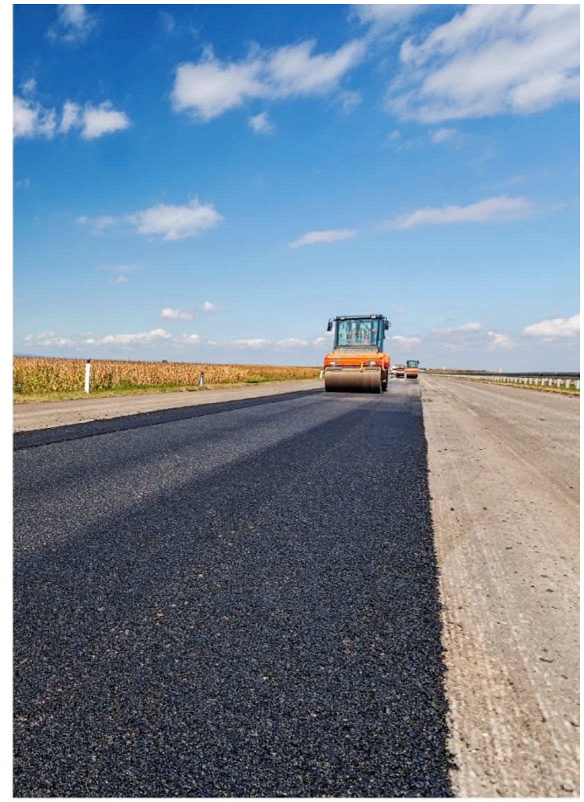
Regenerating Reclaimed Binders

PERFORMANCE. RELIABILITY.



FTBA Construction Conference, 2020
Presented by: Dallas Little, P.E.

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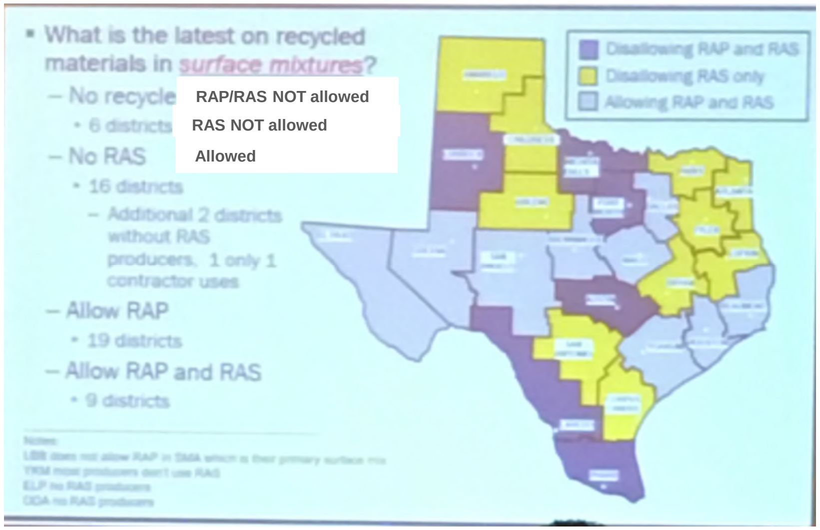
Background – Material Reuse

- **Why use reclaimed asphalt pavement (RAP)?**
  - ➢ Sustainability (raw materials, landfills)
  - ➢ Reduced construction costs (contractor profit $)
- **Why not?**
  - ➢ Lower quality (highly aged/brittle binder)
  - ➢ Mix too stiff
  - ➢ Premature cracking
  - ➢ Cost agencies and tax payers $
- **RAP allowed in all 50 states**
- **Average RAP usage**
  - ➢ 2007: 12%
  - ➢ 2009: 14%
  - ➢ 2014: 20%



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Asphalt Concrete Pavement Performance

Building the case for better asphalt mixes:

- **The United States has over 2.25 million miles roads paved with asphalt.**
- **Average rating of asphalt roads is a 'D-'.**
- **Over 20% of the mileage is listed to be in poor condition.**
- **Annual construction backlog of approximately $80B.**

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **ACTION:** Recycled Materials in Asphalt Pavements

Date: October 20, 2014

Recently there have been an increasing number of state highway agencies reporting pre-mature cracking in relatively new asphalt pavements. A similarity in many of these pavements is the high content of recycled asphalt binder.

cracking due to low temperatures or thin pavement sections. Additionally, there is concern for potential increased asphalt aging during the pavement performance life, in particular with RAS that contains already higher aged asphalt binder. There is also an inability to accurately predict an asphalt mixture's cracking potential with existing laboratory test procedures that are not always related to actual pavement condition and might provide conflicting recommendations.

Key Points:

1. **High RAP can be used *with success.***
2. **Not all rejuvenators are created equal.**
3. **Short-term performance does not imply long-term durability.**
4. **Durability can be economically engineered through selecting the correct solutions.**

Starting with Aged Binders…

Huber, AMAP 2019

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RAP Use Begins 40 Years Ago in U.S & Japan: Two Opposing Approaches

JAPAN:

- Avg RAP content = 47%
- ***97%*** roads in 'good' condition
- RAP binder quality viewed as waste/very poor
- Use of rejuvenator(s) is required
- Elastic-Recovery testing is required
- Lowest ***Life-cycle*** cost wins bid
- ***Long-term*** warranties are mandatory

UNITED STATES:

- Avg RAP content = 20%
- ***30%*** roads in 'good' condition
- RAP binder quality characterized as good enough to replace virgin ac
- Rejuvenator(s) not required, unless intended to 'soften' binder
- No RAP binder testing required
- Lowest ***Initial cost*** wins bid
- Mixes/construction often warrantied for < 2 years.

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Europe Delivers Longevity Under Extreme Traffic Conditions:

Europe Delivers Longevity under Extreme Traffic Conditions

European engineers have certainly had no problem handling the heavy traffic issue as pointed out in this 2016 article: *Why are America's Roads so much worse than Europe's*?

The article states that European autobahns carry "more traffic" and "considerably heavier truck weights" yet are "smoother" and "far sturdier" than American highways. European highways are designed and constructed to last 40 years. It isn't an issue of traffic intensity but an issue of targeting longevity, including materials and specifications capable of delivering it.

"American contracting procedures discourage the use of novel techniques. In Europe, governments dictate only how long a highway should last under what conditions, and contractors are left to their own devices to deal with the challenge. In the U.S., contractors must meet an avalanche of government specifications on materials and procedures but are not required to guarantee the road's performance. The Europeans create a contract climate that stimulates innovation; here we squash it," laments Douglas Bernard, director of the Office of Technology Applications in the Federal Highway Administration.

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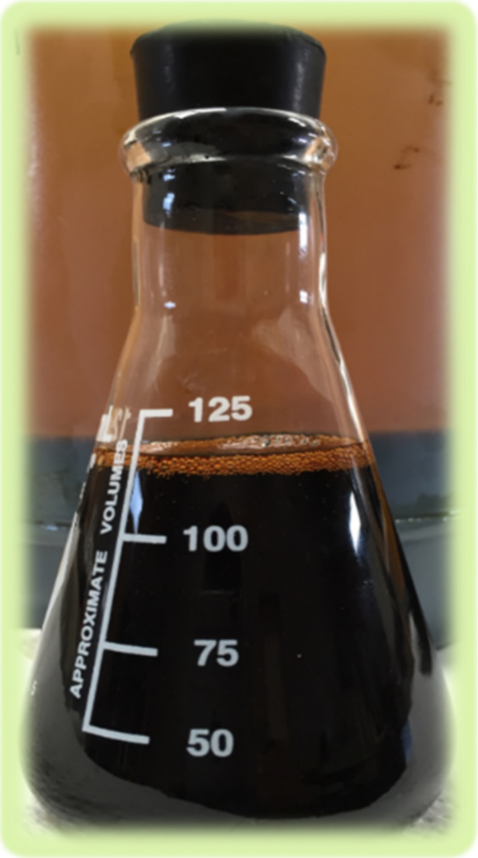
Binder Regenerators

Purpose:

Restore characteristically flawed asphalt binder to a highly durable and cracking-resistant state. The result is a product that will meet all of the highest standards to permit reliable high-performance PG-graded binder replacement in asphalt mixtures.

ReGen® offers transformative material reuse, pavement performance, cost savings, and environmental impact for contractors, agencies, and tax-payers.



Not All Rejuvenators Are Created Equal:

Basic Components of Asphalt Chemistry:

1. **Saturates/Resins**
2. **Aromatics (Maltenes)**
3. **Asphaltenes**

As maltenes oxidize, they begin to form long, polymeric chains that contribute to binder brittleness (increase asphaltenes).

Regenerators…not simply rejuvenators.

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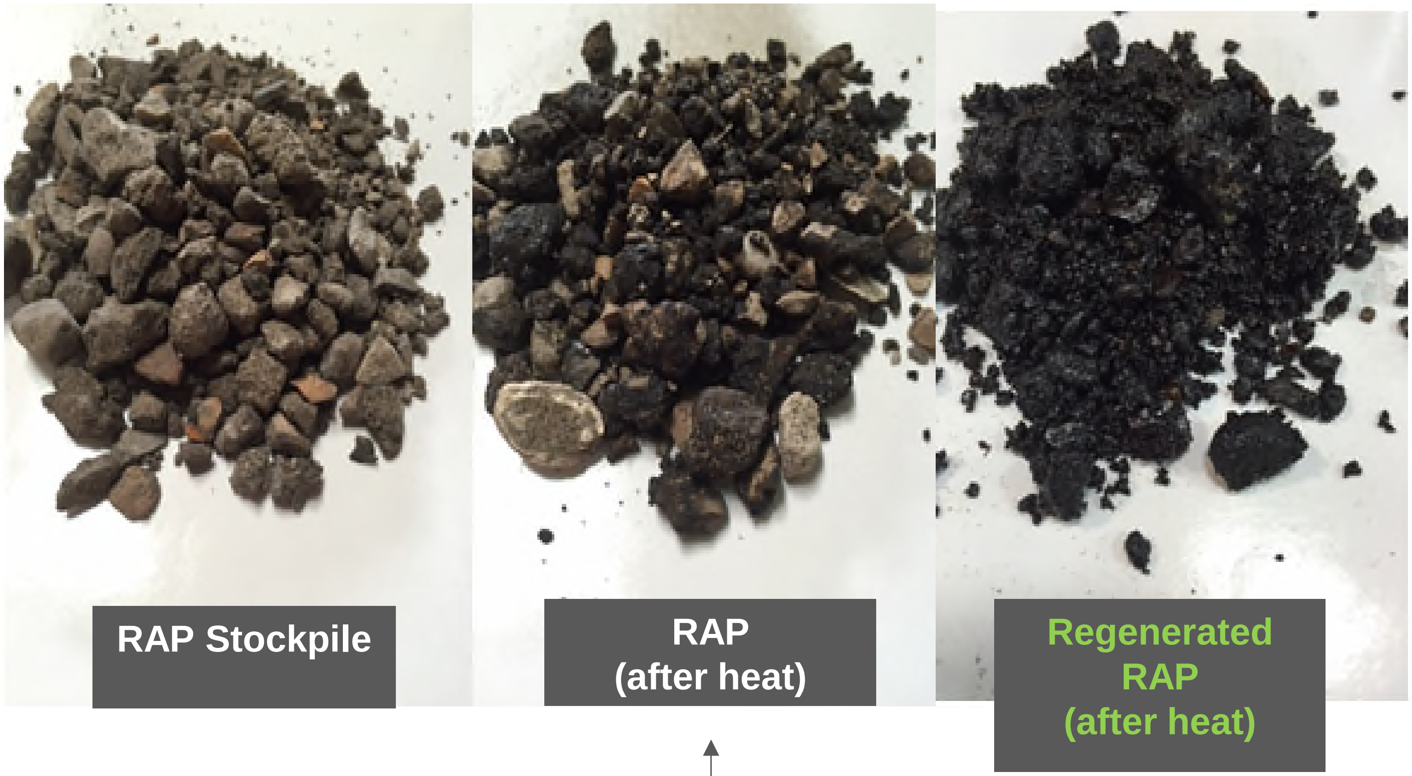
Reclaimed Asphalt Pavement (RAP)



Currently approved in most states to
replace up to 20% of required binder in mix.

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Reclaimed Asphalt Shingles (RAS):

RAS + Virgin Aggregates (after heat)

RAS + Virgin Aggregates + Regenerator (after heat)

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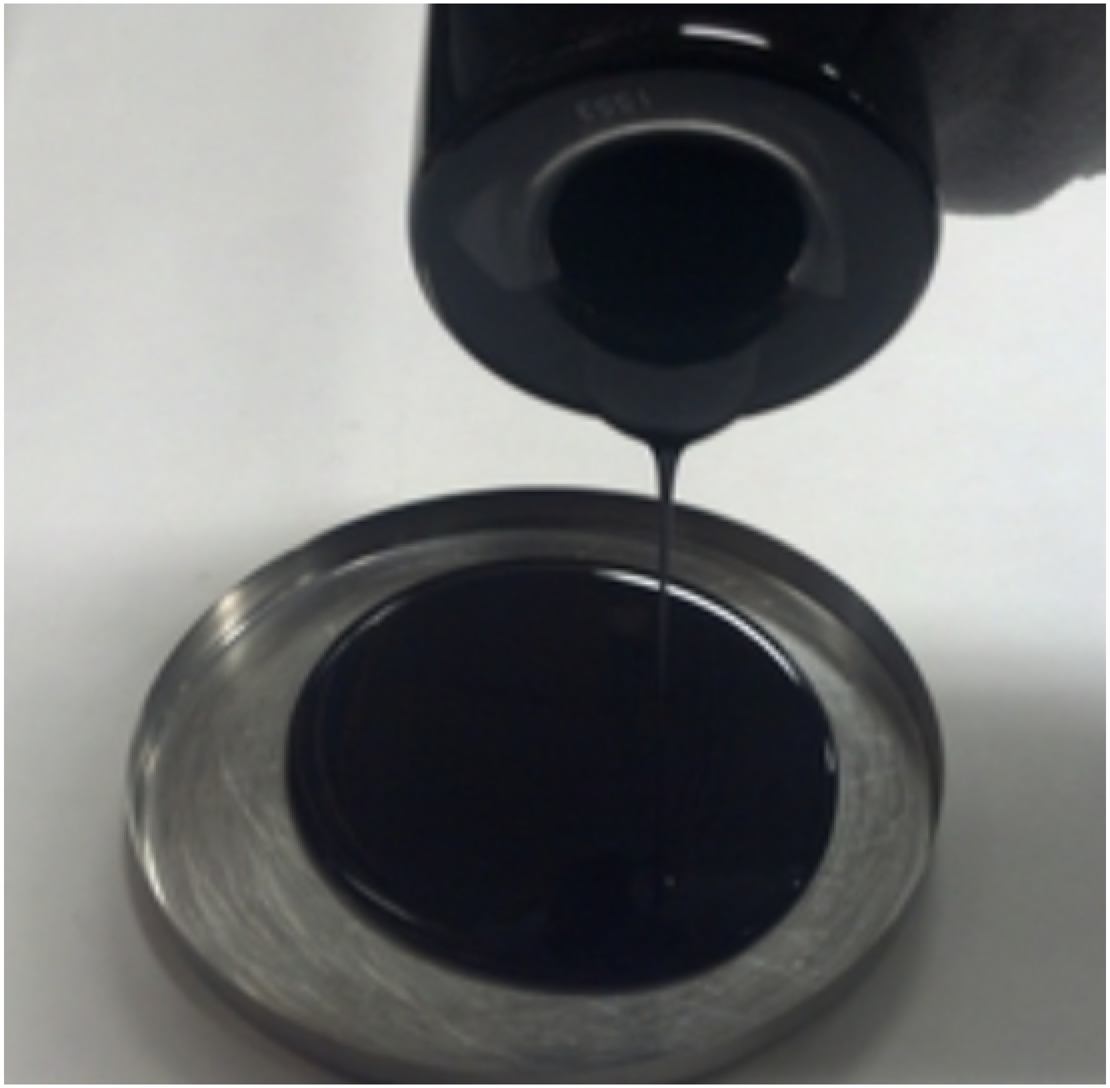
Binder Performance After Regeneration:



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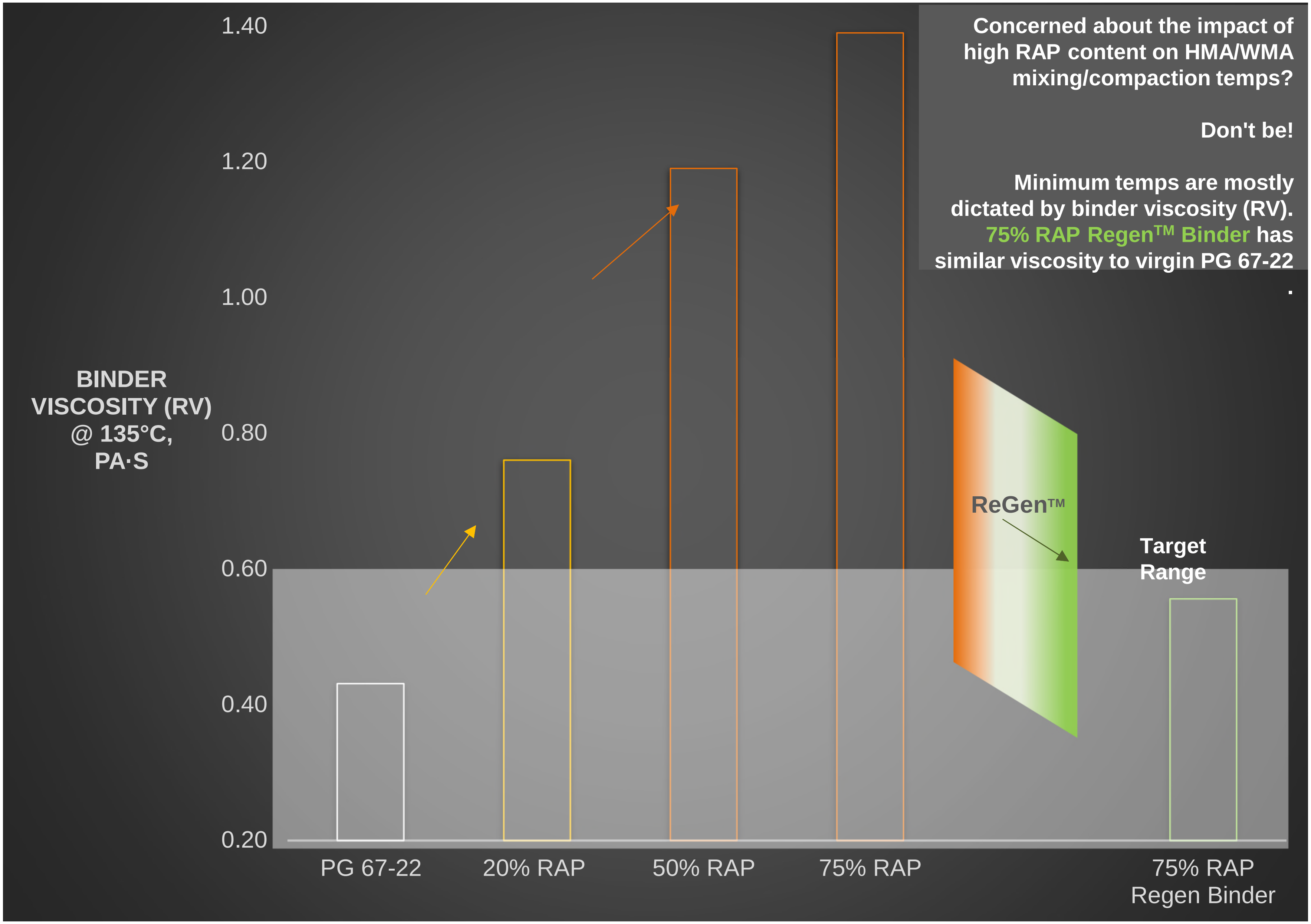
Concerned about the impact of high RAP content on HMA/WMA mixing/compaction temps?
Don't be!
Minimum temps are mostly dictated by binder viscosity (RV). 75% RAP Regen™ Binder has similar viscosity to virgin PG 67-22
BINDER VISCOSITY (RV) @ 135°C, PA·S
1.40
1.20
1.00
0.80
0.60
0.40
0.20
ReGen™
Target Range
PG 67-22
20% RAP
50% RAP
75% RAP
75% RAP Regen Binder

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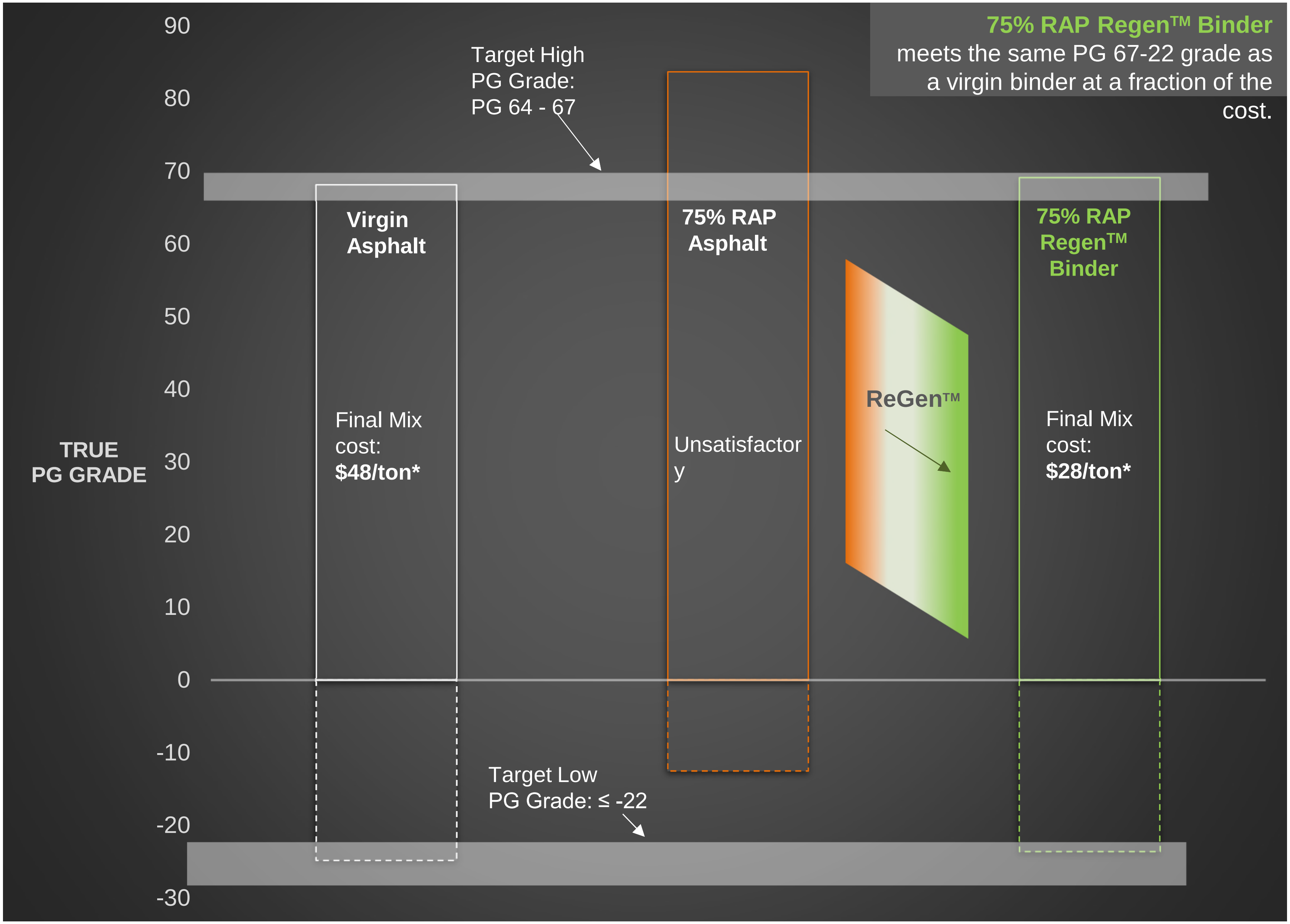
75% RAP Regen™ Binder
meets the same PG 67-22 grade as a virgin binder at a fraction of the cost.
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
TRUE PG GRADE
Target High PG Grade: PG 64 - 67
Virgin Asphalt
Final Mix cost: $48/ton*
75% RAP Asphalt
Unsatisfactory
ReGen™
75% RAP Regen™ Binder
Final Mix cost: $28/ton*
Target Low PG Grade: ≤ -22

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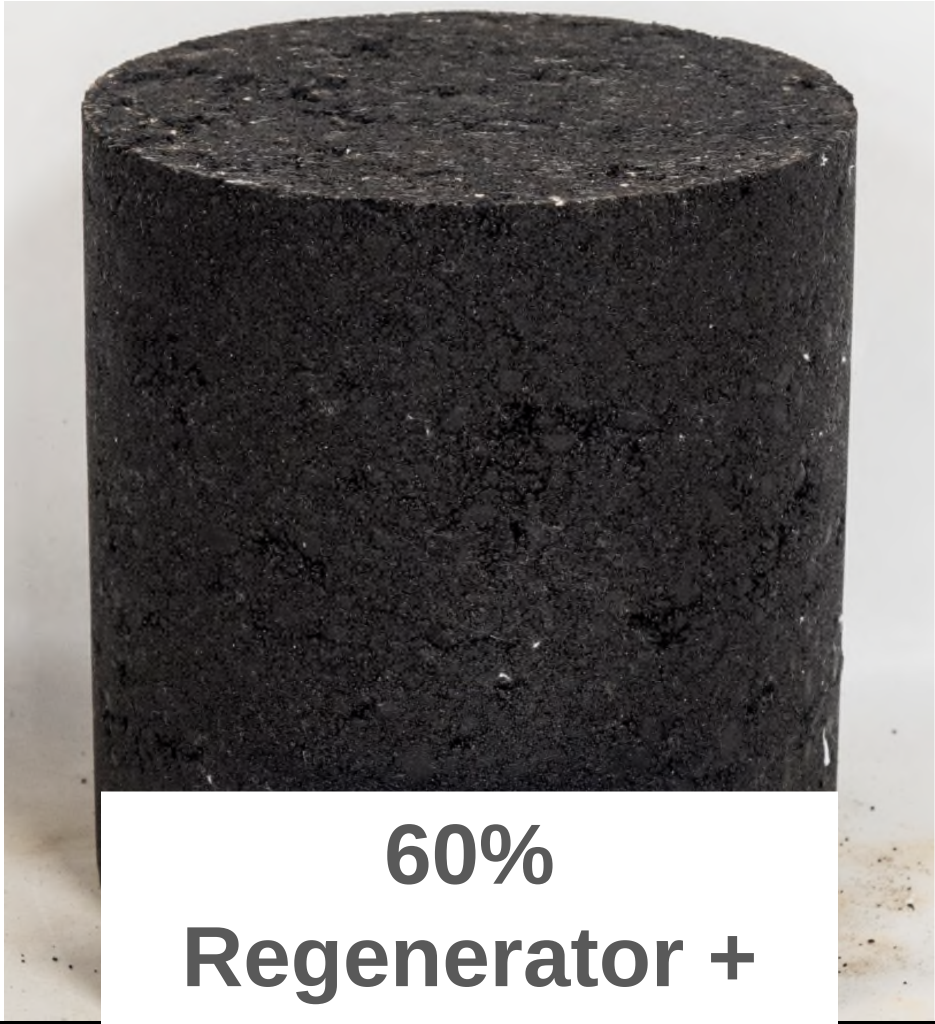
Mixture Performance:



60%
Regenerator +
RAP

Photo by NCAT (2017)

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Table 4. Summary of 35% RAP Design Performance

Properties		Test Methods	Results
Recovered Binder from 2,500g sample (toluene), g		ASTM D2172 / D7906	127.9
Hamburg Wheel Tracking @ 50°C	Ave. Deformation, mm	AASHTO T 324	3.29
	Passes to 12.5 mm		>20,000
	Passes to Stripping Inflection Point, SIP		>20,000
I-FIT @ 25°C	Flexibility Index	AASHTO TP 124	5.04
	Fracture Energy (J/m^2)		1,449.3
	Strength (psi)		56.67
Cantabro, Mass Loss, %	Short-Term Oven Aging	AASHTO TP 108	7.0
	Long Term Oven Aging		7.3

Comments: The production of the 35% RAP mixture was produced within Florida DOT production & specification limits.

Source: Asphalt Testing Solutions and Engineering, LLC (ATS, Duval Asphalt), January 2018.

Table 7. Summary of 45% RAP Design Performance

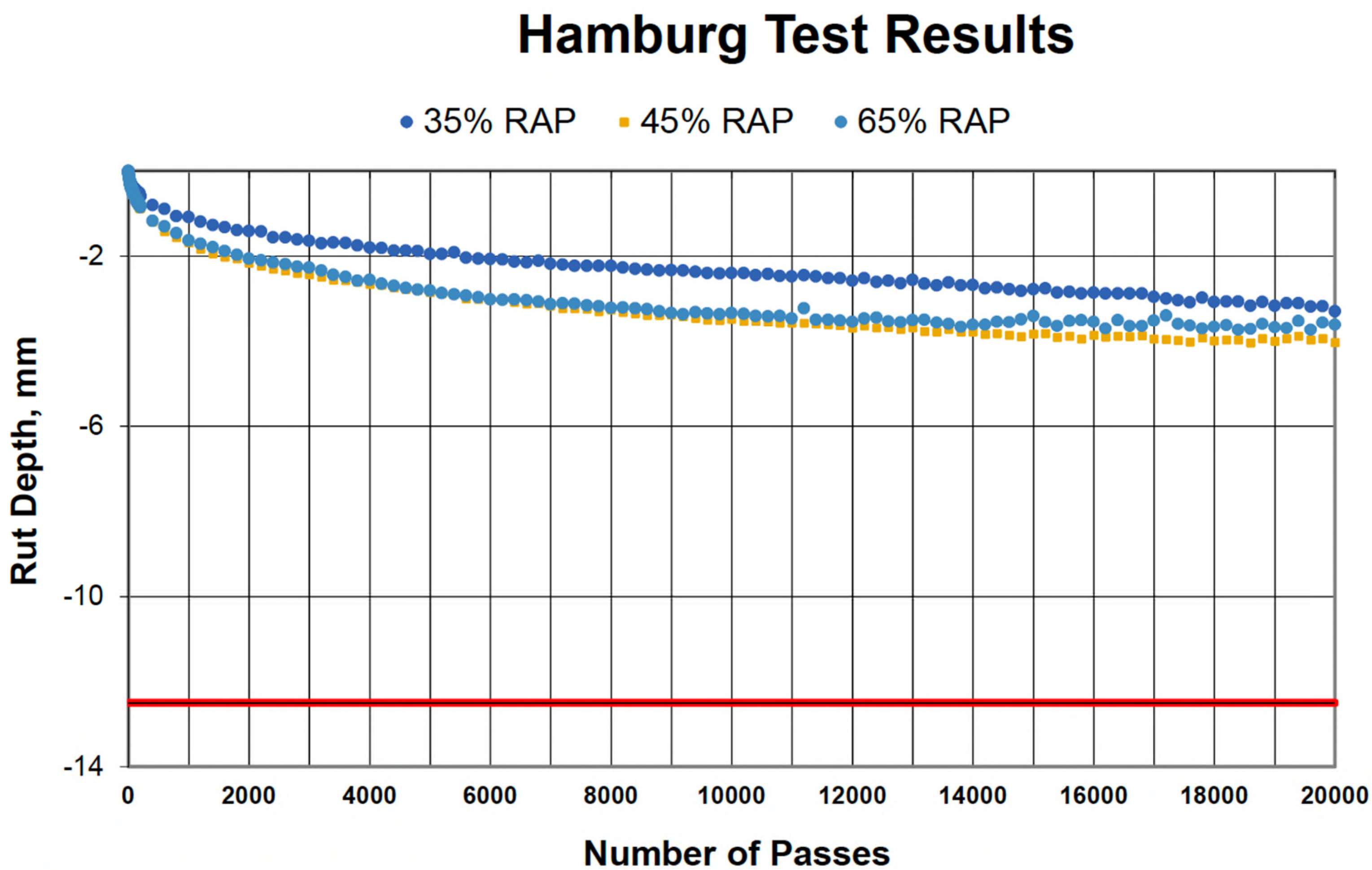
Properties		Test Methods	Results
Recovered Binder from 2,500g sample (toluene), g		ASTM D2172 / D7906	121.8
Hamburg Wheel Tracking @ 50°C	Ave. Deformation, mm	AASHTO T 324	4.03
	Passes to 12.5 mm		>20,000
	Passes to Stripping Inflection Point, SIP		>20,000
I-FIT @ 25°C	Flexibility Index	AASHTO TP 124	4.86
	Fracture Energy (J/m^2)		1,111.4
	Strength (psi)		44.76
Cantabro, Mass Loss, %	Short-Term Oven Aging	AASHTO TP 108	8.5
	Long Term Oven Aging		10.9

Comments: The production of the 45% RAP mixture was produced within Florida DOT production & specification limits.

Table 10. Summary of 60% RAP Design Performance

Properties		Test Methods	Results
Recovered Binder from 2,500g sample (toluene), g		ASTM D2172 / D7906	135.3
Hamburg Wheel Tracking @ 50°C	Ave. Deformation, mm	AASHTO T 324	3.61
	Passes to 12.5 mm		>20,000
	Passes to Stripping Inflection Point, SIP		>20,000
I-FIT @ 25°C	Flexibility Index	AASHTO TP 124	4.52
	Fracture Energy (J/m^2)		1,463.6
	Strength (psi)		58.75
Cantabro, Mass Loss, %	Short-Term Oven Aging	AASHTO TP 108	8.0
	Long Term Oven Aging		9.8

Comments: The production of the 60% RAP mixture was produced within Florida DOT production & specification limits.



35% RAP SIP = None
Passes @ 12.5 mm: N/A
Max deflection: -3.29 mm

45% RAP SIP = None
Passes @ 12.5 mm: N/A
Max deflection: -4.03 mm

65% RAP SIP = None
Passes @ 12.5 mm: N/A
Max deflection: -3.61 mm

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Summary of Testing:

Rutting: The rutting for all mixtures was minimal and well below the 12.5mm maximum (**Figure 1**). None of the mixtures displayed signs of stripping through a stripping inflection point (SIP). The high RAP and Regen mixtures peformed the the same as the control 35% RAP mixture.

Cracking: The Illinois Flexibility Index Test (I-FIT) for each mixture resulted in Flexibility Indexes (FI) above 4.00. Increasing the RAP content from 35% to 65% would typically see a drop in the FI of about half due to the high recycled binder replacement and the stiffness of the binder. The addition of the Regen resulted in comparable performance with the control mixture with not only the FI, but strength and fracture energy.

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Summary of Testing:

Durability: Each mixture was conditioned per AASHTO R 30 for short-term oven aging (STOAS) and long-term oven aging (LTOA). The plant mix was conditioned at compaction temperature for 2-hours prior to compacting each mixture in triplicate. The air void content used was 7.0 ± 0.5% for comparison to the other performance tests in lieu of 4.0%, as prescribed by AASHTO TP 108. Using the higher air void content is more representative of a new pavement, giving an indication of the durability of the mixture in the beginning of its life.

After compaction, specimens were placed in an 85°C forced-draft oven for five days to complete LTOA aging per AASHTO R 30. The specimens were also compacted to 7.0 ± 0.5% air for easier comparison. There is no statistical difference between the three mixtures, and due to the lack of repeatability within the test, they are considered comparable in mass loss for both STOA and LTOA specimens.

The average mass loss of each mixture, even after LTOA, were all under 10% with the exception of the 45% RAP, which was 10.9%. The maximum mass loss for a dense graded mixture is typically around 10% with specimens compacted to 4.0% air voids. Since, these specimens were compacted at 7.0± 0.5%, they would be expected to have a slightly higher mass loss.

What is possible with Regenerators?

- **Average RAP usage**
  - 2007: 12%
  - 2009: 14%
  - 2014: 20%

  - 2020: 60%?

Photo by NCAT (2017)

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Economic Considerations:

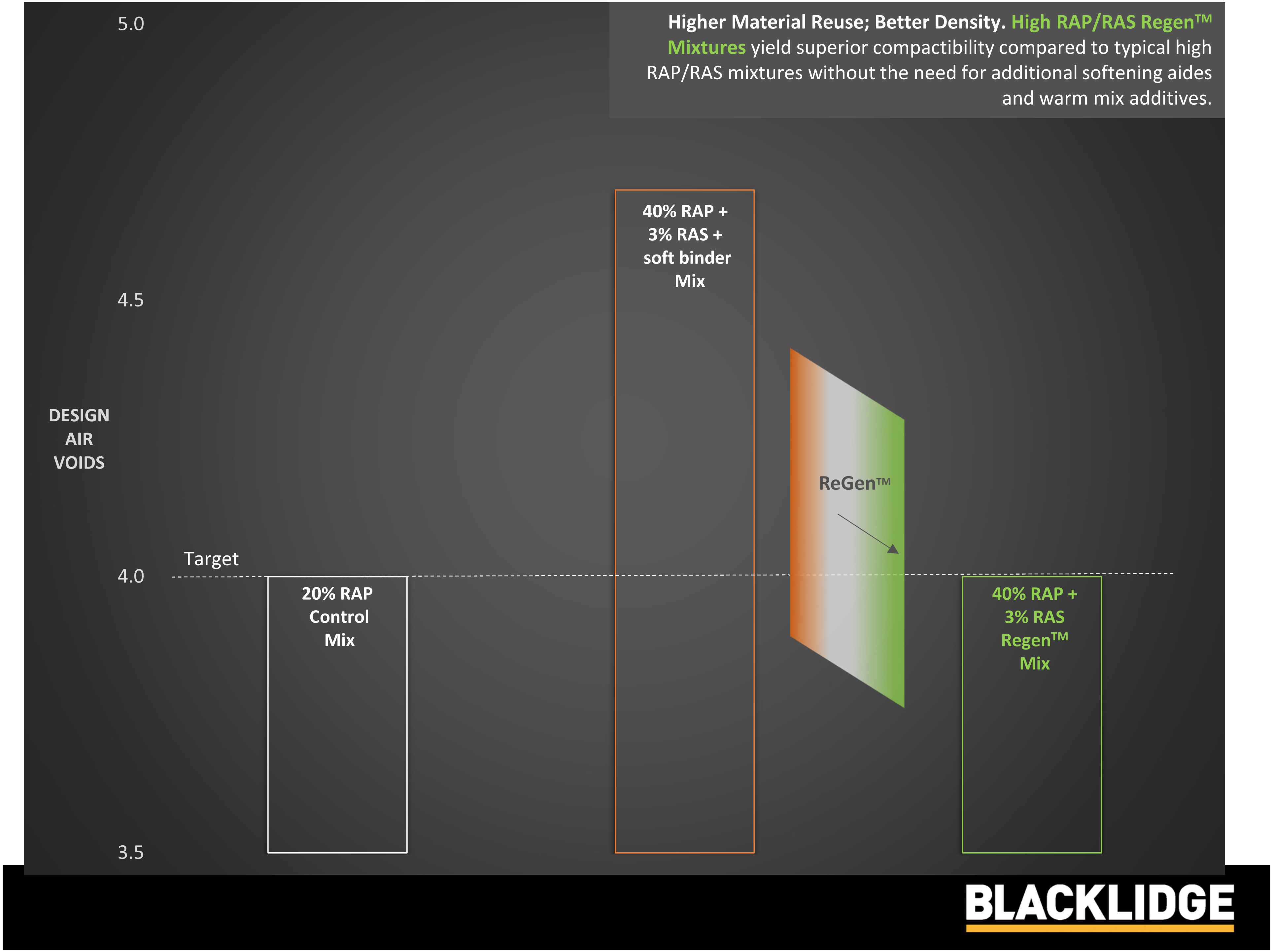
- **Even a slight increase in RAP use has demonstrated savings relative to cost of using regenerators.**
- **Savings of as little as $2.00 per mix ton can mean as much as $500,000 savings over the course of a year’s production (250,000 tpy producer).**
- **The added assurance of using a quality additive reduces risk associated with using higher levels of reclaimed binder.**

Summary:

- **Regenerators are part of a separate additive class relative to additives whose performance falls off over time.**
- **Performance has been demonstrated in short AND long-term evaluations.**
- **Mixes containing regenerators are capable of offering cost savings, sustainability and superior performance.**

THANK YOU!

Supplemental Data


5.0
4.5
4.0
3.5
DESIGN AIR VOIDS
Target
Higher Material Reuse; Better Density. High RAP/RAS Regen™ Mixtures yield superior compactibility compared to typical high RAP/RAS mixtures without the need for additional softening aides and warm mix additives.
20% RAP Control Mix
40% RAP + 3% RAS + soft binder Mix
ReGen™
40% RAP + 3% RAS Regen™ Mix
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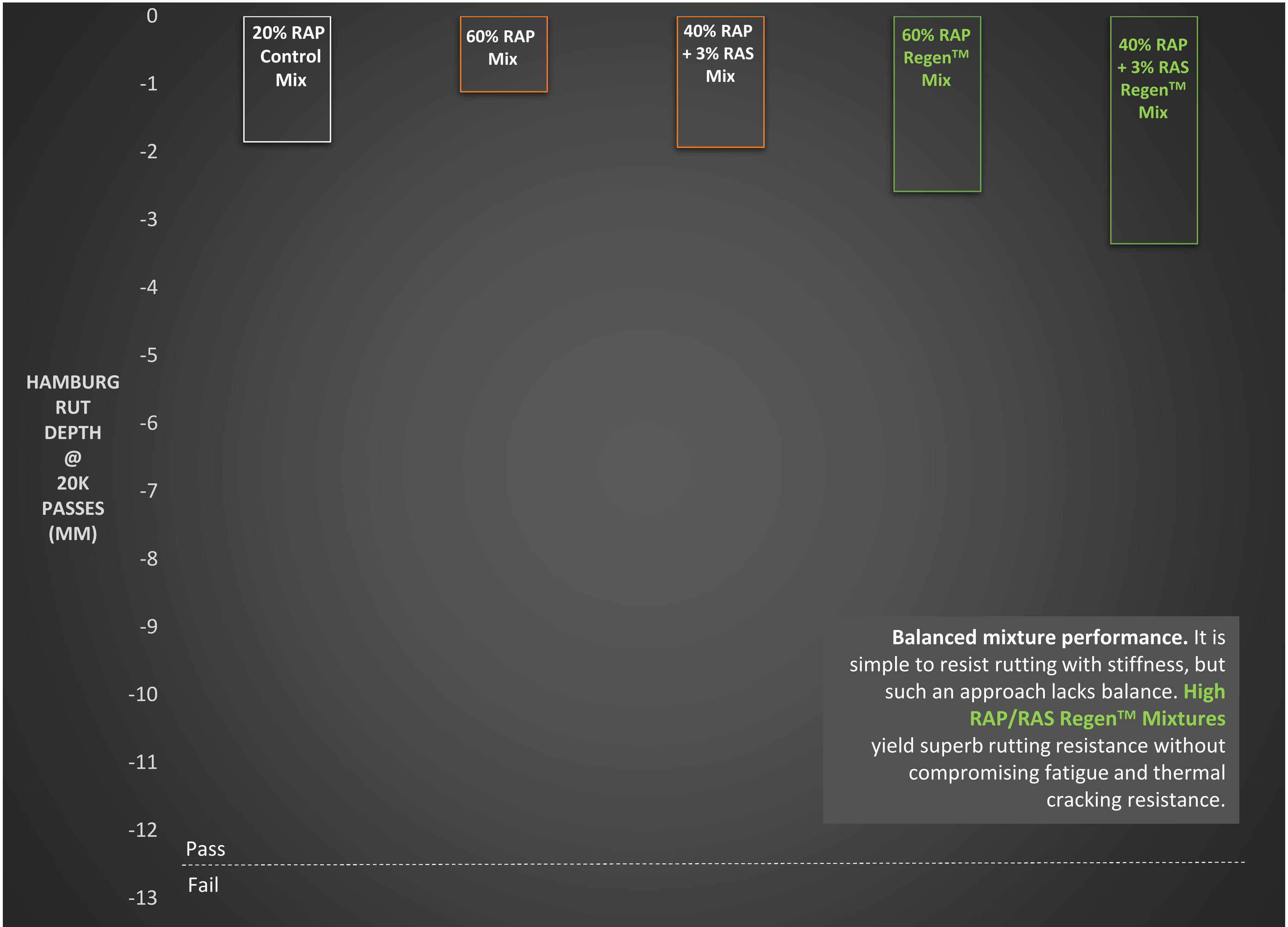
HAMBURG RUT DEPTH @ 20K PASSES (MM)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
20% RAP Control Mix
60% RAP Mix
40% RAP + 3% RAS Mix
60% RAP Regen™ Mix
40% RAP + 3% RAS Regen™ Mix
Pass
Fail
Balanced mixture performance. It is simple to resist rutting with stiffness, but such an approach lacks balance. **High RAP/RAS Regen™ Mixtures** yield superb rutting resistance without compromising fatigue and thermal cracking resistance.

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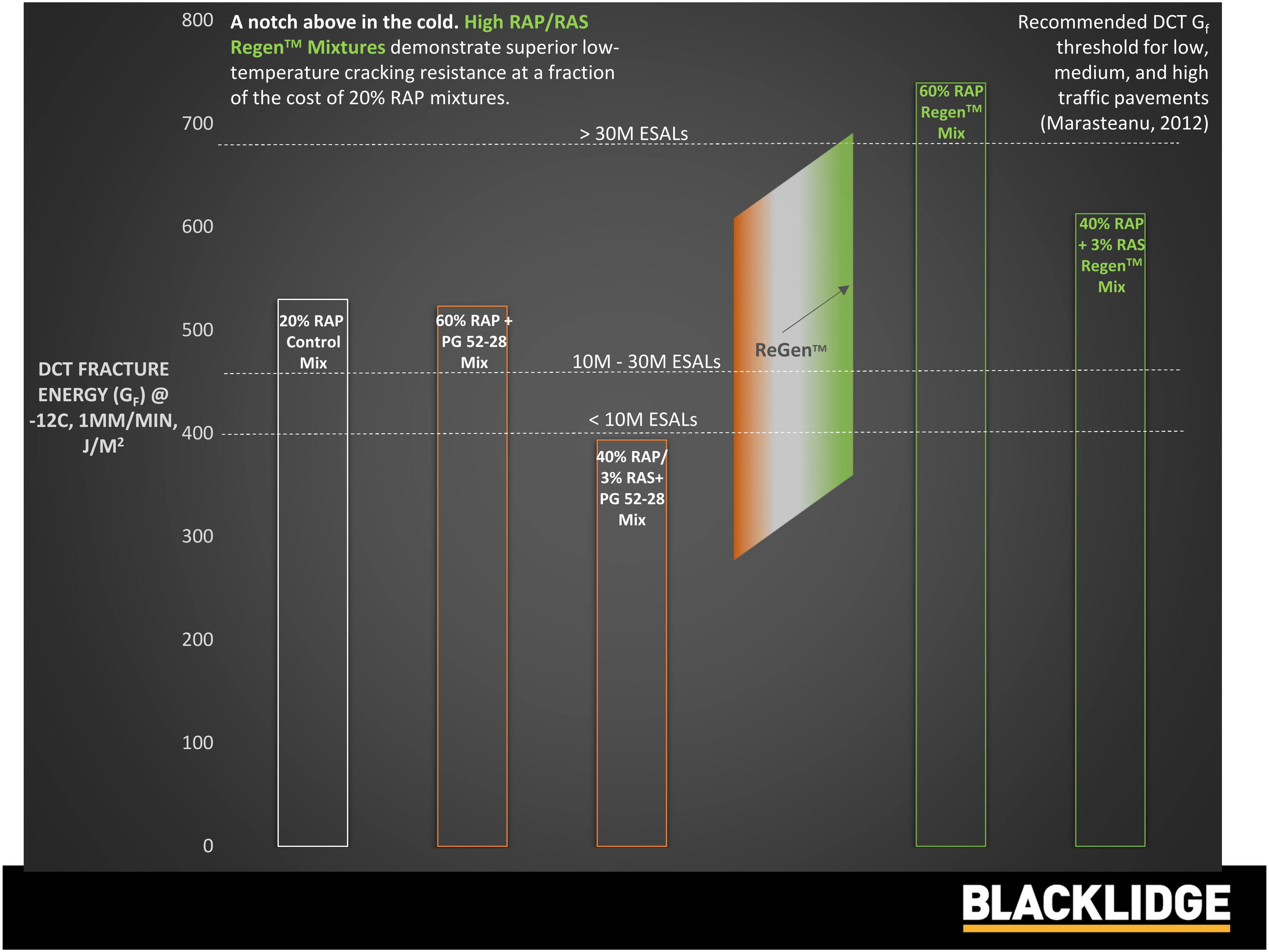
A notch above in the cold. High RAP/RAS Regen™ Mixtures demonstrate superior low-temperature cracking resistance at a fraction of the cost of 20% RAP mixtures.
Recommended DCT G_f threshold for low, medium, and high traffic pavements (Marasteanu, 2012)
DCT FRACTURE ENERGY (G_F) @ -12C, 1MM/MIN, J/M²
800
700
600
500
400
300
200
100
0
> 30M ESALs
10M - 30M ESALs
< 10M ESALs
20% RAP Control Mix
60% RAP + PG 52-28 Mix
40% RAP/ 3% RAS+ PG 52-28 Mix
ReGen™
60% RAP Regen™ Mix
40% RAP + 3% RAS Regen™ Mix
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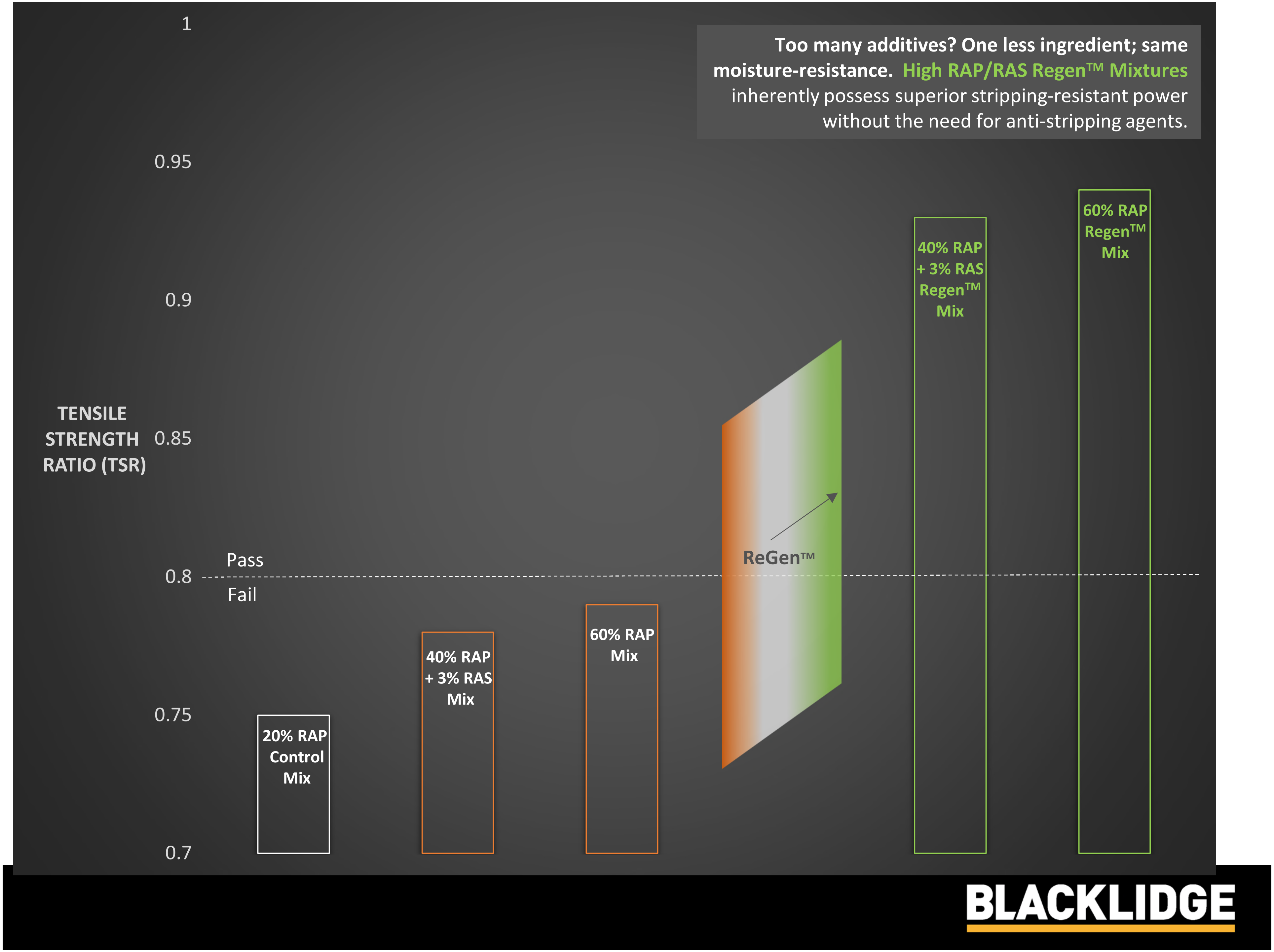

Too many additives? One less ingredient; same moisture-resistance. High RAP/RAS Regen™ Mixtures inherently possess superior stripping-resistant power without the need for anti-stripping agents.
TENSILE STRENGTH RATIO (TSR)
1
0.95
0.9
0.85
0.8
0.75
0.7
Pass
Fail
20% RAP Control Mix
40% RAP + 3% RAS Mix
60% RAP Mix
ReGen™
40% RAP + 3% RAS Regen™ Mix
60% RAP Regen™ Mix
BLACKLIDGE