

Sustainable Additives Help Reduce Carbon Footprint of Asphalt Pavements

Vince Aurilio, P.Eng.
Canadian Airfield Pavement Technical Group
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Serving the Asphalt Industry Since 2006



info@sripath.com
+1.201.721.7562
sripath.com

Vince Aurilio
vaurilio@sripath.com
+1 (416) 721-1521





- Focus on Sustainability
- Performance
- Sustainable Additives for Paving Applications
 - Asphalt Rejuvenator-Recycling Agent
 - Bitumen-Friendly Polymeric-Additive
 - Warm Mix Additive
- Questions & Answers



Airfield Pavements Challenges

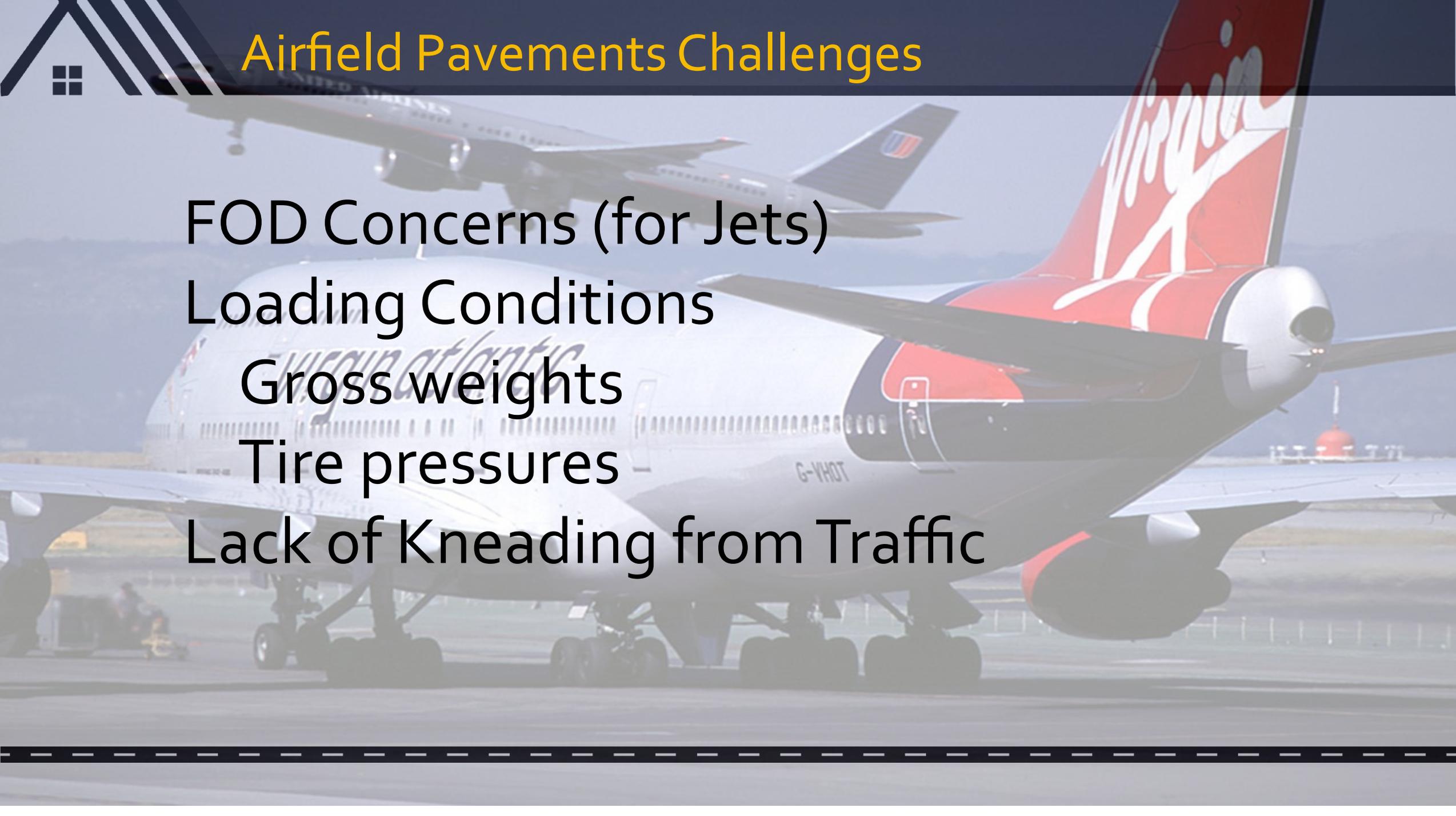
FOD Concerns (for Jets)

Loading Conditions

Gross weights

Tire pressures

Lack of Kneading from Traffic



Focus on Sustainability

The Global Imperative for Sustainability



- The global market for asphalt production is expected to reach 138 million tons by 2027.
- 107 countries have made pledges to pursue net-zero emissions according to the United Nations.
- 85% percent of all bitumen is used in asphalt paving, and bitumen production remains a key contributor to carbon emissions.
- Sustainability for Airports?

The Road to Sustainable Paving: Approaches and Additives

1) Recycle Binder & Aggregate

- Increase Reclaimed Asphalt Pavement (RAP) Usage
- Asphalt Rejuvenator/Recycling Agents

2) Improve Asphalt Pavement Performance

- Improve Durability
- Bitumen-Friendly Polymeric-Additive

3) Reduce Energy Consumption

- Lower Mix & Paving Temperatures
- Warm Mix Additive



Sustainable Additives for Paving Applications



Sustainable Additives That Enhance Asphalt Performance



Asphalt Additive	Impact on Sustainability
Rejuvenator / Recycling Agent <i>An Elixir of Bio-Based Oils - ReLIXER®</i>	<ul style="list-style-type: none">• Incorporate higher amounts of Reclaimed Asphalt Pavement (RAP)• Lower Need for Virgin Binder and Aggregate• Lower Low Carbon Footprint with Negative Global Warming Potential
Bitumen-Friendly Polymeric-Additive <i>Uniquely Engineered Additive - PGXpand®</i>	<ul style="list-style-type: none">• Improve Roadway Performance and Durability• Lower Mixing and Shear Processes Lower Energy Consumption• Reduce Temperature and Energy to Pave• Reduce Repair and Maintenance Resource Consumption
Warm Mix Additive <i>A Specially Engineered Molecule - PHALANX®</i>	<ul style="list-style-type: none">• Reduce Energy Consumption with Lower Mix Production & Paving Temperatures• Lower Overall Carbon Footprint

Sustainable Additives Help Reduce Carbon Footprint of Asphalt Pavements



Sustainable Additives with Transparent Environmental Impact

ReLIXER®

Environmental Product Declaration

An Asphalt Rejuvenator or Recycling Agent
An Elixir of Bio-Based Oils



PGXpand®

Environmental Product Declaration

A Bitumen-Friendly Polymeric-Additive
for Paving & Roofing Applications



PHALANX®

Environmental Product Declaration

A Warm Mix Additive
for Paving Applications



Environmental Product Declarations Easily Accessible Online

Heavy Loads





Raytheon King Air 200: Max Wt 12,500 lbs
Tire Pressure: 150 psi



RAP, Asphalt Rejuvenators, and Sustainability Goals

Reuse & Recycling of Reclaimed Asphalt Pavement (RAP)

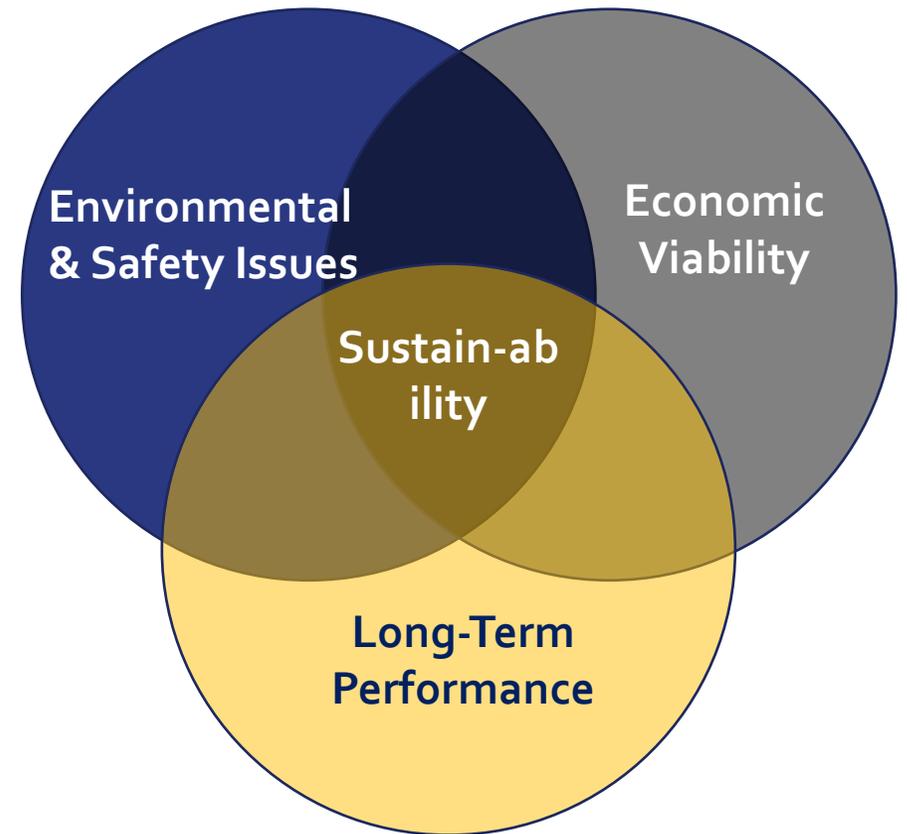
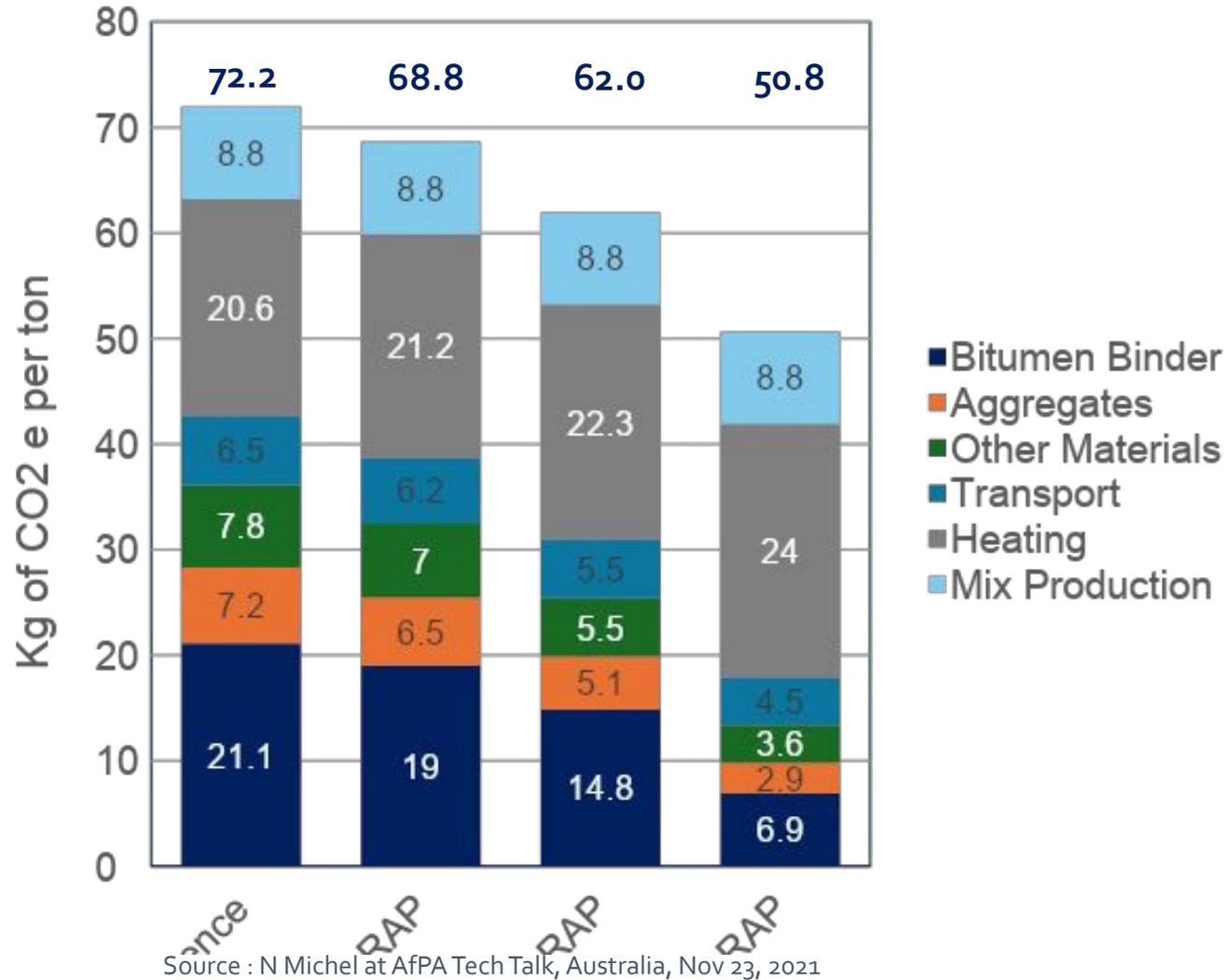
- As global economy and population grow, we need to expand our network of roadways
- We accumulate mountains of RAP
 - Over 750 million tons of RAP per year worldwide
- We continue to deplete natural resources to build and rebuild roadways
 - Need to refine oil to make virgin bitumen
 - Need to mine stone quarries for aggregates



An Effective Rejuvenator Helps Utilize High Levels of RAP in Roadways to Promote Sustainability.

Recycling RAP: A Way to Convert Existing Roadways into Mines & Refineries of the Future

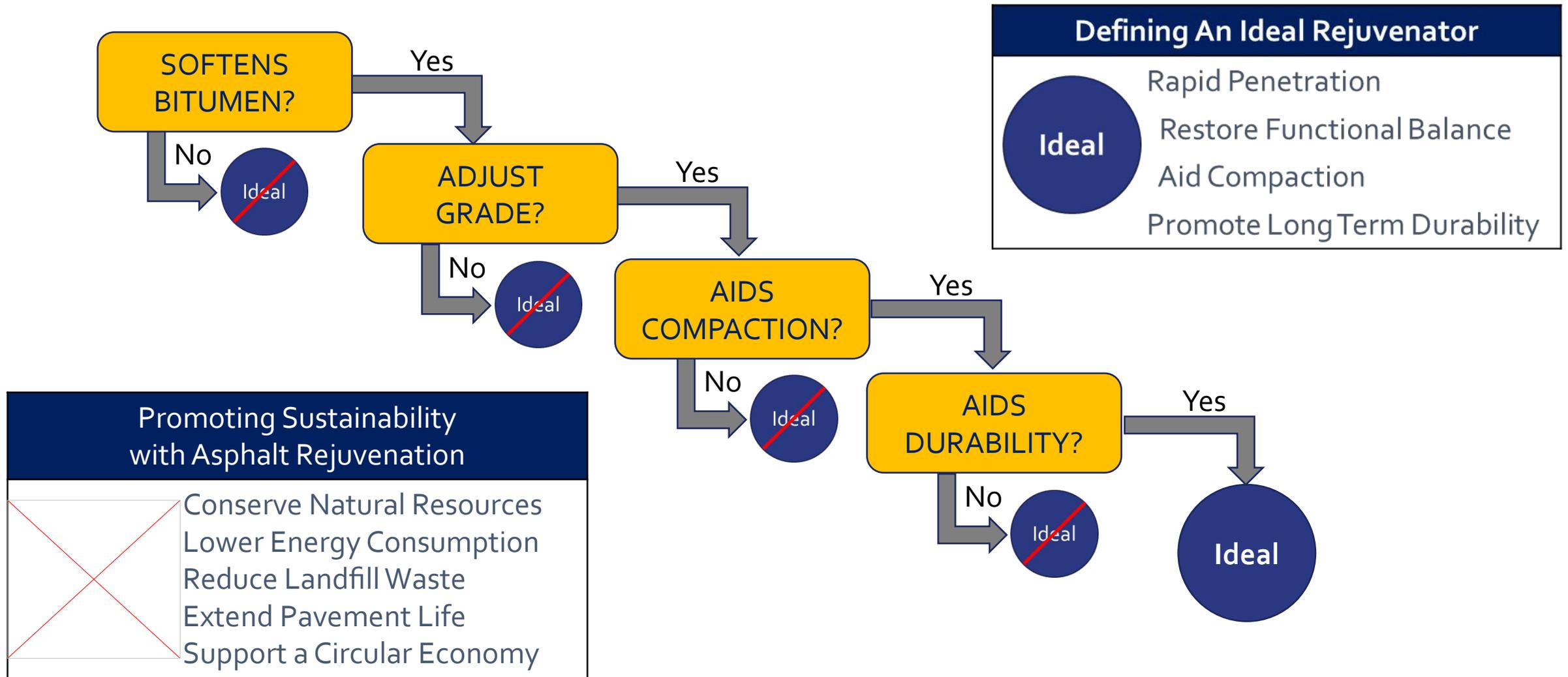
Why Consider Reclaimed Asphalt?



High-RAP Usage is Better for the Environment. Asphalt Rejuvenators Make High-RAP Mixes a Viable Reality.

Sustainability vs. Economic Viability vs. Roadway Performance

What is an Effective Rejuvenator or Recycling Agent?



GOAL: No Difference in Roadway Performance & Durability Between No RAP & High-RAP Mixes.

An Effective RAP Rejuvenator / Recycling Agent

ENVIRONMENTALLY FRIENDLY

- Blend of Green Bio-Based Oils
- No Burden on Food Sources
- No Volatile Organic Compounds
- Lower GHG & Carbon Footprint

HELPS REDUCE MIX COST

- Designed for High-RAP Mixes
- Reduces Need for Virgin Bitumen
- Reduces Need for Fresh Aggregates

ReLIXER®

Environmental Product Declaration

An Asphalt Rejuvenator or Recycling Agent

An Elixir of Bio-Based Oils



Global Warming Potential

GWP = - 0.317

USER FRIENDLY

- Highly Efficient at Low Dosages
- Easy to Use in a Mix Plant
- Non-Hazardous, Safe to Handle
- Works with Range of Bitumen & RAP

EXCELLENT ROADWAY PERFORMANCE

- Restores Functional Balance to Aged Bitumen in RAP
- Improves Crack Resistance Properties
- Confers Excellent Durability

R&D & Initial Trials

2011 - 2014

2015

2016

2017

2018

2019

2020

2021

2022

2023

2024

2025

N America

India

EU & S America

AUS

Tested, Trusted, and Used Worldwide for 10+ Years

Impact of an Effective Rejuvenator on High RAP-Mixes

Sample	Recycled Bitumen Content %	Virgin Binder PG 64-22 %	ReLIXER® wt.% of mix	High Temp. True Grade °C	Low Temp. True Grade °C	Viscosity @ 135°C cps	Softening Point °C	Pen dmm
Mix 1A	45 %	2.50	0.00	82	-14	8500	80.6	16
Mix 1B		2.15	0.28	76	-22	3000	61.1	32
Mix 2A	50 %	2.50	0.00	98	-15	9500	86.7	12
Mix 2B		2.15	0.28	87	-24	3100	65.0	30
Mix 3A	70 %	1.60	0.00	94	-7	12500	83.3	10
Mix 3B		1.20	0.45	83	-21	3800	59.4	28
Mix 4A	80 %	0.90	0.00	104	-6	47600	223	4
Mix 4B		0.90	0.90	80	-23	4800	68.9	30

High-RAP Mixes Dosed with an Effective Rejuvenator Deliver Outstanding Performance.

High-RAP Mixes Dosed with an Effective Rejuvenator on Illinois Tollway

Production Mix: 40% Recycled Bitumen Content

Property	PG 46-34 Mix	PG 58-28 + ReLIXER® (2% of total binder)	PG 58-28 + ReLIXER® (3.6% of total binder)	Specification (Target)
DCT -12°C, J/m ²	435	497	544	450
Hamburg Wheel Test @20k, mm	6.34	8.70	8.77	12.5
Voids, %	3.7	3.6	4.9	4.0
Total AC, %	6.0	6.1	5.8	6.1
Virgin Binder, %	4.3	4.0	3.7	
Binder Grade	PG 64-22	PG 64-22	PG 64-28	PG 64-22
ΔTc, °C	-5.8	-5.4	-3.7	-6

One Grade Softer



Good Balance of Properties | Save on Mix Costs | AsphaltPro Article on Illinois Tollway

60% RAP Mixes in Ireland

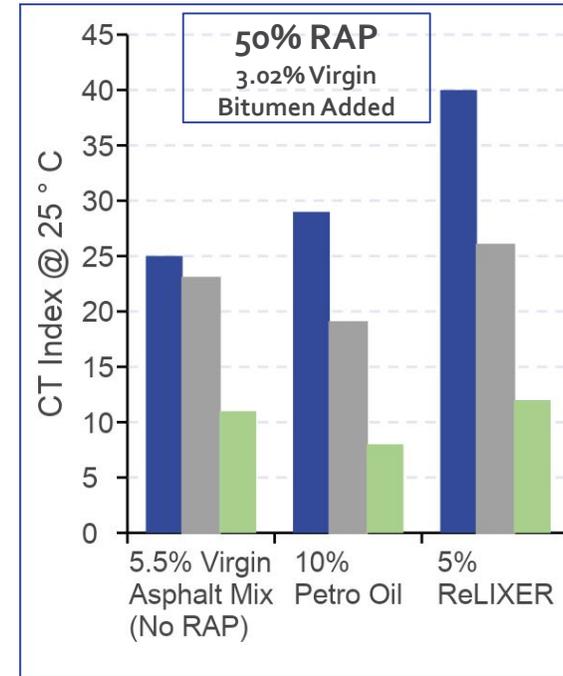
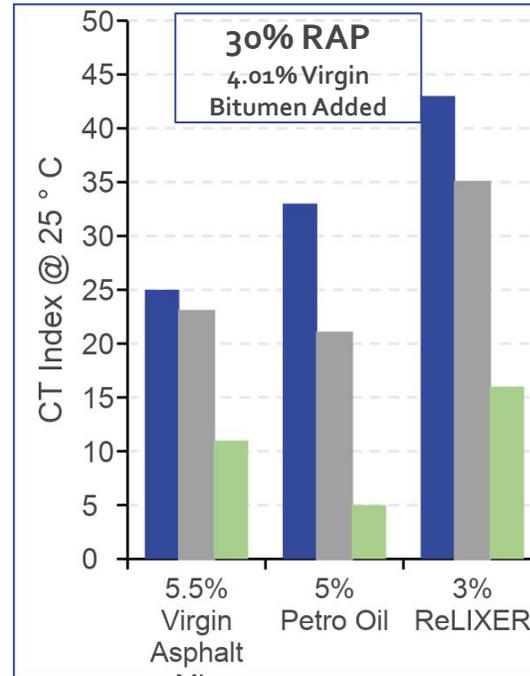
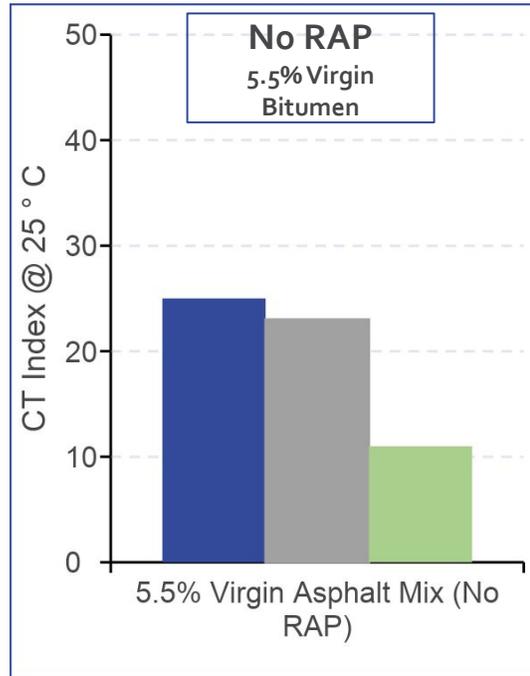


Source : William Wilson, Roadstone Ltd.
Presentation at Irish Annual Conference, 2023

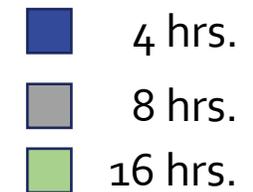
Mix	% RAP	Rejuvenator	Stiffness MPa	Water Sensitivity ITSR	Permanent Deformation WTS _{Air}	Penetration dmm	Total GWP kg CO ₂ e/T
AC20	0%	No Rejuvenator	3300	94	0.26	45	51
AC20	60%	ReLIXER®	3100	90	0.33	40	45
AC32	0%	No Rejuvenator	4500	91	0.12	45	55
AC32	60%	ReLIXER®	4100	90	0.24	38	46

An Effective Rejuvenator Helps Reduce the Carbon Footprint of Ireland Roadway.

Roadway Durability Profile



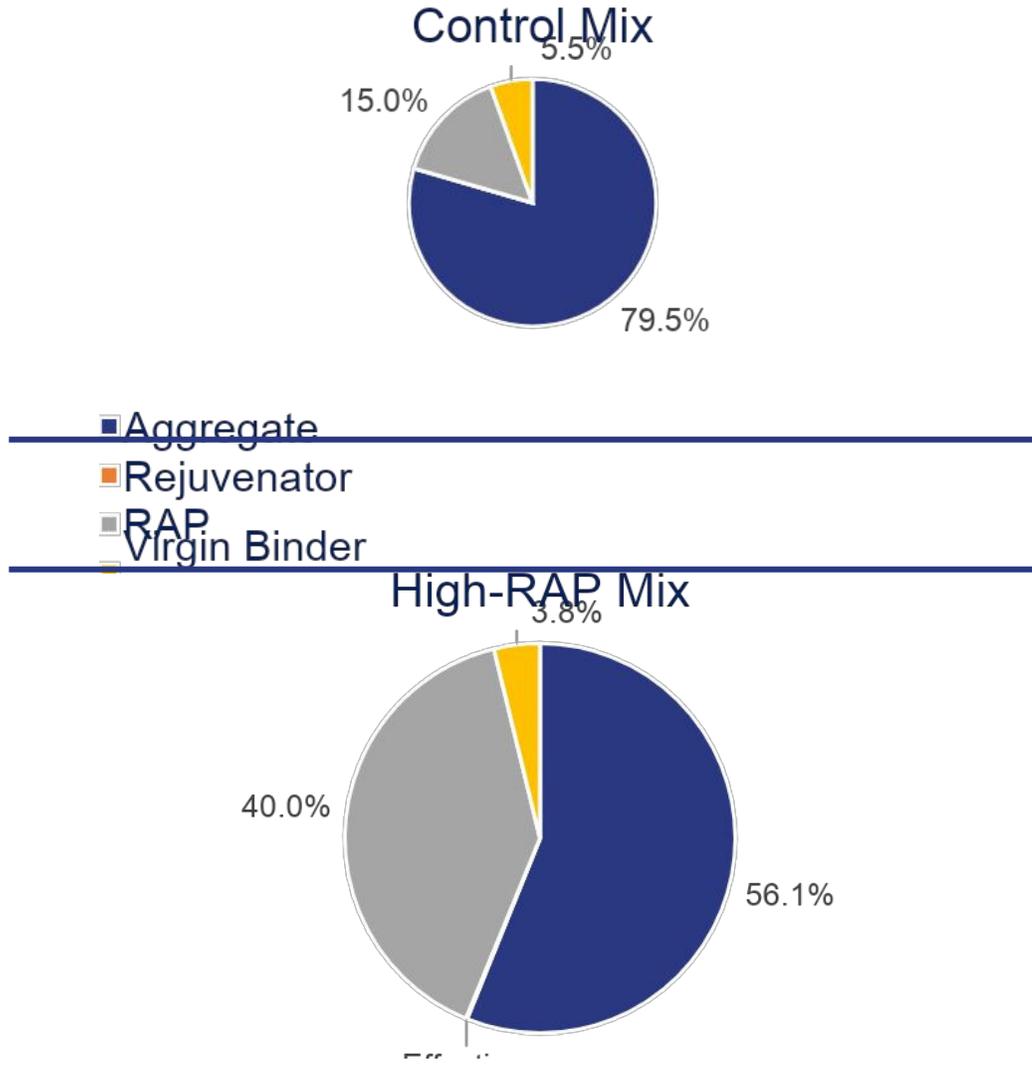
Aging Time



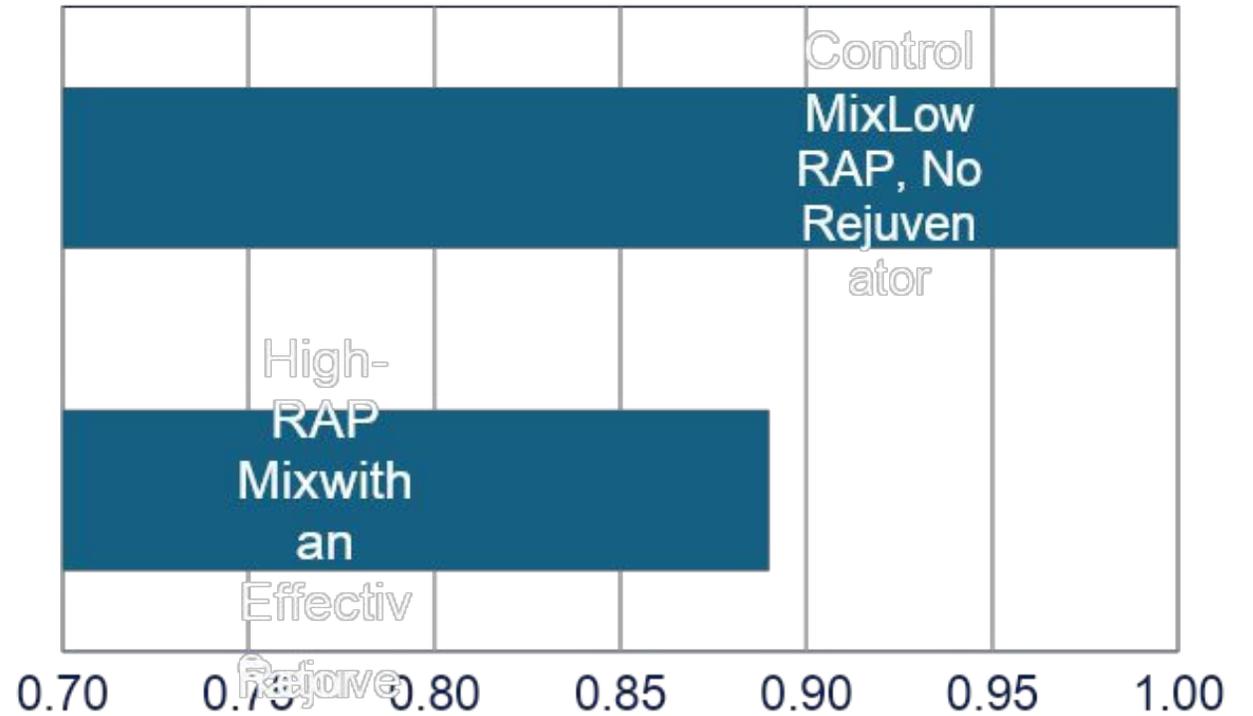
- An ideal rejuvenator improves fracture toughness in mixes.
 - An effective, bio-oil based rejuvenator can help maintain aging performance unlike petrochemical rejuvenators.
- 30-50% RAP mixes with an effective rejuvenator give equivalent performance to No-RAP mixes.

Properly Rejuvenated Mixes Can Give Equivalent Performance to Low-RAP and No-RAP Mixes, Even After Extended Aging

Reduce Mix Cost While Pursuing Sustainability Goals



Rejuvenation Helps Reduce Cost



Actual Mix Costs Depend on Mix Details & Raw Material Costs

Environmentally-Friendly Bio-Oil Based Asphalt Rejuvenator

ReLIXER®

Environmental Product Declaration

An Asphalt Rejuvenator or Recycling Agent
An Elixir of Bio-Based Oils



- Lower Energy Consumption
- Highly Dosage Efficient
Less Additive Needed
- Lower Carbon Footprint
- Lower Greenhouse Gases
- Improved Roadway
Performance & Durability
- Less Frequent Road Repair

Global Warming Potential

GWP = - 0.317

ReLIXER®

A Technical Overview

The Leading RAP Rejuvenation Technology



Environmentally Sustainable & High-Performing Recycling Agent

Improve Roadway Durability for More Sustainable Surfaces



A Bitumen-Friendly Polymeric-Additive

BITUMEN-FRIENDLY ADDITIVE

- Low Shear Mixing Process
- Short Mixing Times
- High Storage Stability
- Very Compatible with Elastomers and Crumb Rubber

HELPS REDUCE PMB COST

- Lower Energy Consumed to Create PMB
- Lower Temperature / Energy to Pave
- Highly Dosage Efficient Compared to SBS

PGXpand®

Environmental Product Declaration

A Bitumen-Friendly Polymeric-Additive
for Paving & Roofing Applications



Global Warming Potential

GWP = 2.947

EXCELLENT PERFORMANCE

- Boosts High Temperature Performance, Paving Grade, and Softening Point
- No Impact on Low Temperature Properties
- Outstanding Rutting Resistance
- Excellent Fatigue Properties
- Low Viscosity Mixes.
- Improves Workability, Easier to Compact
- Excellent Weathering Performance

R&D & Initial Trials

2011 - 2015

2016

2017

2018

2019

2020

2021

2022

2023

2024

2025

USA

Canada

Middle East

AUS

Asia

Tested, Trusted, and Used Worldwide for 9+ Years

A Unique Polymeric Molecule

Traditional ELASTOMERIC POLYMERS

Fatigue: Good
Rutting: Acceptable
Elastic Recovery: Good

Mixer: High Shear
Mixing Time: Long

Mix Temperature: High
Paving Temperature: High

Crosslink Additive: Needed
Warm Mix Additive: Needed

PGXpand® BITUMEN-FRIENDLY POLYMERIC ADDITIVE

Fatigue: Good
Rutting: Excellent
Elastic Recovery: Poor

Mixer: Low Shear
Mixing Time: Short

Mix Temperature: Low
Paving Temperature: Low

Crosslink Additive: Not Needed
Warm Mix Additive: Not Needed

Traditional PLASTOMERIC POLYMERS

Fatigue: Poor
Rutting: Good
Elastic Recovery: Poor

Mixer: Medium
Mixing Time: Medium

Mix Temperature: High
Paving Temperature: High

Crosslink Additives: Not Needed
Warm Mix Additive: Needed

Specifically Designed Chemistry Delivers Outstanding Performance

Solving the Problems?



Looking south on Taxi A at AD



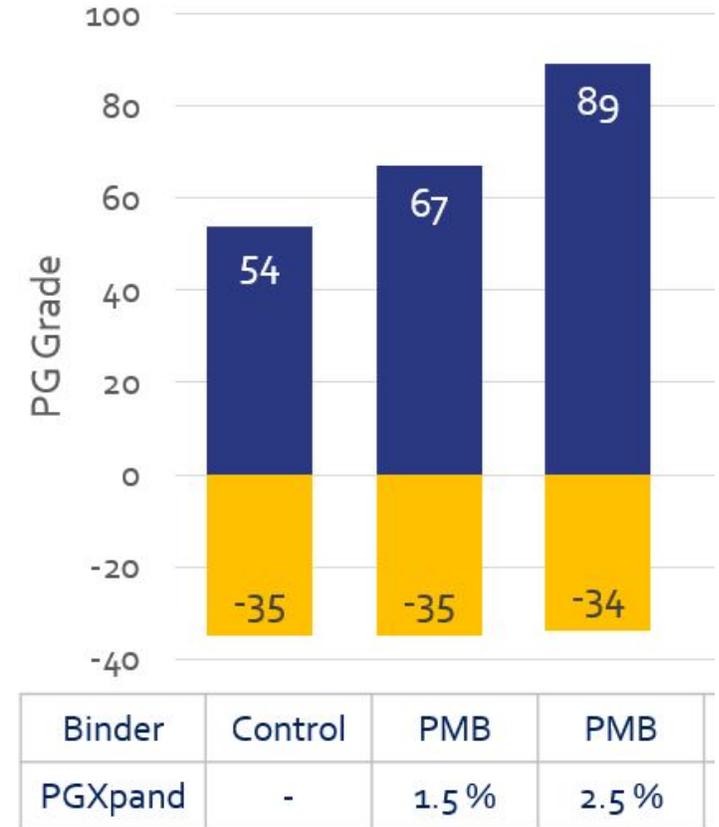
Impact on Properties

Bitumen-Friendly Polymer Modified Bitumen

With PGXpand®	Softening Point (°C)	Penetration (dmm)	True Grade (°C)	Viscosity @ 163° C, cps
Base Binder PG 64-22	48	67	66.8 – 26.1	450
1.5%	98	45	85.3 – 25.1	402
2%	122	40	95.0 – 25.0	384
3%	123	39	95.0 – 25.0	370

Hybrid Polymer Modified Bitumen: PGXpand® + SBS

With PGXpand®	Softening Point (°C)	Penetration (dmm)	True Grade (°C)	Viscosity @ 163° C cps	Elastic Recovery (% , 15 °C)
Base Binder + 2.5% SBS	66	74	73.1 – 29.0	844	80
1.5%	105	47	85.6 – 28.4	800	65
2%	125	42	95.0 – 28.1	786	61
3%	124	38	95.0 – 28.0	780	57



Improves High Temperature & Anchors Low Temperature Properties

A Specially Engineered Unique Innovative Polymer for a Variety of Applications

Impact on Storage Stability and Compactability

STORAGE STABILITY

USA Binder	True Grade
Base Binder	66.0 -26.7
Binder With 1.5% PGXpand®	75.3 -24.8

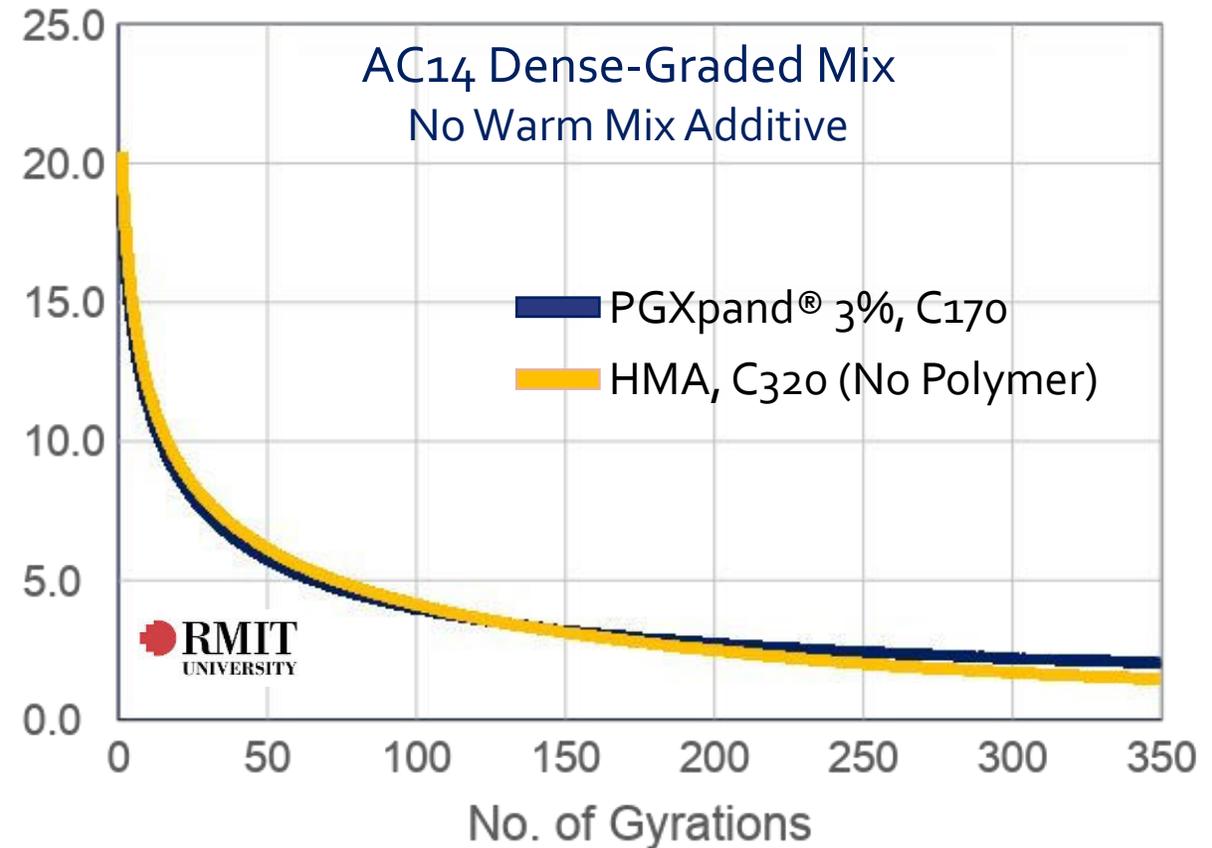
Cigar Tube Storage Stability

With 1.5% PGXpand®

Temperature °C	Top to bottom difference*
70	-1.92%
76	-3.09%
82	-4.81%

* Samples held at 165 °C for 72 hours. $G^*/\sin\delta$ of the top and bottom portions of the cigar tube measured at above temperatures.

% Voids Content

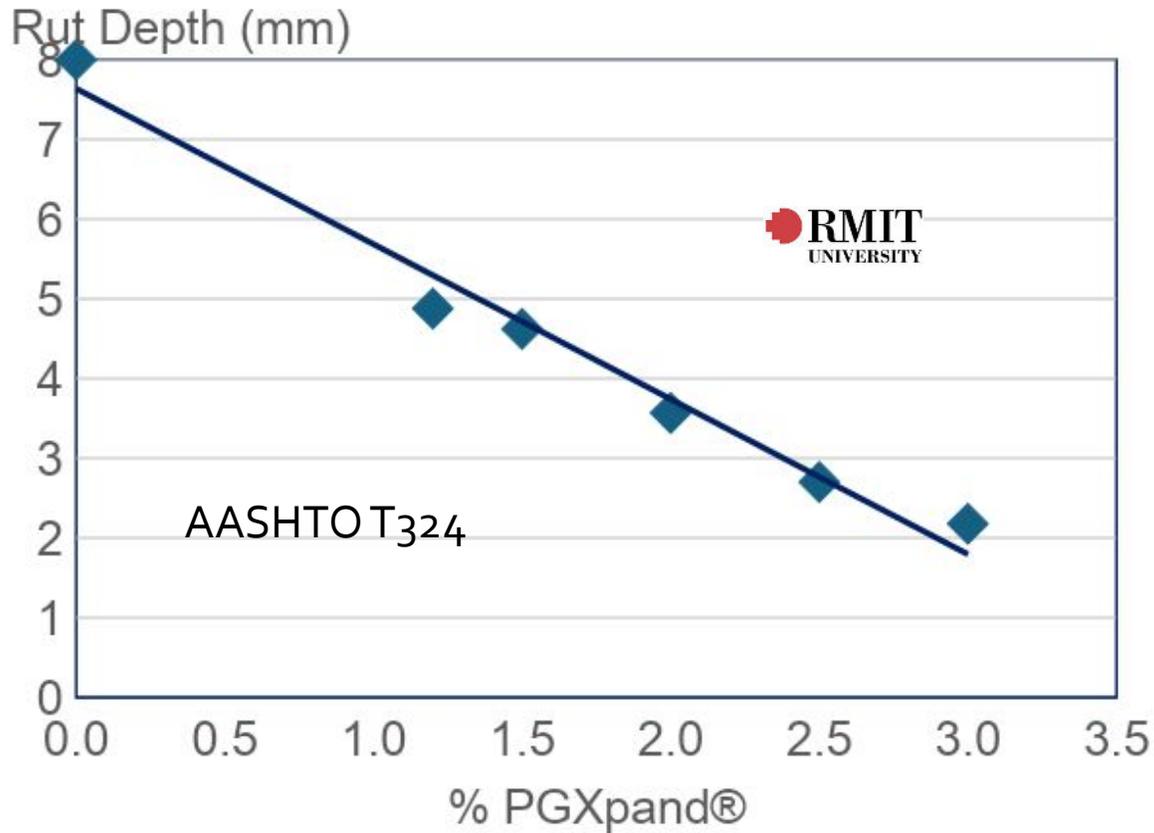


Outstanding Storage Stability

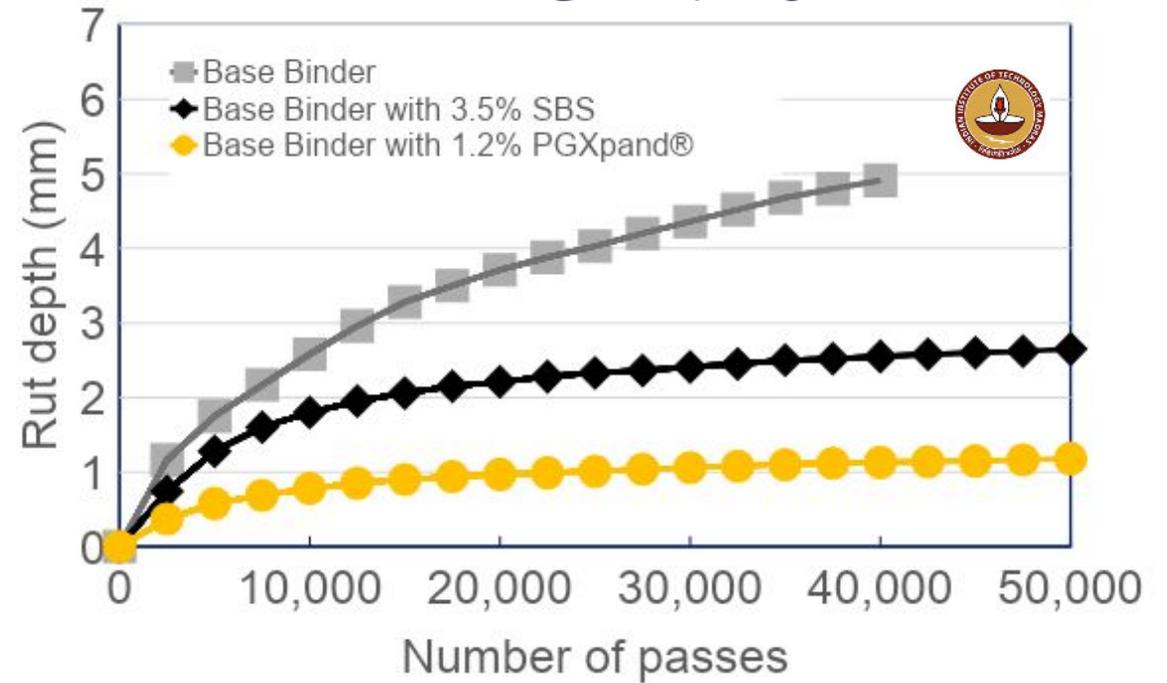
Excellent Compaction Characteristics

Rutting Resistance

Hamburg Wet Wheel Tracking Test
RMIT @ 50 C, 20K cycles, C170



Hamburg Wheel Tracking Test
India @ 60 C, VG30



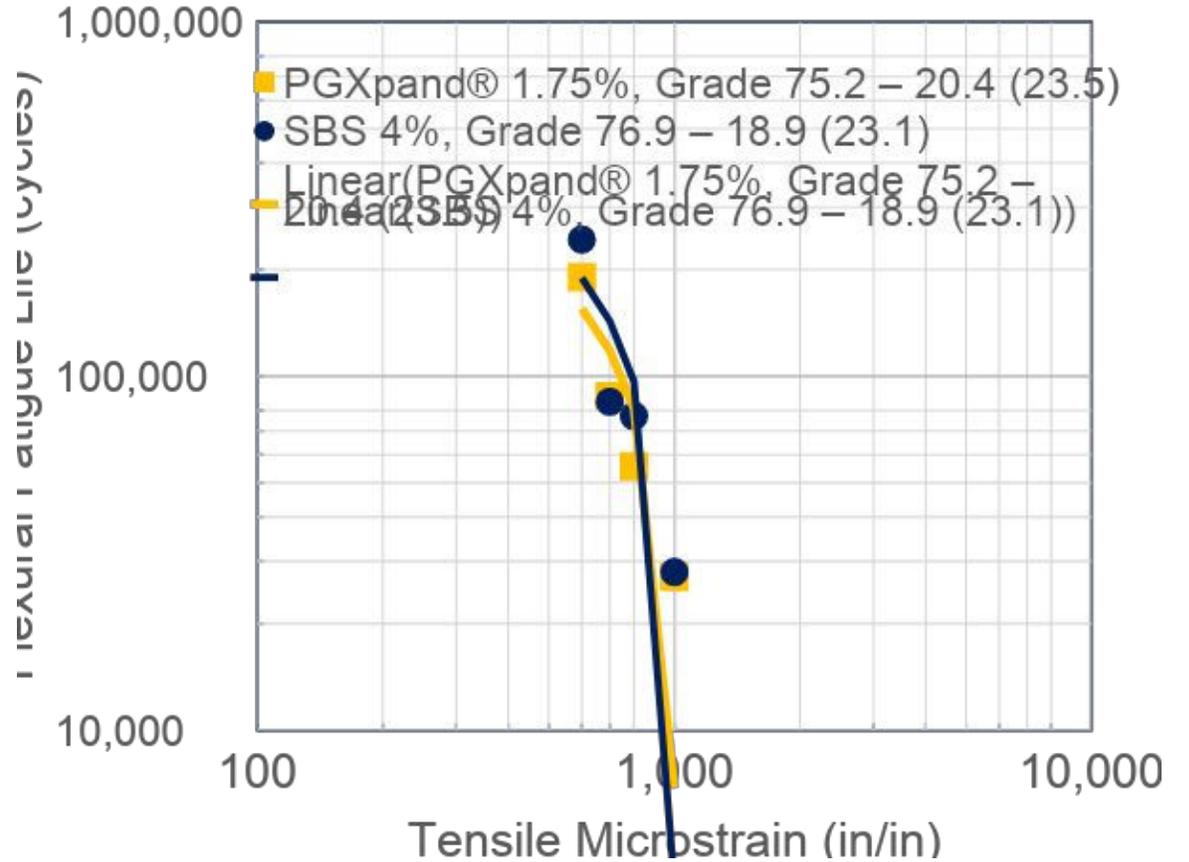
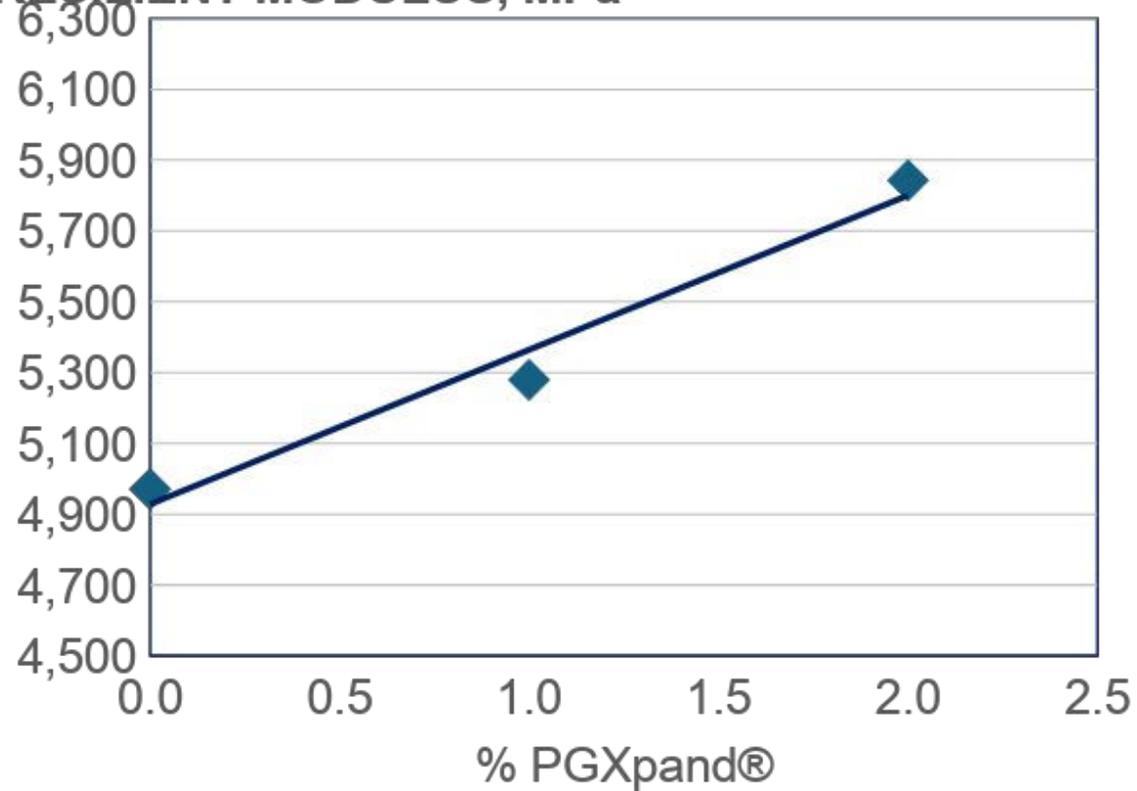
MSCR Tests @ 64 °C	VG30 + SBS	VGS + PGXpand
$J_{nr3.2}, kPa^{-1}$	1.2	1.4

Lower Dosage for Stiffer Bitumen (C320)

Excellent Rutting Resistance | Highly Dosage Efficient

Resilient Modulus and Fatigue Properties

RESILIENT MODULUS, MPa



Key Test Parameters

Temperature: 20 °C

Sinusoidal;

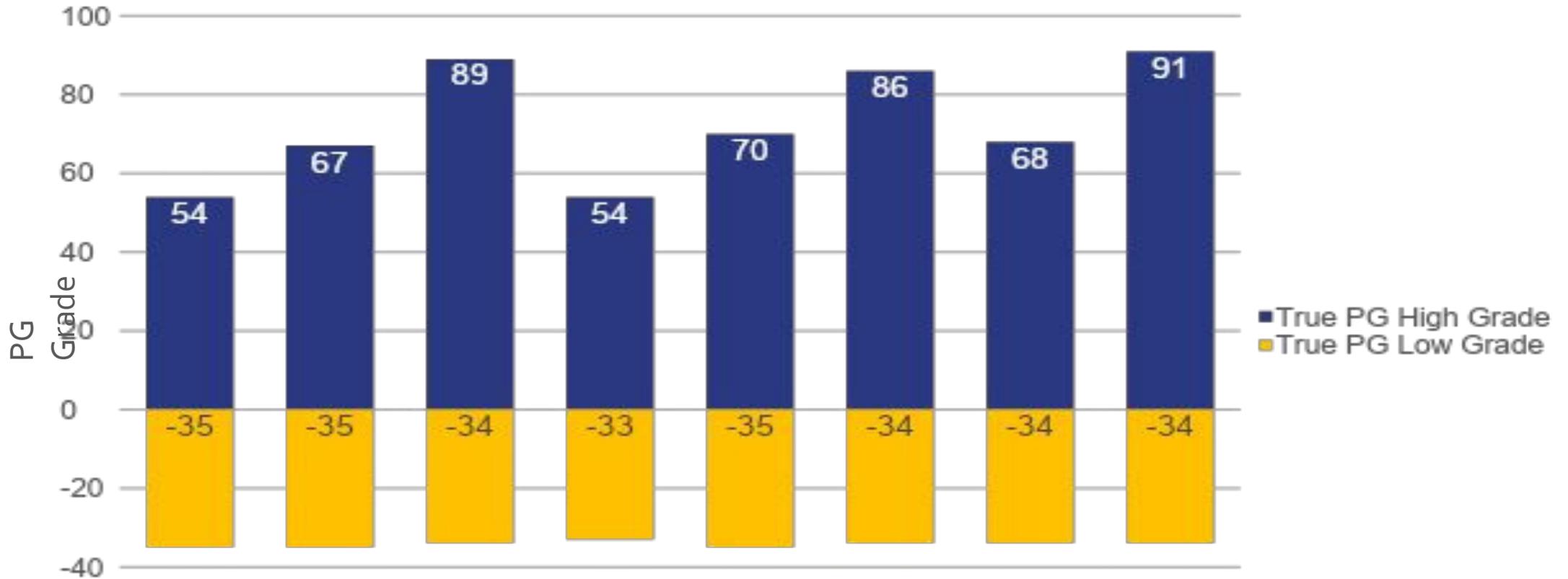
Loading Frequency: 10 Hz



PGXpand® Improves Resilient Modulus

Comparable Fatigue Life at More Efficient Dosage Levels

Aging of PGXpand® in Bitumen



Binder	Control	PMB	PMB	Control	PMB	PMB	PMB	PMB
PGXpand®	-	1.5 %	2.5 %	-	1.5 %	2.5 %	1.5 %	2.5 %
Aging	No Aging			12-hr Oven Aging @ 135°C			1-wk Aging @ 90°C	

PGXpand® Based PMBs Demonstrates Good Resistance to Aging

A Bitumen-Friendly Polymeric-Additive

PGXpand®

Environmental Product Declaration

A Bitumen-Friendly Polymeric-Additive
for Paving & Roofing Applications



- Lower Energy Consumed to Produce PMB
- Lower Temperature to Pave & Compact
- Lower Energy to Pave & Compact
- Lower Greenhouse Gas Emissions
- Highly Dosage Efficient
- Outstanding Rutting Resistance
- Good Fatigue Properties
- Excellent Aging Behavior
- Improved Roadway Durability
- Less Frequent Road Repair
- Overall Lower Energy Consumption

Global Warming Potential
GWP = 2.947

PGXpand®

A Technical Overview

A Bitumen-Friendly Polymeric-Additive
for Paving & Roofing Applications



A Unique Innovative Molecule

Using Warm Mix Technology to Reduce Energy Consumption

An Engineered Warm Mix Additive

PHALANX®

A Specially Engineered Warm Mix Additive

Specially Engineered Molecule, Highly Dosage Efficient

Environmentally Friendly Product

Improves Wettability, Acts as a Lubricant,
and Helps Better Coat the Aggregates

Reduces Compaction Temperature & Improves Compactability

Reduces Mix Production Temperature

Reduces Overall Energy Consumption

OHS Friendly

May Help Lower Carbon Footprint

Lowers Overall Cost of Mix and Paving

PHALANX®

Environmental Product Declaration

A Warm Mix Additive
for Paving Applications

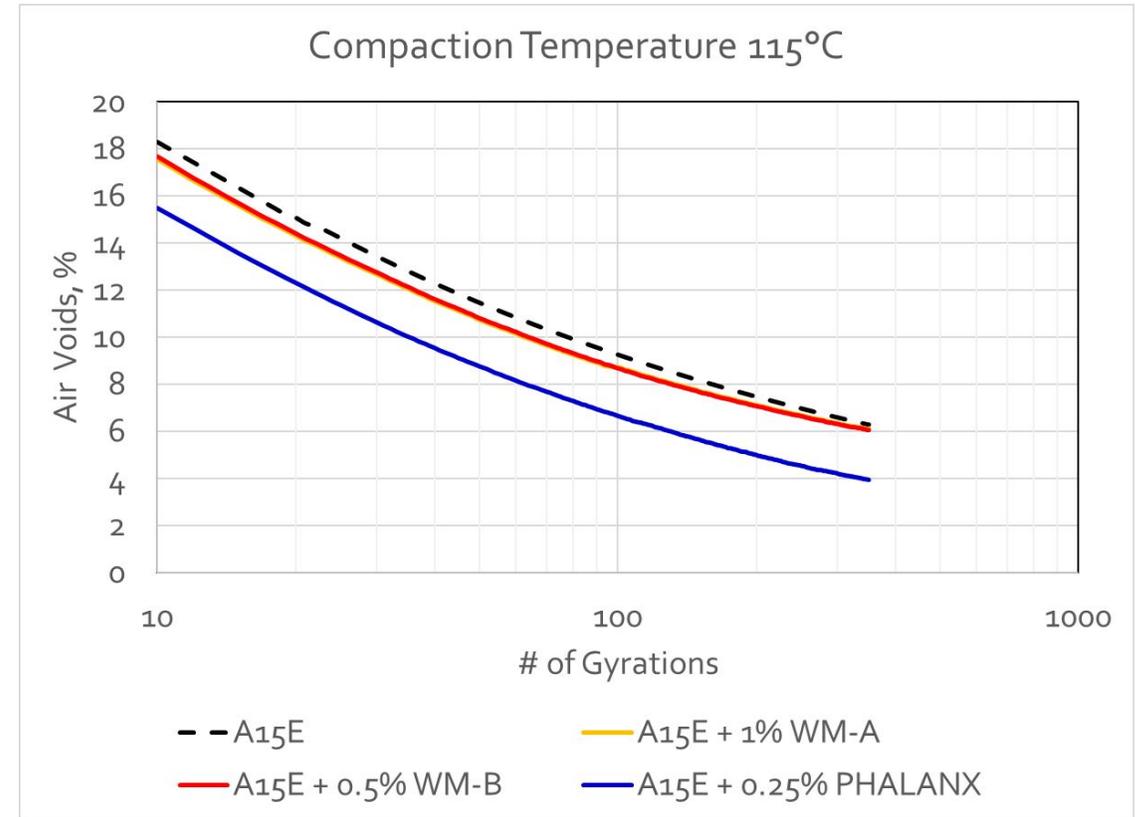
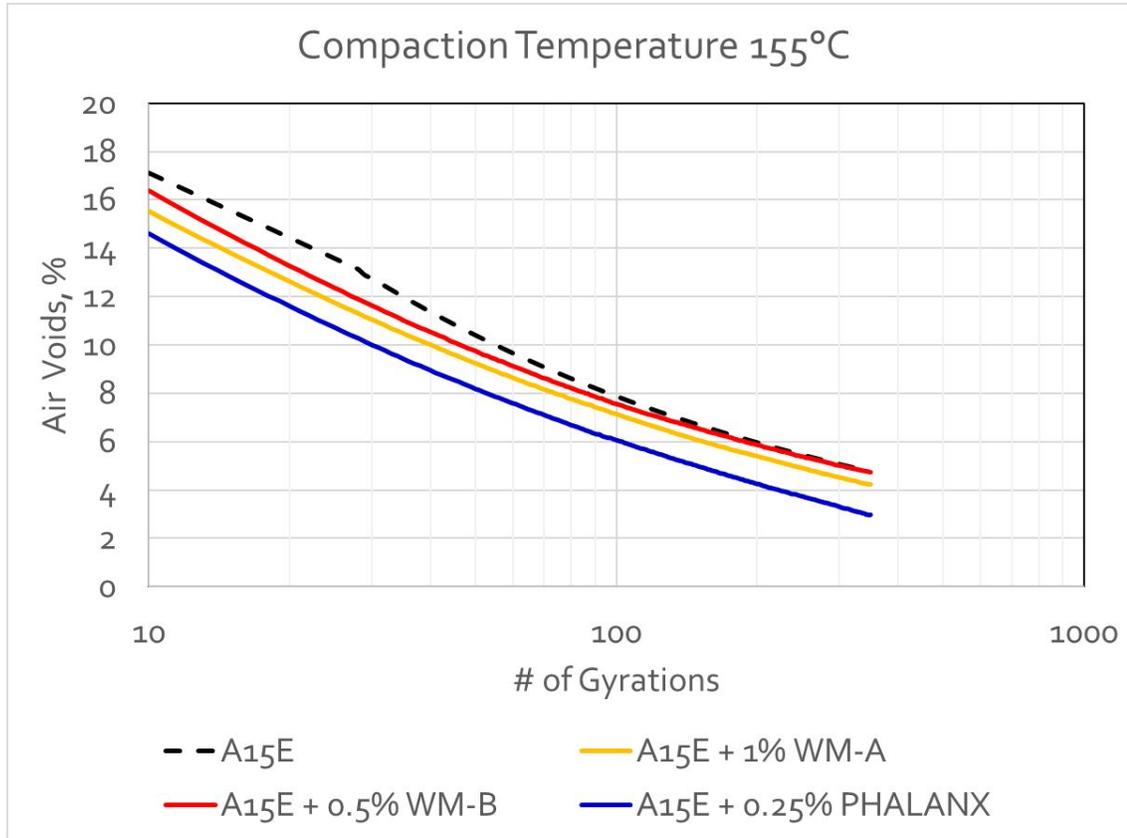


Global Warming Potential

GWP = 2.99

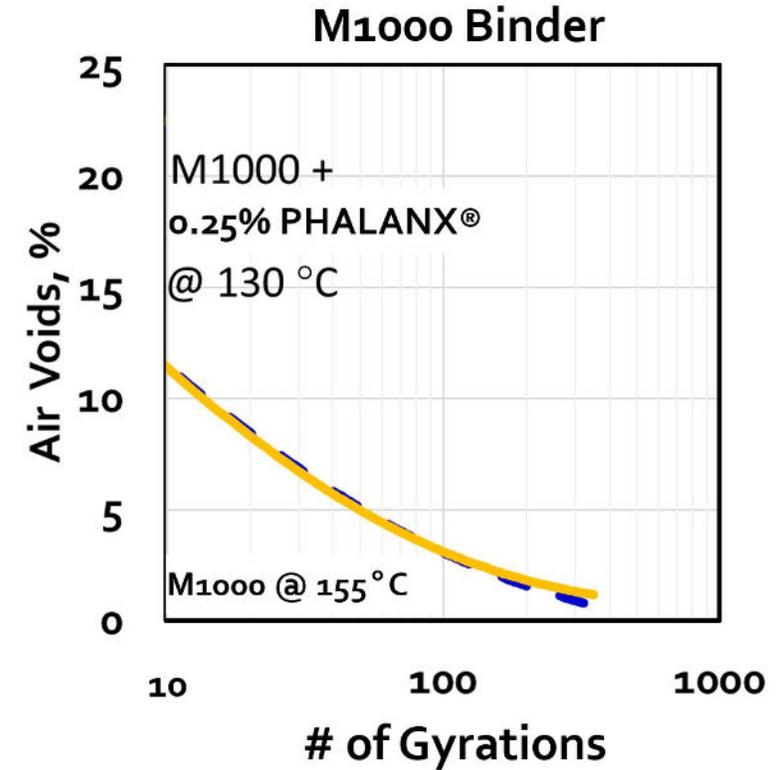
Easy to Use. Highly Dosage Efficient. A Superior Warm Mix Technology.

WMA Evaluation at Compaction Temperatures of 155°C & 115°C



Evaluation of M1000 Binder and 0.25 % Warm Mix Additive

Day	Mix	PHALANX® %	Mix Qty t	Mix Temp °C	Paving Temp, °C
1	Control	-	150	163	150
	Control + WMA	0.45	150	136	120
2	Control	-	150	163	150
	Control + WMA	0.25	150	136	120

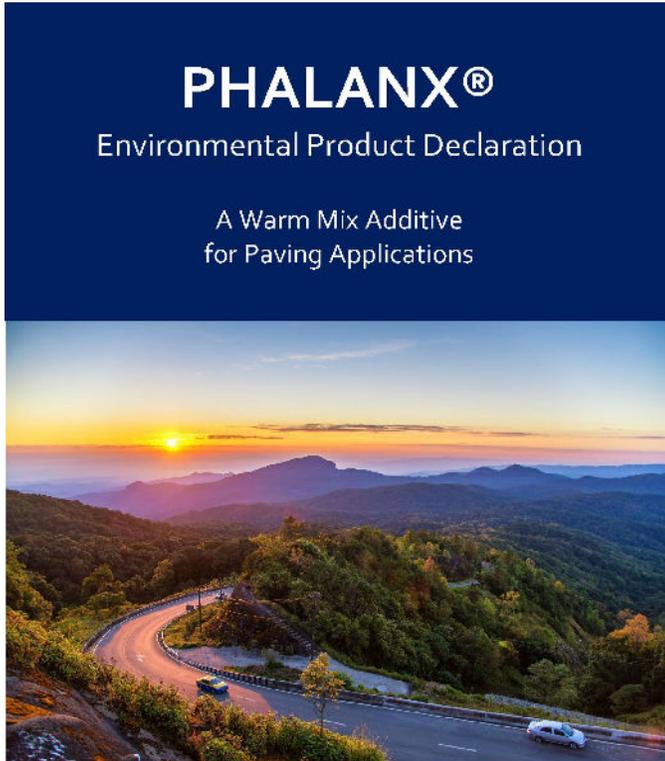


M1000 Based Mixes Dosed with WMA Show Comparable Compactability at 130 °C Compared to Control Mix at 155°C

Good Construction Techniques



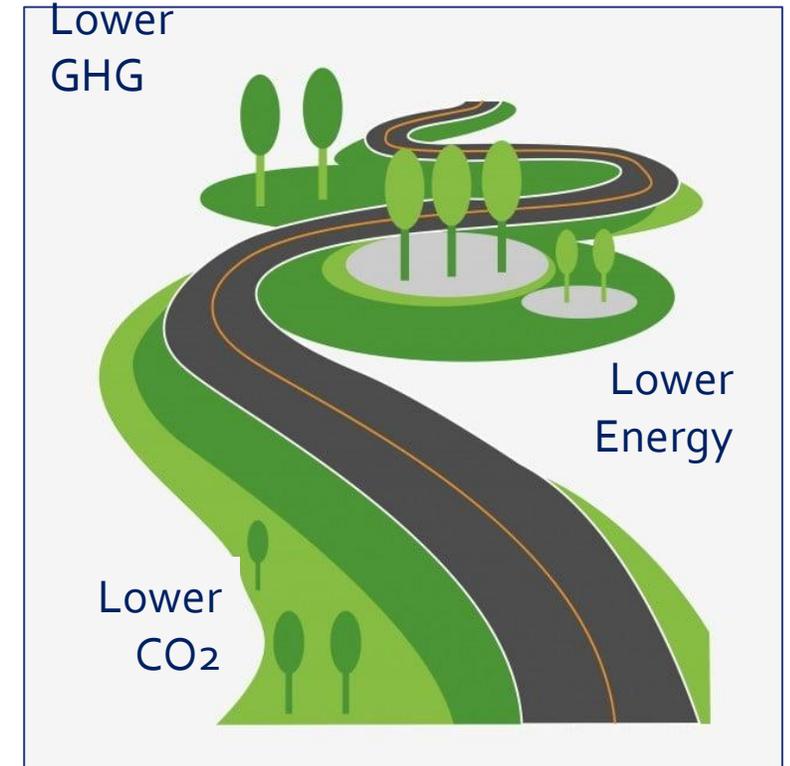
Warm Mix Additives Promote Sustainable Production and Paving



- Lower Energy Consumption
- Reduced Paving Temperatures
- Reduced Compaction Temperatures
- Lower Carbon Footprint
- Lower Greenhouse Gases

Global Warming Potential

GWP = 2.99



Environmentally Sustainable & High-Performing Warm Mix Additive

Thank You!

Connect with us!

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www.sripath.com

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