




**Georgia-Pacific**  
Chemicals

# Improving Asphalt Pavement Performance With RAP Mixes Using Bio-Based Oils

1. Identify asphalt pavement performance challenges
2. Solutions using bio-based oils
3. How bio-based oils can be used in RAP mixes for asphalt pavements
4. Examples of past successes using bio-based oil strategies for higher RAP mixes



**Identify The Challenges**




“The effects of air and water on deterioration of asphalt mixtures, known as durability, continues to present a challenge.”

Dr. Stephen Brown, University of Nottingham, UK

Keynote: Achievements and Challenges in Asphalt Pavement Engineering

ISAP's 8<sup>th</sup> International Conference on Asphalt Pavements – Seattle, 1997



“Since the late 1990s, pavement durability and cracking have become the primary asphalt pavement distress.”

Dr. John D’Angelo, D’Angelo Consulting  
Pavement Cracking: What Binder Properties Control  
Asphalt Magazine – Summer, 2019

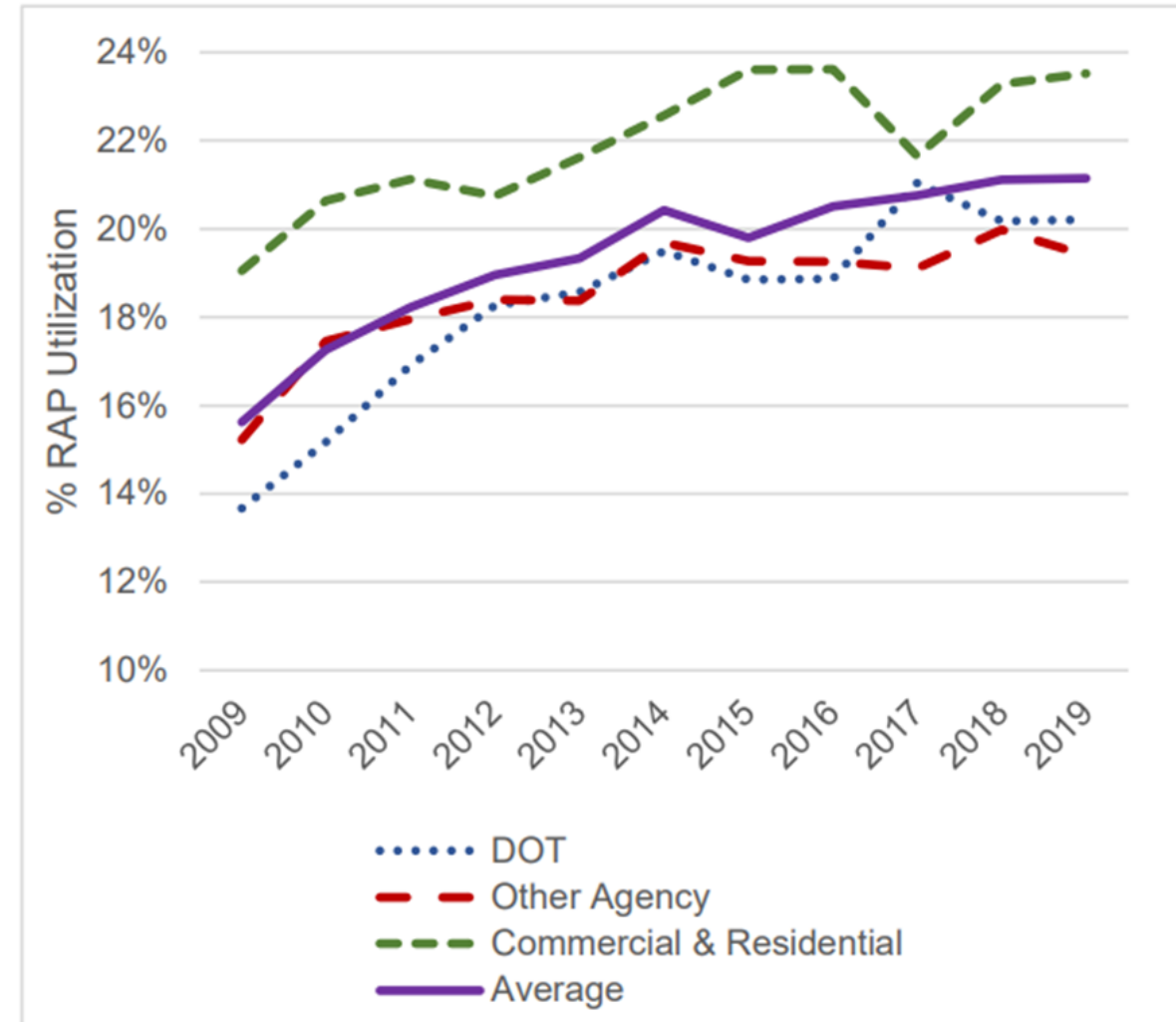
# POTENTIAL SOURCES OF DURABILITY & CRACKING ISSUES

- Loss of aggregate-asphalt adhesion
- RAP binder acting as a black rock
- Not enough asphalt binder in the mixture
- Low in-place density
- Asphalt binder aging properties
- Insufficient low temperature PG



# RAP TRENDS

- 56 Million Tons of RAP used in new mixes - 2009
- 89 Million Tons of RAP used in new mixes - 2019
- Greater amounts of RAP may require a softer virgin binder to improve durability and cracking resistance properties



# Asphalt Binder Availability Considerations for Transportation Network Owners

- A softer asphalt binder is not always an available solution

## Supplier Constraints

- Regional availability of softer grades of asphalt may be limited in warmer climates

## Mix Producer Constraints

- Hot mix producers may have tank limitations





# Helping to Solve Durability Challenges with Bio-Based Oils

# Asphalt Binder Durability

- Asphalt binders become stiffer and more brittle with age
- Cracking is more dependent on the aged condition of asphalt
- Asphalts that are less durable tend to age faster than expected



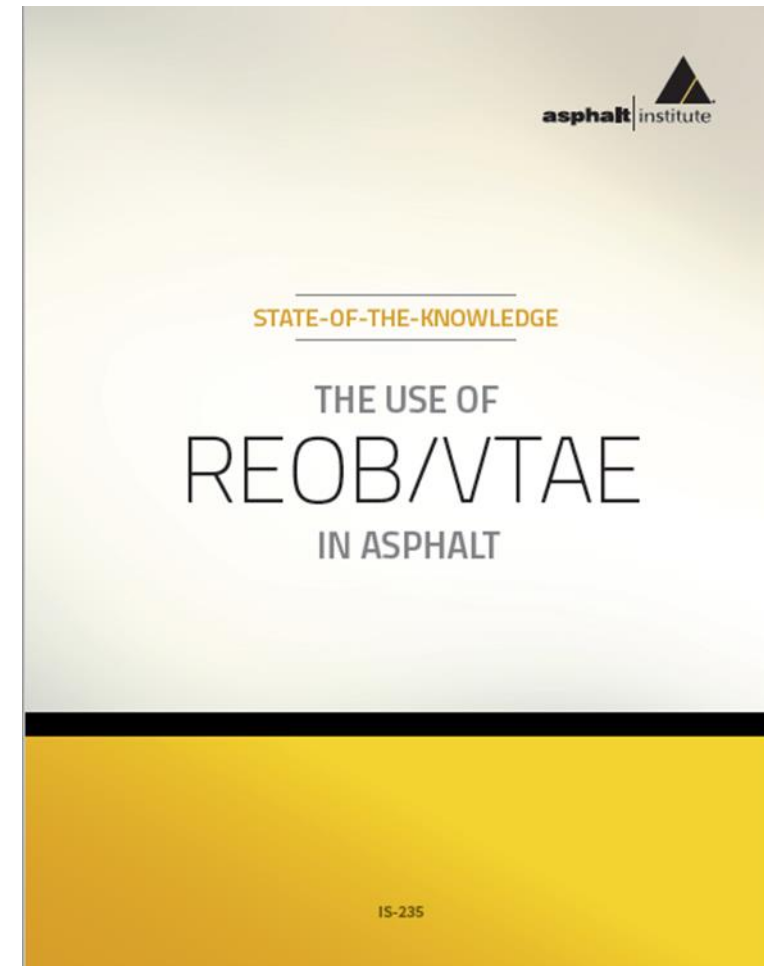
# Asphalt Parameters That Indicate Durability and Brittleness

- Glover-Rowe
- Cross-over Temperature
- R-value
- Phase Angle
- $\Delta T_c$
- More



# LESSONS LEARNED

- Certain types of oils, while lowering PG, can increase age-related cracking
- Effects on asphalt can be similar to those from:
  - Waxes or waxy crudes
  - Oxidized asphalt
  - Aged asphalt



# Bio-Based Oils for RAP Mixes

- Agricultural or Plant based (“Organic Material”)
  - Fatty acid-based chemistries
  - Nonvolatile vegetable oils
  - Reacted bio-based oils
  - Tall oils
- Can be compatible additives to asphalt
  - Storage stable
  - Phase stable
- Lower asphalt stiffness (reduces high and low PG)
- Restore properties of aged asphalt

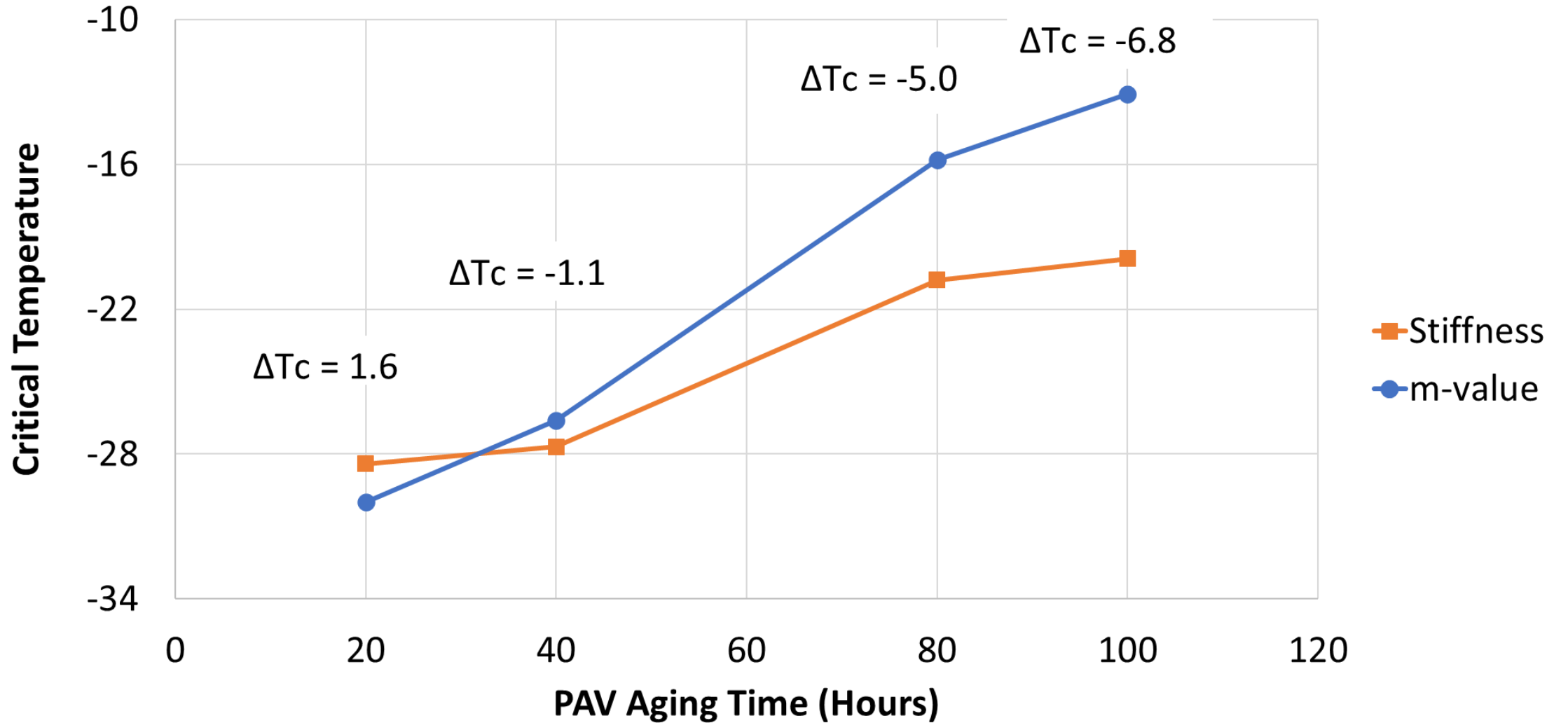


# What Research Tells Us About $\Delta T_c$

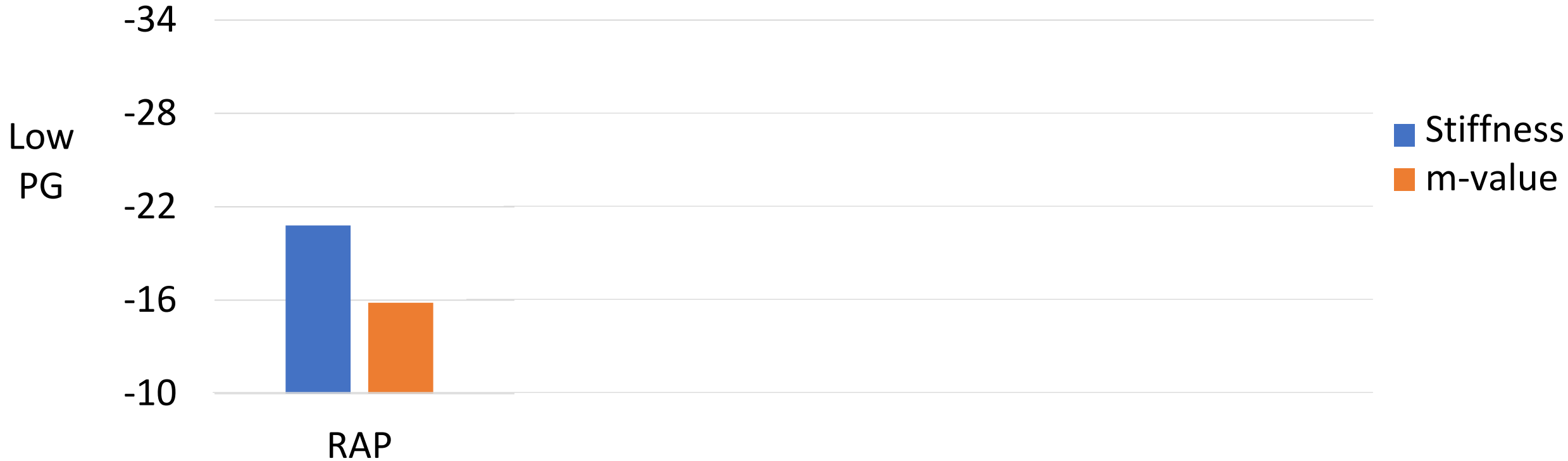
- As binders age, they lose ductility and  $\Delta T_c$  decreases
- $\Delta T_c$  reaching -5.0 may be the tipping point for age-related cracking
- Measuring  $\Delta T_c$  after more severe laboratory aging gives us the tools to evaluate durability
  - 40hrs PAV is helpful for research and forensic analysis



# $\Delta T_c$ DECREASES WITH AGE



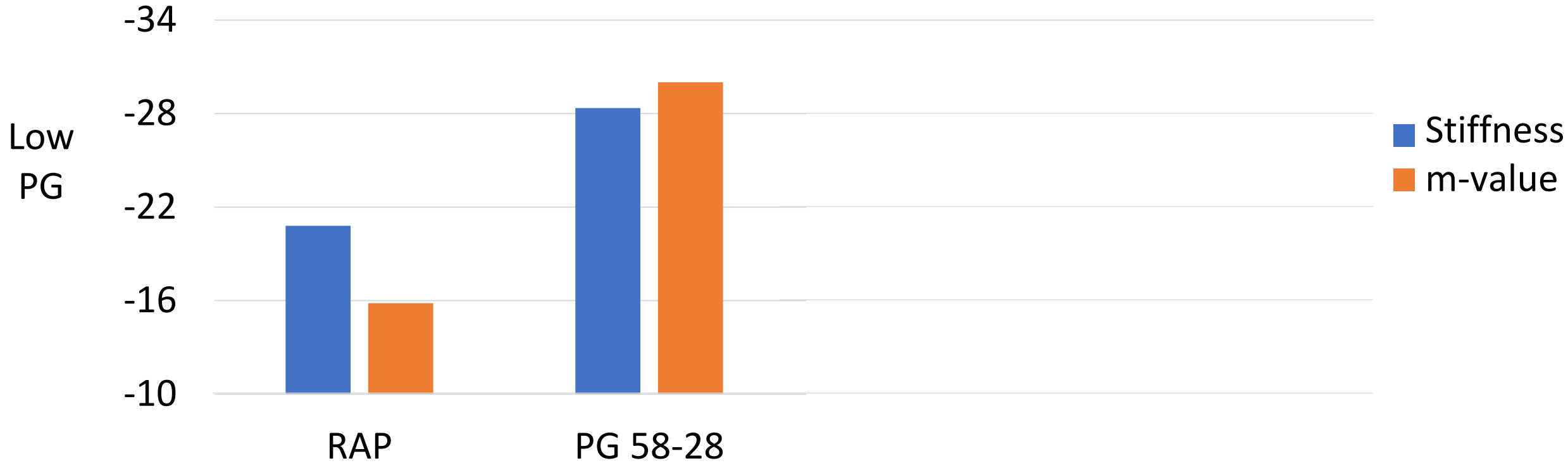
# Bio-based Oil Blending with RAP & Virgin Binder



<b>Continuous PG</b>	<b>PG 95-16</b>
<b>40hr PAV <math>\Delta T_c</math></b>	<b>-6.8</b>

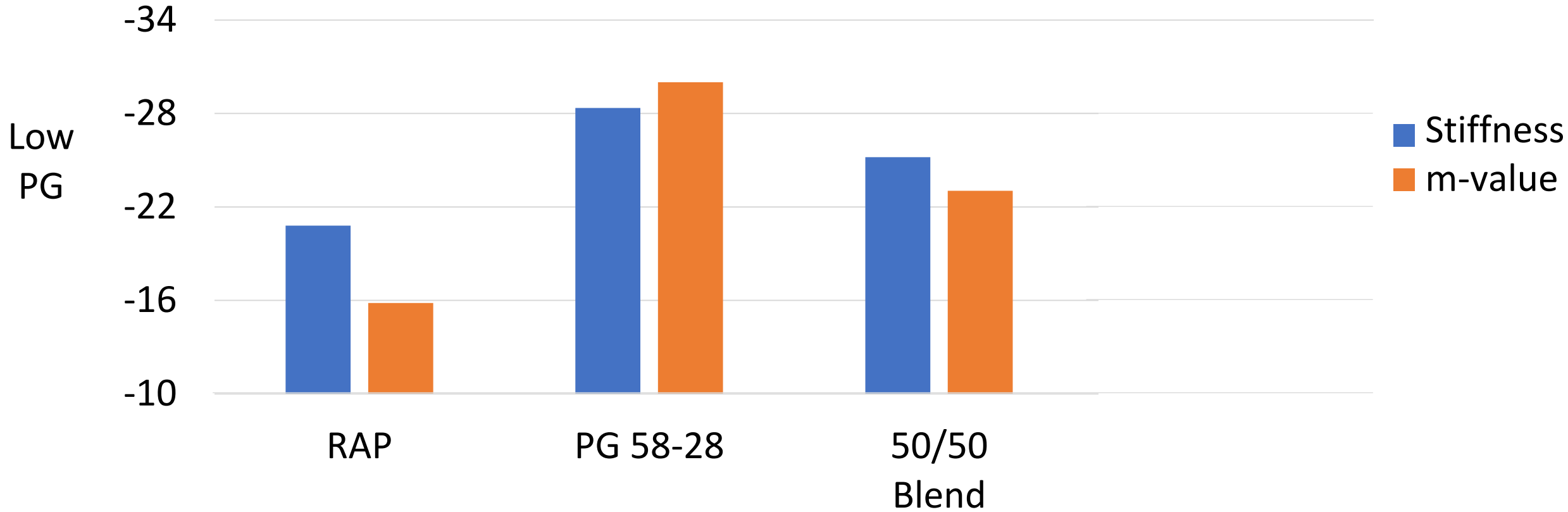


# Bio-based Oil Blending with RAP & Virgin Binder



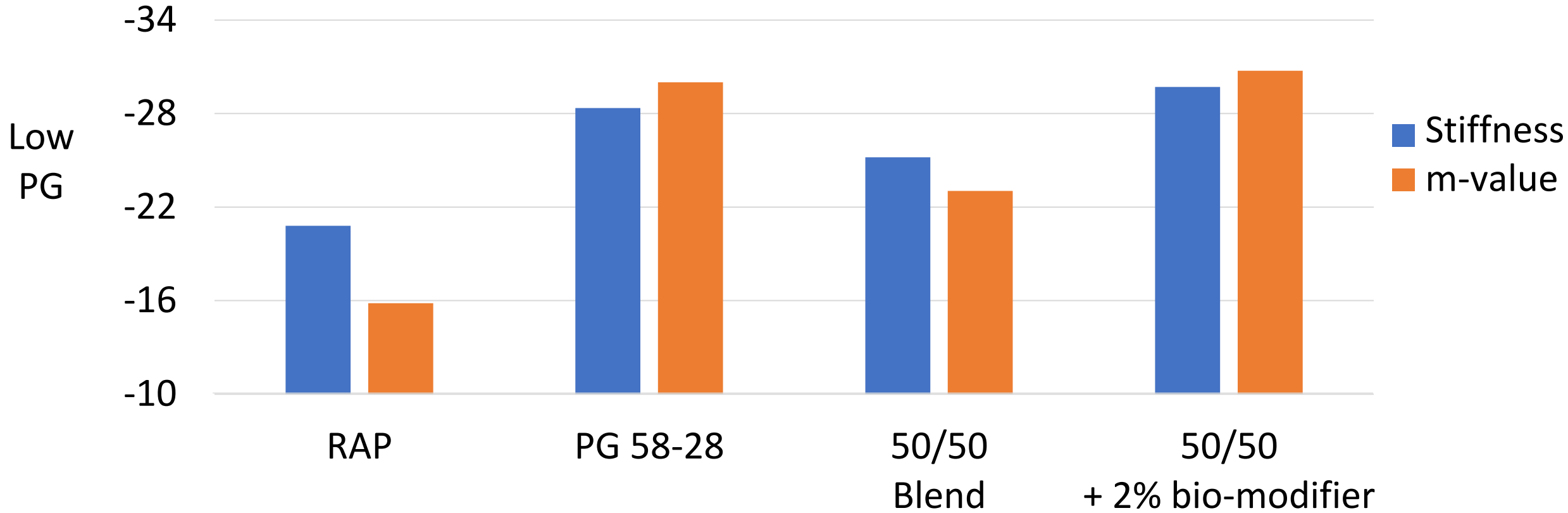
Continuous PG	PG 95-16	PG 60-28
40hr PAV $\Delta T_c$	-6.8	-1.1

# Bio-based Oil Blending with RAP & Virgin Binder



<b>Continuous PG</b>	<b>PG 95-16</b>	<b>PG 60-28</b>	<b>PG 77-23</b>
<b>40hr PAV <math>\Delta T_c</math></b>	<b>-6.8</b>	<b>-1.1</b>	<b>-3.8</b>

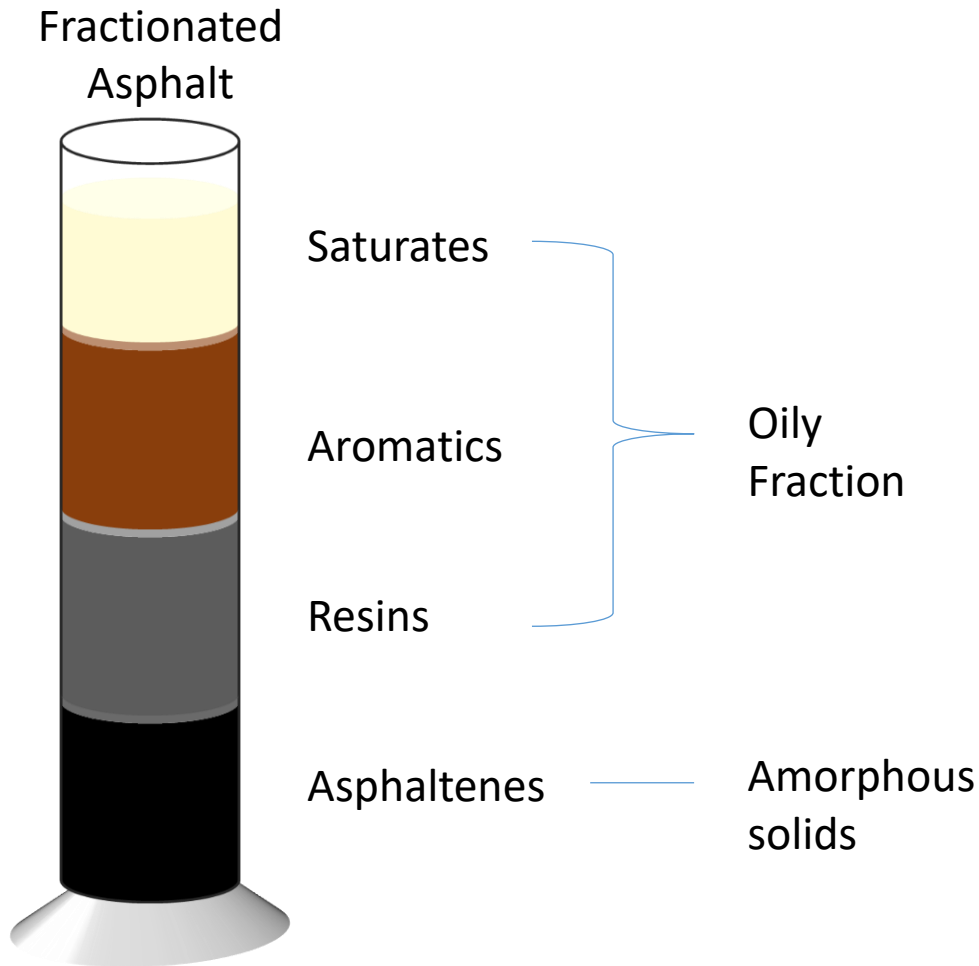
# Bio-based Oil Blending with RAP & Virgin Binder



Continuous PG	PG 95-16	PG 60-28	PG 77-23	PG 63-30
40hr PAV $\Delta T_c$	-6.8	-1.1	-3.8	-1.2

Softened  
+  
"Rejuvenated"

# How Do Bio-Based Oils Work?



## Bio-Based Oils

- Interact with asphaltenes
- Stabilize asphaltenes in the oily fraction of asphalt
- Act almost like an emulsifier for asphaltenes
- Improve asphaltene mobility
- Result in better cracking resistance

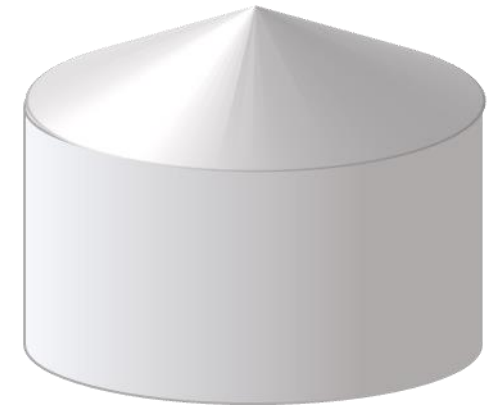
Martin A. E., et al. (2020) "Evaluating the Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios", NCHRP Report 927, National Cooperative Highway Research Program, Washington, DC.



# Using Bio-Based Oils

# Terminal-Blended Options

- **Bio-based oils can be used to manufacture less available, softer binders**
- Gives ability to produce a PG XX-40
- Options include mixing in a tank or blender
- Final product is certified to meet specifications



Typically  
Add 3-6%

PG 52S - 34



PG 46S - 40

# In-line Blending Options

- Bio-based oils can be blended “in-line” with the asphalt binder during HMA production
- Alleviates contractor storage tank constraints
- Gives contractors the ability to:
  - Reduce the total binder PG when using higher amounts of RAP
  - Switch between mix designs with different RAP contents





# Successful Bio-Based Oil Strategies

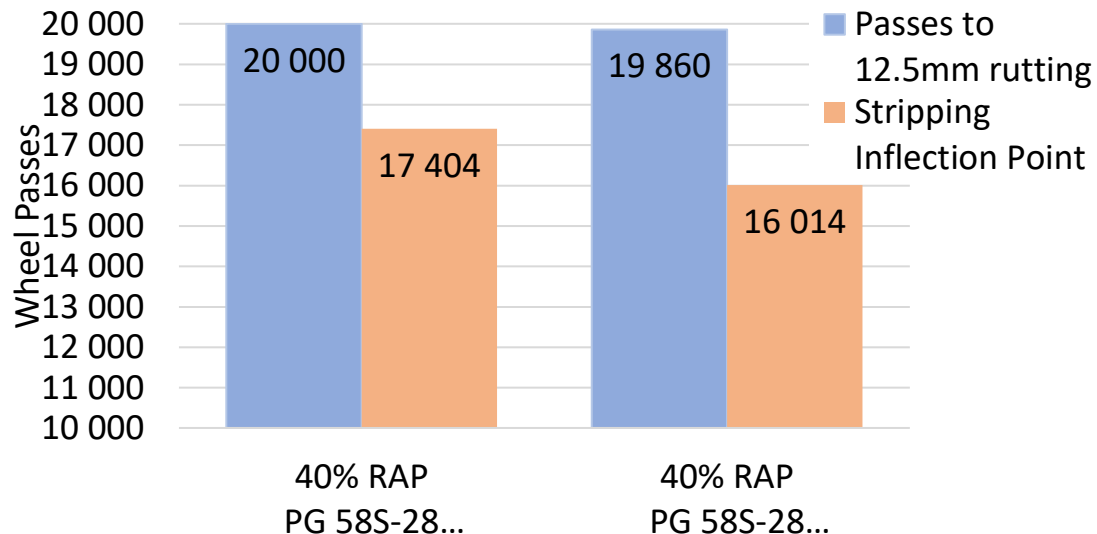


# Balanced Mix Design Approach

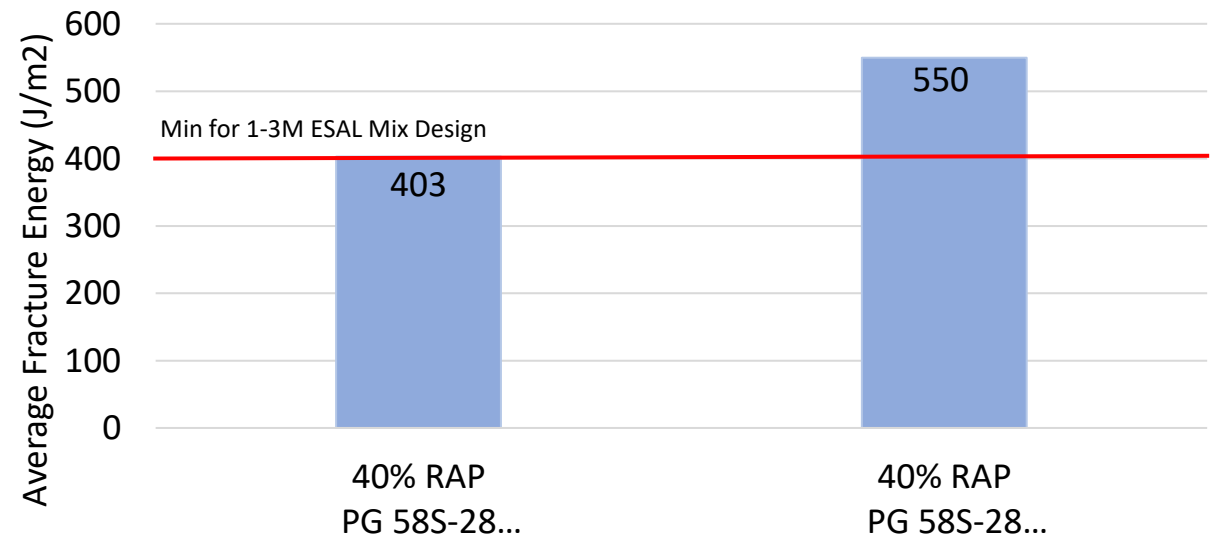
- Trunk Highway 6 (Emily, MN)
- NRRA Rejuvenator Comparison Project (August 2019)
- 40% RAP

Laboratory Testing	PG	40hr PAV $\Delta T_c$
RAP	79.6 – 21.0	-6.1
RAP + 58S-28 w/6% TUFFTREK 4002	60.7 – 32.3	-1.5
RAP + 58S-28 w/8% TUFFTREK 4002	58.8 – 34.3	-1.7

Hamburg Wheel Tracking (45°C)



DCT Fracture Energy at -18°C

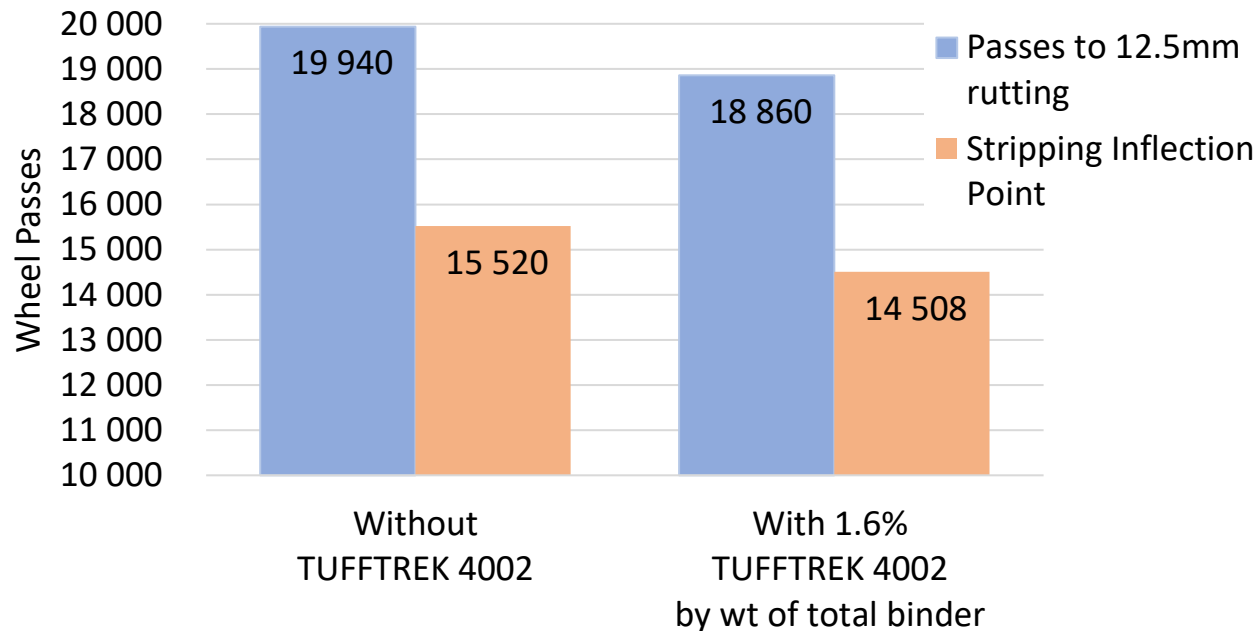


# Terminal-Blended Polymer Modified -40

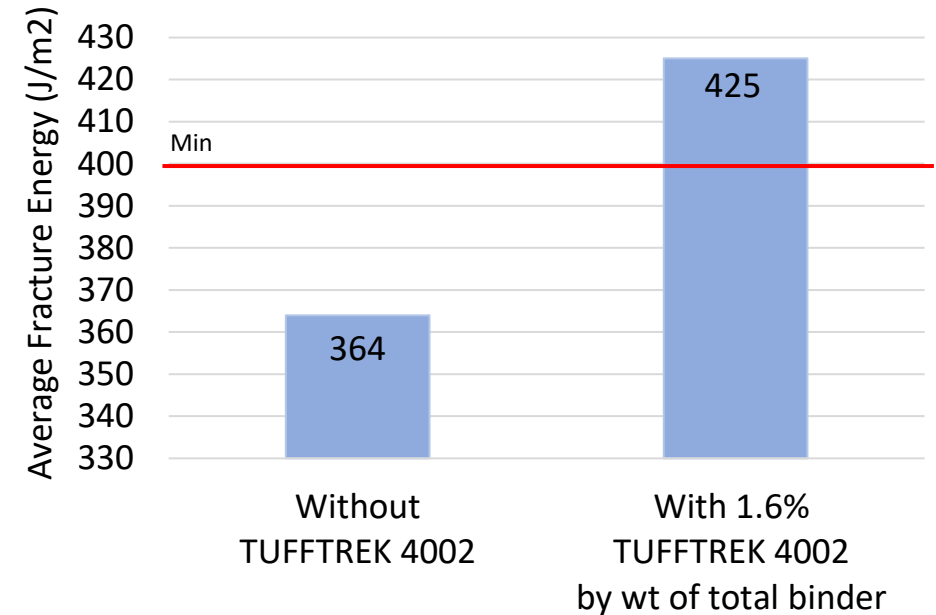
- Hwy 21 (Lexington, NE)
- 50% RAP Aggregate
- 60% Binder Replacement

Laboratory Testing	High PG	Low PG	40hr PAV $\Delta T_c$
PG 58V-34	67.7	-36.9	-3.4
PG 58V-34 w/4% TUFFTREK 4002	58.7	-40.4	0.0

Hamburg Wheel Tracking (45°C)

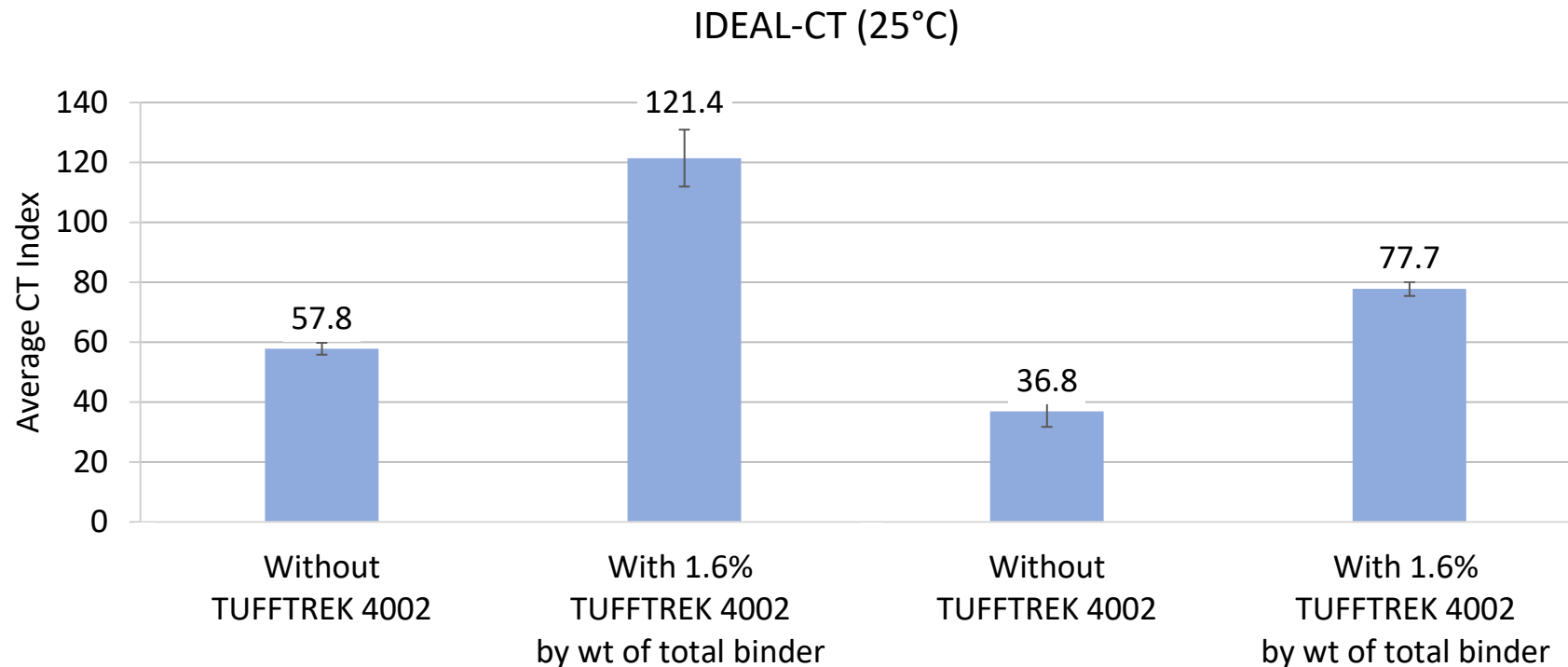


DCT Fracture Energy at -18°C



# Long-Term Mix Aging

- Verify asphalt binder durability in the mix
- Conduct cracking performance testing after long-term oven aging
- 6hrs loose mix aging in a 135°C oven



- Asphalt pavement durability and cracking are key pavement performance challenges, particularly in RAP mixes
- Bio-based oils can improve durability of RAP mixes and allow pavement engineers to specify softer binders
- Durability parameters can be used to assess bio-based oil performance in asphalt binders
- Mix performance testing can be used to assess the durability of RAP mixes with bio-based oils



# Questions

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