Current Research in the US to Address Inferior Binders and Cracking

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Sarnia, ON, CAN, June 18, 2019

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Outline

- **WRI – An overview**
- **Context: Asphalt Variability - The “New Normal”**
- **The WRI-Fingerprinting Approach to Cope with the New Normal**
- **Case study: NCHRP 9-60**
  - **Objectives**
  - **Approach**
  - **Examples of Findings**
- **Summary / Perspectives**

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WRI overview

- **US non-profit company 501-C3**
  - **Affiliate of the U of Wyoming**
  - **45+ scientists, engineers & suppor**
- **Facilities in Laramie, Wyoming**
- **Fields of expertise Technologies**
  - **Energy: oil, coal, biomass processes and products**
  - **Materials: asphalt and others**
  - **Environment**

- **A long history**
  - **<u>1924</u>: Petroleum lab to study WY high-sulfur crude oil**
  - **<u>1983</u>: DOE Laramie Energy Tech Center de-Federalized to become WRI**
- **Annual sponsored events in July**
  - **Petersen Asphalt Research Conference - <u>56th PARC</u>: July 14-17, 2019**
  - **ISAP 2016 symposium**
  - **Training on "Asphalt Chemistry & Relations to Properties" in 2015**

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WRI overview - Facilities

Bureau of Mines Building - UW Campus

- ✓ Asphalt and Petroleum Technologies (APT)

Advanced Technology Center - North of Laramie

- ✓ Bitumen Partial Upgrading
- ✓ Processes
- ✓ Coal and Biomass Activities
- ✓ Environmental Management

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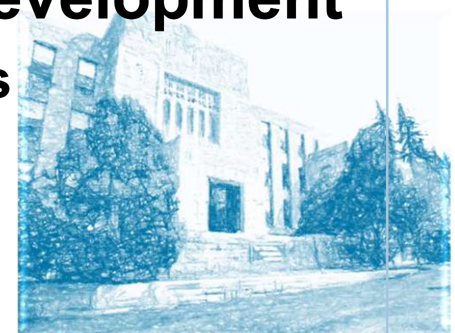
WRI/APT Activity

- **Main activity: Research, Technology and Development**
  - **Petroleum – problematic crude oils and products**
  - **Asphalt for paving and roofing**
  - **Additives / Modifiers / Materials**
  - **Analytical methods/tools**
  - **Analysis, Characterization, Formulation, Forensics**
    - **Helping companies develop products / processes**
- **Development of Synergies: to advance the knowledge & toolkit on Petroleum, Asphalt, Coal, Additives and Materials (Carbon fibers…)**



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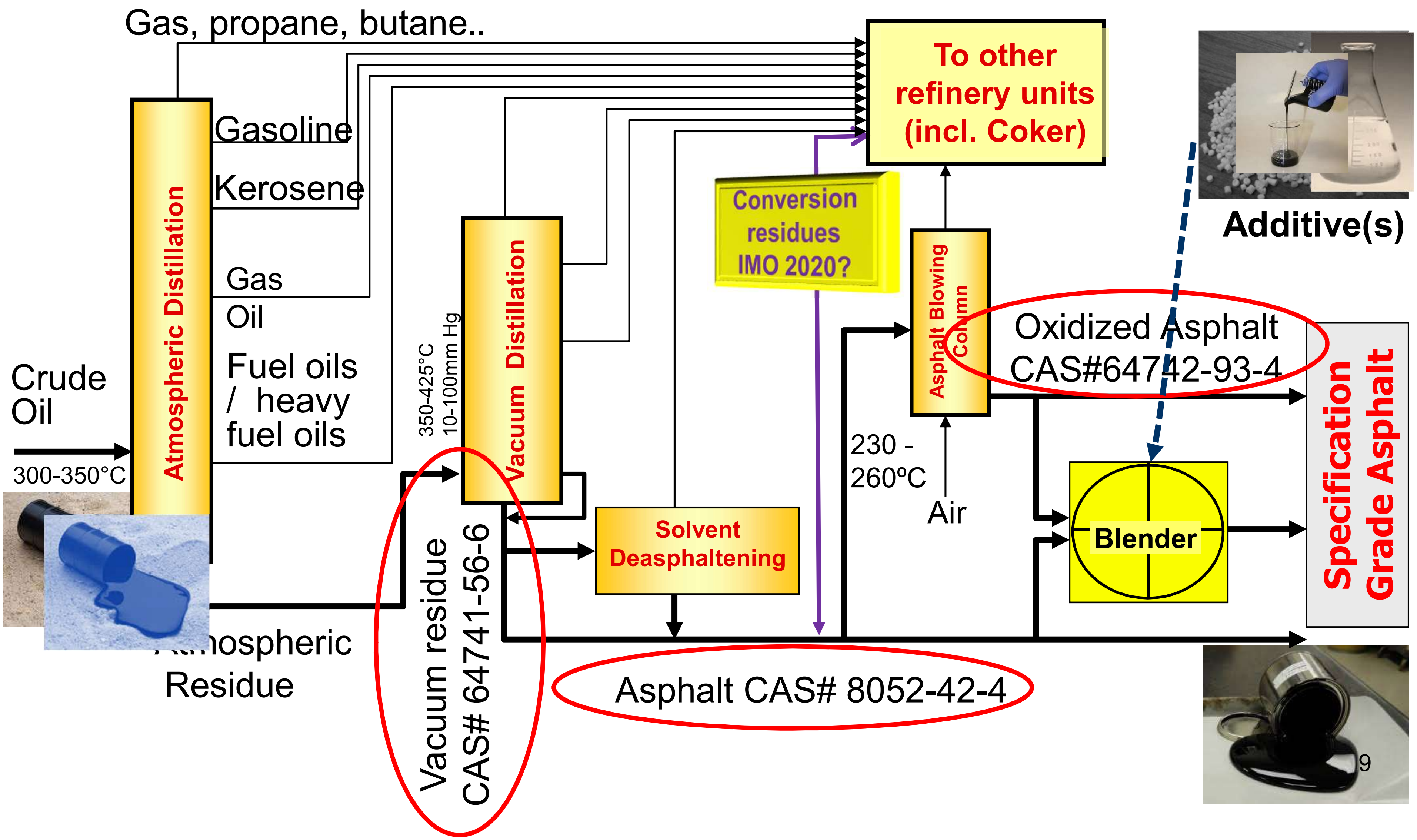
Context - "360" Industry Changes

- Drivers: economics, geopolitics, societal, regulatory
  - Changes in crude oils and processes
    - Tight oils / heavy oils / cocktails, and others…
    - Blends of various refining bases
  - New world of additives and modifiers with different:
    - Functions: modifiers, antistrips, rejuvenators, WM-A, surfactants…
    - Chemistries: polymers, X-linkers, acids, waxes, bio-based, oils…
  - Market changes: WMA and Recycling
    - RAP / RAS / REOB / GTR / Plastics / …
  - Specifications changes
    - Superpave and other specs: not truly Perf. related but evolving
    - *Other petroleum products*: 2020 IMO on Marine fuel (% Sulfur) may release high conversion residues to the asphalt pool?
  - LCA/LCI/LCCA
  - IARC classification
  - REACH regulation (Europe)

Adapted from Al-Eurobitume document

Context: Changes in Processes



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Consequences:
Binder Composition & Quality Changes

- **Superpave binder specs and quality issues**
  - **PG specs and test methods, designed in the 90's for asphalts from the 90's**
    - **Not for today's binders**
    - **And even less for tomorrow's binders**
- **Binder variability and inconsistent quality**
  - **Not prevented and not captured by current specs**
- **Binder quality has an impact on pavement performance**

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NCHRP 09-60
NCAT- Agency Survey

❑ Identified Issues

Transverse Cracking

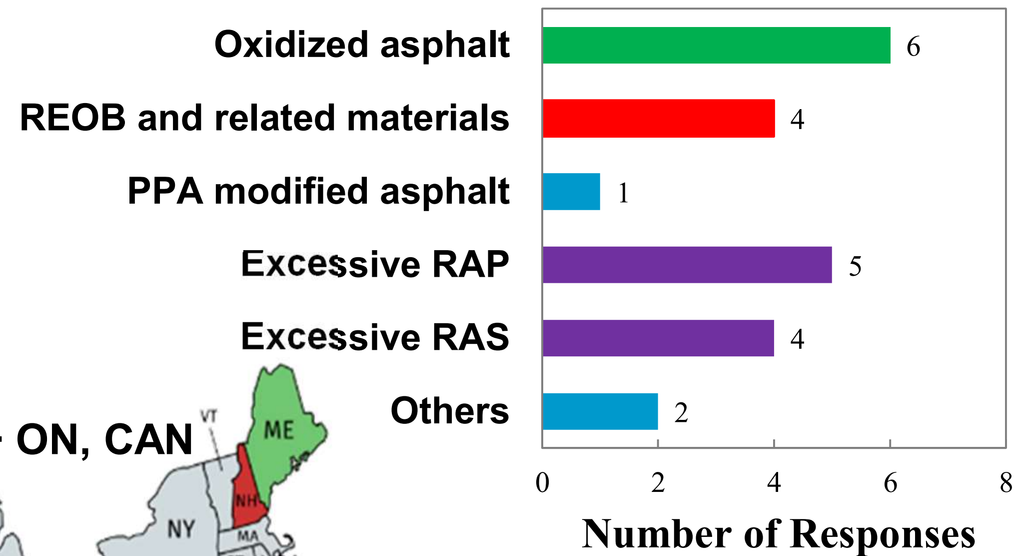
Miscellaneous Surface Cracking

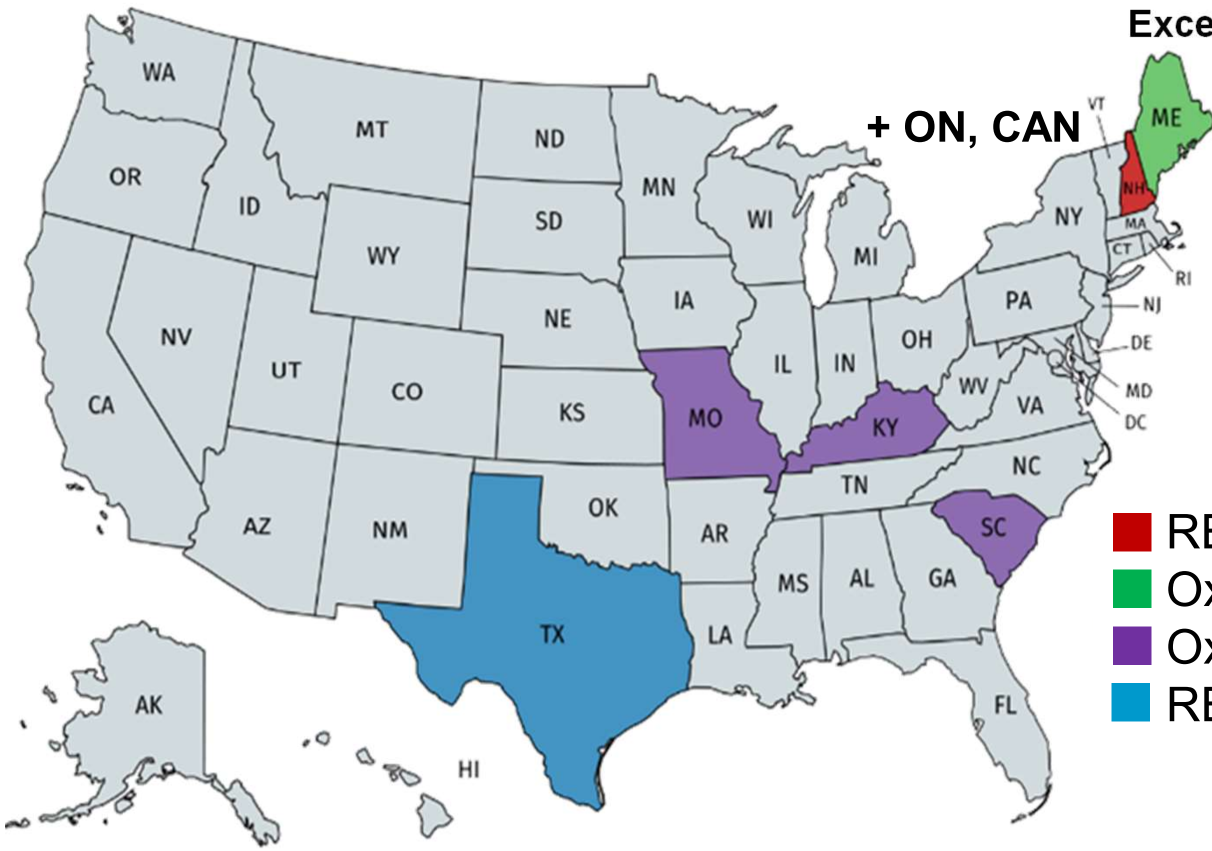
Block Cracking

Raveling

NCHRP 09-60
NCAT- Agency Survey

❑ Potential Binder Issues





- REOB
- Oxidized Asphalt, Others
- Oxidized Asphalt, RAP, RAS
- REOB, PPA, RAP, RAS

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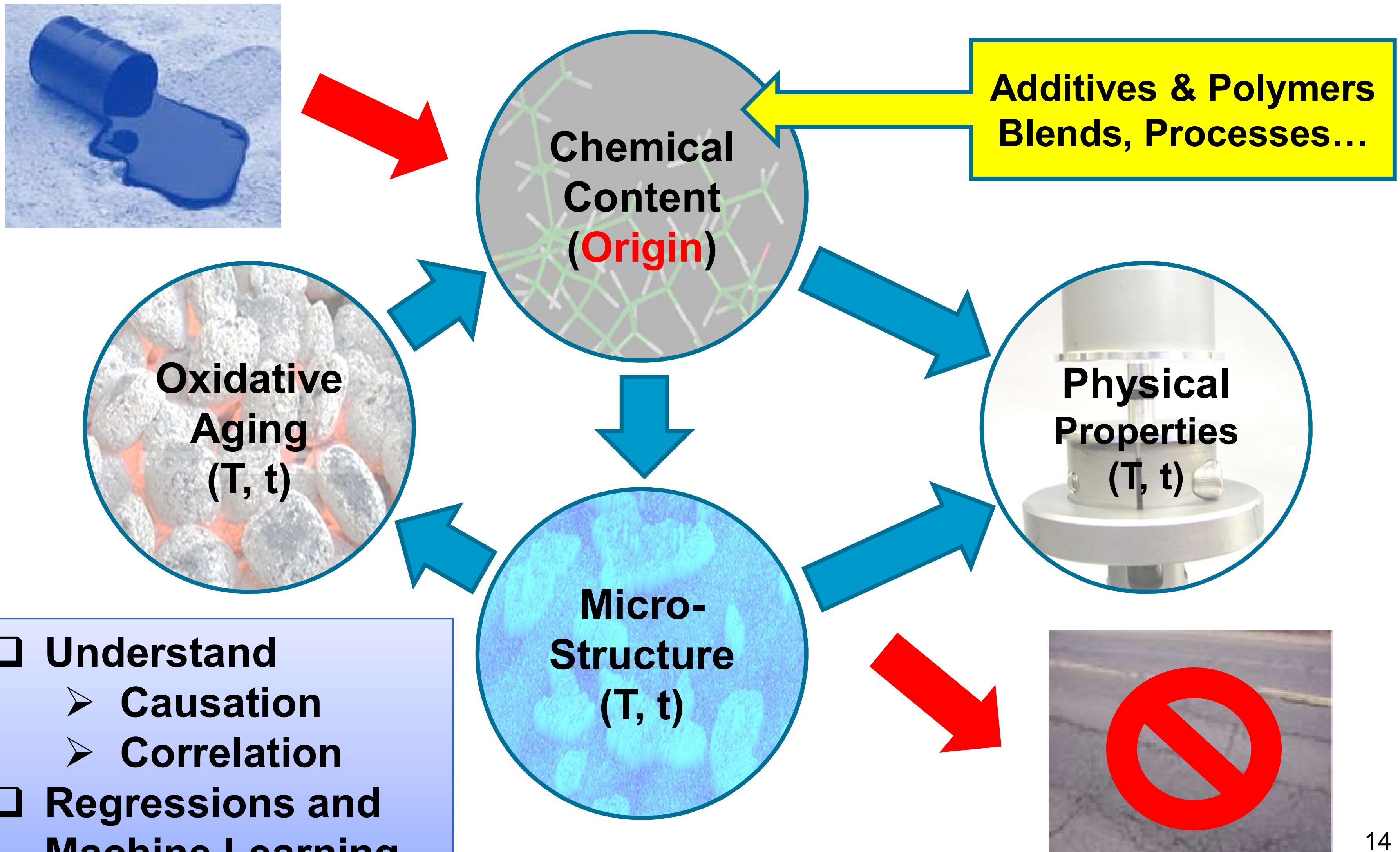
Chemo-Mechanical Fingerprinting to cope with the "New Normal"



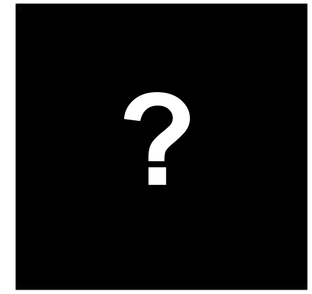
- ❑ Understand
  - ➢ Causation
  - ➢ Correlation
- ❑ Regressions and Machine Learning

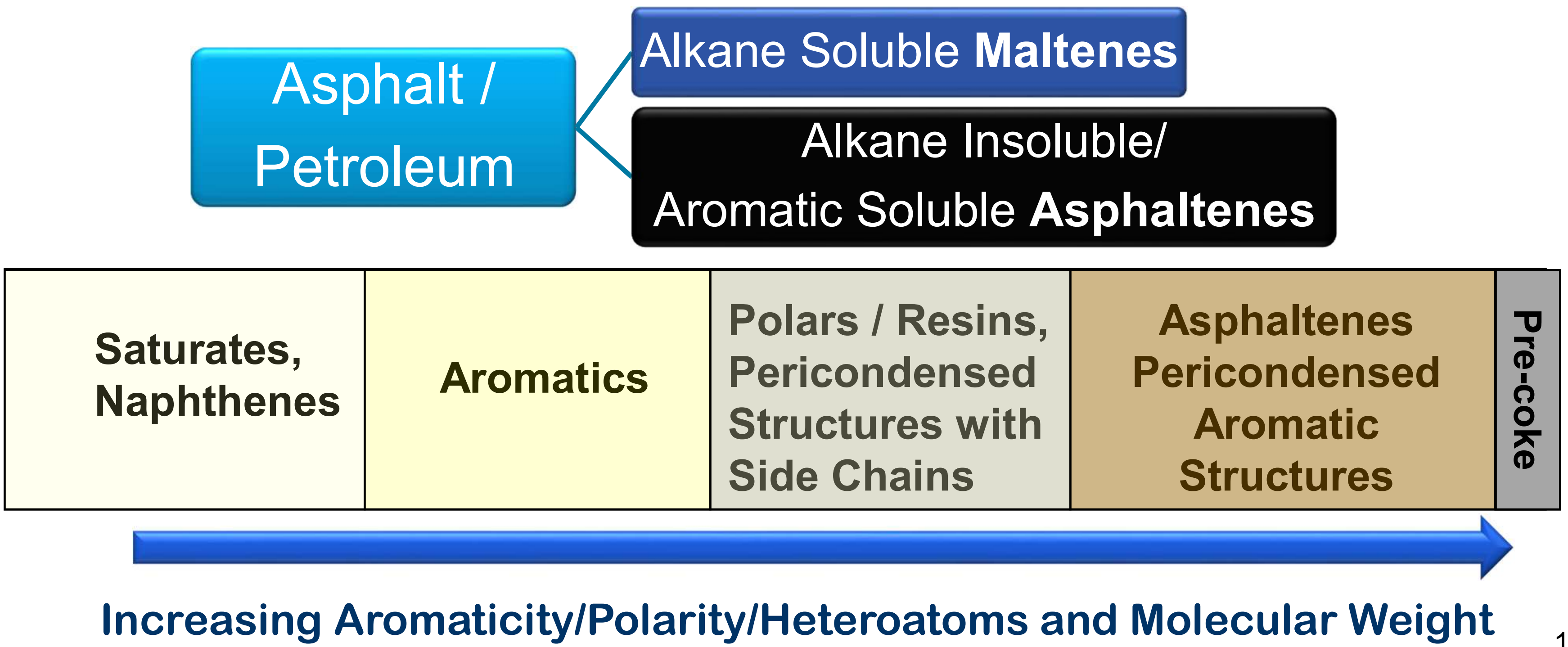
The WRI Fingerprinting Approach with Partners

- *SHRP* — *1987*
- *FP I, II, III & ARC - FHWA-WRI* — *90'-2015*
    - *The tools*
- **Eurovia / WRI cooperation** — **2013**
    - *The initial "Fingerprint" project*
- **WRI – Asphalt Industry Research Consortium #1 (AIRC)** — **2015**
- **NCHRP 9-60 – WRI-AAT-NCAT-GHK** — **2016**
- **WRI-AIRC #2** — **2018**
- **Others….**

The tools
Understanding Asphalt Composition

- **Asphalt chemical composition**
  - Complex: 100,000s of molecules
  - Continuum:
    - From Hydrogen-saturated to H-deficient molecules
    - Solubility parameters
  - Complex interactions: time, temp., oxidation and additive dependent





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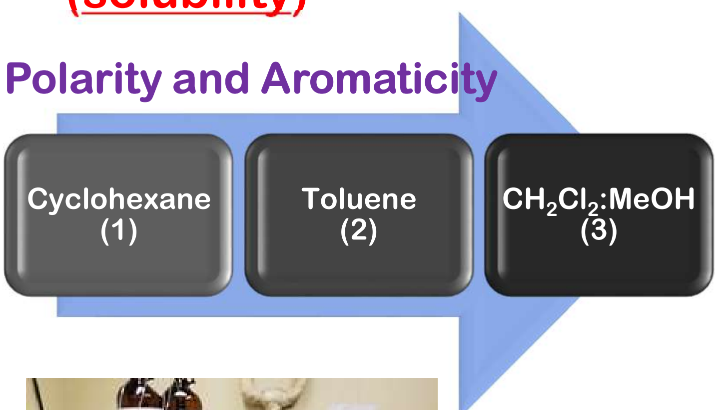
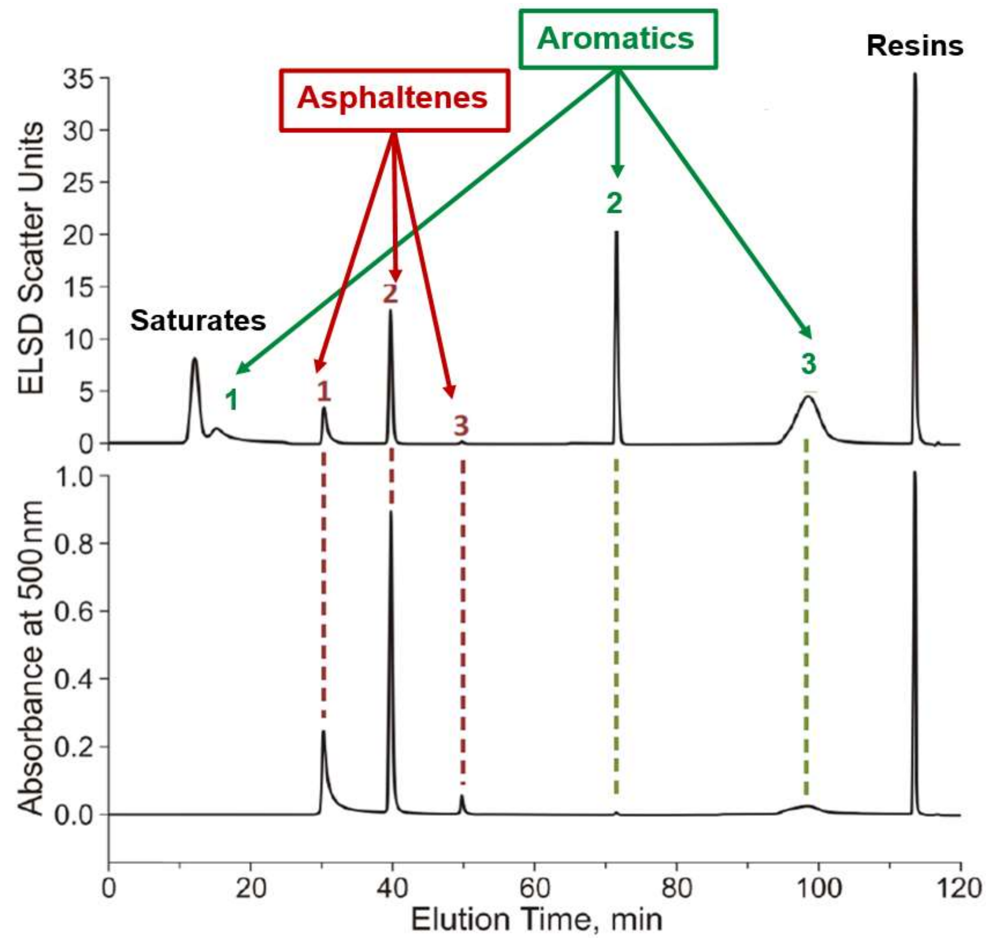
The tools
Understanding Asphalt Composition

Using Saturates, Aromatics, Resins, Asphaltene-Determinator SAR-AD™

Fully automated SAR separation (chromatography) coupled to AD asphaltene fractionation (solubility)

Polarity and Aromaticity





Patented

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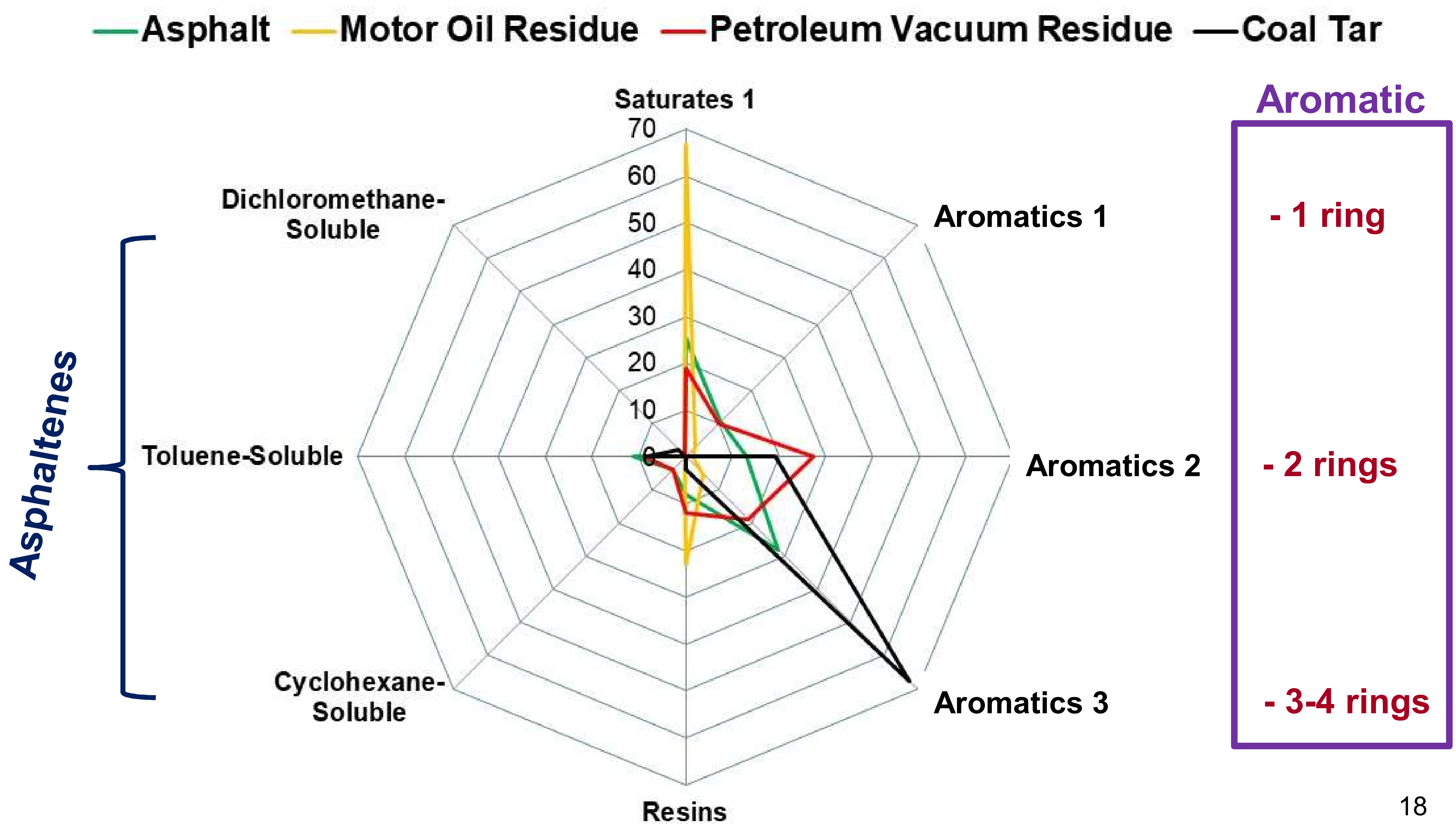
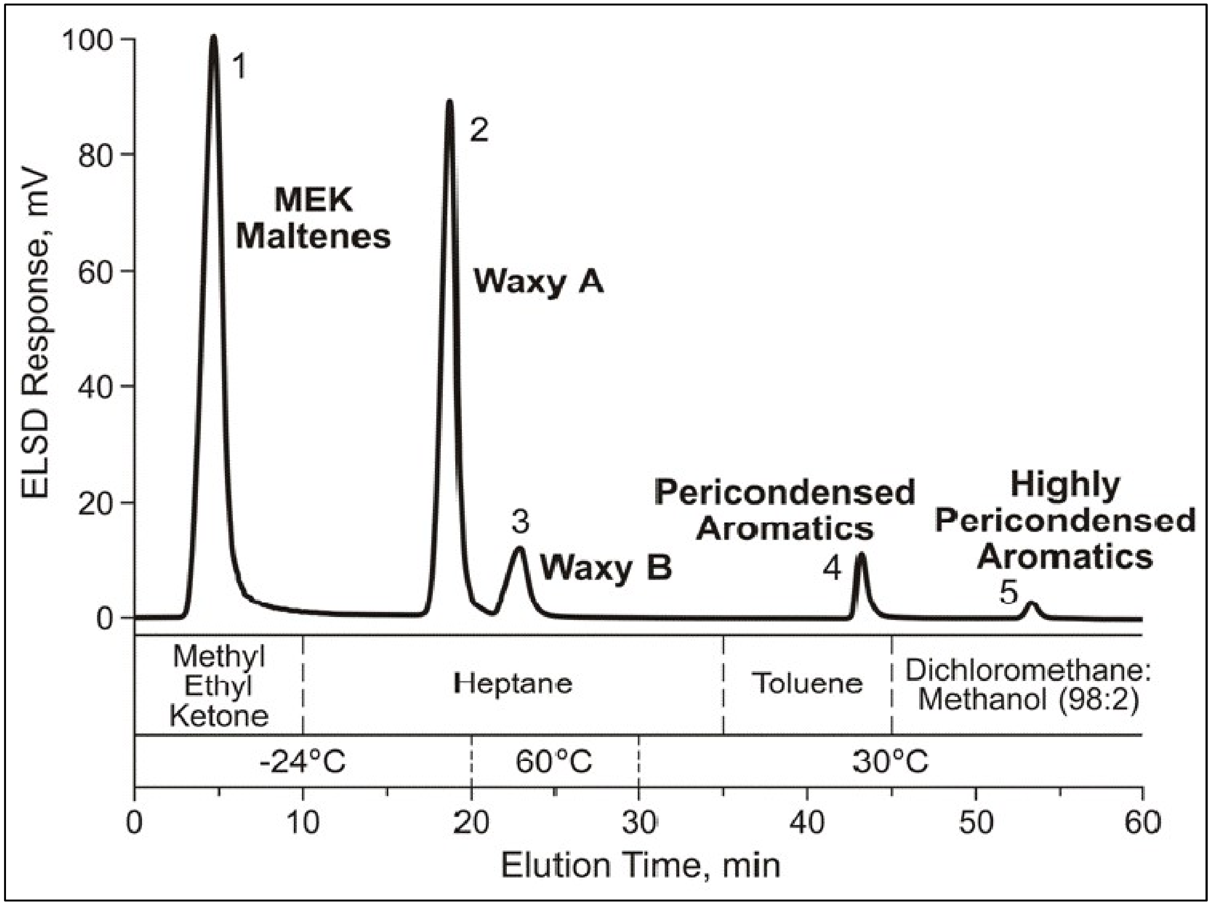
The tools
Understanding Asphalt Composition

SAR-AD Fractions: ELSD Area Percent = Weight %

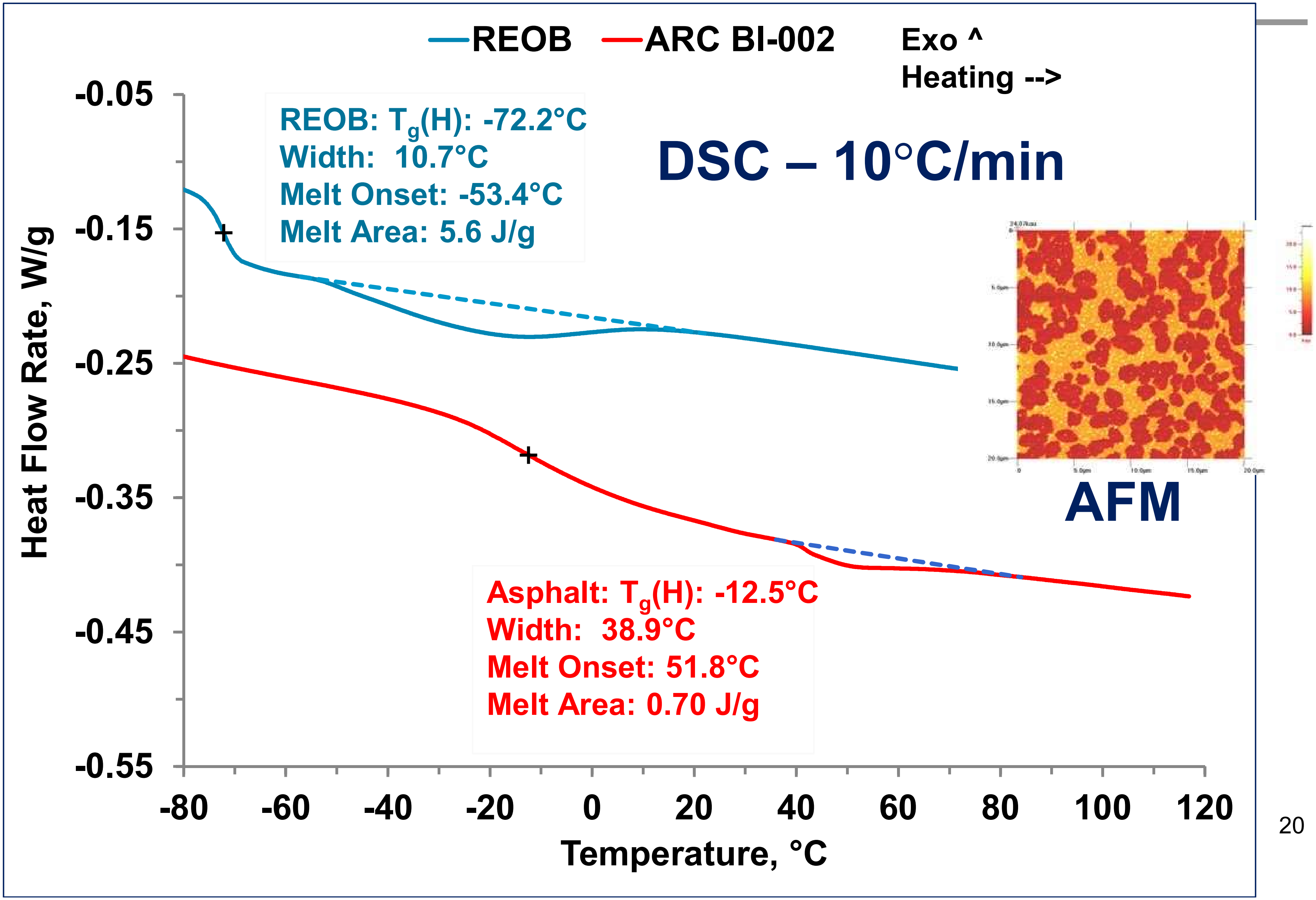


The Tools
Understanding Asphalt Composition

- **Characterization of waxy materials as a function of solubility + temperature - Waxphaltene Determinator™**



The Tools: Thermal Analysis
To measure Tg and Crystallinity



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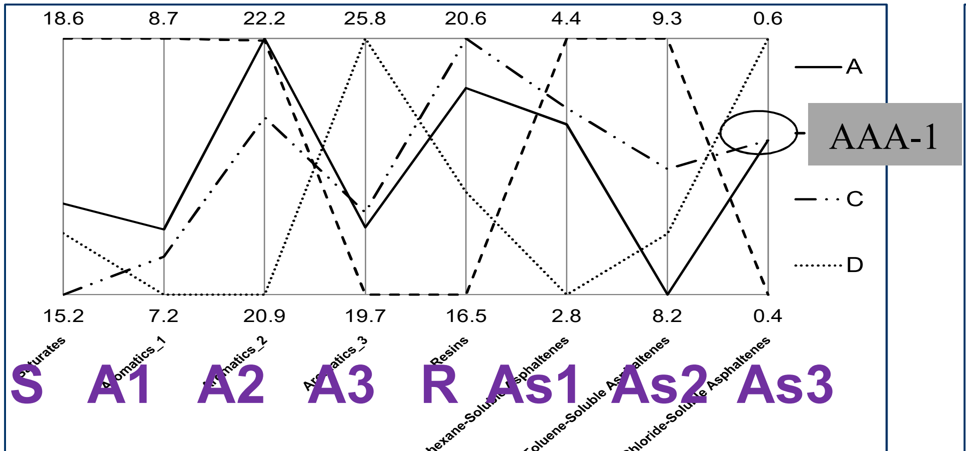
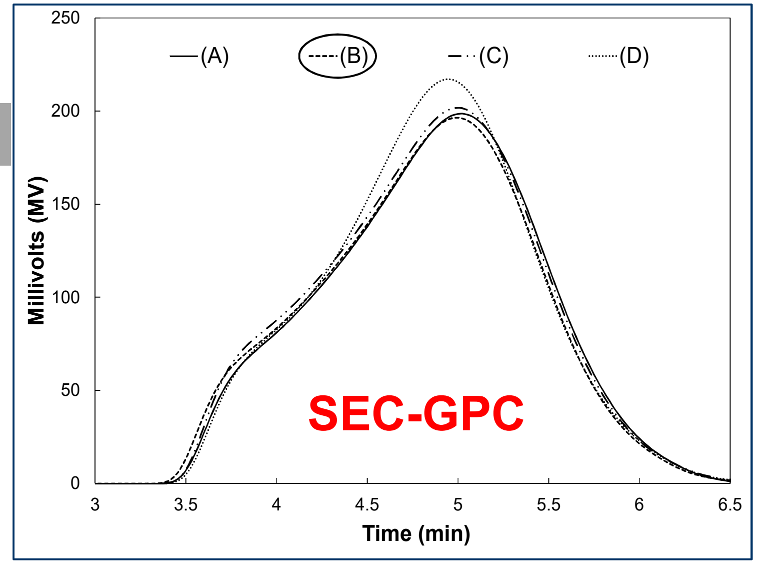
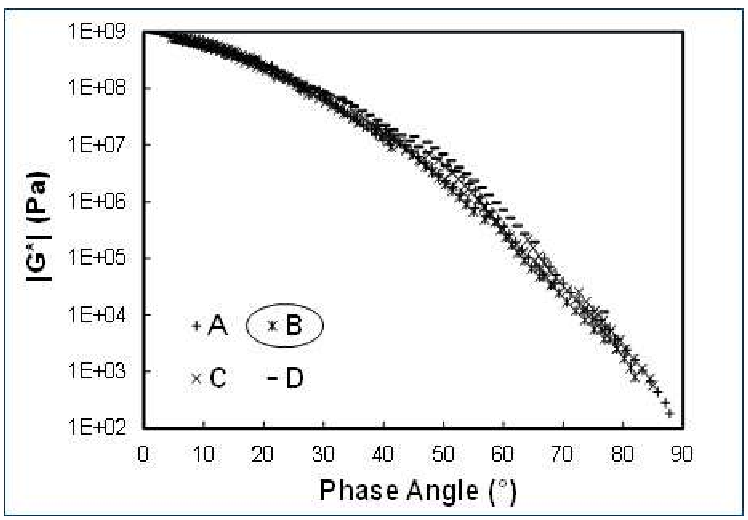
The Tools: The Holistic Approach
case of “Old Normal” binders



SAR-AD – Fractions in Parallel Coordinates





DSR- Black Space Diagram

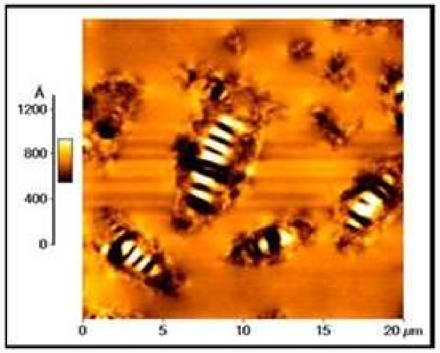
Straight runs asphalts

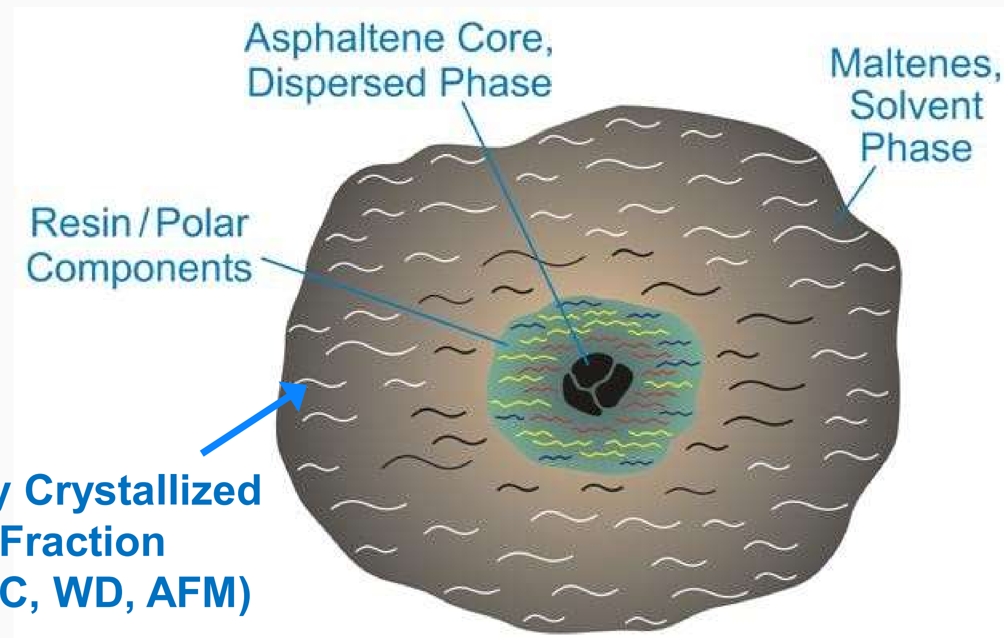
- Different fraction composition but within fairly narrow limits (SAR-AD)
- Fairly similar molecular associations & weight distribution (SEC)
- Fairly similar & simple rheological behavior (DSR)

WRI-AIRC/09-60 data – E&F paper 2019

The Tools - Structural Model of Asphalt

Colloidal suspension of asphaltenes in a maltene matrix (SARA – SAR-AD)





Waxy Crystallized Fraction (DSC, WD, AFM)

Dependence:

- Crude oil origin
- Refining process
- Temperature
- Aging stage
  - Tank (unaged)
  - Short Term - Mixing/Construction
  - Long term - Pavement

➢ **Molecular weight / associations and Polymer/additive addition**
  - ➢ Microscopy, GPC, IR, SAR-AD,AFT

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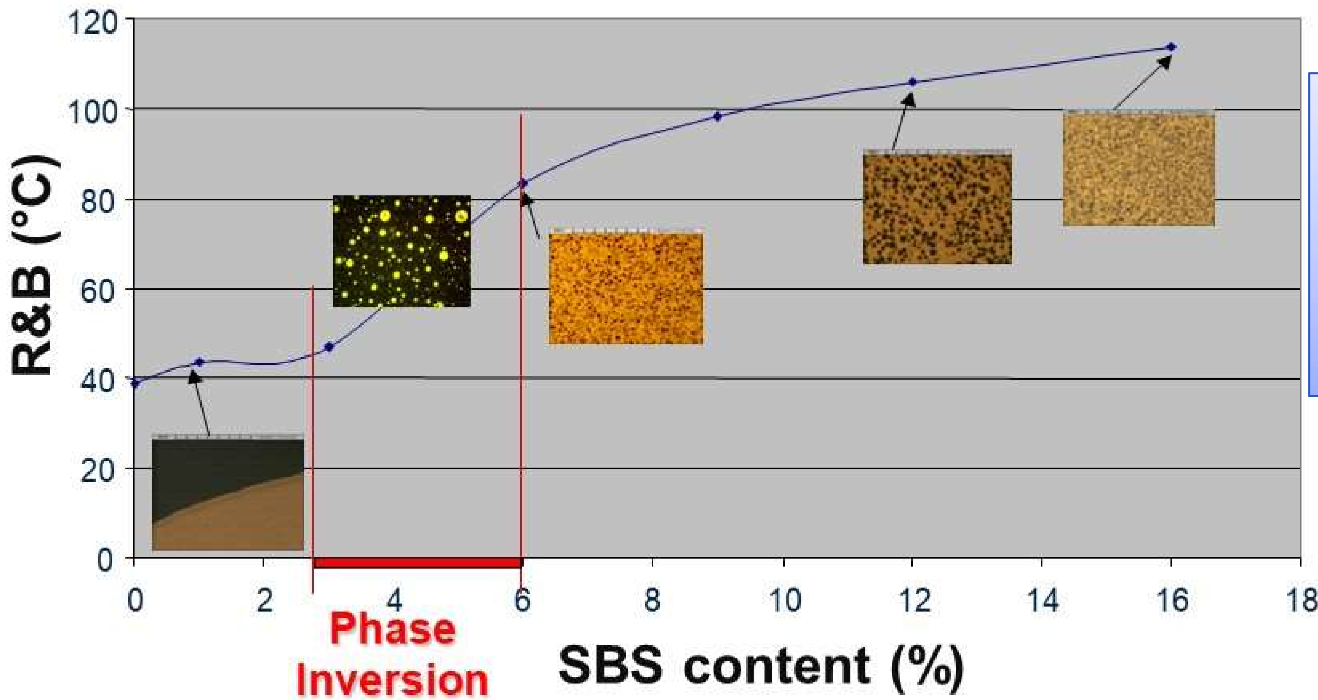
The Tools
-Structural Model of PMA's

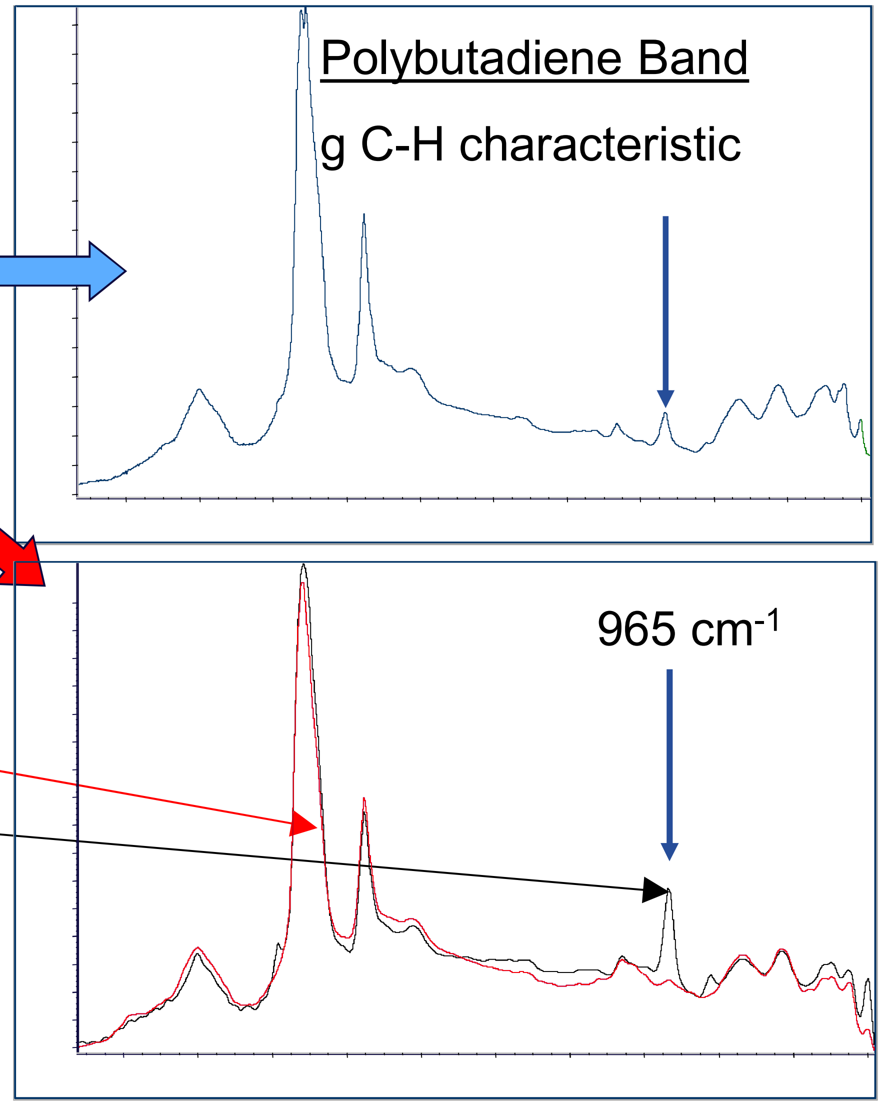


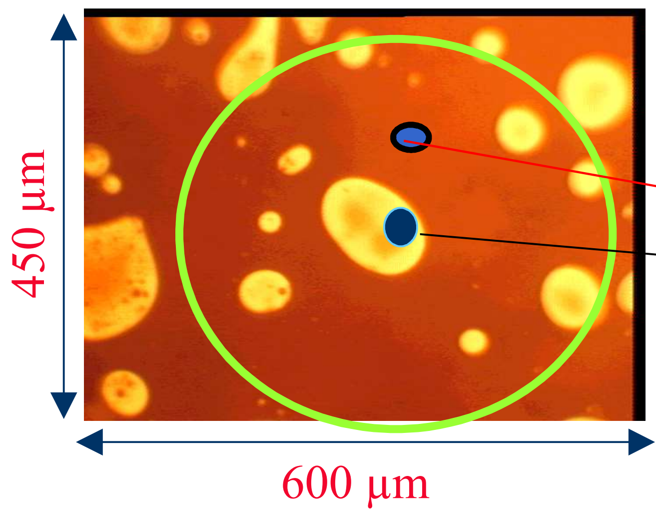
Ref from 80's-90's, mainly from Europe
- *LCPC*
- *Shell, Elf, Enichem*
- *Others…*

- **Effect of polymer modification on microstructure & properties** ***by UV fluorescence microscopy: Multiphase system***
  - **Polymer swollen with light aromatic oils from maltenes**
  - **Maltene phase enriched in asphaltenes, impoverished in aromatics**
  - **Polymer phase inversion between 3 and 6% polymer**
  - **Jump in consistency (R&B softening point, G*/sin δ…)**

The Tools -Structural Model of PMA's

- **IR Microscopy to analyze PMA structure**
  - **Spectroscopy = Global Analysis**
  - **IR Microscopy = Local Analysis**
- ***Study: LCPC-TOTAL-U Marseilles***





Ref.: Mouillet et al, BLPC 2000, Fuel 2008

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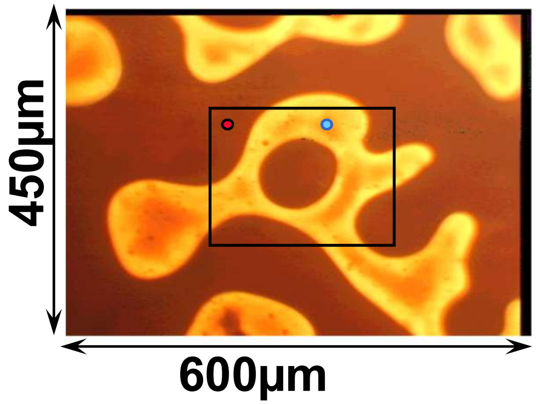
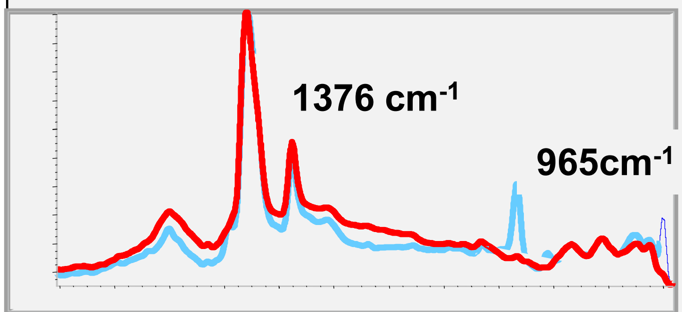
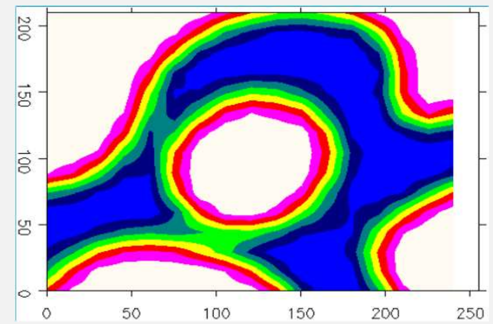
The Tools -Structural Model of PMA's

SBS m Bitumen

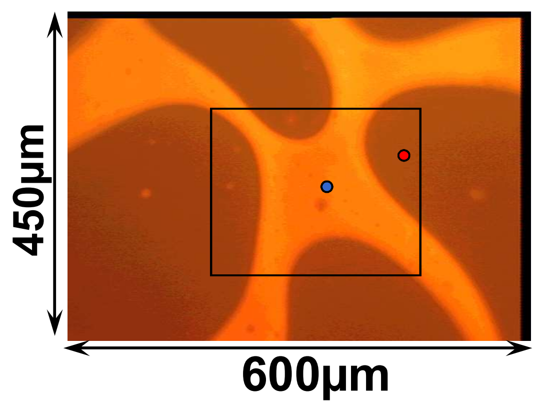


$$\frac{\gamma\text{CH SBS band @ } 965\text{cm}^{-1}}{\delta\text{CH}_3\text{ bitumen band @ } 1376\text{cm-}^{1}}$$

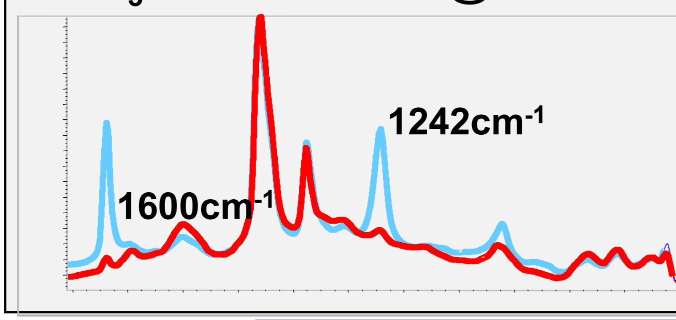


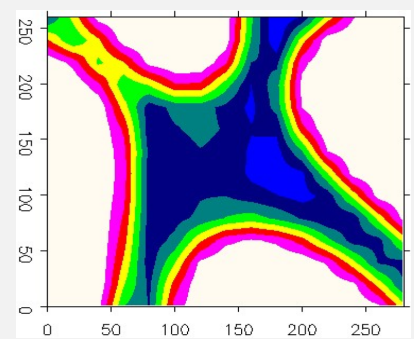


EVA m Bitumen



$$\frac{\nu\text{C-O EVA band @ } 1242\text{cm}^{-1}}{\delta\text{CH}_3\text{ bitumen band @ } 1376\text{cm}^{-1}}$$

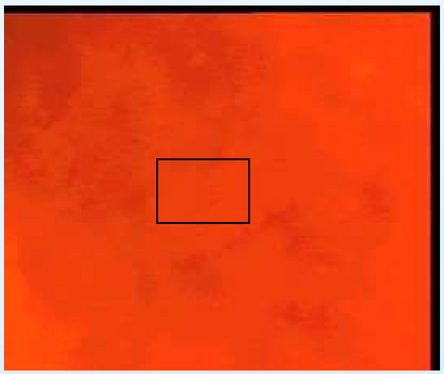


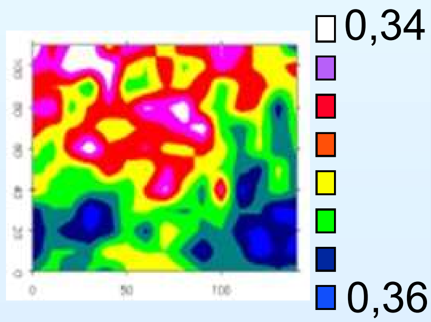


Ref.: Mouillet et al, BLPC 2000, Fuel 2008

The Tools -Structural Model of PMA's

FTIR Microscopy





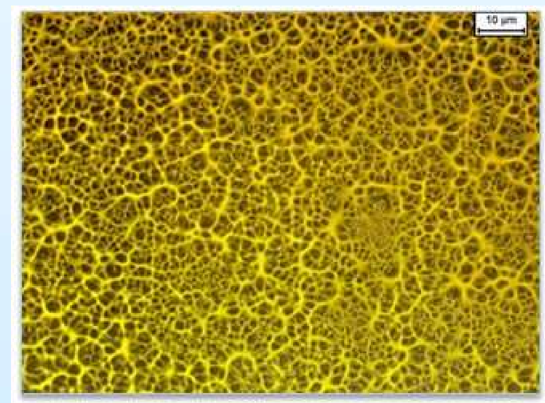
Fine dispersion of a cross-linked PMA

✓Homogeneous at micron level

✓Storage stable

✓Less evolving during aging

UV Fluorescence Microscopy



Microstructure of a cross-linked PMA

3-D Network revealed by N-hexane rinse

Ref.: Mouillet et al, BLPC 2000, Fuel 2008

The WRI Fingerprinting Approach with Partners

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- FP I, II, III & ARC - FHWA-WRI 90'-2015
  - The tools
- The initial "Fingerprint" project (2013)
  - Eurovia / WRI cooperation
- WRI – Asphalt Industry Research Consortium #1 (AIRC) (2015)
- NCHRP 9-60 – WRI-AAT-NCAT-GHK (2016)
- WRI-AIRC #2 (2018)
- Others….

1st Asphalt Fingerprint Study

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- **Binder Chemical**
  - Infrared
  - Differential Scanning Calorimetry
  - SEC/GPC

- **Binder Mechanical**
  - US: Superpave DSR, BBR, SCR, LAS, ABCD cracking
  - EU: Pen, R&B,

- **Mixture tests**
  - G. Compactor
  - Rutting- Wheel tracking
  - Trapezoidal fatigue
  - TSRST - cracking
  - Moisture resistance

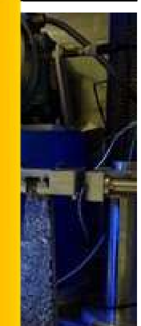
→ Chemometrics correlations for 14 neat binders

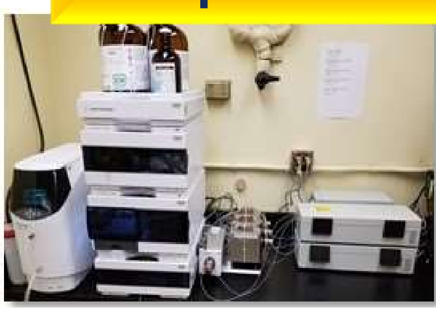
- **Asphalt composition correlated with mech. properties and some asphalt mix properties – SAR-AD + ExpliFit software**

➢ **Binder impact: fatigue, stiffness modulus, and cracking**

➢ **Aggregate impact: sensitivity to water, compaction, …**

❑ **Papers:** EE 2016, ISAP 2016, PARC 2017, CTAA 2017





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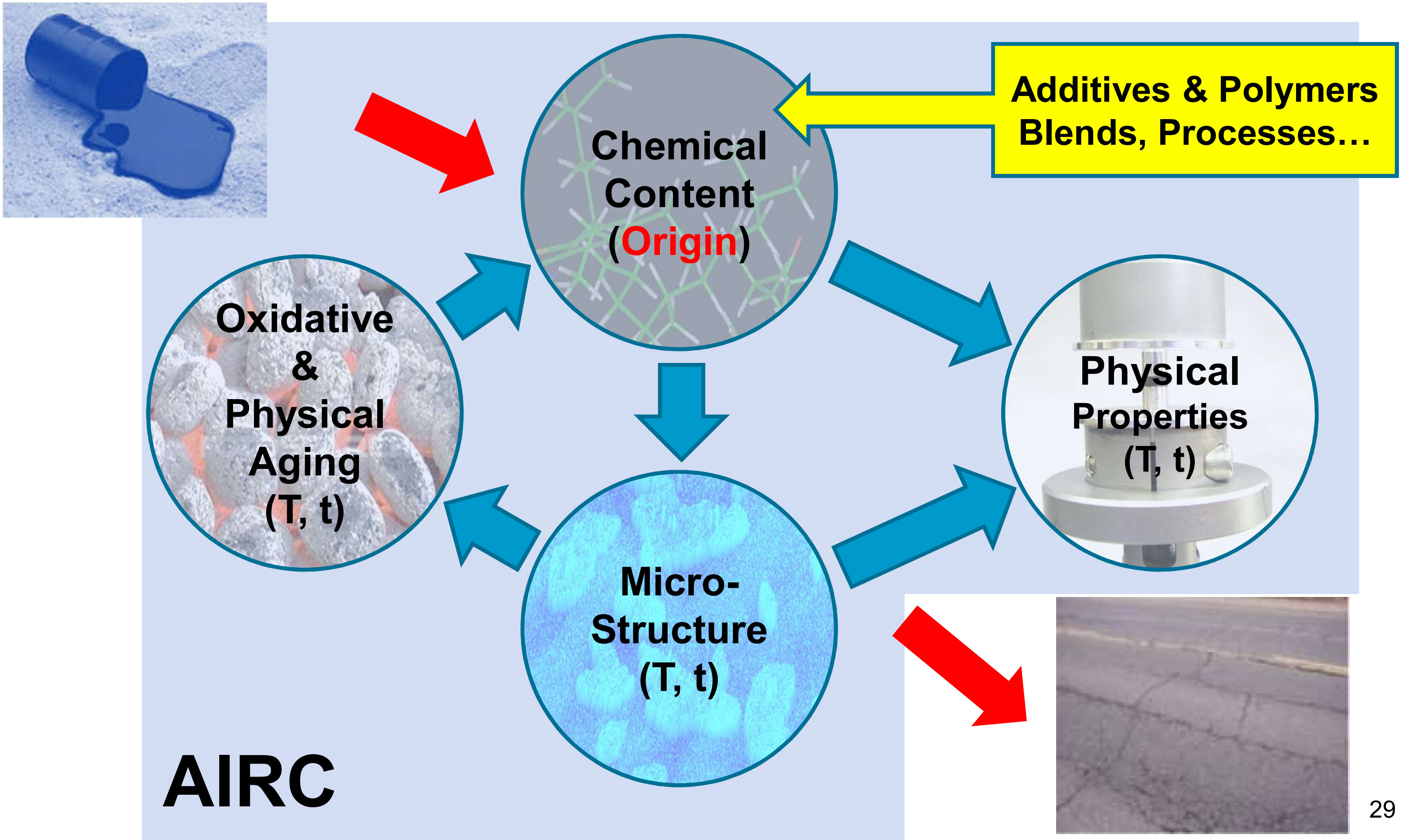
Approach: Tying Chemical and Rheological Analysis



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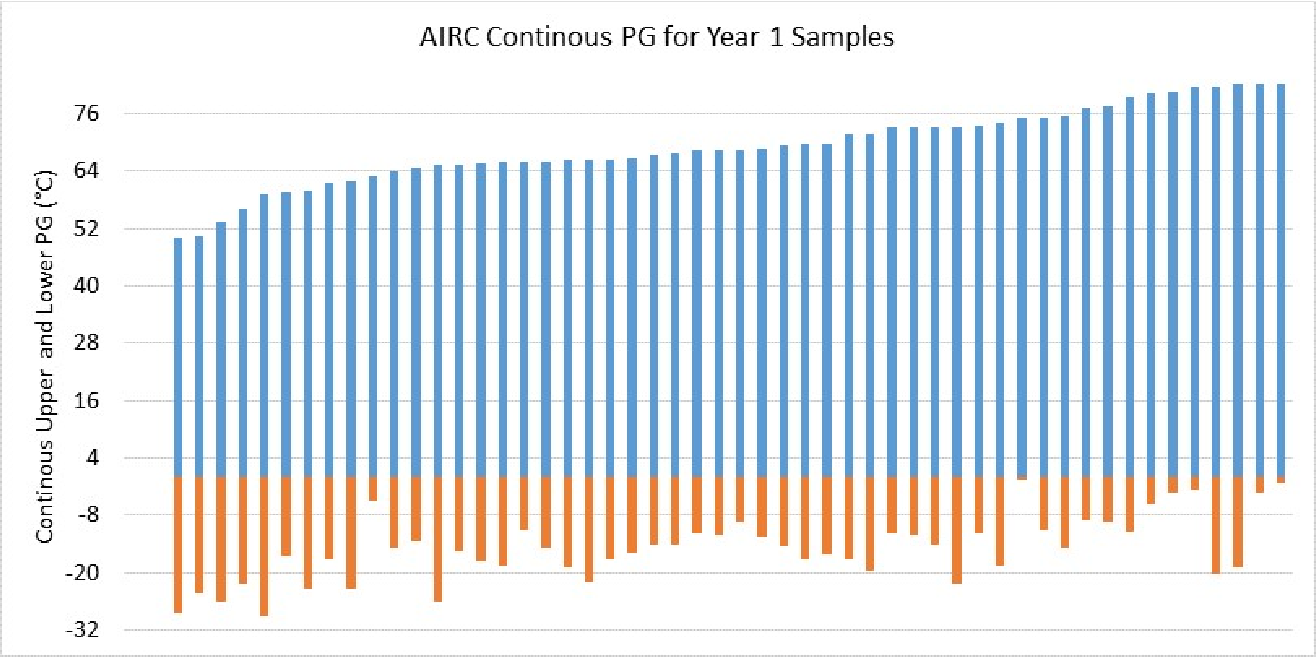
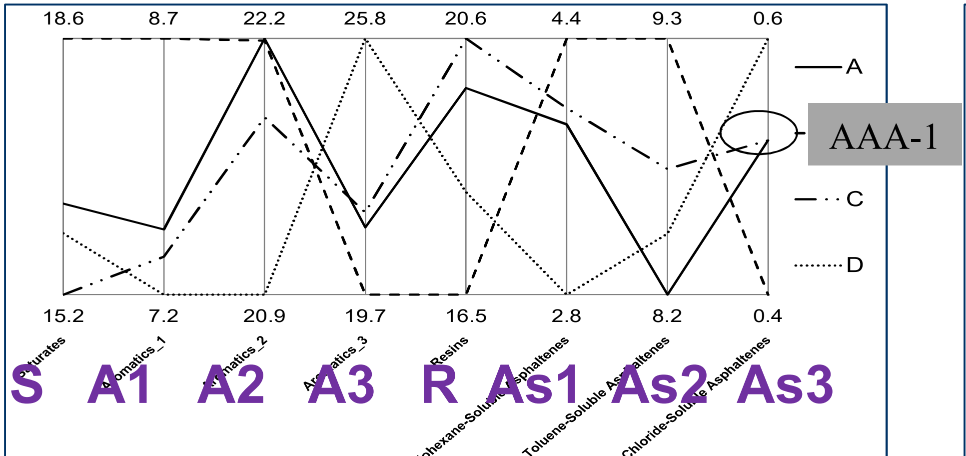
WRI-AIRC
Asphalt Industry Research Consortium

- Launched by WRI in 2015 (2nd iteration in progress)
- Goal: Fingerprint asphalt binders to understand and assess the source variability and impact on properties
- Partners (worldwide)
  - Road administrations, Road contractors
  - Additive suppliers, Asphalt suppliers / producers

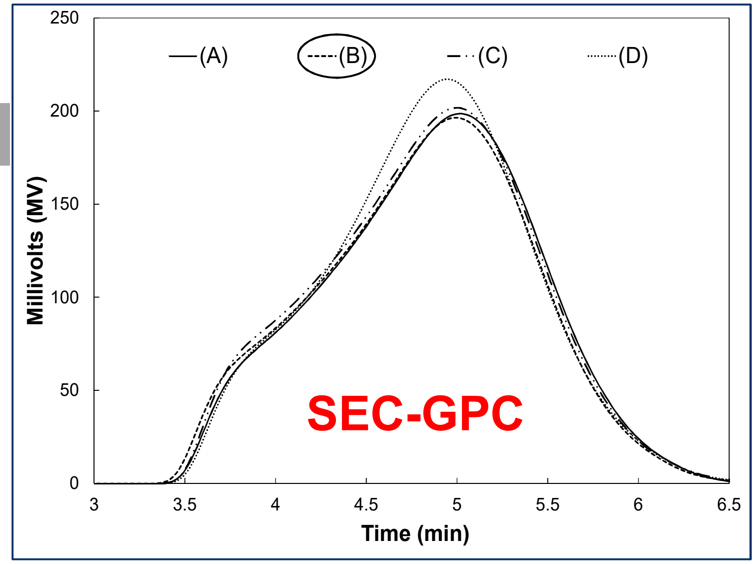
- **Worldwide Database of 90+ different asphalt binders (some with field data)**
  - **SHRP and ARC asphalts references**
  - **Unmodified – straight run, airblown, SDA, and VB blends**
  - **Modified with polymers / additives /…RAP…**
  - **Bio-binder**



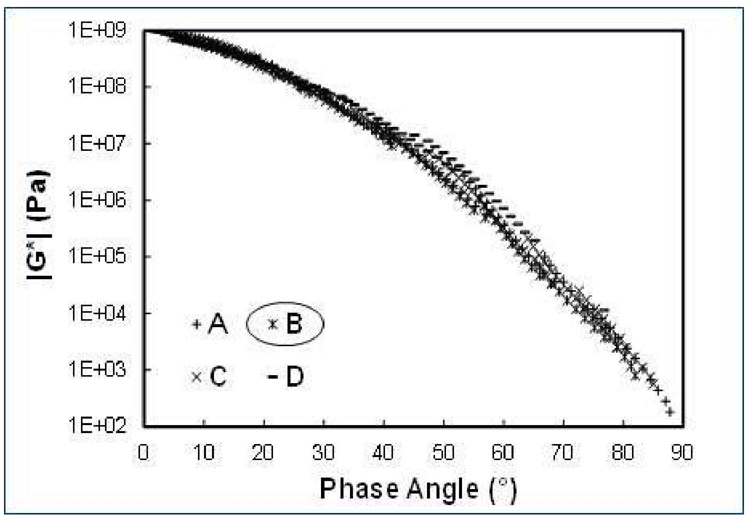
“Old Normal” binders



SAR-AD – Fractions in Parallel Coordinates



SEC-GPC



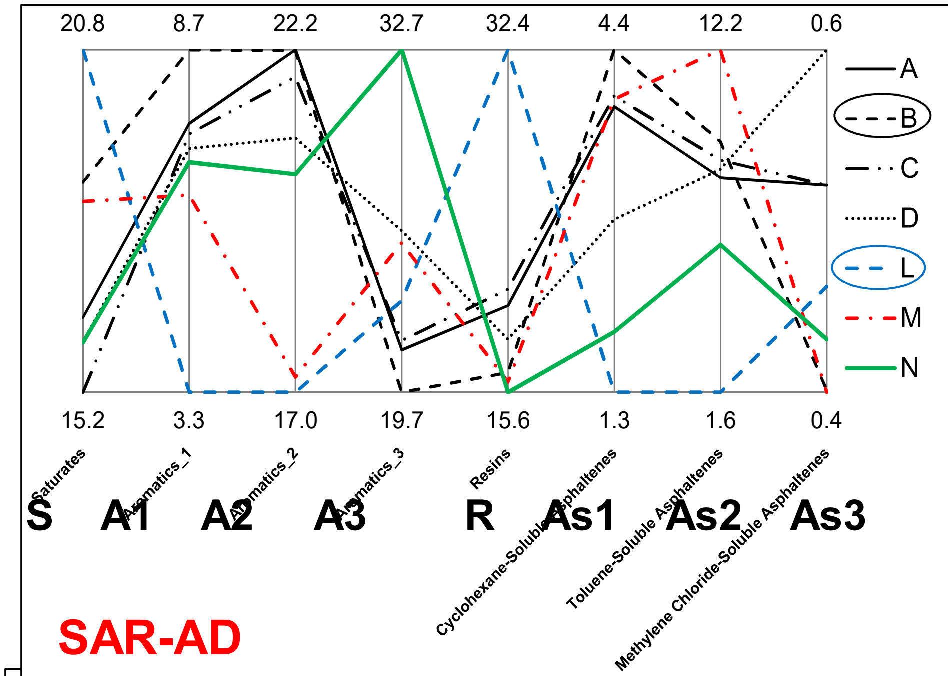
DSR- Black Space Diagram

Straight runs asphalts

- Different fraction composition but within fairly narrow limits (SAR-AD)
- Fairly similar molecular associations & weight distribution (SEC)
- Fairly similar & simple rheological behavior (DSR)

WRI-AIRC/09-60 data – E&F paper 2019

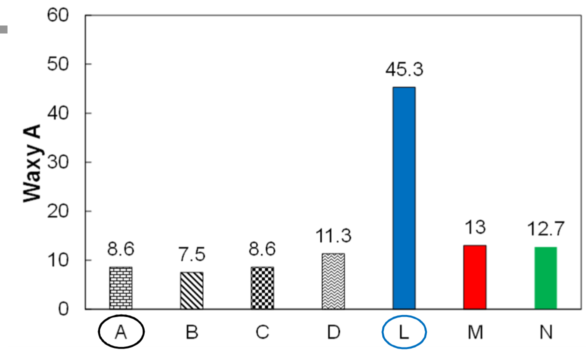
Waxy binders

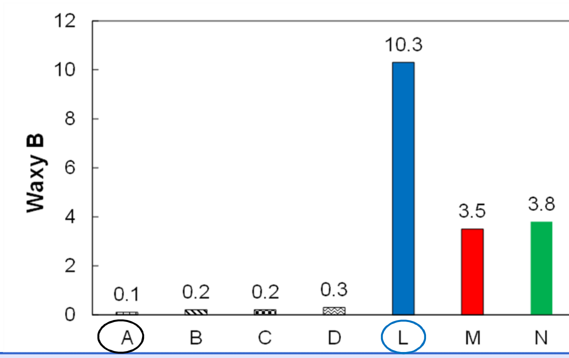


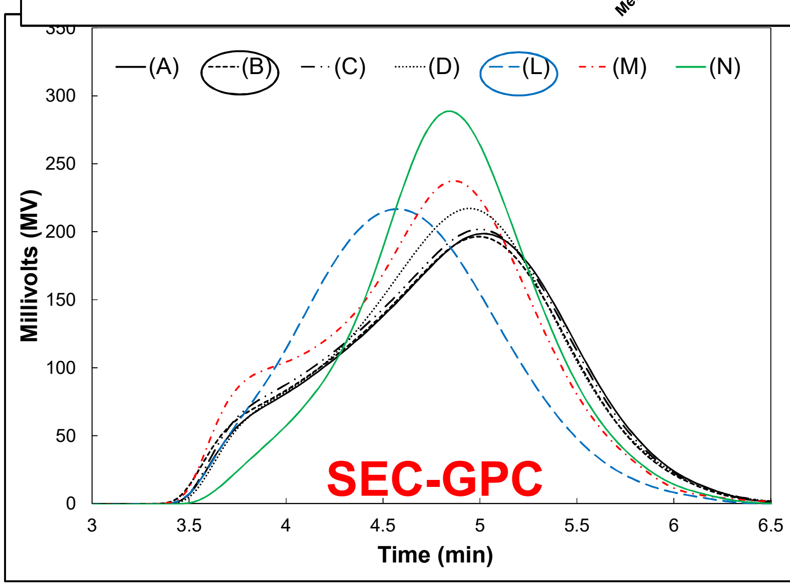
AAA-1

WD

AAM-1





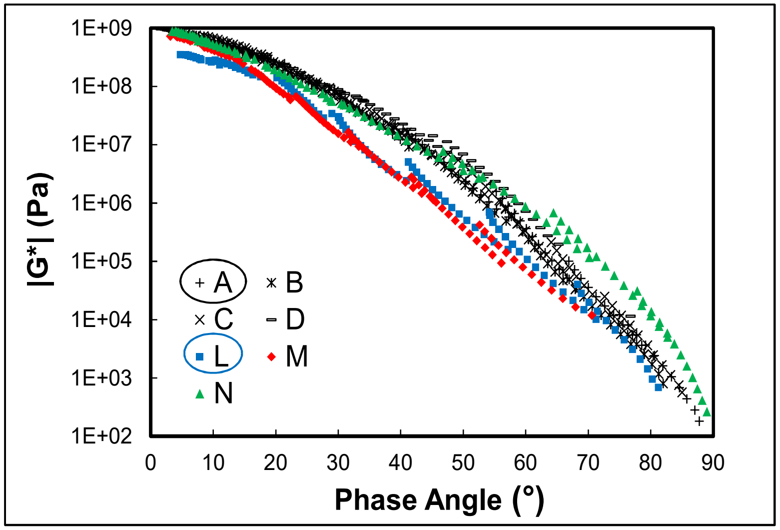


Waxy binders

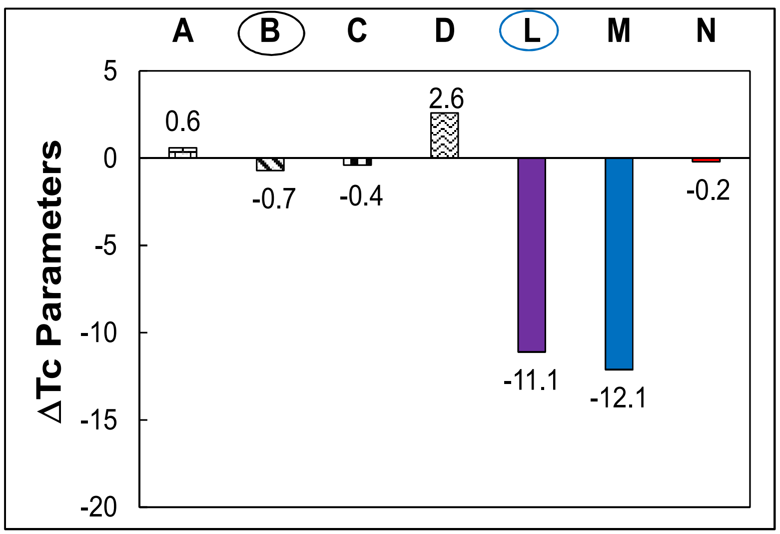
- Very diverse fraction composition (SAR-AD) – requires other technique
- High waxy fractions (WD) and CF (DSC)
- Low molecular associations & high molecular weight distribution (SEC)

WRI-AIRC/09-60 data

Waxy binders (cont'd)



DSR- Black space diagram



AAA-1

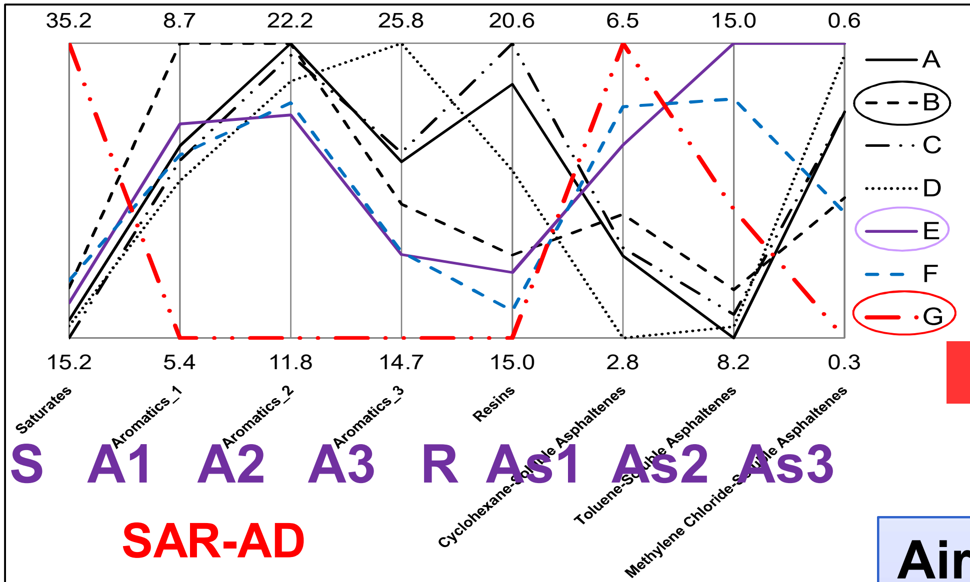
AAM-1

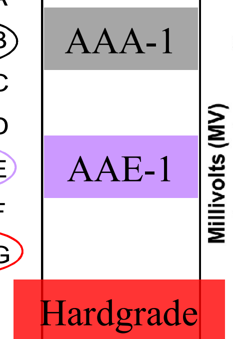
Waxy binders

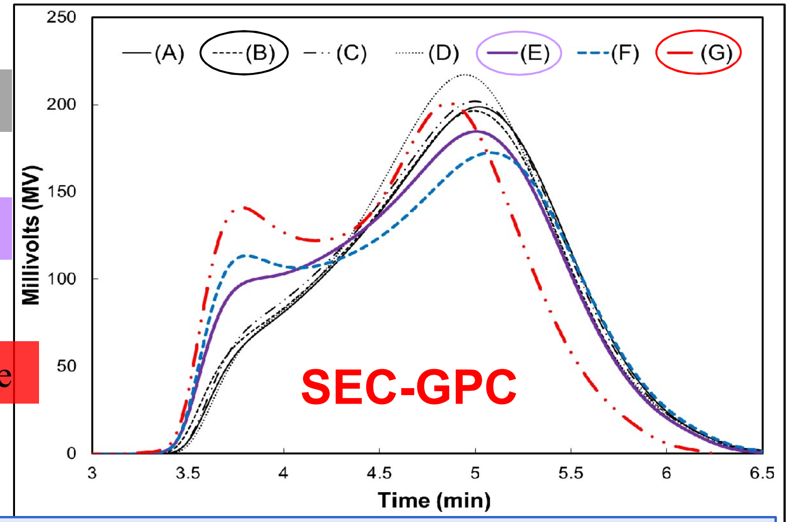
- Very diverse fraction composition (SAR-AD) – requires other technique
- High waxy fraction (WD)
- Low molecular associations & high molecular weight distribution (SEC)
- Elastic & complex rheological behavior (DSR)
- **Negative ΔTc (relaxation/ brittleness issue) when high waxy fraction and low aromatics**
- **Prone to physical hardening**

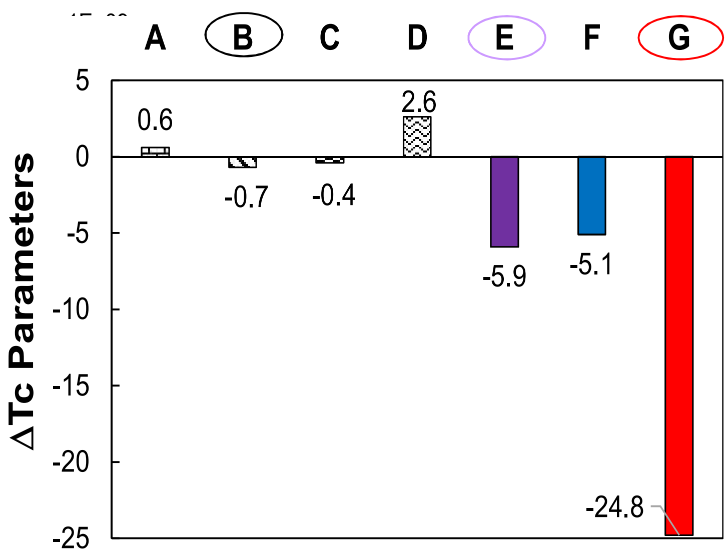
WRI-AIRC/09-60 data

Airblown binders







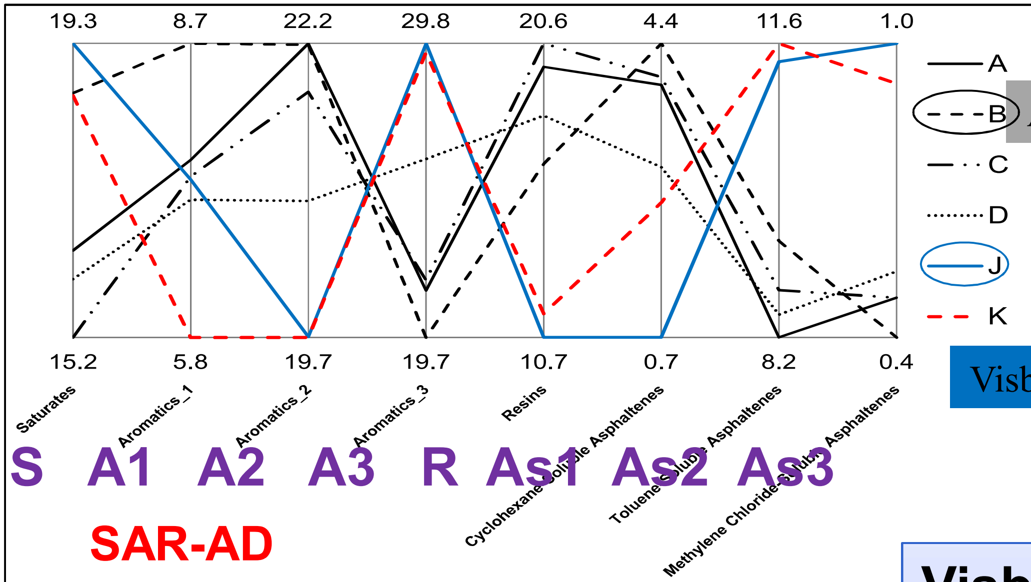


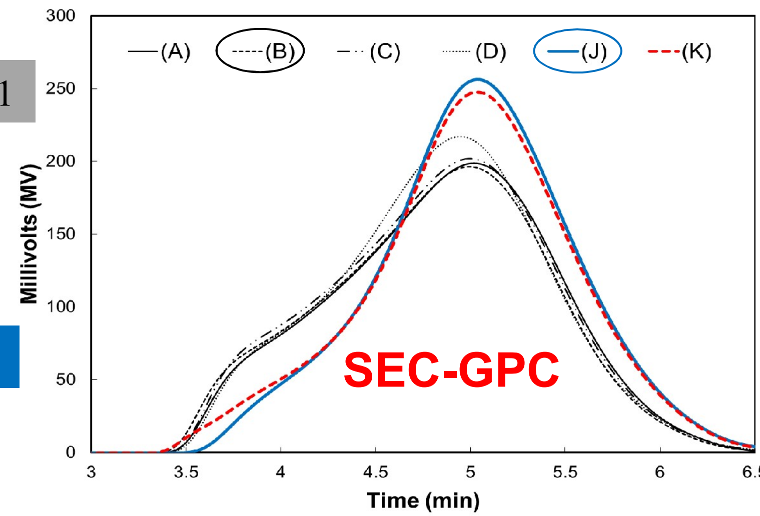
Air blown binders

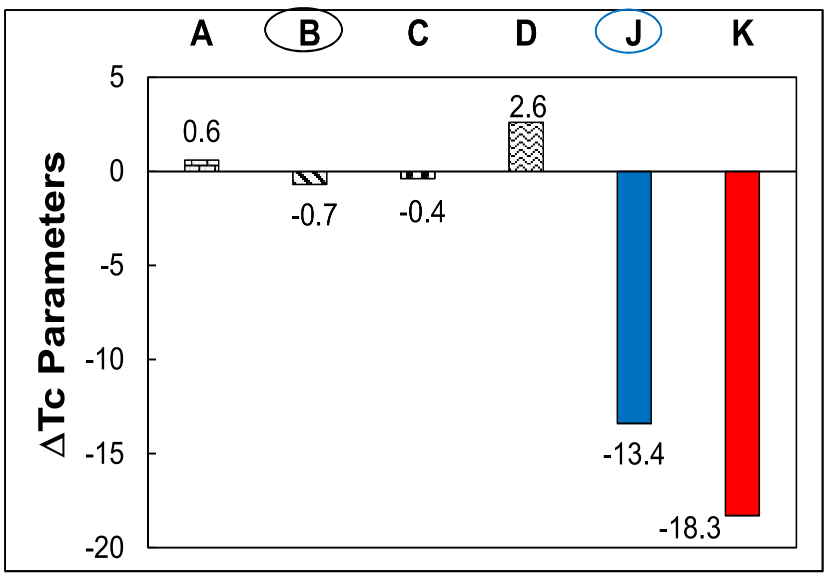
- Very wide fraction composition (SAR-AD): high instability & As(1,2)
- Higher molecular associations (SEC) function of %As and compatibility
- More elastic & complex rheological behavior (DSR) – above 25 deg angle
- **Very negative ΔTc (relaxation and brittleness issues)**

WRI-AIRC/09-60 data – E&F paper 2019

Conversion (Visbroken) residues





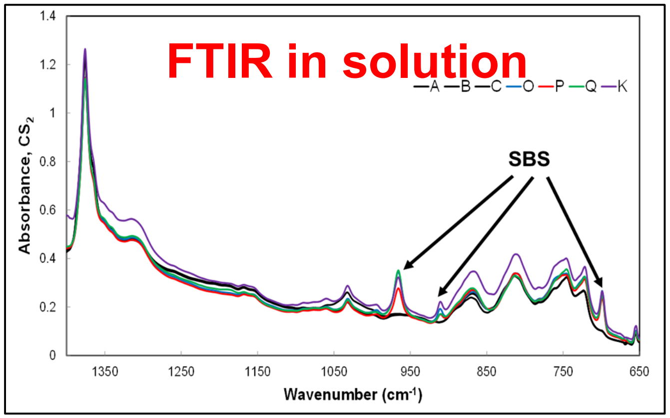


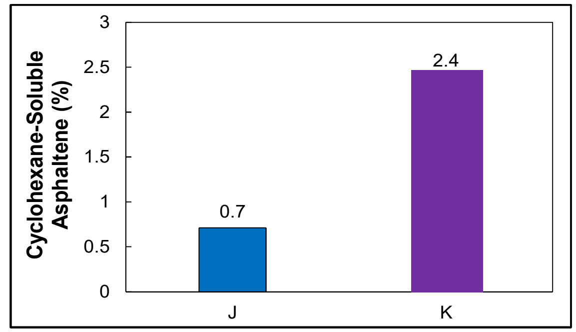
Visbroken binders

- Unbalanced fraction composition (SAR-AD) – R & As1↘ and As2-3↗
- Low molecular associations & weight distribution (SEC)
- Very elastic & complex rheological behavior (DSR)
- **Very negative ΔTc (poor relaxation / brittleness)**

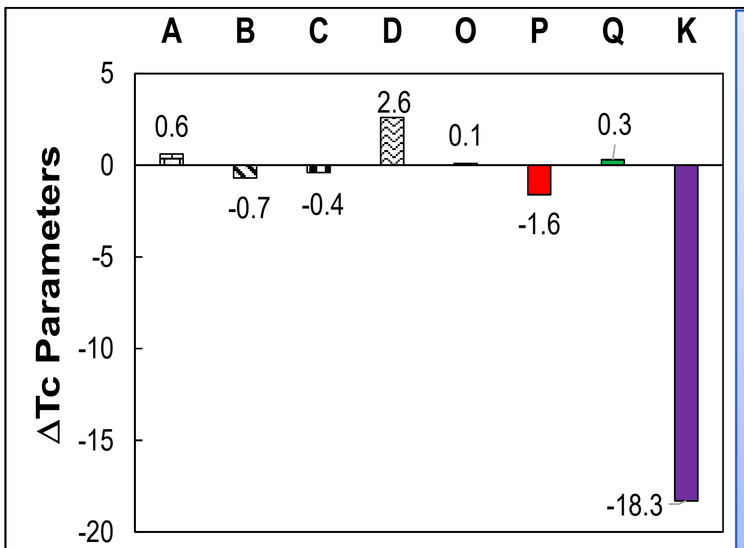
WRI-AIRC/09-60 data – E&F paper 2019

PMA binders





SAR-AD (Base and SBS-PMA)



DSR- Black space diagram

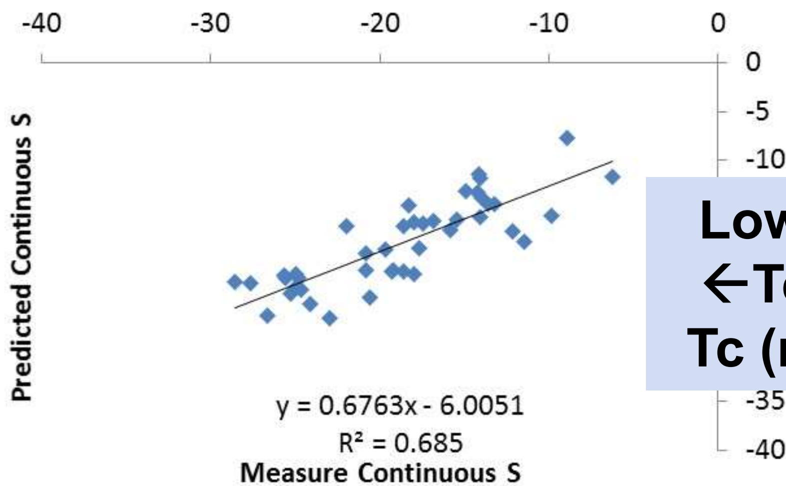
PMA binders

- **Polymers easy to detect** (FTIR)
- **SBS in asphaltene fractions** (SAR-AD)
- **Multimodal molecular weight** distribution (SEC) – shown before
- **Elastic & complex rheological behavior**
    - Polymer plateau with variable intensity
    - Variable ΔTc (good to bad relaxation)
- **Related to microstructure & compatibility**
- **Base asphalt dependency**

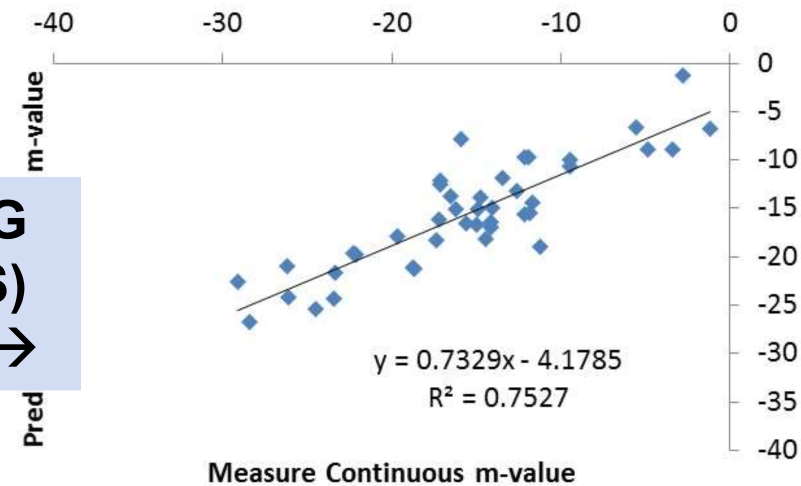
WRI-AIRC/09-60 data – E&F paper 2019

How to estimate PG in less than 90 min

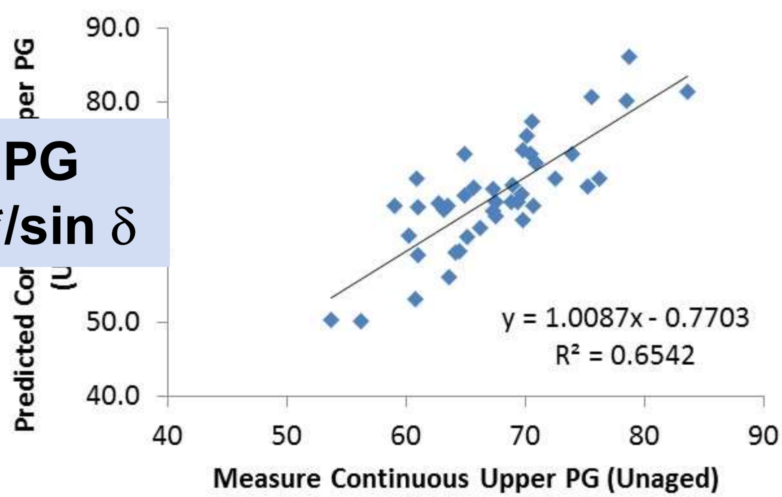
❑ PG estimated from SAR-AD & ExpliFit software



Low PG
←Tc (S)
Tc (m) →



High PG
Tc G*/sin δ



- **"Outliers" with unique composition…**
  - ➢ **require "holistic analysis"!**

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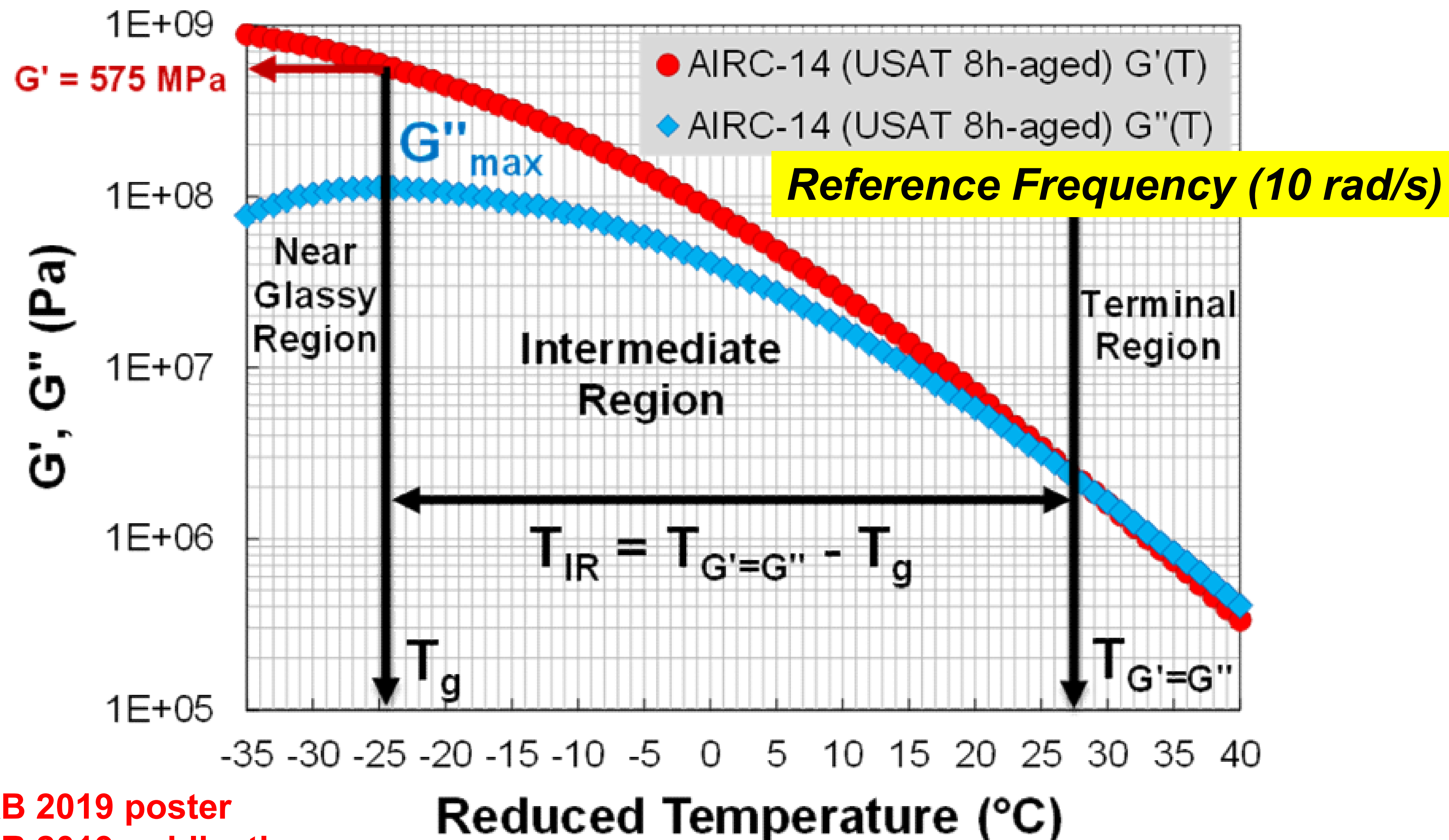
WRI – AIRC Highlight

"New" Rheological Parameter

❑ Viscoelastic Temperature Range ($T_{IR} = T_{G'=G''} - T_g$)



TRB 2019 poster
TRR 2019 publication

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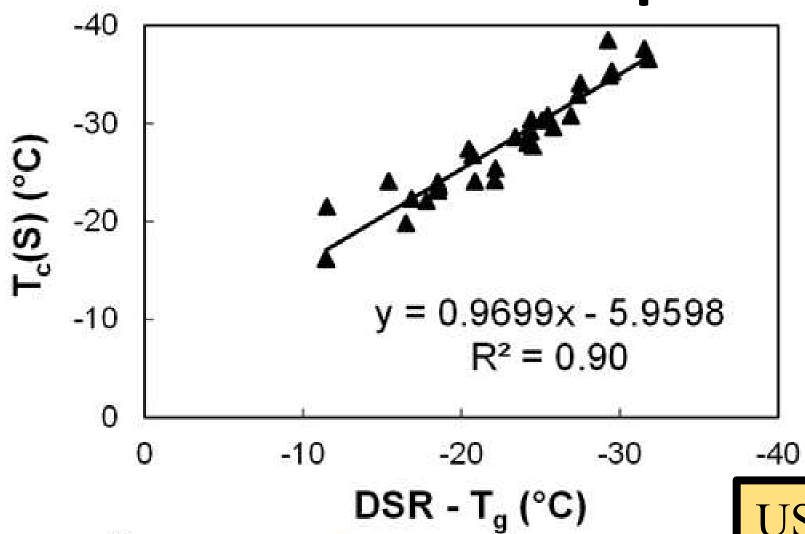
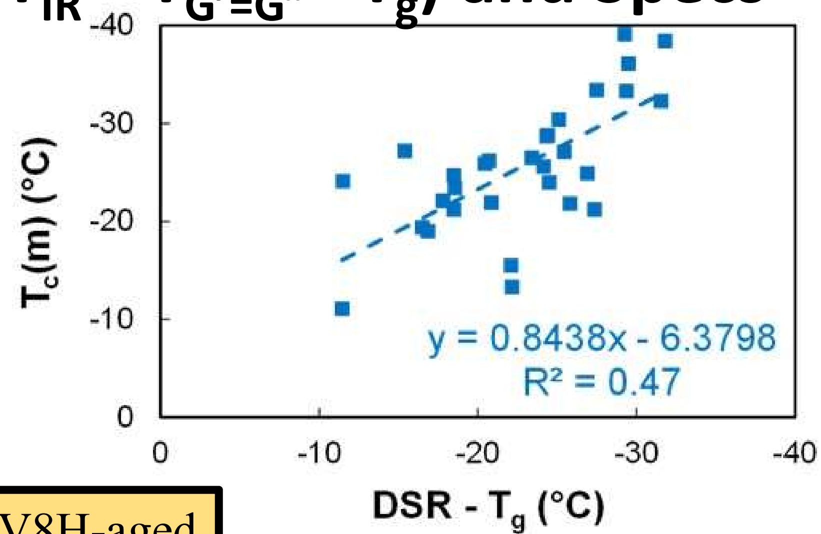
WRI – AIRC Highlight

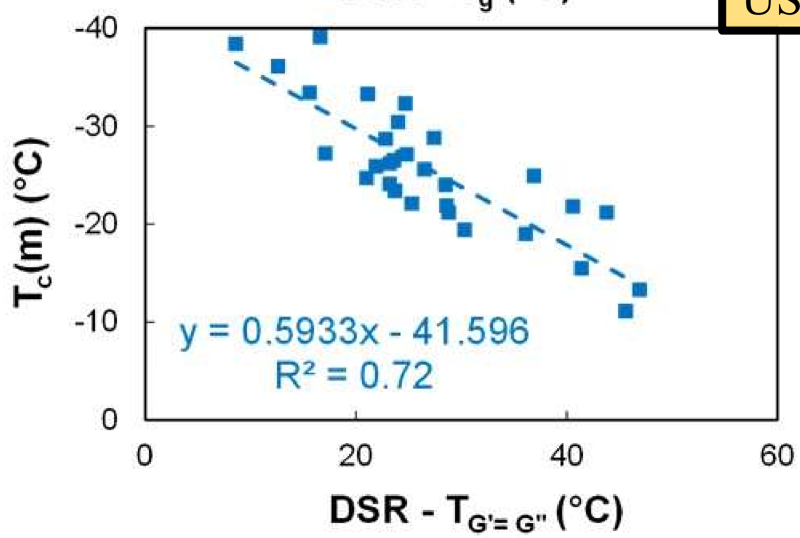
"New" Rheological Parameter

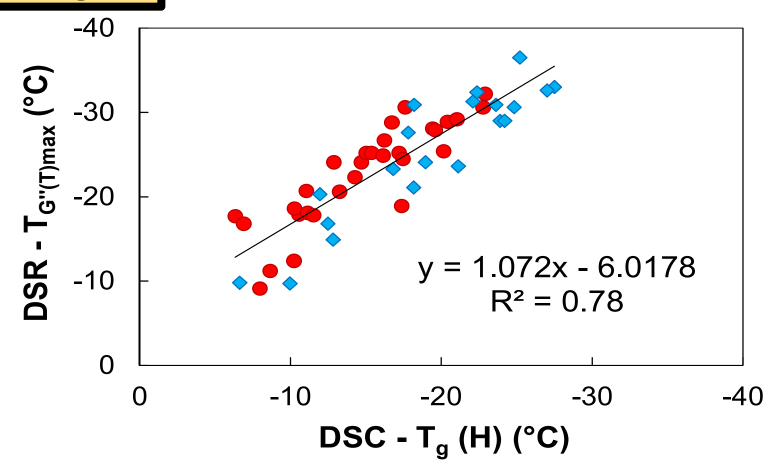
- **Viscoelastic Temp. Range ($T_{IR} = T_{G'=G''} - T_g$) and Specs**





USAT-PAV8H-aged

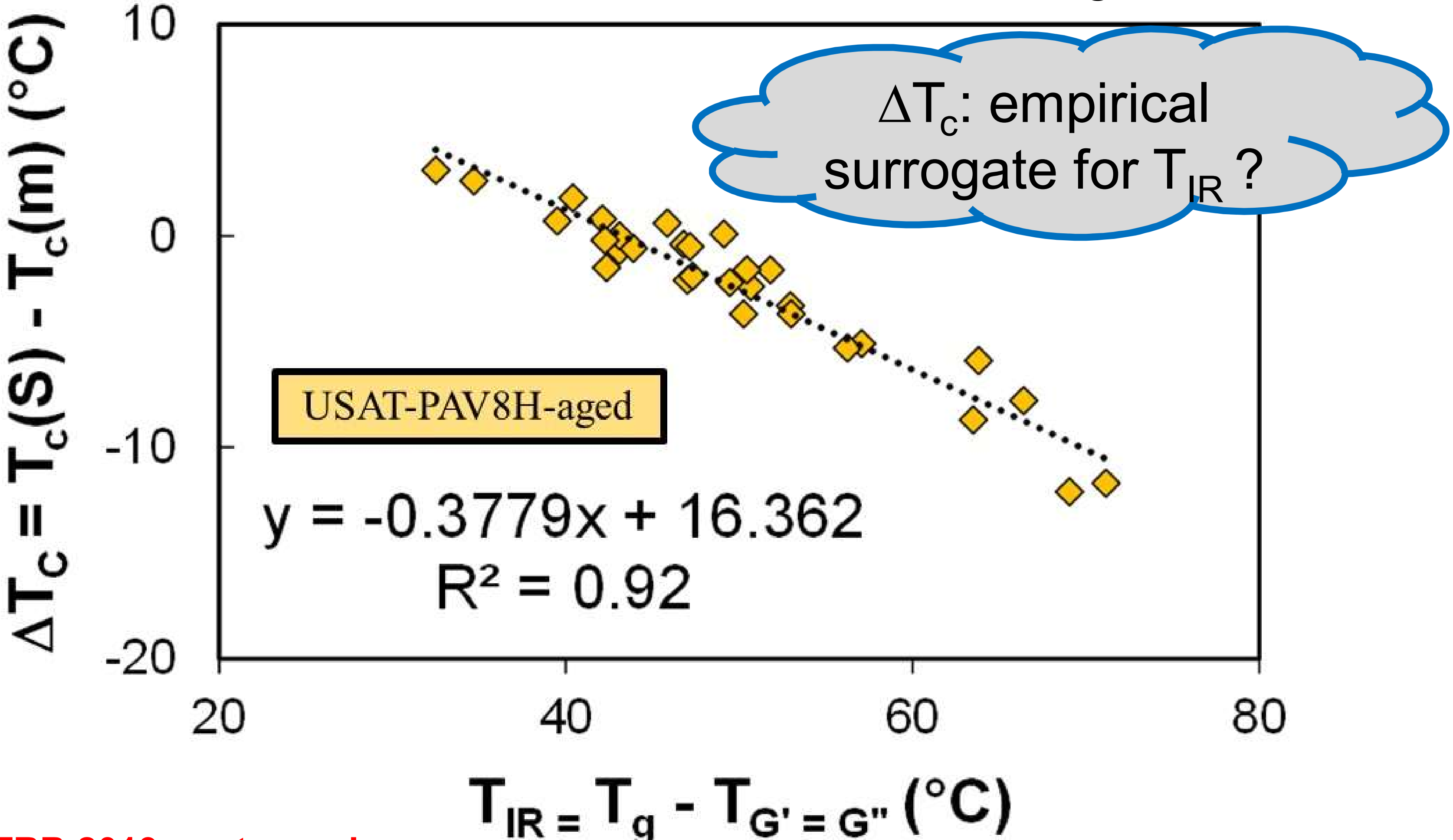




TRB 2019 poster and TRR 2019 publication

"New" Rheological Parameter

- Viscoelastic Temp. Range ($T_{IR} = T_{G'=G''} - T_g$) and ΔTc



TRB 2019 poster and
TRR 2019 publication

Outline

- WRI – An overview
- Context: Asphalt Variability - The "New Normal"
- The WRI-Fingerprinting Approach to Cope with the New Normal
- **Case study: NCHRP 9-60**
  - **Objectives**
  - **Approach**
  - **Examples of Findings**
- Summary / Perspectives

The WRI Fingerprinting Approach with Partners

- *SHRP* — *1987*
- *FP I, II, III & ARC - FHWA-WRI* — *90'-2015*
  - ***The tools***
- ***The initial "Fingerprint" project*** — **2013**
  - **Eurovia / WRI cooperation**
- **WRI – Asphalt Industry Research Consortium #1 (AIRC)** — **2015**
- **NCHRP 9-60 – WRI-AAT-NCAT-GHK** — **2016**
- **WRI-AIRC #2** — **2018**
- **Others….**

NCHRP 09-60
Project & Objectives

Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications

1. Understand the Market Trends and their Consequences

↓

2. Improve the Understanding of Various Damage Mechanisms and Factors Affecting their Severity

↓

3. Propose Revised Specifications to Address Current Challenges (premature cracking and raveling)

↓

4. Develop Formulation Guidelines for Suppliers to Meet Proposed Specifications & Expected Performance

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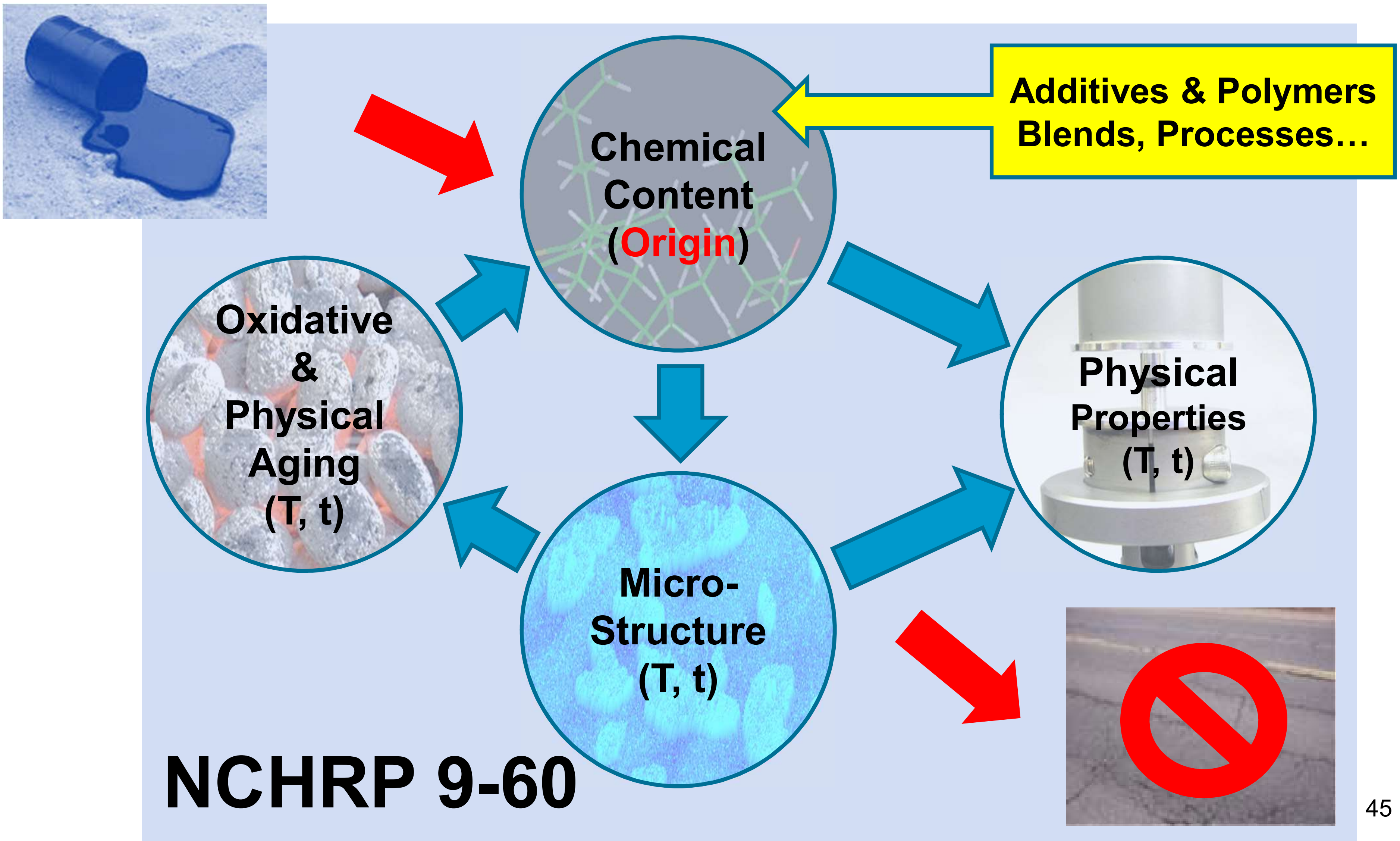
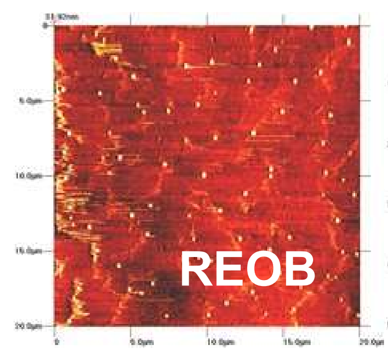
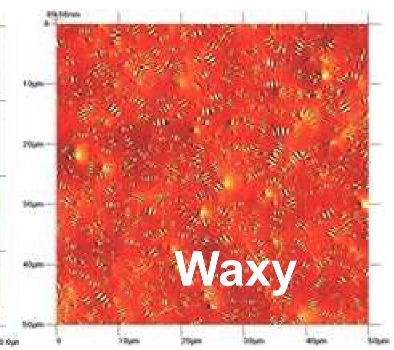
Approach: Tying Chemical and Rheological and Field Analysis

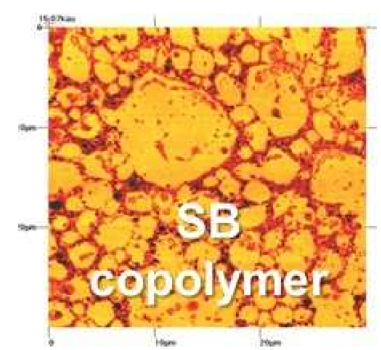


1. Understand the Market Trends and their Consequences

- **Classical Binders** – straight runs, modified and compatible blends
- **Unconventional (sometimes problematic) Binders**
  - ➢ Some high ΔT_c - “out of balance” / incompatible blends
  - ✓ Waxy binders
  - ✓ Airblown, oxidized blends
  - ✓ Hard SDA / Soft blends
  - ✓ Conversion residue (IMO 2020)
  - ✓ Modified binders
    - Polymers: SBS, SBR, Terpolymer, ~~EVA~~
    - Additives – REOB, PPA, Wax, Biomass
    - Bio-binder
  - ✓ High RAP / RAS
  - Incompatible crudes (Fracking / Heavy)?







50 binders

Binder with Corresponding Field Sections

- Highway 655, Ontario, Canada MTO (7 sections)
- Rochester, MN (4 sections)
- US 93, AZ (4 sections)
- I 295 SB, Portland, ME
- Route 1, Presque Isle, ME
- Route 11, Wallagrass, ME
- Route 12, Westmorland, NH
- SH 195, Florence, TX

MTO ON-Hwy 655 2003 Sections

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2008

❑ Almost same ranking between Transverse Cracking, Total Cracking, and (Total – Transverse) Cracking

Ranking	Section ID	Trans.	Section ID	Total		Tota-Trans.
1	1	0.3	1	34.9		34.6
2	5	4.3	5	103.4		99.1
3	2	38.2	2	130.9		92.7
4	6	42.5	6	209.3		166.8
5	3	51.4	3	295.1		243.7
6	7	60.2	7	427.6		367.4
7	4	139.7	4	587.2		447.5

- **09-60 Project compares field sections differentiated by binder type**, with consistent climate, traffic, mix properties, pavement structure, subgrade materials, construction quality …
- **Problematic binders (incompatible binders with very low ΔTc) would perform badly for all kinds of cracking**.
- **Internal restraint damage will compromise the integrity of the mixture** and lead to mixture generally prone to all sorts of cracking.

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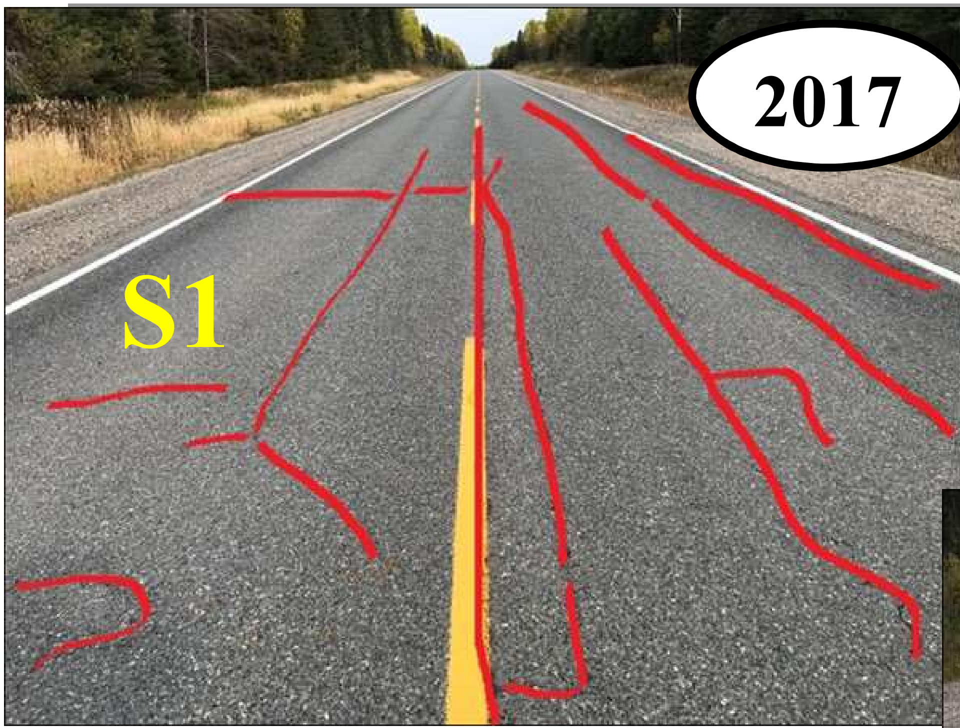
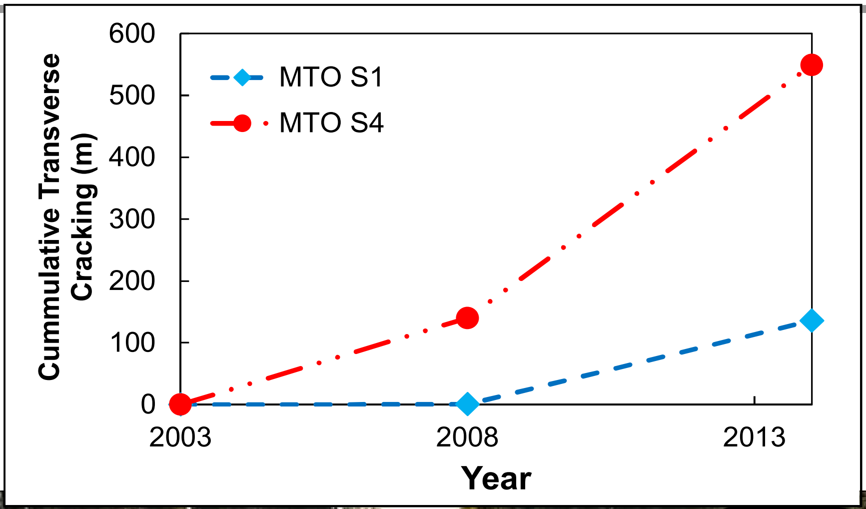
MTO ON-Hwy 655 Sections #1&4





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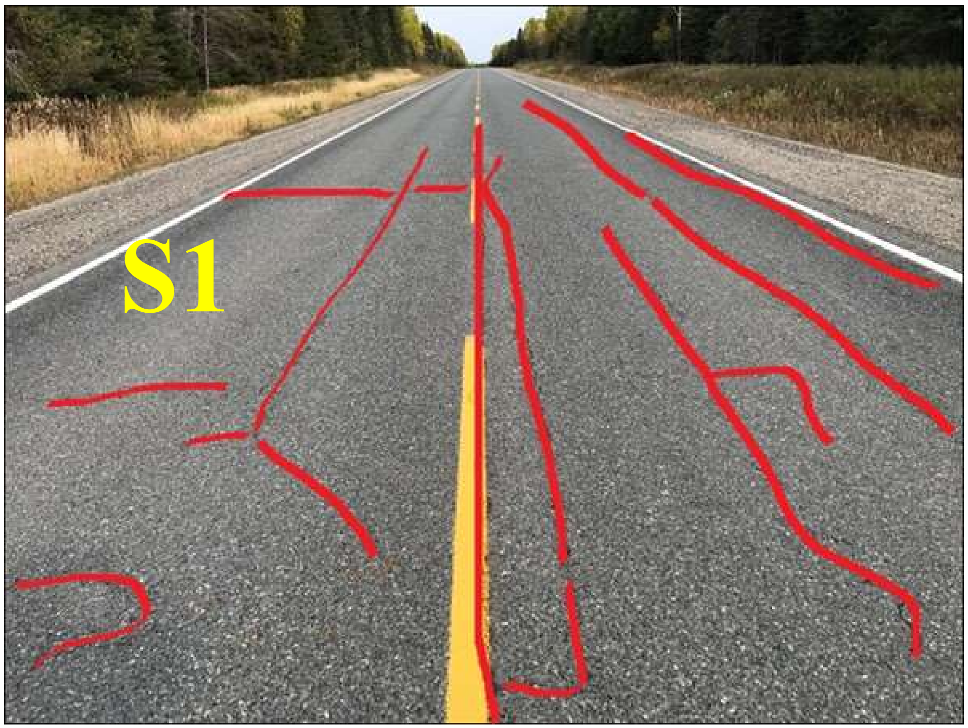
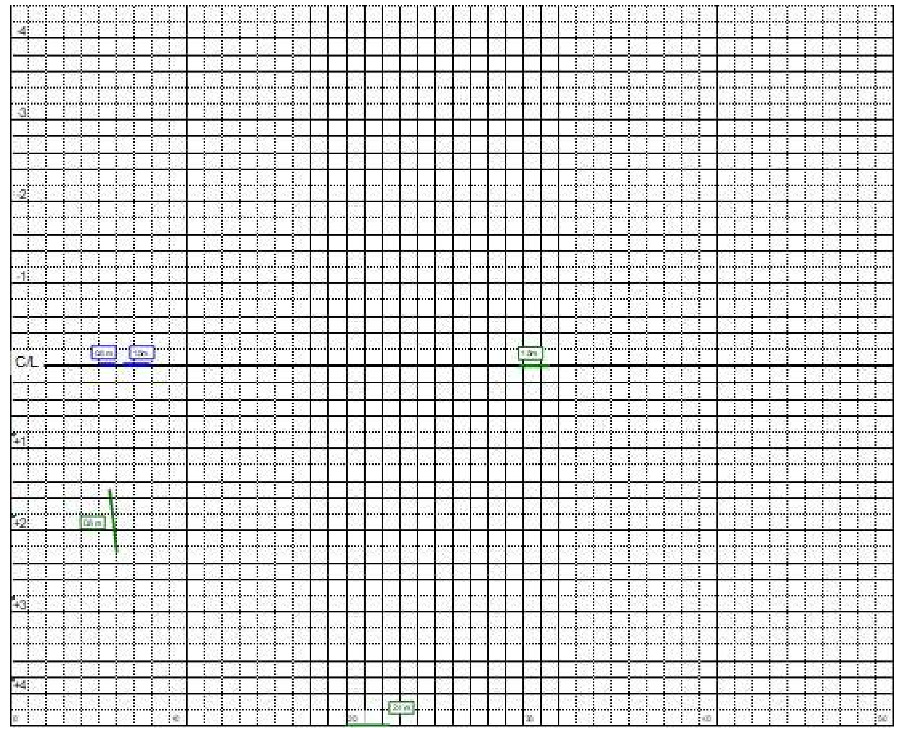
MTO ON-Hwy 655 Sections #1&4

2017

2008

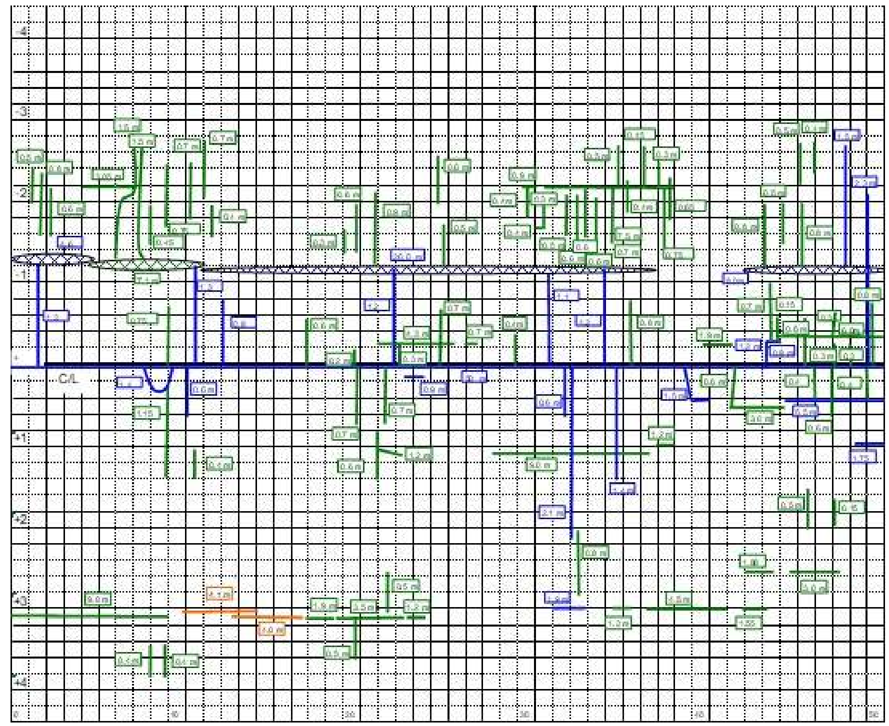




MTO ON-Hwy 655 Sections #1&4

2017

2008



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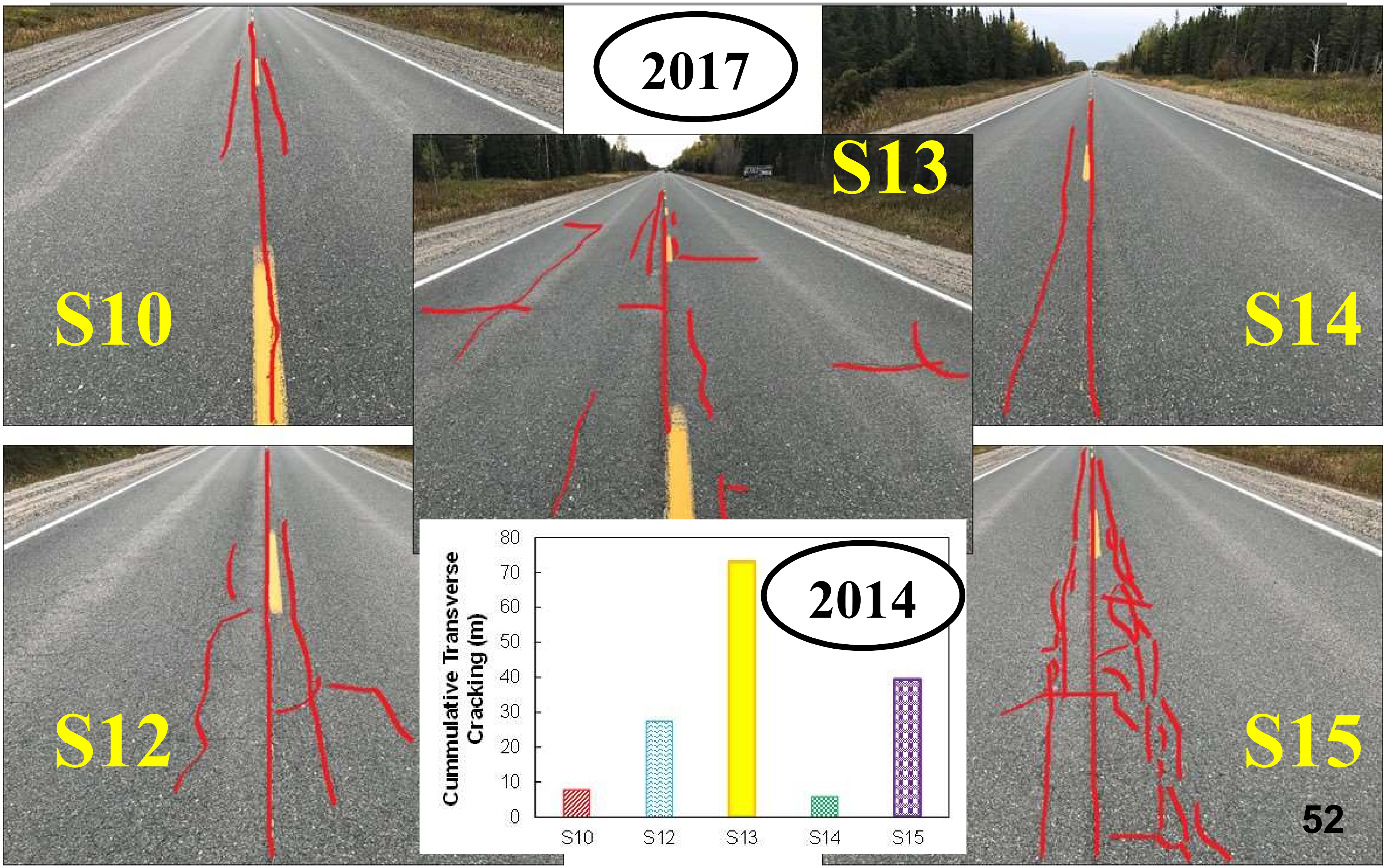
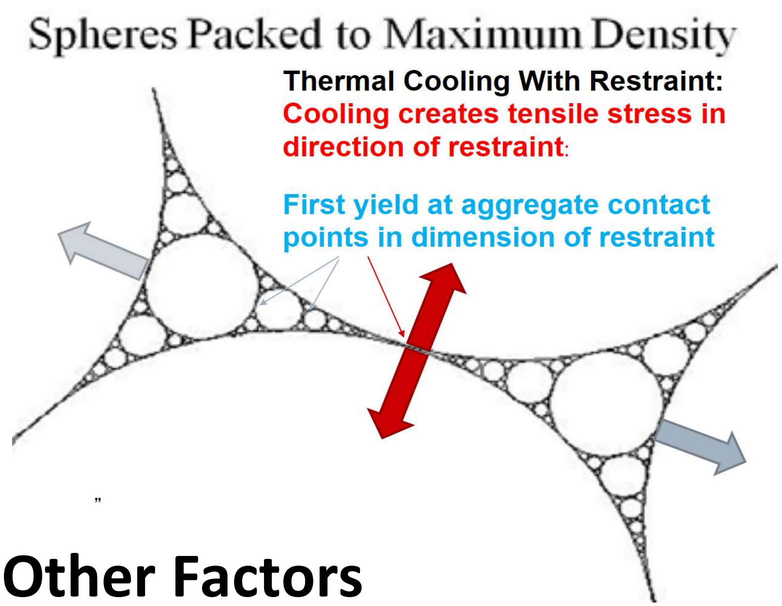
MTO ON-Hwy 655 Sections #10-15



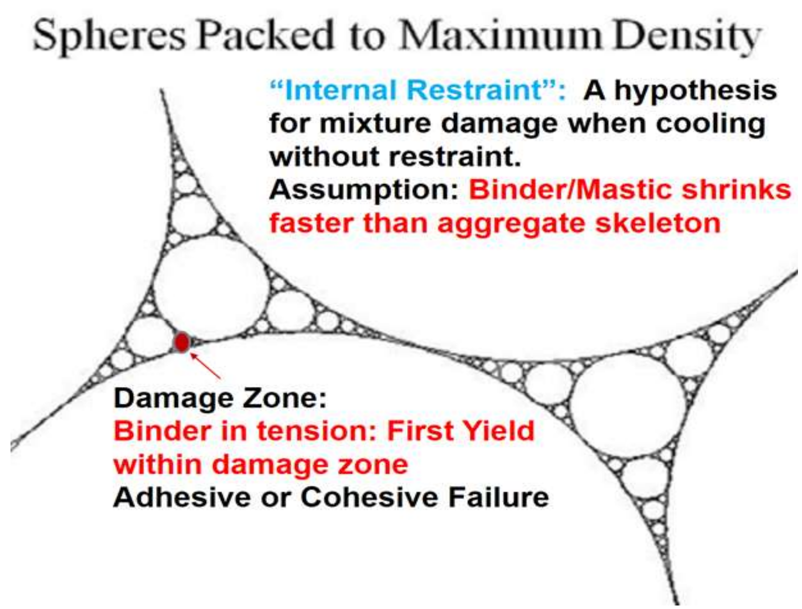
2. Improve the Understanding of Various Damage Mechanisms and Factors Affecting their Severity

- **Internal Restraint Mechanism Hypothesis**

External Mix Restraint
in red or gray directions



Internal Mastic Restraint
within the aggregate structure

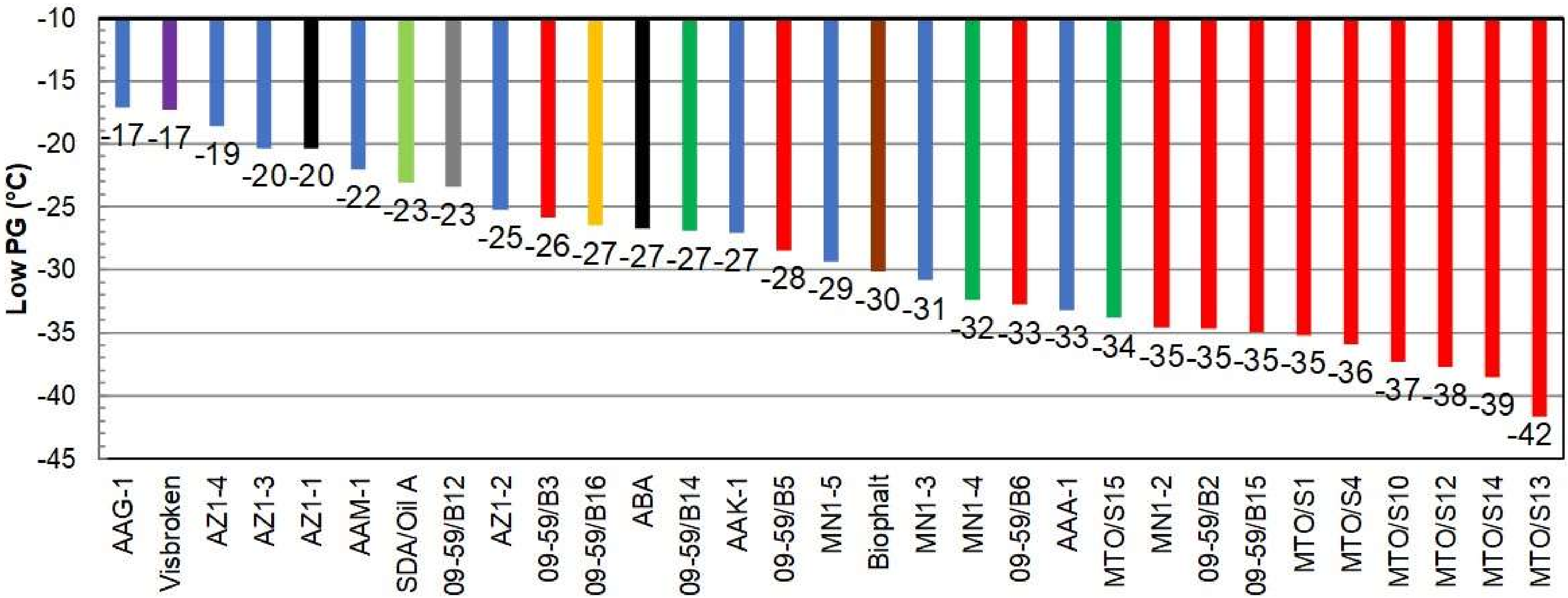


- **Other Factors**
  - **Long-Term Aging Potential**
  - **Physical Hardening**
  - **Healing Potential**

✓ *Confirmed by FEA & Sliver test*
✓ *White Paper, Interim report + AAPT 2019 paper*

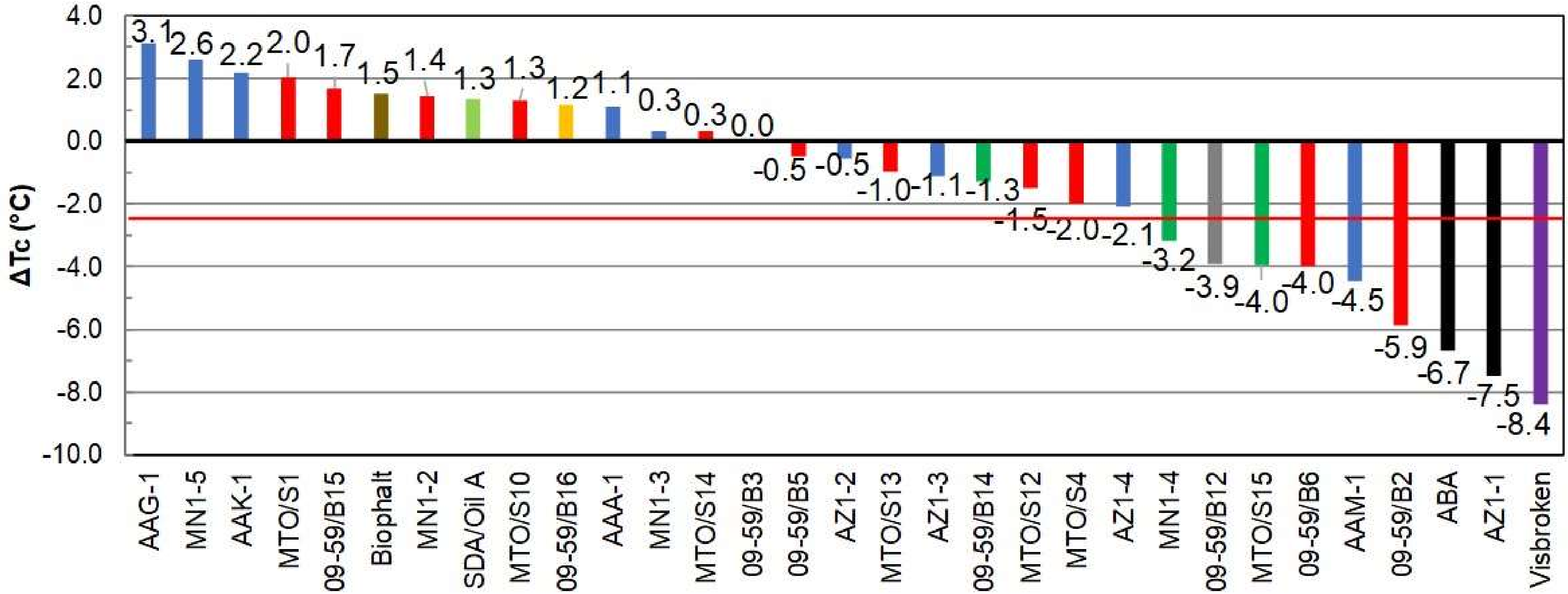
09-60 Binder Database Mapping

- **BBR-Low PG Ranking of 31 Binders after PAV<u>20H</u>-Aging**
  - Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken.



09-60 Binder Database Mapping

- **BBR-ΔT_c Ranking of 31 Binders after PAV20H-Aging**
  - Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken.



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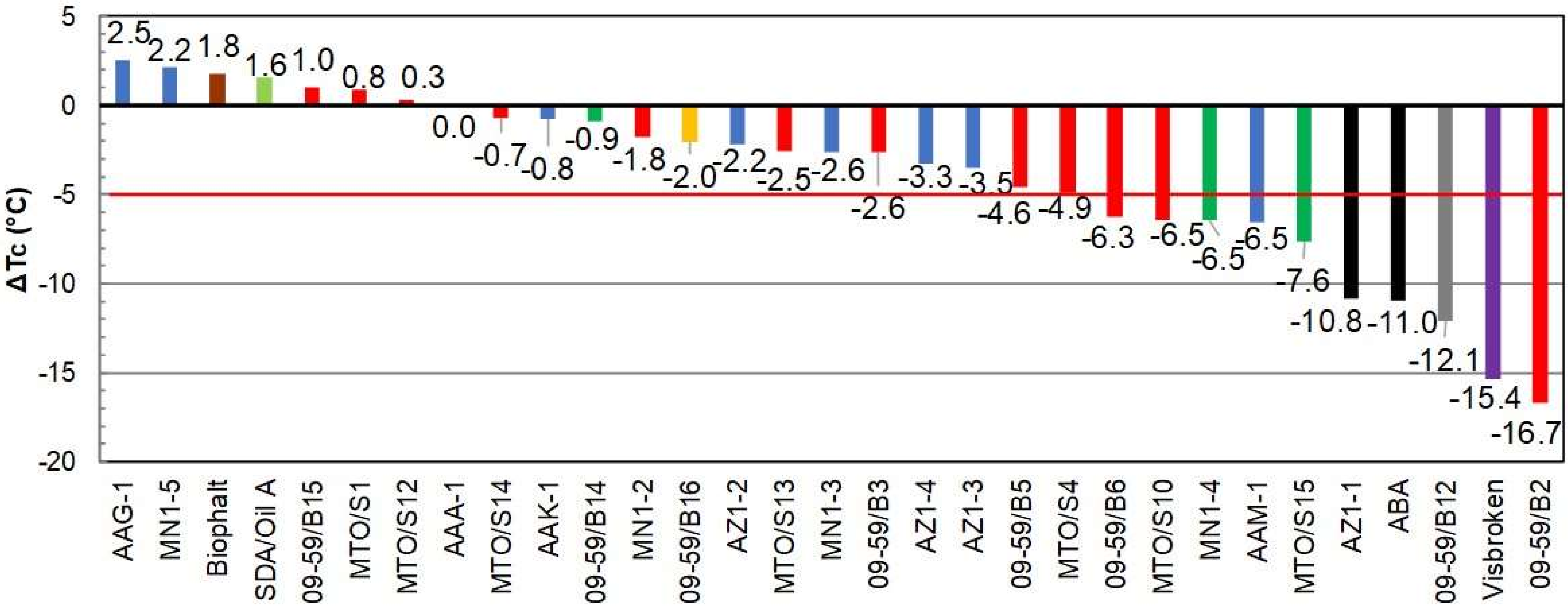
09-60 Binder Database Mapping

- **BBR-ΔT_c Ranking of 31 Binders after PAV40H-Aging**
  - Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken.



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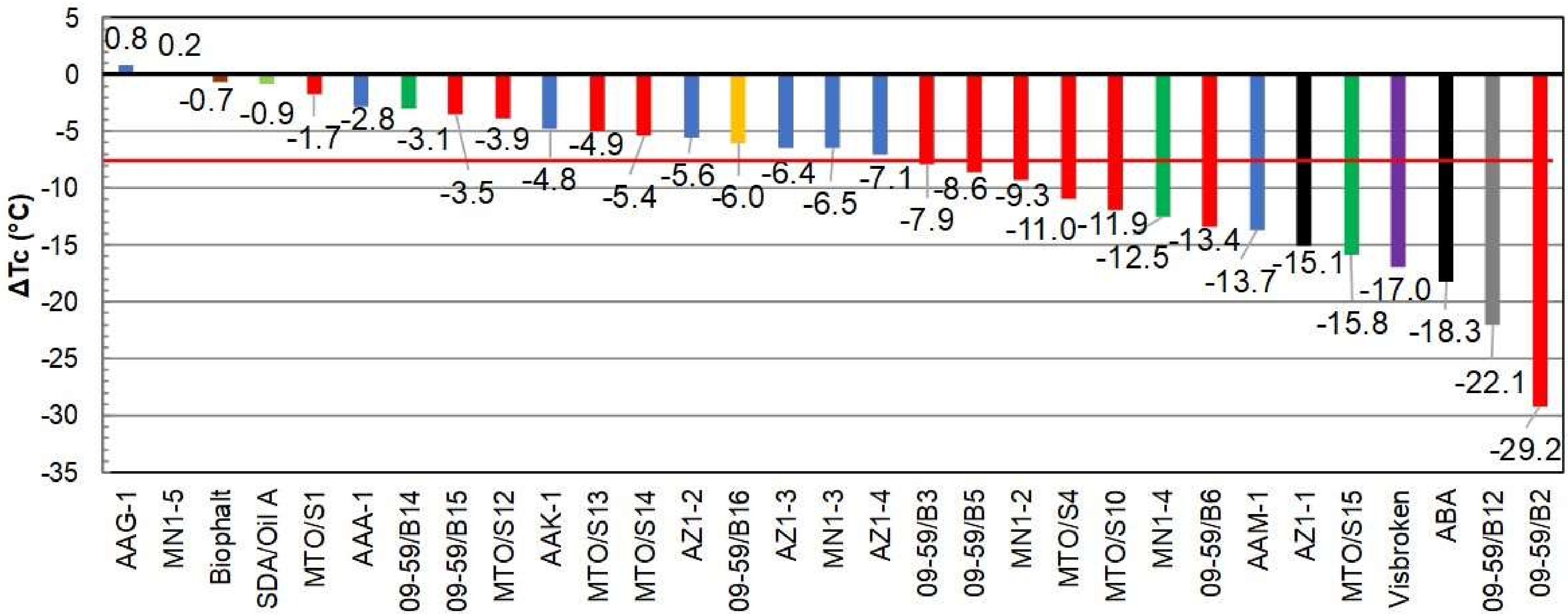
09-60 Binder Database Mapping

- **BBR-ΔT_c Ranking of 31 Binders after PAV40H+PH72H**
  - Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken.

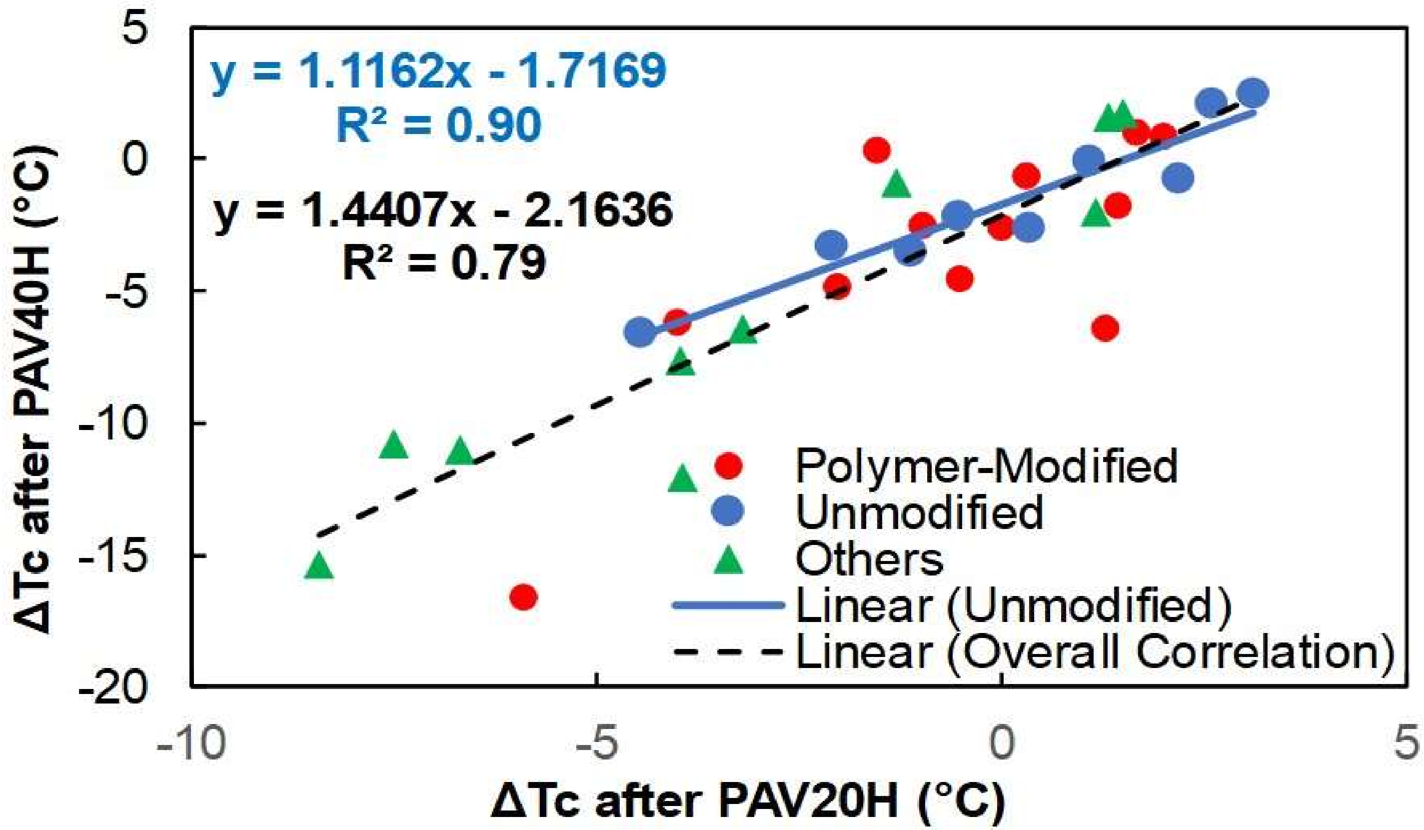


PH72H: 72 hr conditioning at PG+10C

09-60 – Effect of PAV aging

❑ ΔTc Correlations after PAV20H and PAV40H-Aging

➢ Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken



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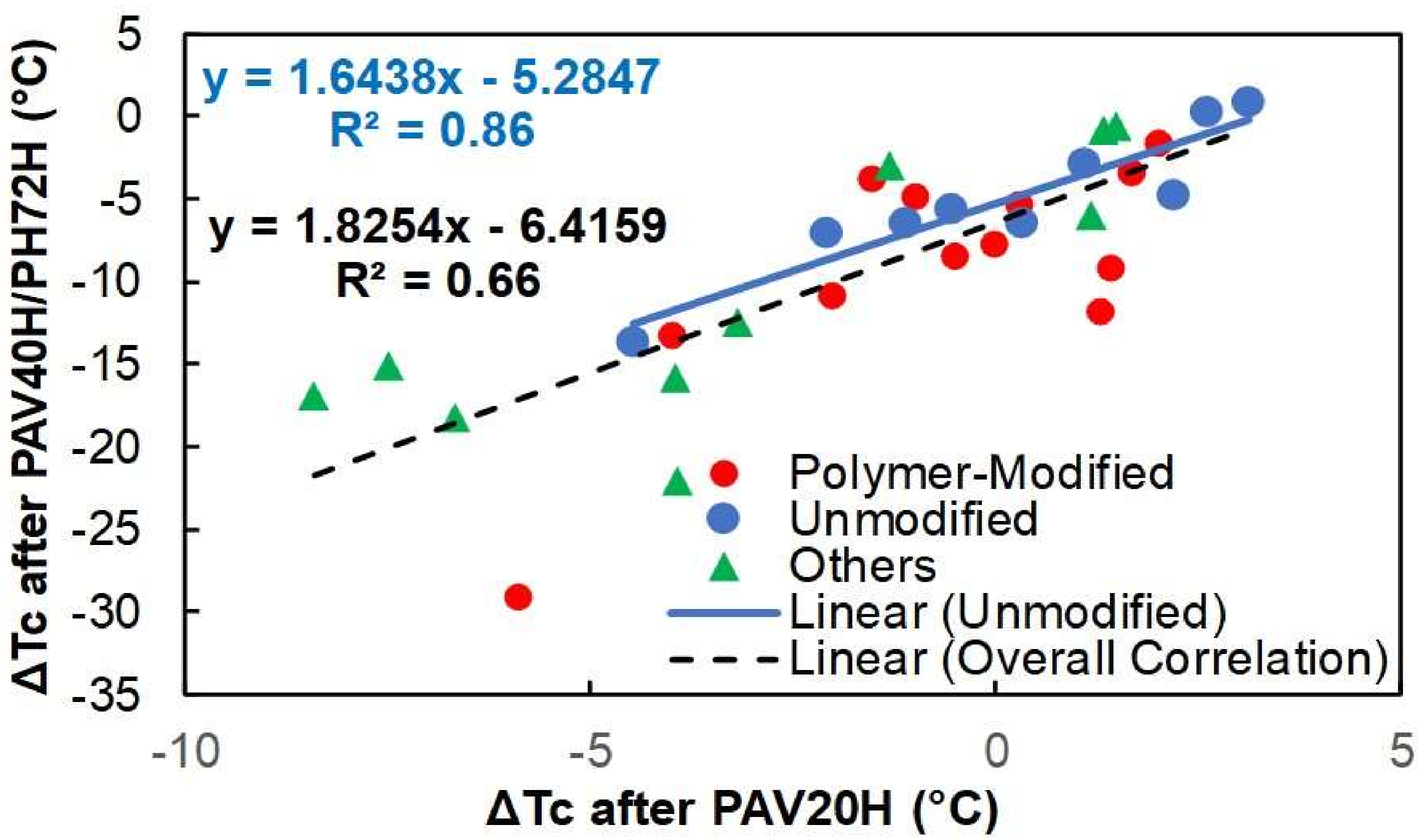
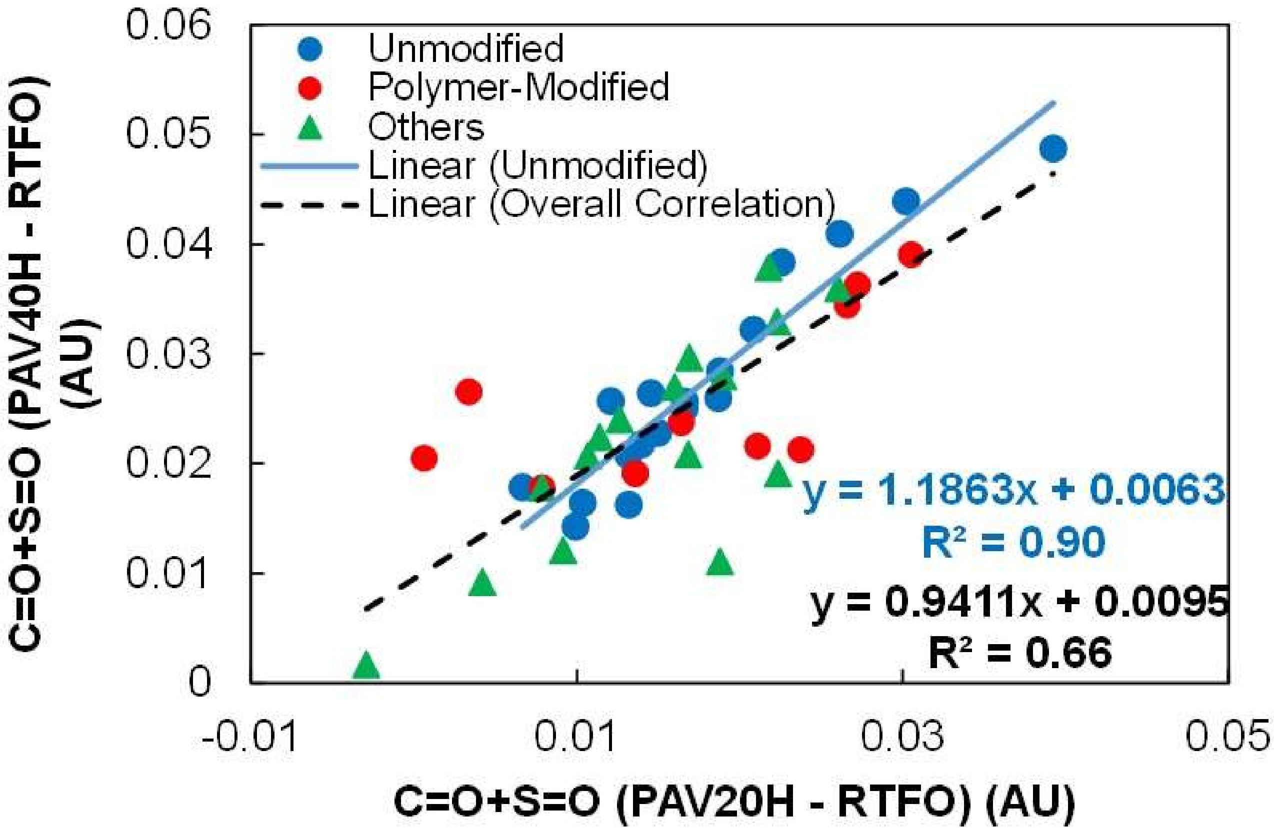
09-60 – Effect of PAV + PH aging

- ΔTc Correlations after PAV20H and PAV40H+PH72H.
  - Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken



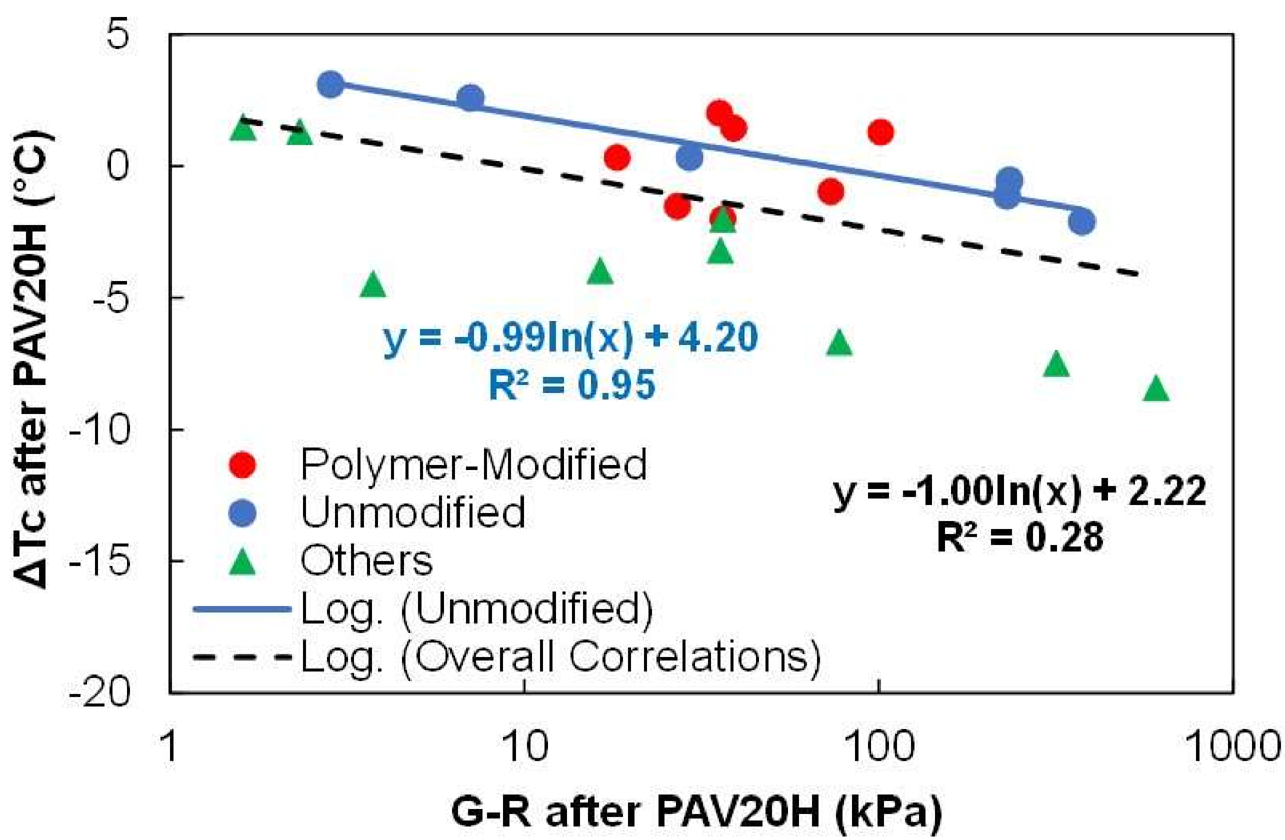
09-60 – Effect of PAV aging on Chemistry

- C=O+S=O Correlations after PAV20H and PAV40H-Aging.
  - Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken



09-60 "Cracking" Parameters

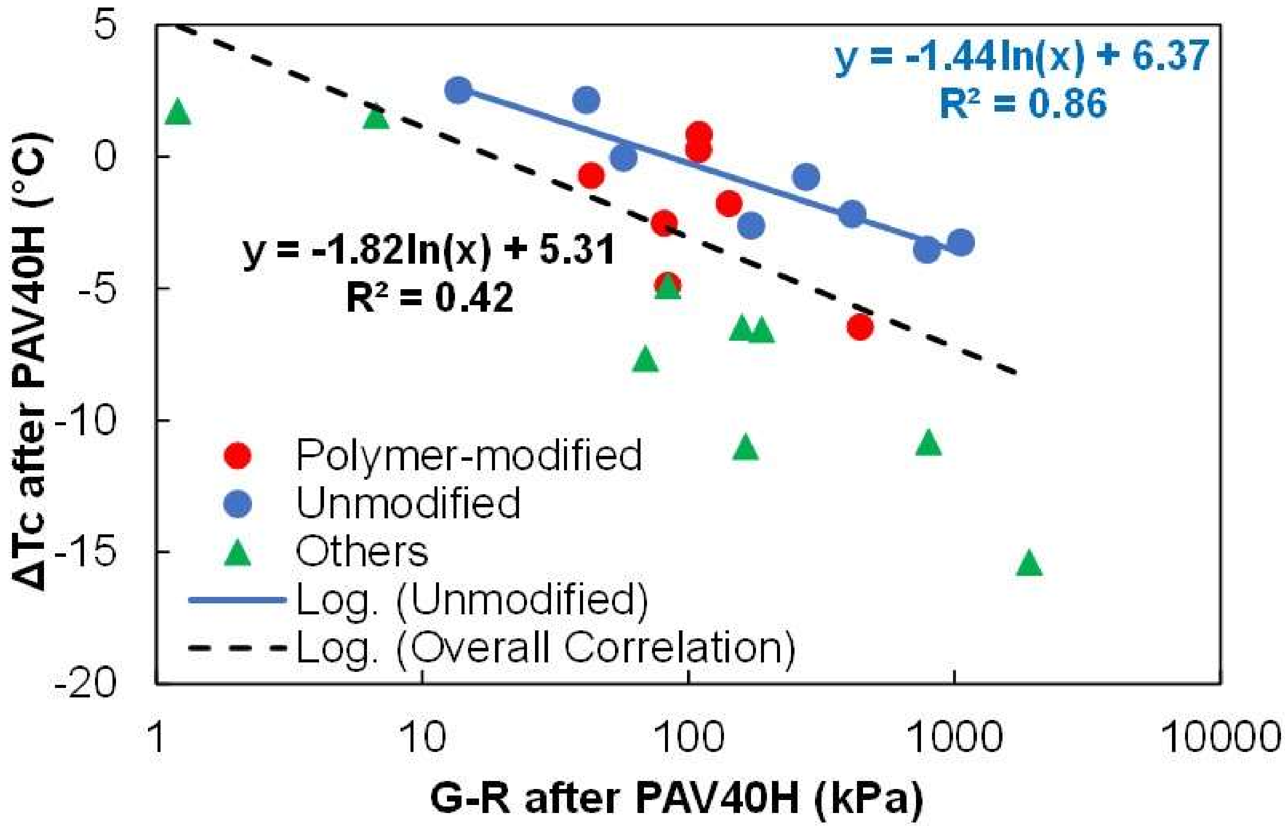
- **G-R and ΔTc Correlations after PAV<u>20H</u>-Aging**
  - **Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken**



G-R and ΔTc are not correlated

09-60 "Cracking" Parameters

- G-R and ΔTc Correlations after PAV40H-Aging
  - Unmodified, Polymer-modified, ReOB-modified, SDA, PPA-modified, Biophalt, Oxidized, Airblown, Visbroken

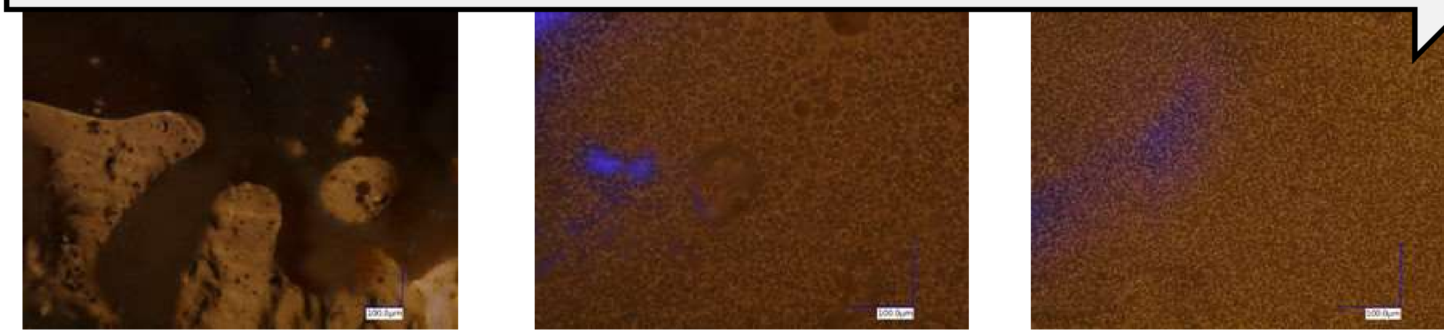


G-R and ΔTc are not correlated

PMA's - Microstructure and ΔTc

- PMA's microstructure: homogeneous or heterogeneous at micron level – captured by Fluorescence Microscopy
  - *Homogenous PMA's often display low ΔTc – why?*

Incompatible – Average – Compatible



  - Multi-phase structure: polymer rich phase and asphaltene rich phase with different ΔTc's (under investigation)
  - Influence of the base binder, the polymer (type, MW and content) and their interactions (compatibility, swelling, reactions…)
- IR microscopy for a more quantitative understanding

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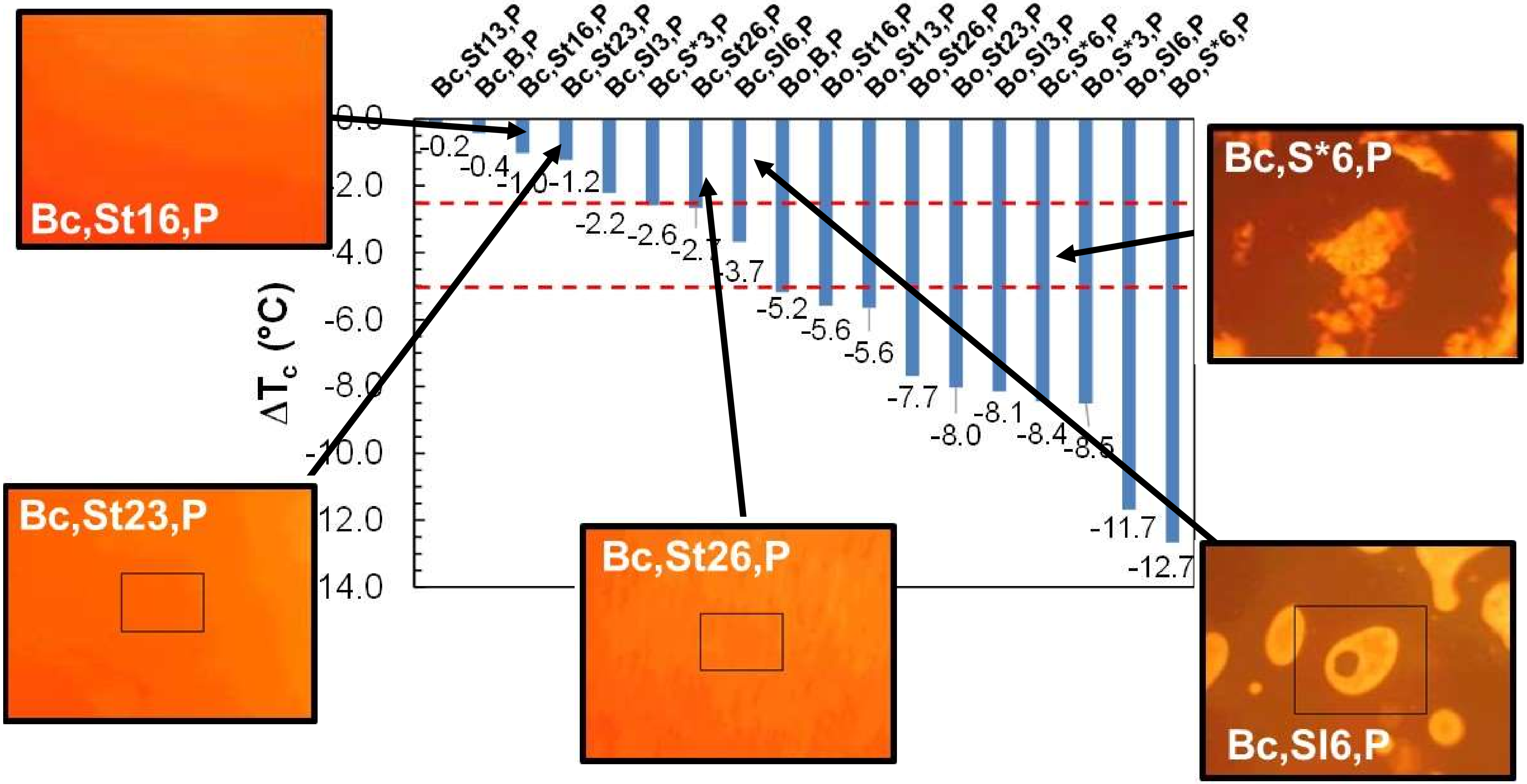
PMA's - Microstructure and ΔTc



- ΔTc for 18 PMA's (SBS's incl. crosslinked) at 3 aging levels (O, RTFO, PAV20)
- Data mined from Durrieu et al, Lapalu et al, Mouillet et al, Planche et al, 2004-2008

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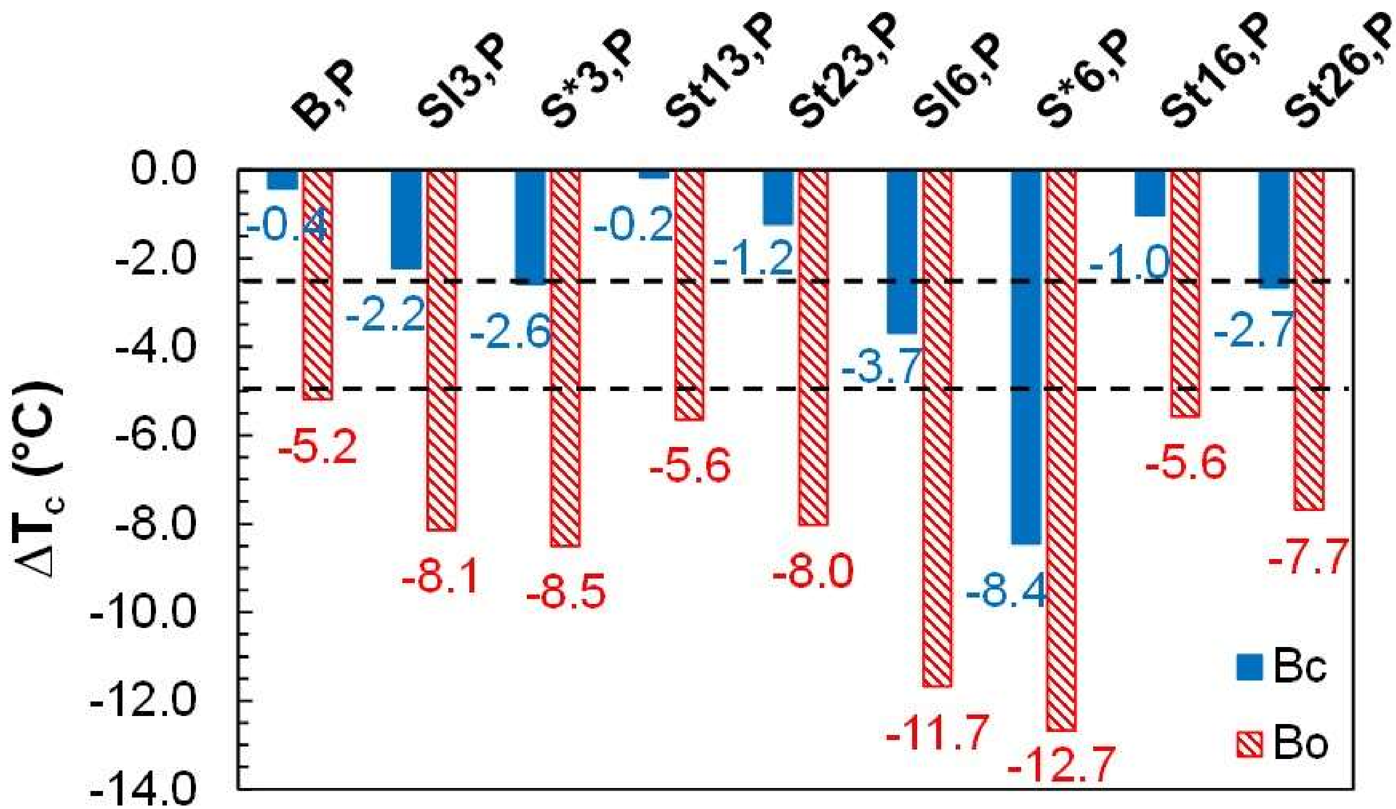
PMA's - Microstructure … and base asphalt and ΔTc



- **2 base asphalts: Bc blue = classical (commercial) – Bo red = oxidizable (lab)**
- ΔTc for 18 PMA's (SBS's incl. crosslinked) at 3 aging levels (O, RTFO, PAV20)
- Data mined from Durrieu et al, Lapalu et al, Mouillet et al, Planche et al, 2004-2008

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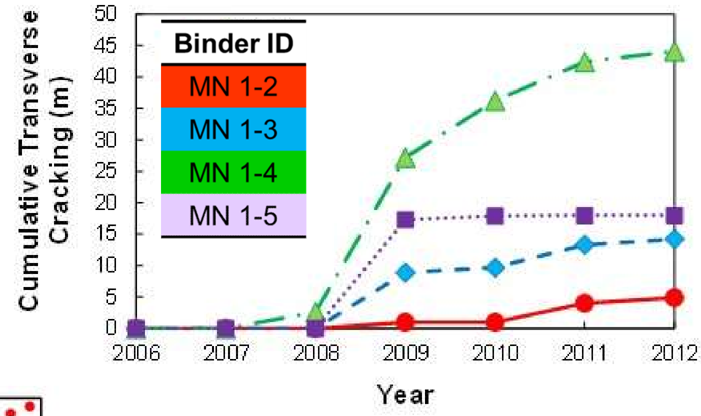
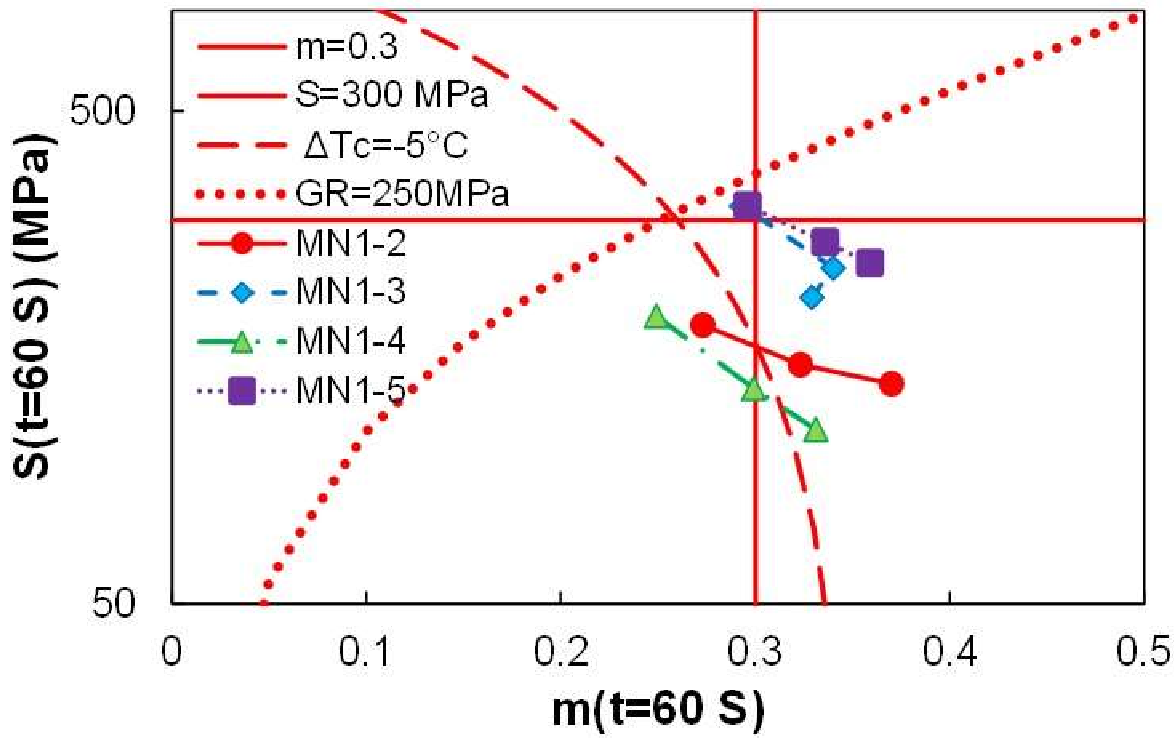
Black Space Analysis of BBR Data

- **Black Space Parameters**
  - **MN Sections (2006)**

(PAV20H, PAV40H, PAV40H/PH72H)





MN1-2: Airblown

MN1-4: REOB

Black Space Analysis of BBR Data

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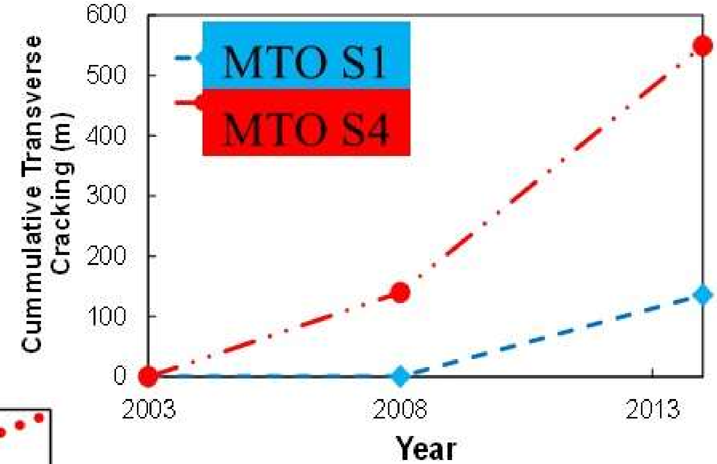
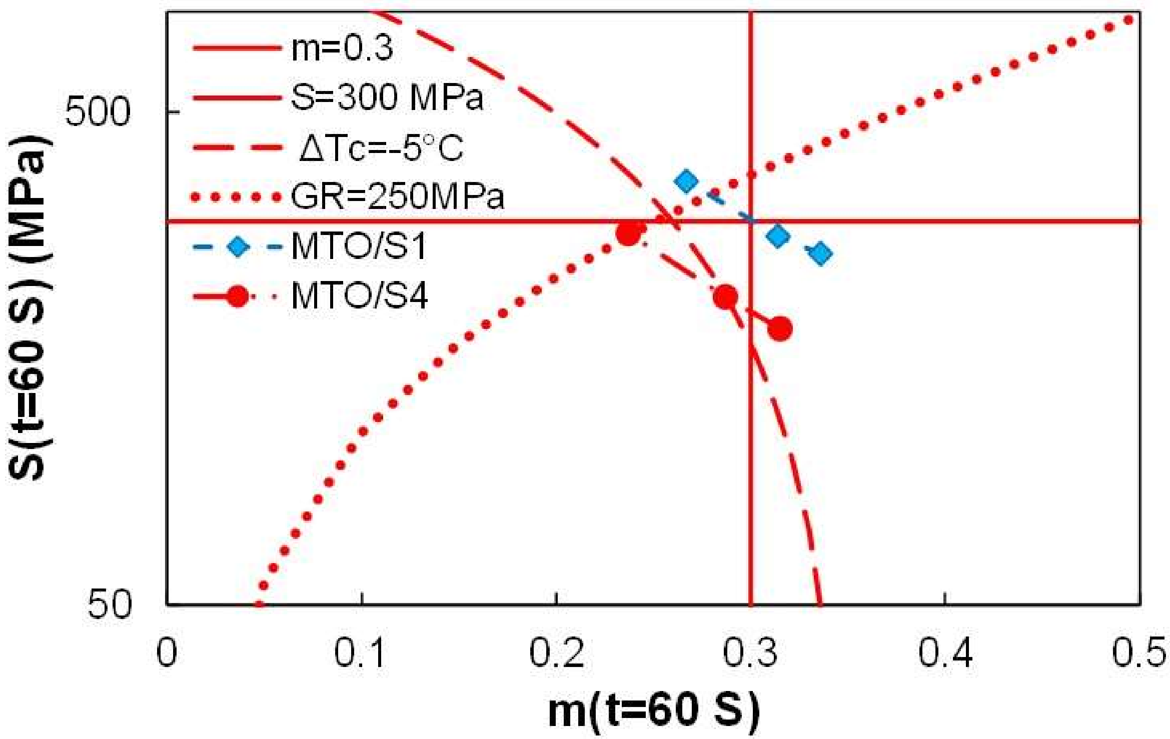
- ❑ **Black Space Parameters**
  - ➢ **MTO Sections (2003)**

(PAV20H, PAV40H, PAV40H/PH72H)





S1: Elvaloy

S4: SBS+REOB

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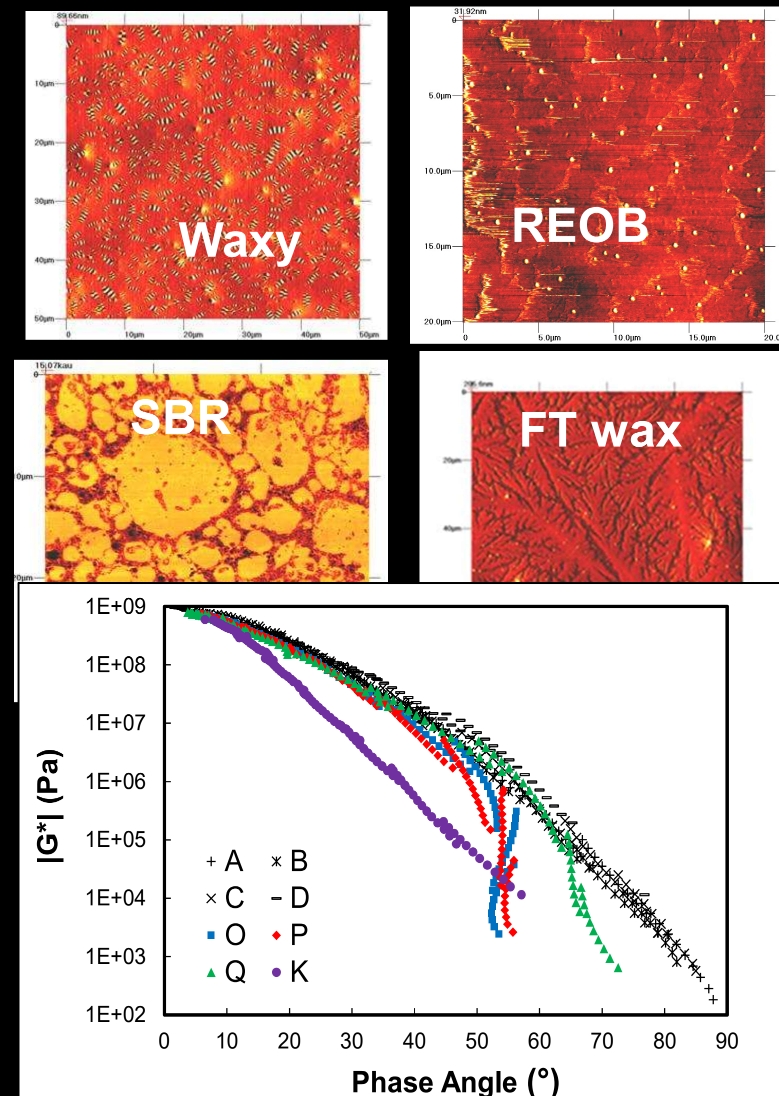
In Progress !

Binder guidelines

- **Unconventional PG Binders**
  - ❑ **Many possibilities**
    - Blends of fracking / heavy crudes
    - Airblown, oxidized blends
    - High RAP / RAS
    - Hard SDA / soft base blends
    - Visbroken residues (IMO 2020)
    - Waxy binders / REOB blends
    - Modified binders
      - Polymers: EVA, SBS, Terpolymers
      - Additives: PPA, wax, biomass…
  - ❑ **Sensitive to aging/cracking**
  - ❑ **“Out of balance” composition – inhomogeneous blends**
  - ❑ **Rheologically complex**
  - ❑ **But: All can be made *suitable* too!**

Complex structure & rheology



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Summary 9-60

- Wide variety of asphalt origins = wide variety of properties
- Rheological parameters appear to rank the bulk of binders against cracking… but not enough (relevant?) for all cases
  - In depth analysis of their meaning is needed and ongoing
  - LVE rheology parameters do not generally capture failure for PMA's with complex morphology. Need for failure strain test?
  - G-R parameter: an improvement over G*.sin δ, but with limitations including binder stiffness (G*) and temp. (climate) dependencies
  - ΔTc: most promising to differentiate binders according to their composition and thermal or aging conditioning.
    - Influenced by asphalt structure – balance asphaltene / maltene
    - Relevance to field cracking propensity is under review for PMA's
- Care with hasty conclusions to avoid "Fort-T syndrome"
  - Clear behavioral trends and correlations for unmodified binders, not true in general for modified binders or complex blends
  - Understanding the trends and outliers need holistic approach

Perspectives 9-60

- Relations Field cracking – Specification parameters
  - Thorough analysis of field cracking data is ongoing to differentiate binder / mix related cracking from construction issues or poor subgrade (field data reports / google maps data as a function of time, climate temperature records…)
  - Review of the relationships of block/thermal/fatigue cracking extent with rheological parameters and possibly failure parameters
  - Impact of binder composition using a holistic approach
    - Understand outliers
    - Establish qualitative composition guidelines (under 09-60)
- 9-60 RECOMMENDATIONS FOR NEW SPECS: END OF 2019
  - Final report draft: September 2019
  - Discussions with Panel
- Presentations to stakeholders in 2020
  - Webinars, TRB 2020 lectern session (?)

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Outline

- WRI – An overview
- Context: Asphalt Variability - The "New Normal"
- The WRI-Fingerprinting Approach to Cope with the New Normal
- Case study: NCHRP 9-60
  - Objectives
  - Approach
  - Examples of Findings
- **Summary / Perspectives**

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Summary

- Asphalt supply chain has changed since SHRP
  - Crudes, refining processes, blends, additives, recycling
- Superpave is not enough to assess the changes
- Rheological assessment beyond (current) Superpave can give important insights
  - Black space, ΔTc, MSCR, G-R, R-value…
  - T_{IR} (Intermediate Region Temperature Range)
    - Temperature difference: Crossover (Tx) - Glass transition (Tg), both temperatures determined by DSR
    - Tg correlated to Tc(S) and Tx to Tc(m)
    - Based on fundamental material properties, represents S- and m-controlled binders, relates to ΔTc, cracking, and healing propensities
- Most production/formulation changes have their own chemical signature and rheological features

Summary - Perspectives

- Fingerprinting is feasible & helps cope with changes
  - ✓ Large and relevant binder database = key
  - ✓ Association of analytical techniques to assess differences
  - ✓ Useful for suppliers, users, owners for formulation and control
- New relevant tools - SAR-AD™ 2G coming into play
  - Holistic analysis combining various conditions, detectors
  - Qualitative and quantitative data - allow correlations + predictions
  - Can be specifically designed for given formulation / application
- Machine learning to tie Chemistry to Structure to Thermal to Rheology and ultimately to Performance

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Acknowledgements

- **FHWA / NCHRP**
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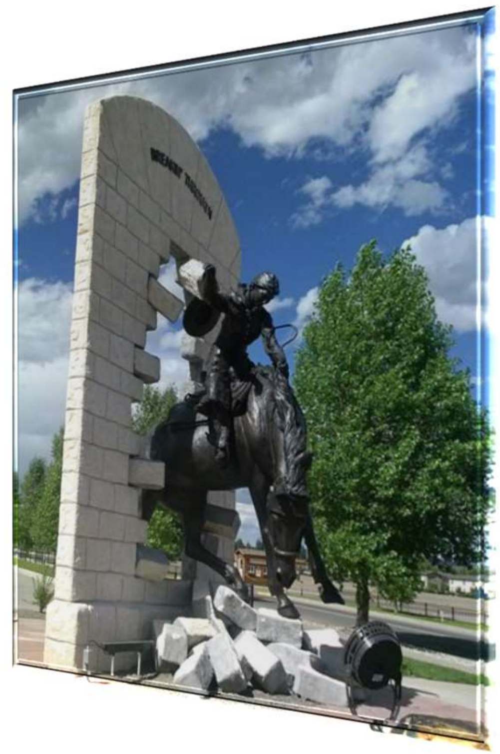
  - **Asphalt Research Consortium**
  - **9-60 Panel and Team**
- **WRI Industry Partners**
  - **WRI-Asphalt Industry Research Consortium**
  - **Paving and Roofing stakeholders**
- **WRI-APT team**
- **Note:**
  - **AIRC outcomes presented in/at**
    - **TRB / AMAP / PARC 2018**
    - **TRB and AMAP 2019**
    - **ACS Energy & Fuel Journal 2019**
  - **NCHRP 9-60 outcomes presented at**
    - **AAPT 2019**
- ***Stay tuned!***



Please join us to PARC 2019!

56th Petersen Asphalt Research Conference

July 14-17, 2019
Laramie, Wyoming

Thank You!

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