Obtaining Mix Performance with High RAP and Modified Binders

Tanya Nash, P.E.
Asphalt Testing Solutions & Engineering, LLC

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Objectives

- RAP
  - Defining High RAP
  - Management and Best Practices
- Modified Binders
  - Classification of modifiers
  - Effects of modification
- Evaluation of Performance

What is High RAP?

- NAPA 2019 Annual Survey - average percent RAP used in HMA / WMA is 21.1%
- Range of Usage
    - Ohio: Average 32%
    - Arizona: Average 9%
- NCHRP Report 927 defined high recycled binder ratios between 0.3 and 0.5

Recycled Asphalt Pavement

It’s as simple as putting it back in the mix

What Is Really Happening?

The 3 “Limits” to High RAP Mixes

- Heat Transfer Capability of the Plant
- Managing Dust in the Final Mix
- Binder Characteristics in the Final Mix

#1: Heat Transfer

- High RAP Plants are often now a two-step process

- Drying and Heating
- Mixing

#2: Managing Dust

- Maintain dust/binder ratio
- Dust in the RAP is “bound” and can’t be “liberated”
- Manage the dust removed from the virgin material (partial dust removal)

➢ Several ways to do this …

Variable Speed Rotary Valve

Variable Speed Air Lock at Transfer Screw

Collection & Return Pod on Load Cells

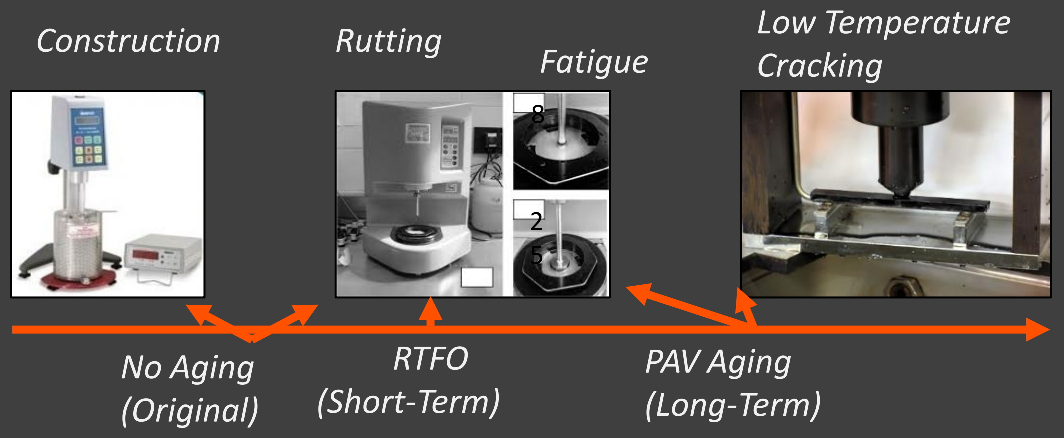
#3: Final Binder Characteristics

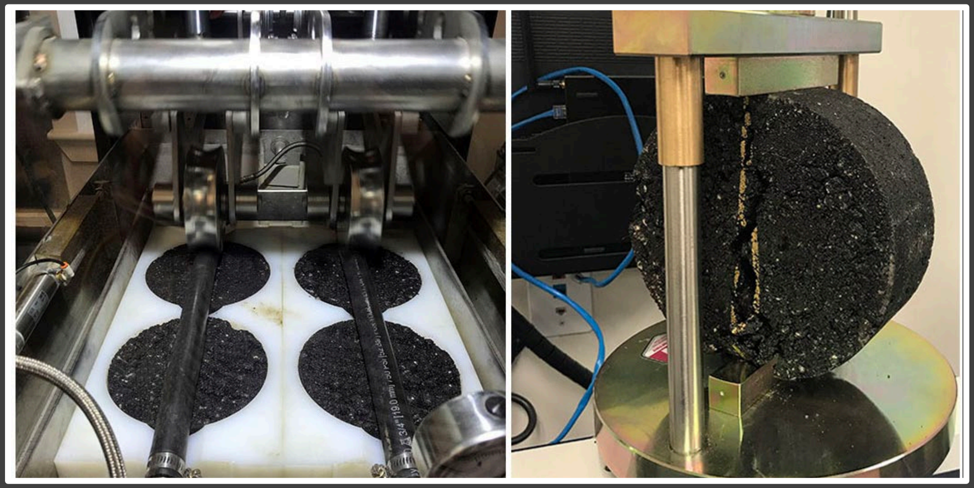
Know Your RAP

Binder Characteristics

Recovered Performance of RAP and Mix

- Binder Performance Testing
- Mixture Performance Testing





What's Really in Your Asphalt Mix?

Chemical

- Anti-Strips
- Warm Mix
- Stiffening / Softening Agents

Anti-Strips

Rejuvenators

- Crude Oil
- Flux
- Bio Oils
- Corn Oils
- Tall Oil

Recycled

- Vacuum Tower Asphalt Extender (VTAE)
- Ground Tire Rubber (GTR)

Polymers

- Elastomers (SBS)
- Plastimers (Elvaloy)
- Latex
- SBR

SBS

Mixture

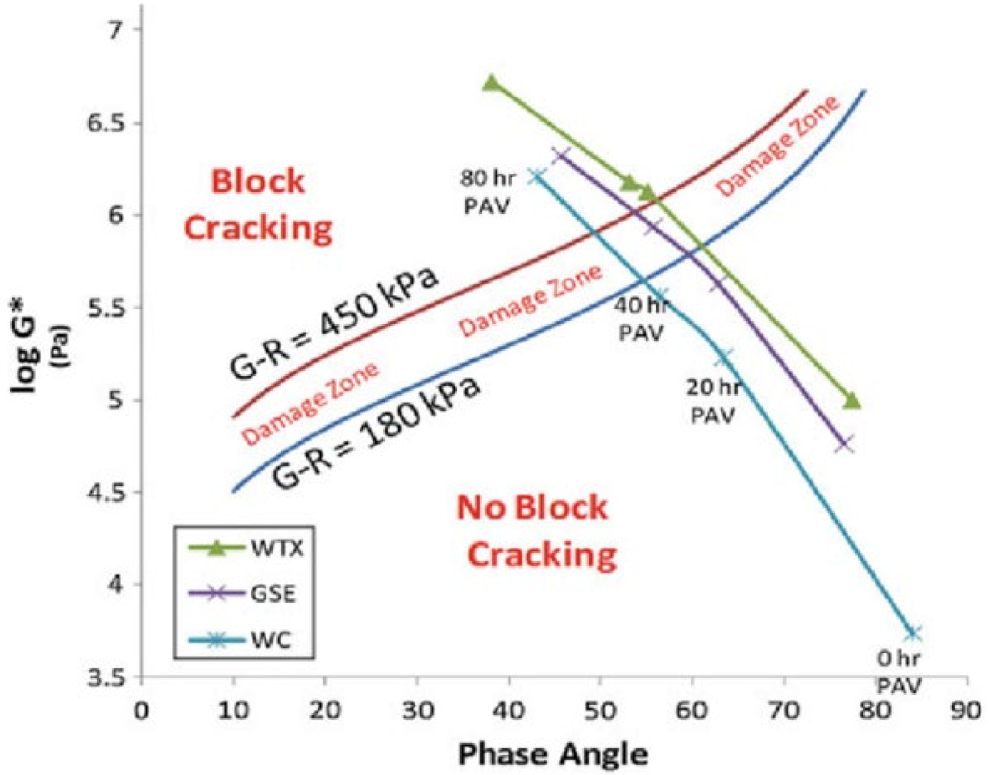
- Fibers
- Lime
- GTR
- Pelletized Polymers
- RAP
- RAS

Performance Beyond PG

- Delta Tc – method for measuring the loss of relaxation properties of asphalt binders
- Ductility – Ability of a material to be stretched without breaking
- Glover-Rowe – simplified equation for the ductility estimated from DSR data

$$G - R = G^* (\cos\delta) \times \frac{2}{\sin\delta}$$

@ 15°C and 0.005 rad/sec



Performance Beyond PG

- Cross-Over Temperature (T_{wc}): binder transitions from a viscous material to an elastic material
  - lower the temperature the less prone the binder is to cracking

- Rheological Index (R-Value): log of the glassy modulus of the binder minus the log of the modulus where the phase angle is 45
  - Larger the **R value**, the more brittle and prone to cracking
  - NCHRP 9-59 uses BBR data to calculate

$$R = \frac{\log(\frac{S}{3000})}{\log(1-m)}$$

Recommended: 1.5 > R > 2.5

Important for the virgin binder and the blended binder

What About the Mix?

1890
- **Barber Asphalt Paving Company**
- Asphalt cement 12 to 15% / Sand 70 to 83% / Pulverized carbonite of lime 5 to 15%

1905
- **Clifford Richardson, New York Testing Company**
- Surface sand mix: 100% passing No. 10, 15% passing No. 200, 9 to 14% asphalt
- Asphaltic concrete for lower layers, VMA terminology used, 2.2% more VMA than current day mixes or ~0.9% higher binder content

1920s
- **Hubbard Field Method** (Charles Hubbard and Frederick Field)
- Sand asphalt design
- 30 blow, 6" diameter **with compression test (performance)** asphaltic concrete design (Modified HF Method)

Stability

1927
- **Francis Hveem** (Caltrans)
- Surface area factors used to determine binder content; **Hveem stabilometer and cohesionmeter** used
- Air voids not used initially, mixes generally drier relative to others, fatigue cracking an issue

Stability + Durability

1943
- **Bruce Marshall**, Mississippi Highway Department
- Refined Hubbard Field method, standard compaction energy with drop hammer
- Initially only used air voids and VFA, VMA added in 1962; **stability and flow utilized**

Stability + Durability

1993
- **Superpave**
- Level 1 (volumetric)
- Levels 2 and 3 (performance based but **never implemented**)

25 Years Without the Promised Performance Test!

BINDER CONTENT LOWER

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http://asphaltmagazine.com/history-of-asphalt-mix-design-in-north-america-part-2/

Rutting & Moisture

- Tensile Strength Ratio

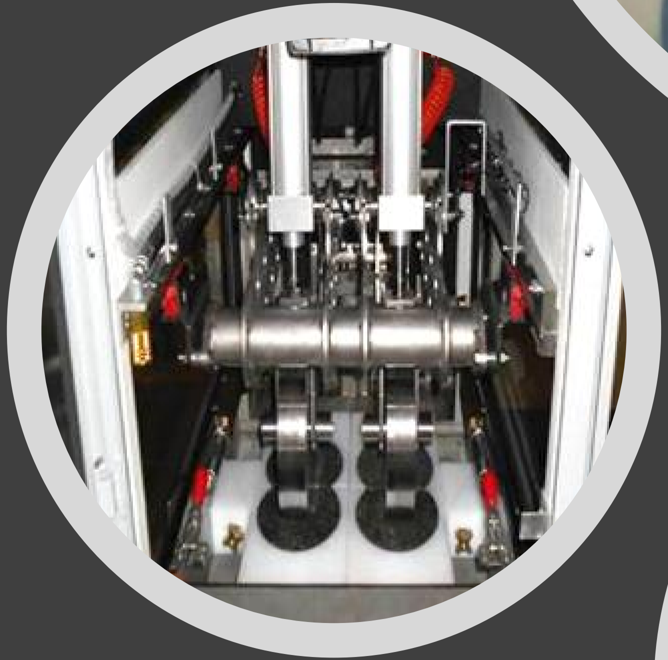
  AASHTO T 283

- Hamburg Wheel Tracking

  AASHTO T 324

- Asphalt Pavement Analyzer

  AASHTO T 340



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Bending Beam Fatigue
AASHTO T 321

Texas Overlay Test
TEX-248-F

Direct Tension Cyclic
Fatigue, S-VECD

Fatigue (Cyclic Loading)

Texas
Overlay Test

SCB
- LTRC – Jc
- IFIT - FI

IDEAL-CT,
Nflex Factor

Superpave IDT
- Energy Ratio

Cantabro

Top-Down Cracking

Low Temperature Cracking

IDT Creep
Compliance
AASHTO T 322

TSRST

SCB at Low Temp
AASHTO TP 105

Disk Shaped Compact
Tension (DCT)

Evaluate your mix

Rejuvenator Study

Evaluation Process

Phase I
Preliminary Testing of Contractor's "Go-To" Superpave Design with 13 recycling agents, 3 warm mix products, 3 PG binders

→ **Baseline Testing**

Phase II
Development of Performance Curves for Hot and Warm Mixtures in the study

→ **Performance Ranking**

Analysis
Determination of Optimum Asphalt Content Range based on Performance

→ **Understanding of Production Parameters**

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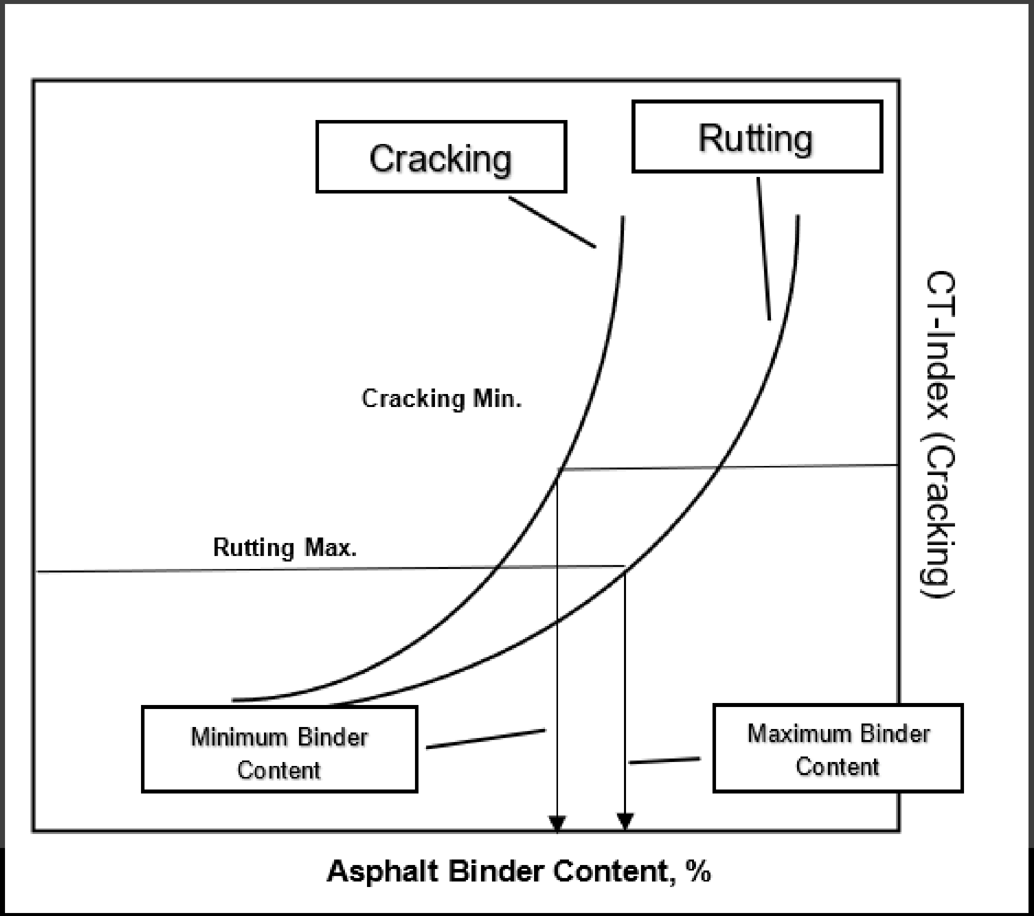
Recycling Agent Performance Evaluation

CONTROL

- 35% RAP (0.38 RBR)
- 12.5mm GA Granite | PG 67-22

13 Recycling Agents - Aromatic (1), Veggie Oil (3), Bio-Based Oil (6), Tall Oil (3)
3 – Warm Mixes produced at 275°C
3 – PG binder grades: PG 52-28, 52-34, 67-22



Recycling Agent Dosage per NCHRP 9-58

$$PGH_{Blend} = (RAP_{BR} \times PGH_{RAP}) + (B_{BR} \times PGH_{Base})$$

$$\%RA = \frac{(PGH_{Blend} - PGH_{Target})}{1.82^{*}}$$

*For aromatic extracts (A), a lower slope rate of 1.38 is recommended

Where:

- *PGH_{Blend} = Continuous PG high temp. (PGH) of recycled binder blend (°C)*
- *RAP_{BR} = RAP binder ratio*
- *PGH_{RAP} = Continuous PGH of the RAP binder (°C)*
- *B_{BR} = Base binder ratio = 1-RBR*
- *PGH_{Base} = Continuous PGH of the base binder (°C)*
- *PGH_{Target} = Continuous PGH of target climate (°C)*

<table>
<tr><th colspan="2">Properties</th><th colspan="2">Results</th></tr>
<tr><td colspan="2">RAP_{BR}</td><td colspan="2">0.38</td></tr>
<tr><td colspan="2">PGH_{RAP}, °C</td><td colspan="2">91.0</td></tr>
<tr><td colspan="2">B_{BR}</td><td colspan="2">0.63</td></tr>
<tr><td colspan="2">PGH_{Target}, °C</td><td colspan="2">70.0</td></tr>
<tr><th colspan="2"></th><th>PG 67-22</th><th>PG 52-28</th></tr>
<tr><td colspan="2">PGH_{Base}, °C</td><td>68.5</td><td>54.5</td></tr>
<tr><td colspan="2">PGH_{Blend}, °C</td><td>77.1</td><td>68.4</td></tr>
<tr><td rowspan="2">%RA</td><td>Non-Aromatic</td><td>3.87</td><td>-0.90</td></tr>
<tr><td>Aromatic</td><td>5.11</td><td>-1.18</td></tr>
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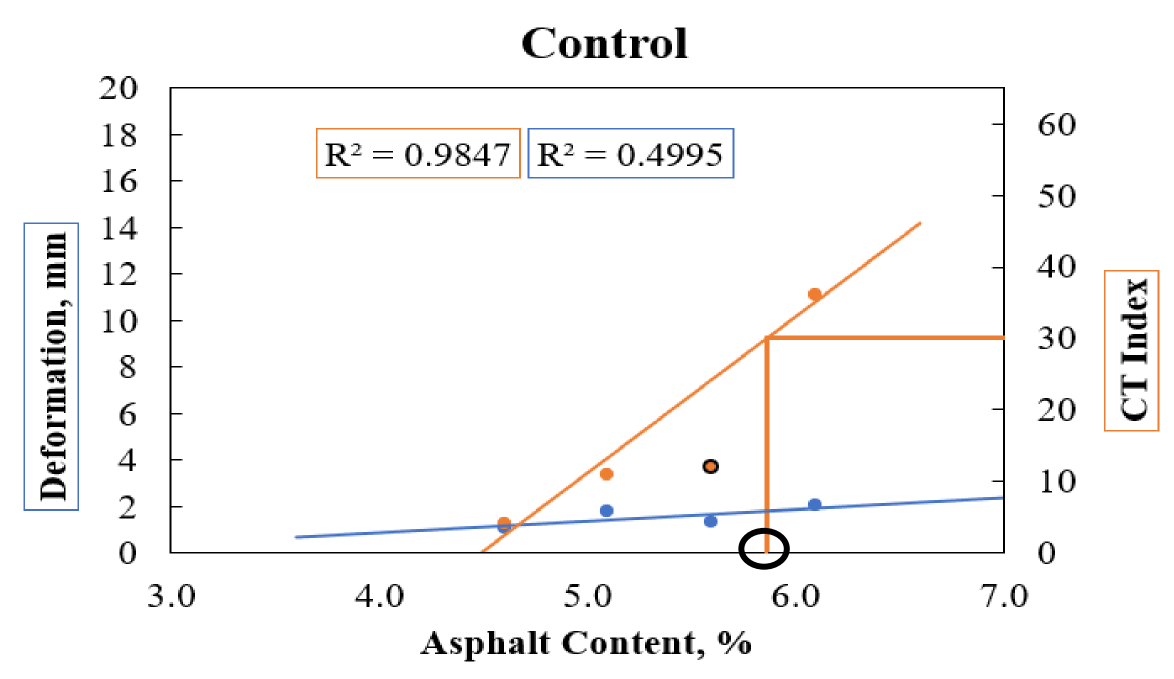
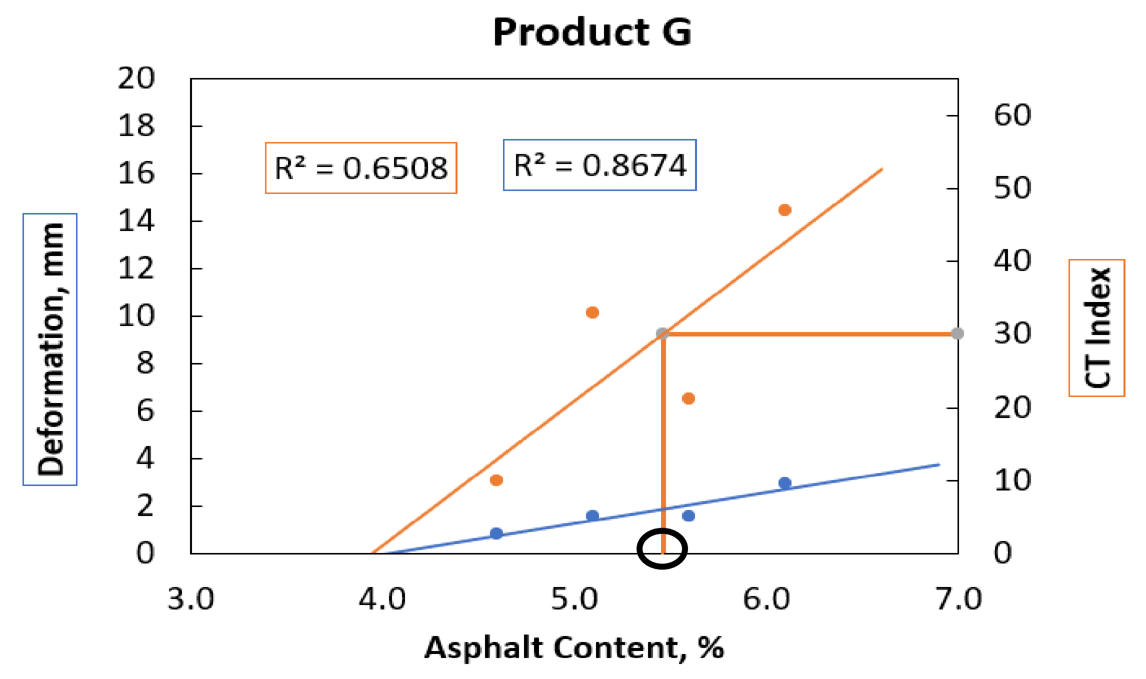
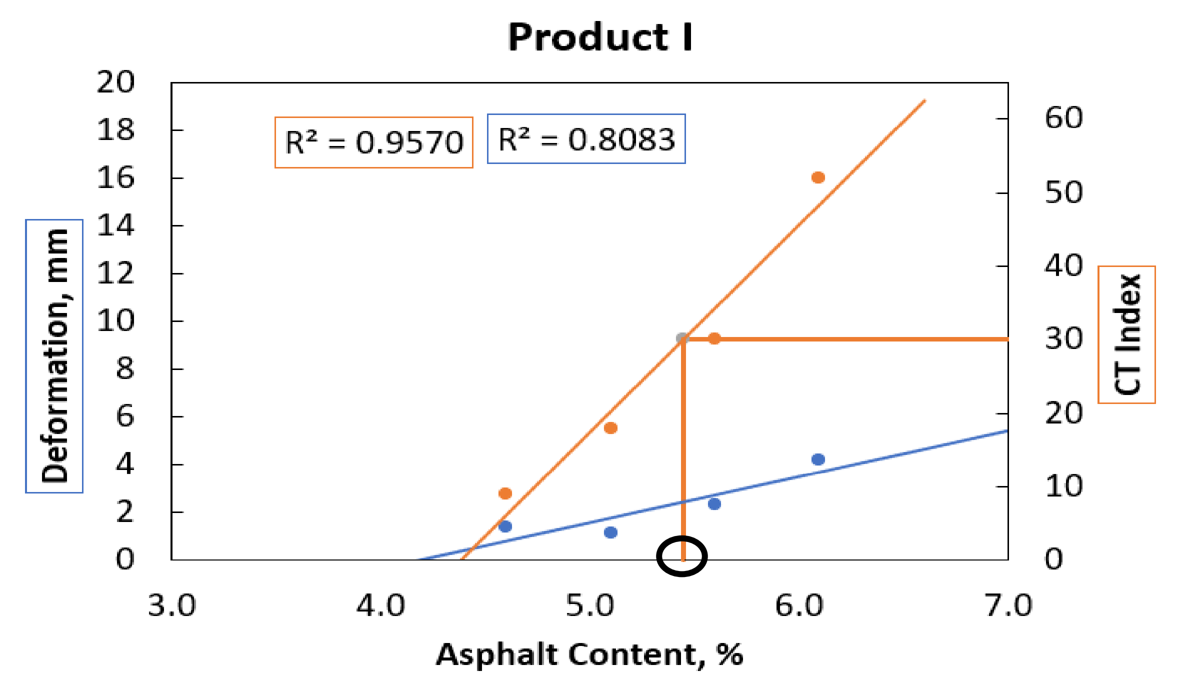
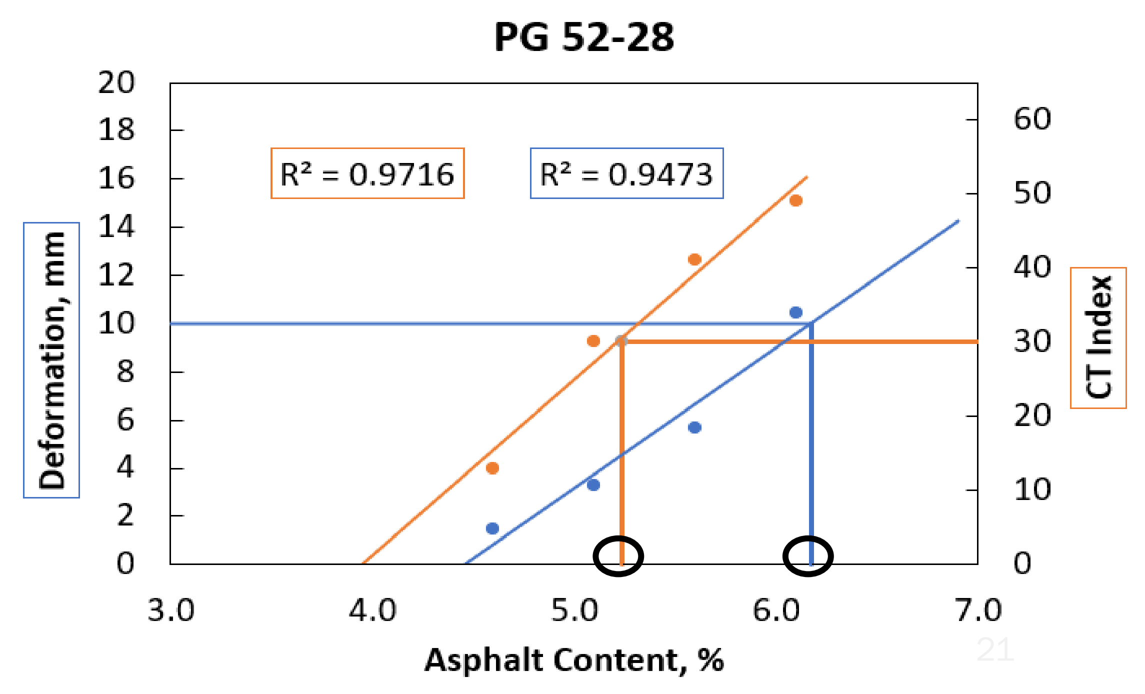
What do these “negative” numbers tell a contractor?


Control
R² = 0.9847
R² = 0.4995
Deformation, mm
CT Index
Asphalt Content, %
20 18 16 14 12 10 8 6 4 2 0
60 50 40 30 20 10 0
3.0 4.0 5.0 6.0 7.0


Product G
R² = 0.6508
R² = 0.8674
Deformation, mm
CT Index
Asphalt Content, %
20 18 16 14 12 10 8 6 4 2 0
60 50 40 30 20 10 0
3.0 4.0 5.0 6.0 7.0


Product I
R² = 0.9570
R² = 0.8083
Deformation, mm
CT Index
Asphalt Content, %
20 18 16 14 12 10 8 6 4 2 0
60 50 40 30 20 10 0
3.0 4.0 5.0 6.0 7.0


PG 52-28
R² = 0.9716
R² = 0.9473
Deformation, mm
CT Index
Asphalt Content, %
20 18 16 14 12 10 8 6 4 2 0
60 50 40 30 20 10 0
3.0 4.0 5.0 6.0 7.0

Production Analysis

Performance Asphalt Content % (CT_{Index} = 30 min.)							
	Control	G	I	K	L	M	N
Product Name	PG 67-22	Tall Oil	Veggie Oil	PG 52-28	Warm Mix	Warm Mix	Warm Mix
Maximum (HWT)	22.58	11.70	9.38	6.17	12.22	9.44	9.40
Minimum (CT_{Index})	6.38	5.96	5.82	5.64	5.47	5.39	5.33
Performance Opt.	6.9	6.5	6.4	6.2	6.0	5.9	5.9
Dosage Efficiency	---	4.08	2.52	1.84	6.45	2.17	3.00

Florida DOT Specification for Asphalt Content

- Design Target ± 0.55% before stopping production

Performance Optimum = Minimum AC + Specification

Control Performance Optimum = 6.38 + 0.55 = 6.88% AC

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Final Comments

- Identify what limits High RAP usage
  - Plant components
  - Binder properties
  - Mixture Properties
- What are the modifiers available to you
  - Approved by the agency
  - Cost
  - Knowledge
- Evaluate
  - What works for one, does not always work for another

Questions?

Tanya Nash, P.E.

tnash@ats.consulting

(904) 510-3072

Asphalt Testing Solutions & Engineering

7544 Philips Hwy

Jacksonville, Florida 32256