICATION
EN15804:2012+A2 serves as core PCR
Third party verification of the declaration, according to ISO 14025

☑ **Internal** Third party verifier
☑ **External** The Right Environmental Ltd.

Environmental Product
Declaration

Ingevity
Warm Mix Asphalt Additive, Warm Mix Asphalt Chemical Additive, Warm Mix Asphalt Chemical Package, Liquid Anti-Strip, Compaction Aid

Product
Evotherm M1

Self-declared core EPD based on the EN15804:2012 + A2

Issue Date	12/2/2021
Valid until	12/1/2026
Collection period	2020

Company
Ingevity Corporation
5255 Virginia Avenue
North Charleston, SC 29406 U.S.A.
www.ingevity.com
+1 800-458-4034

DEMONSTRATION OF VERIFICATION
EN15804:2012+A2 serves as core PCR
Third party verification of the declaration, according to ISO 14025

☑ **Internal** Third party verifier
☑ **External** The Right Environmental Ltd.

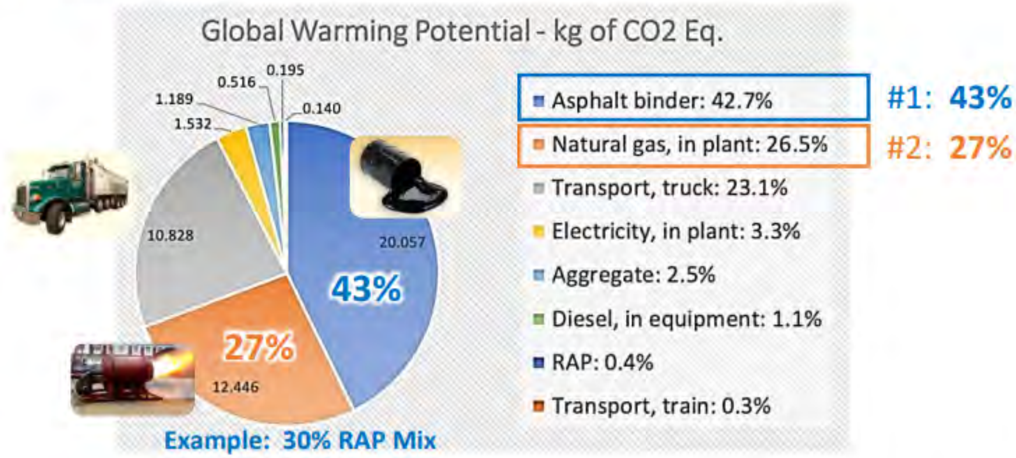
EPD Summary (Feb 21, 2023)

- Several Colorado producers see value in transferring their EPD program from their Environmental Manager to their QC Manager.

- Colorado Office of the State Architect (OSA) also implemented an EPD Program. OSA Policy and GWP Limits will take effect Jan 1, 2024. These will apply to state facilities, including parking lots.

- CDOT began collecting EPD data on July 1, 2022 and their policy and GWP Limits will take effect January 1, 2025.
- The Biden administration on September 15, 2022 announced an updated Federal Buy Clean policy, which directs federal agencies to buy low-emissions asphalt.

- **Sensitivity Factors**
  - **#1 Virgin Binder Content %**
  - **#2 Burner Fuel** (natural gas fuel has lowest EPD).
  - #3 LONG Transport distance (this factor can overwhelm the EPD if VERY long).



- Asphalt Binder EPD. Currently ECO Label uses four national standard inputs (virgin binder, polymer binder, etc.). Asphalt Institute is developing an EPD tool for specific binders/producers. This may/may not have a very significant impact on EPD's and thresholds established.

- Concerns about CO thresholds/limits. How will future methodologies (e.g., BMD, asphalt specific EPD) impact EPDs? In response, CDOT will be creating subcategories for new technologies.

- CDPHE wants producers to wash aggregates (reduce air particulates). Some producers require the dust as part of their mix design. The increased moisture content in the aggregate requires more energy to dry and is larger than the initial dust impact. Example of CDPHE vs CDOT and competing goals.

- **Rules of Thumb**

1% aggregate moisture ≈ 50° drum temp. ≈ 0.5% AC binder ≈ 3 kg GWP

Eliminate/reduce the use of hydrated lime can drop EPD up to 25%

(Solterra Materials in PHX has demonstrated this with lime/liquid antistrip combination)

Concrete Industry: ≈ 85% of the EPD for PCC mixes is attributed to % cement in mixture.

Asphalt Industry: ≈ 70% -80% of EPD is attributed to % binder + burner fuel

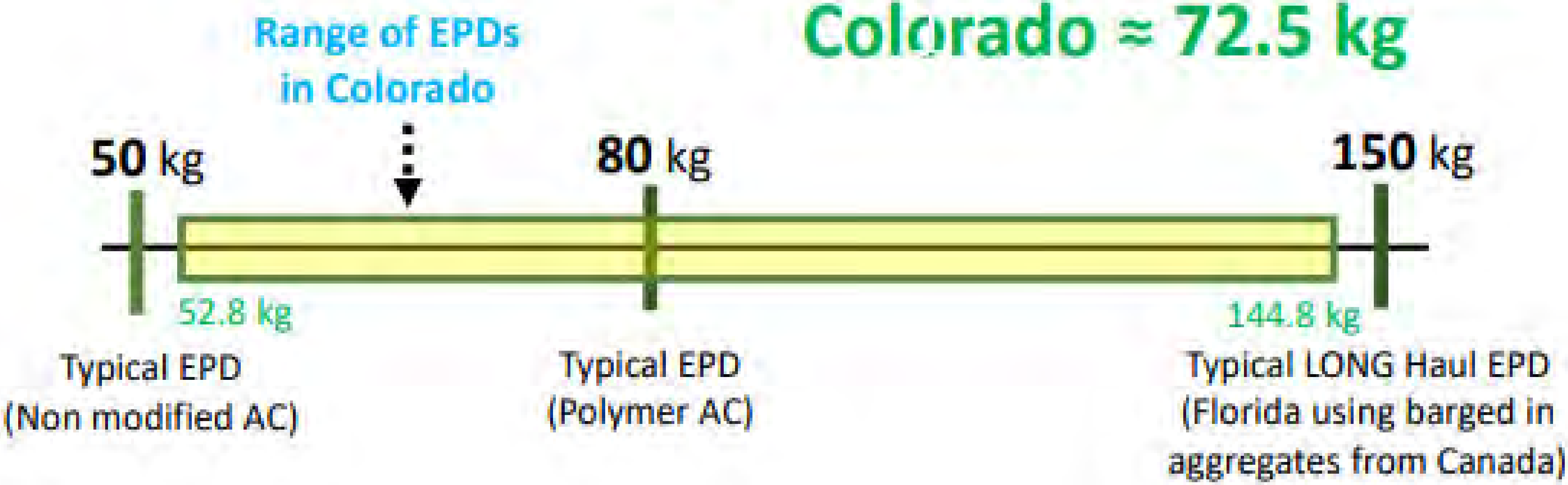
Emerald ECO LABEL

Colorado Asphalt Pavement Association

EPD

CO_2 Equiv. (Global Warming Potential)

Colorado ≈ 72.5 kg



Federal "Buy Clean" Implementation
DOT projects and Federal Facility Projects

The Biden administration on September 15, 2022 announced an updated Buy Clean policy, which directs federal agencies to buy low-emissions steel, concrete, asphalt, and flat glass. The policy is a major step toward decarbonizing the U.S. industrial sector and reducing emissions.

The purpose of Federal Buy Clean Initiative is to spur the development of low-carbon construction materials by leveraging the Federal government's purchasing power to buy cleaner materials, create a market differentiation for low-carbon construction materials, and provide incentives for lower-carbon materials.

Key Actions under September 15th announcement as follows:

- The Federal government *will prioritize* the purchase of low carbon steel, concrete, asphalt, and flat glass construction materials.

Questions?

If you see something that you want to hear more about, we have additional data available to present in more detail on these topics.

Jeff LeCorchick

Technical Marketing Manager

Jeffrey.LeCorchick@Ingevity.com

814-746-5191