Intermediate Temperature Fracture Properties of Asphalt Mixtures Containing RAS: Impact of Recycling Agents

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FHWA Asphalt Binder Expert Task Group
Fall River, MA
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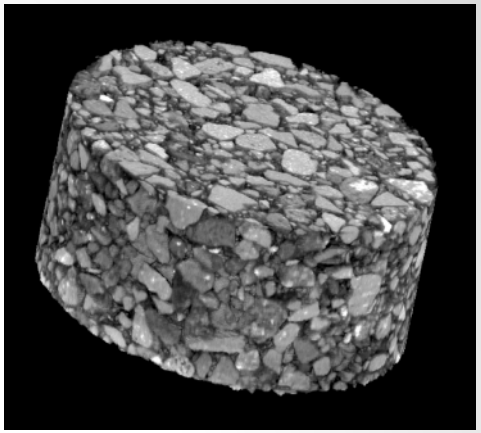
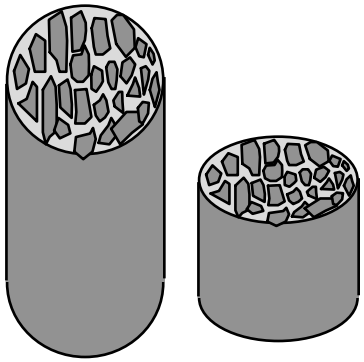
The Story!

- Background
- Objective/Scope
- Methodology
  - Mixture Experiment
    - Fracture Properties at Intermediate Temperature
  - Binder Experiment
    - Binder Fractionation by MW
- Results
- Summary

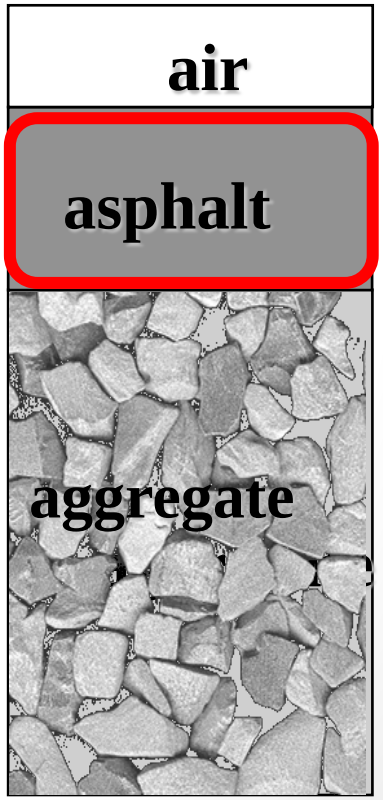
Asphalt Mixture Design



- Optimum asphalt cement content
  - Asphalt Binder from RAS and/or RAP
  - Availability
  - Quality



VOLUME **MASS**

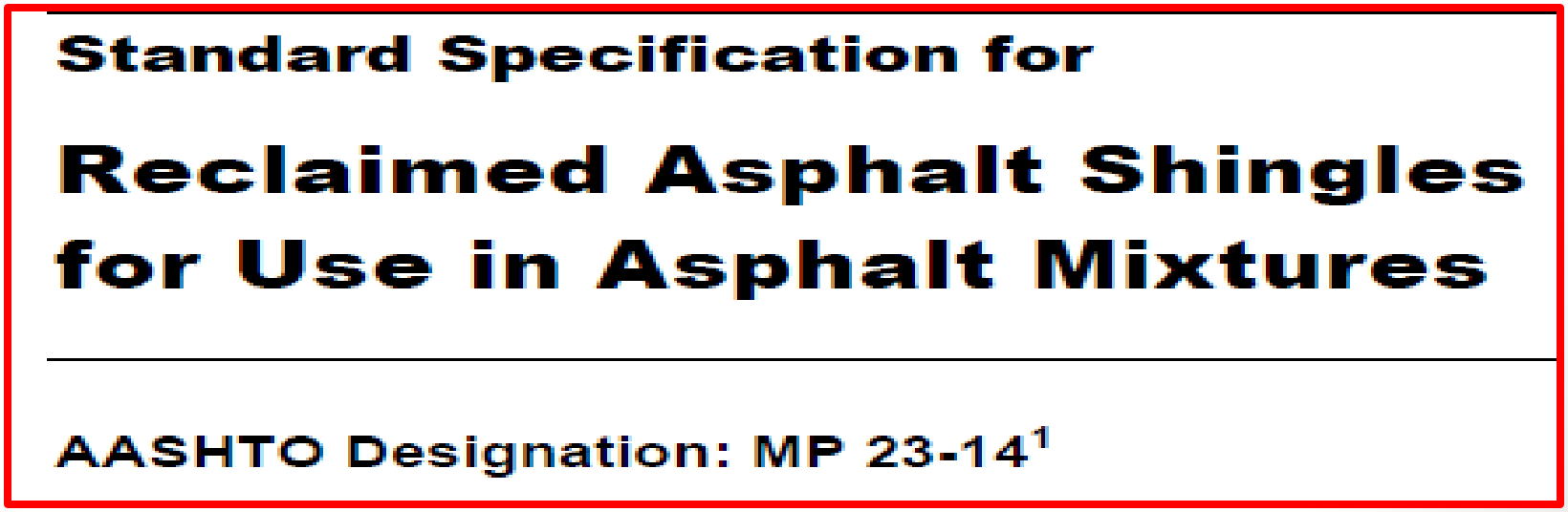


Total Volume

Total Mass

Use of RAS in Asphalt Mixtures

- **AASHTO MP 15-09 → AASHTO MP 23-14**
  - ***Use of RAS as an Additive in Hot Mix Asphalt (Asphalt)***
- **Provides Standard definitions for RAS**
- **Process RAS**
  - **100% passing 12.5-mm sieve**
  - **Allows blending of RAS with fine aggregate**
    - **Prevent agglomeration**
  - **Addresses deleterious materials**


Standard Specification for

Reclaimed Asphalt Shingles for Use in Asphalt Mixtures

AASHTO Designation: MP 23-14[1]

How to incorporate RAS in Asphalt Mixtures

- **AASHTO PP53 → AASHTO PP 78-14**
  - ***Standard Practice for Design Considerations When Using RAS in Asphalt Mixtures***
- **Design Considerations When Using RAS in Asphalt Mixtures**
- **Determining the Shingle Aggregate Gradation and Specific Gravity**
- **Determining Adjustment to the New Asphalt Binder Grade**

Note 6—The RAS asphalt binder availability factor is assumed to range from 0.70 to 0.85 for this practice. Additional research is required to define the interaction of asphalt binder from RAS.

Standard Practice for

Design Considerations When Using Reclaimed Asphalt Shingles (RAS) in Asphalt Mixtures

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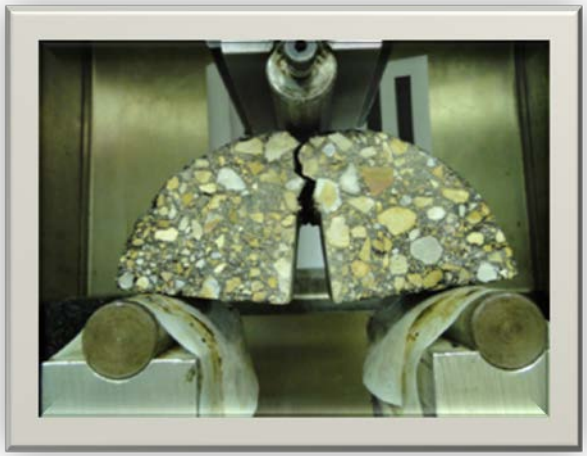
AASHTO Designation: PP 78-14[1]

Objective

- **Laboratory Performance at intermediate temperature**
  - **mixtures containing RAS and/or RAP**
  - **Effect of recycling agents (RAs)**

Fatigue
Cracking



Scope

- 12.5 mm Asphalt Mixture
- RAS: Post-Consumer
- Binder: PG 70-22M

Mix ID	Mix Code	RAP	RAS	Recycling Agent
Mix 1	70CO	0	0	None
Mix 2	70PG5P	0	5	None
Mix 3	52PG5P-RA 1	0	5	PG 52-28
Mix 4	70PG5P-RA 2	0	5	5% V. D. O.
Mix 5	70PG5P-RA 3	0	5	12% N.O.
Mix 6	70PG5P-RA 4	0	5	20% S.A.
Mix 7	70PG5P15RAP-RA 2	15	5	(0.75% + 5%) V. D. O.
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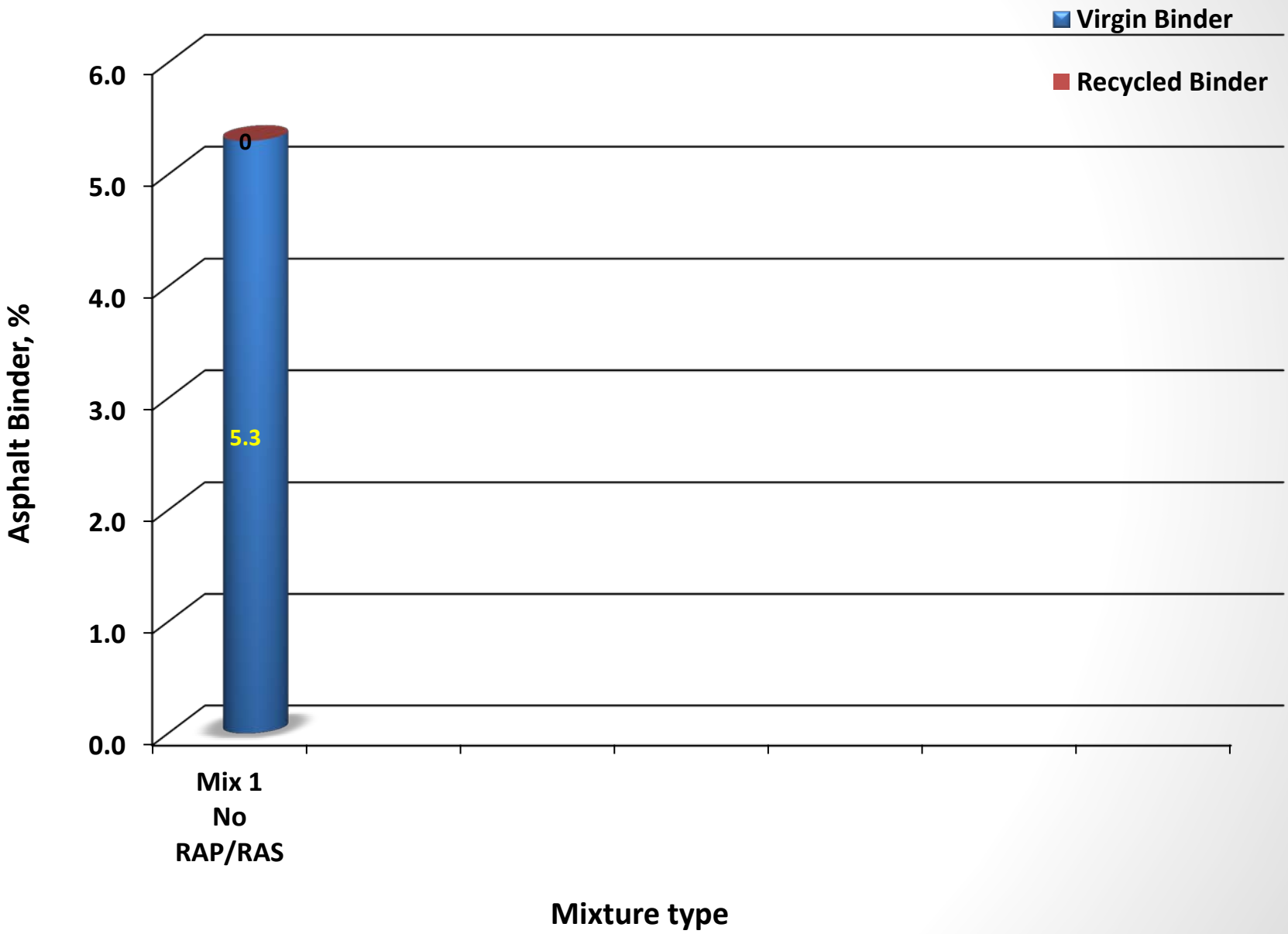
Design Consideration – OAC=5.3%

air

asphalt

Mix 1 = 70CO

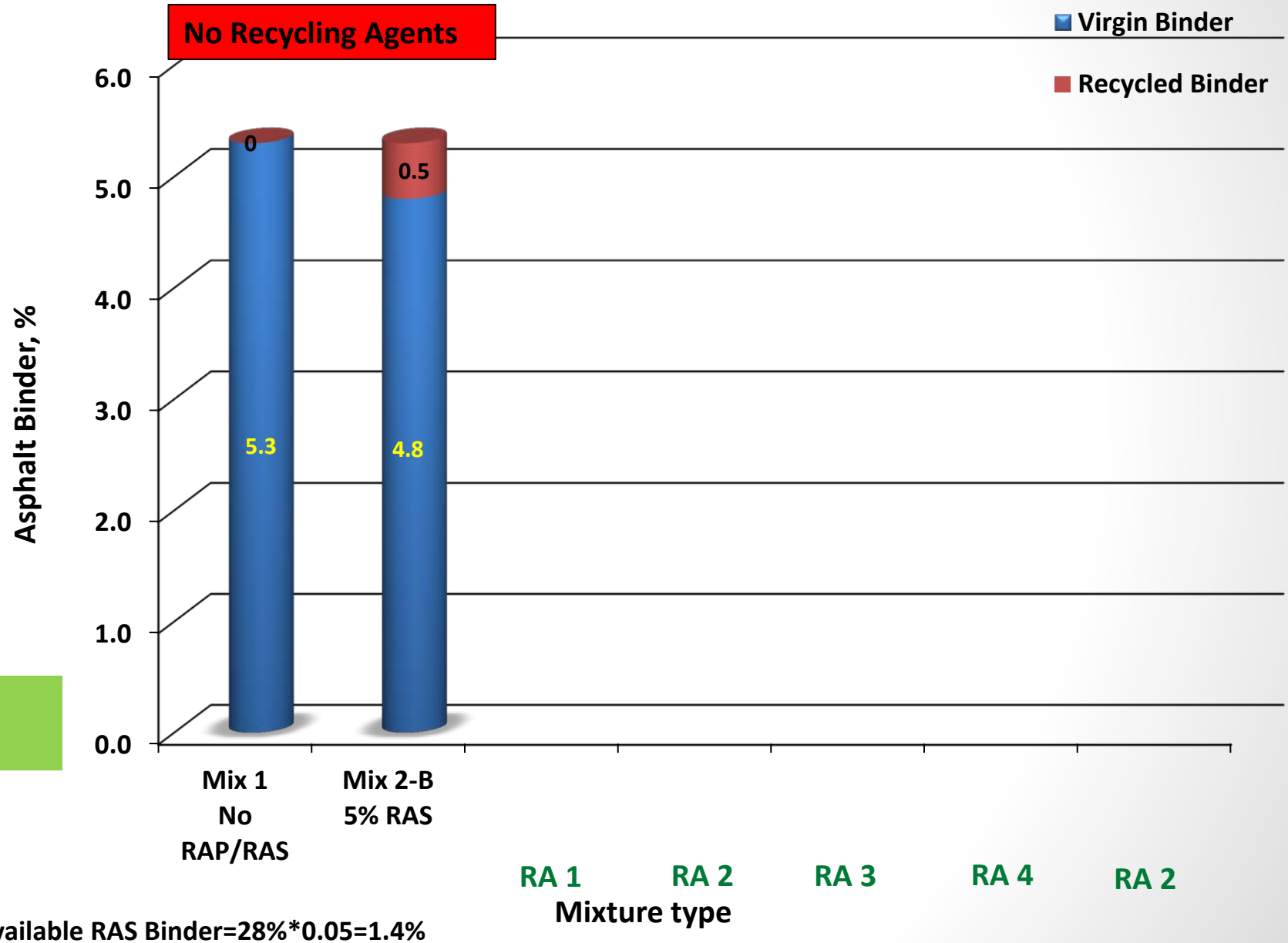


Design Consideration – OAC=5.3%

air

asphalt

Mix 1 = 70CO
Mix 2 = 70PG5P



Available RAS Binder=28%*0.05=1.4%

Mixture Design Concerns

RAS Type	%RAS Total AC Content	%RAS in Mix Design	%RAS AC Binder Available
PCWS	28.6	5.0	1.4

- **Classes of Recycling Agents**

REJUVENATING AGENTS	SOFTENING AGENTS
Lube Extracts	Lube Stock
Extender Oils (aromatic oils)	Lubricating or Crankcase Oil
Anti-Stripping Agent	REOB (RA-5)
Naphthenic Oil (RA-3)	Asphalt Flux Oils
Vegetable Derived Oils (RA-2)	Soft Asphalt Binders (RA-1)

- **Purpose of Recycling Agents**
  - Softening Agents
    - lower the viscosity of the ***aged binder***
  - Rejuvenators
    - help restore physical and chemical properties of ***aged binder***
    - contain a high proportion of maltene constituents

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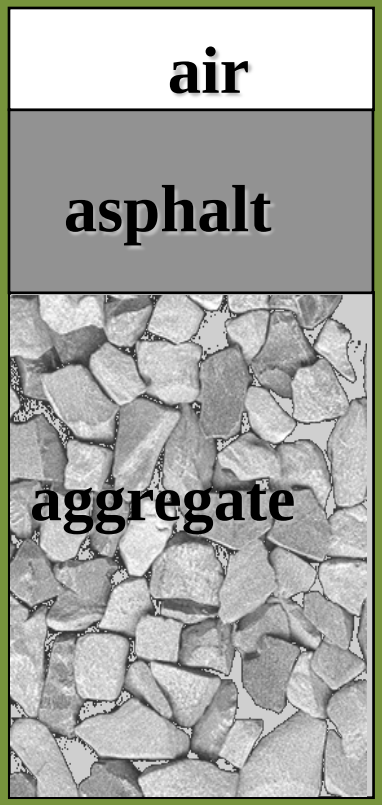
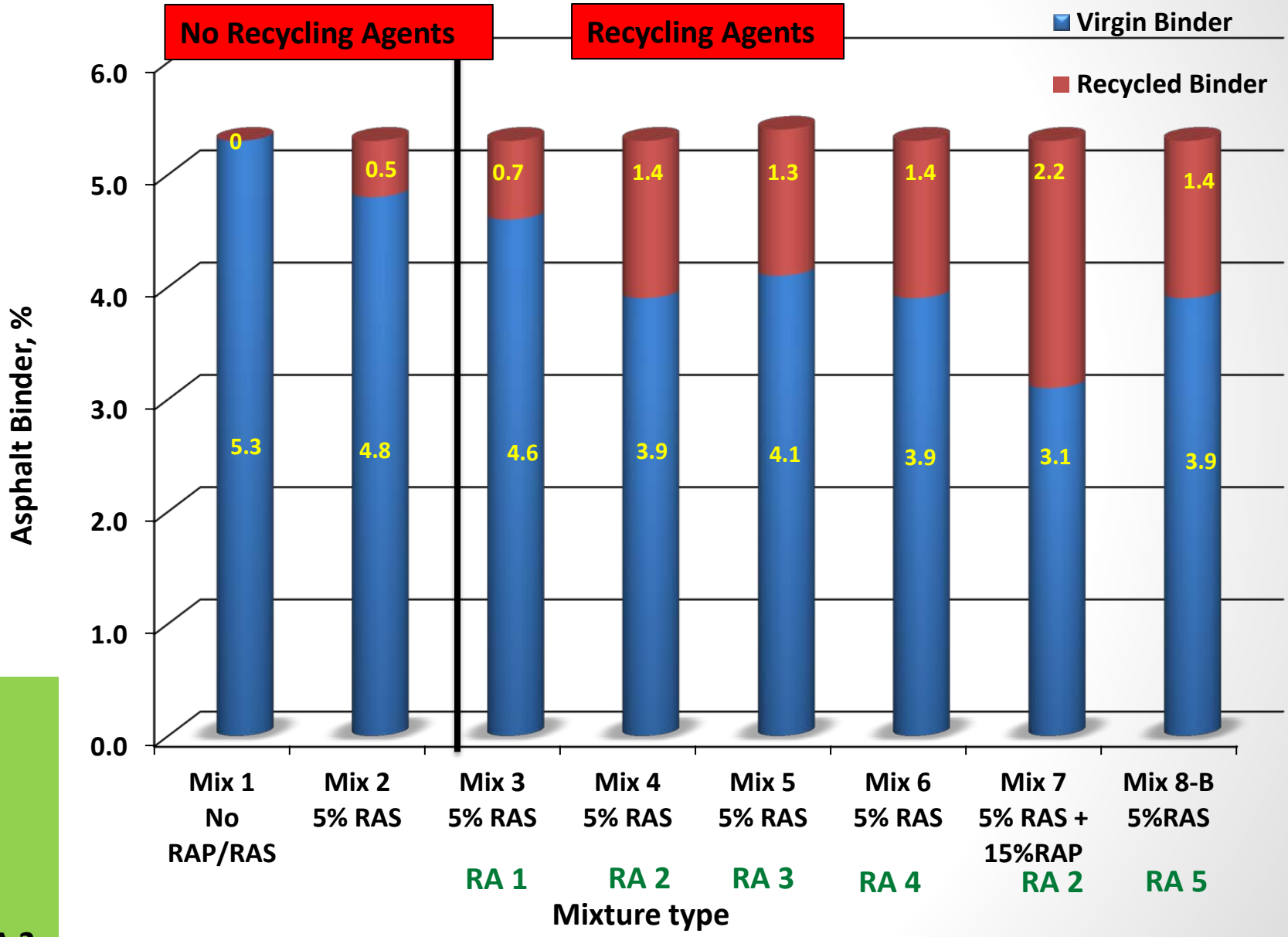
REJUVENATING AGENTS	SOFTENING AGENTS
Lube Extracts	Lube Stock
Extender Oils (aromatic oils)	Lubricating or Crankcase Oil
Anti-Stripping Agent	REOB – RA 5
Naphthenic Oil (NO) – RA 3	Asphalt Flux Oils – RA 4
Vegetable Derived Oils (VDO) – RA 2	Soft Asphalt Binders – RA 1

- **Purpose of Recycling Agents**
  - Softening Agents
    - lower the viscosity of the ***aged binder***
  - Rejuvenators
    - help restore physical and chemical properties of ***aged binder***
    - contain a high proportion of maltene constituents

Design Consideration – OAC=5.3%





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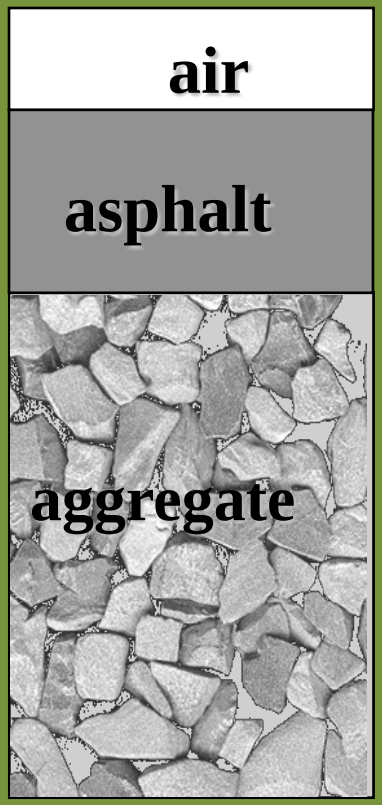
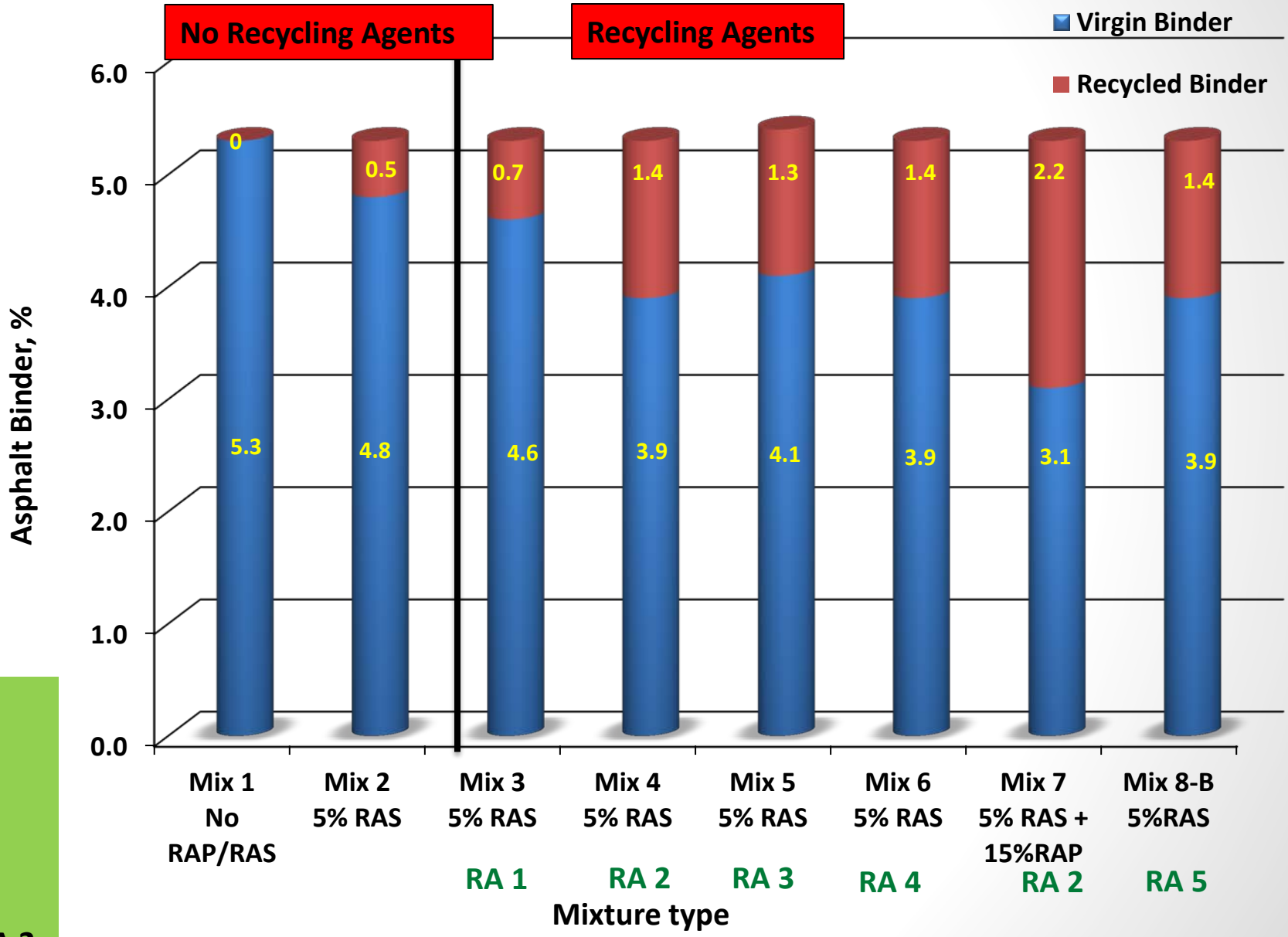
Design Consideration – OAC=5.3%





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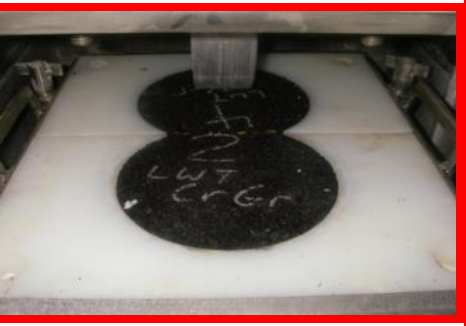
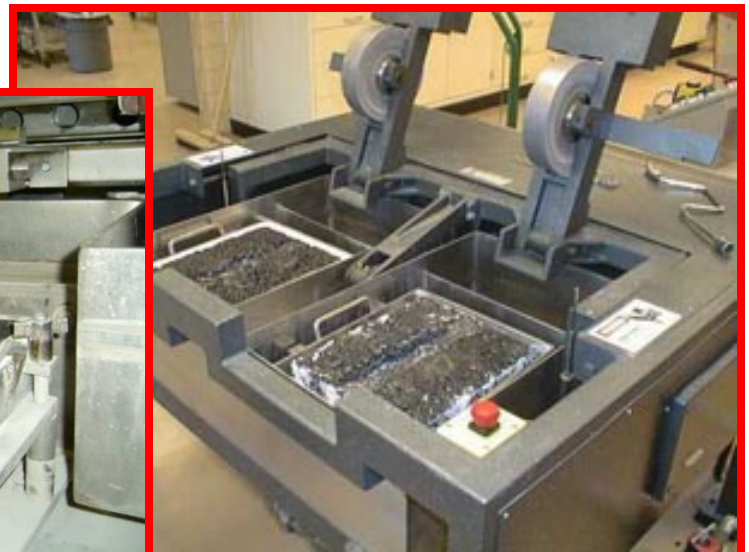
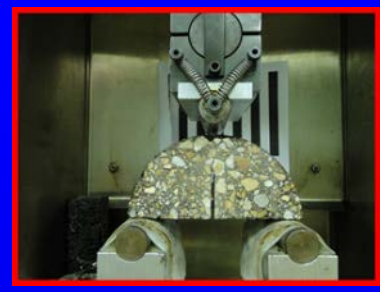
Louisiana Balanced Asphalt Mixture Design

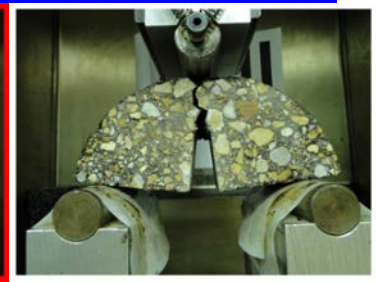
- **High temperature Performance**
  - **Loaded Wheel Tracking Test**
  - **Rutting**
- **Intermediate temperature Performance**
  - **Semi Circular Bend Test**
  - **Cracking**



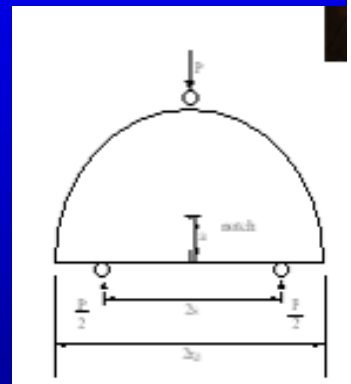


Semi Circular Bend (SCB) Test

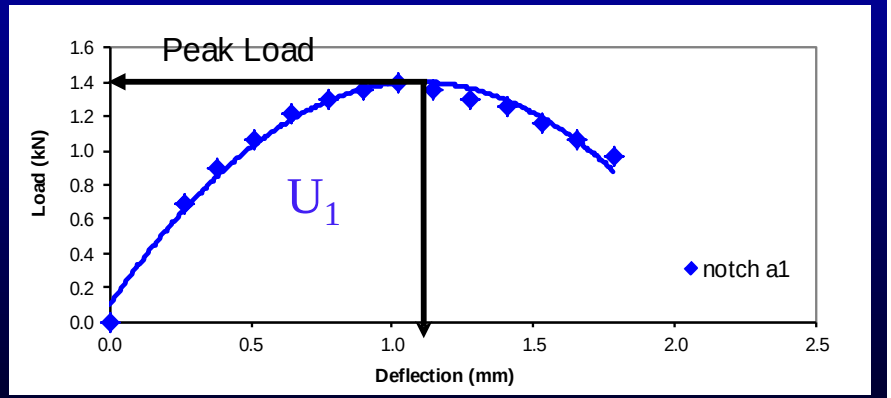




- Fracture mechanics
- Temperature: 25°C
- Half-circular Specimen
  - Laboratory prepared
  - Field core
  - 150mm diameter X 57mm thickness
  - simply-supported and loaded at mid-point
- Notch controls path of crack propagation
  - 25.4-, 31.8-, and 38.0-mm



- Aging: 5 days, 85°C
- Loading type
  - Monotonic
  - 0.5 mm/min
  - To failure

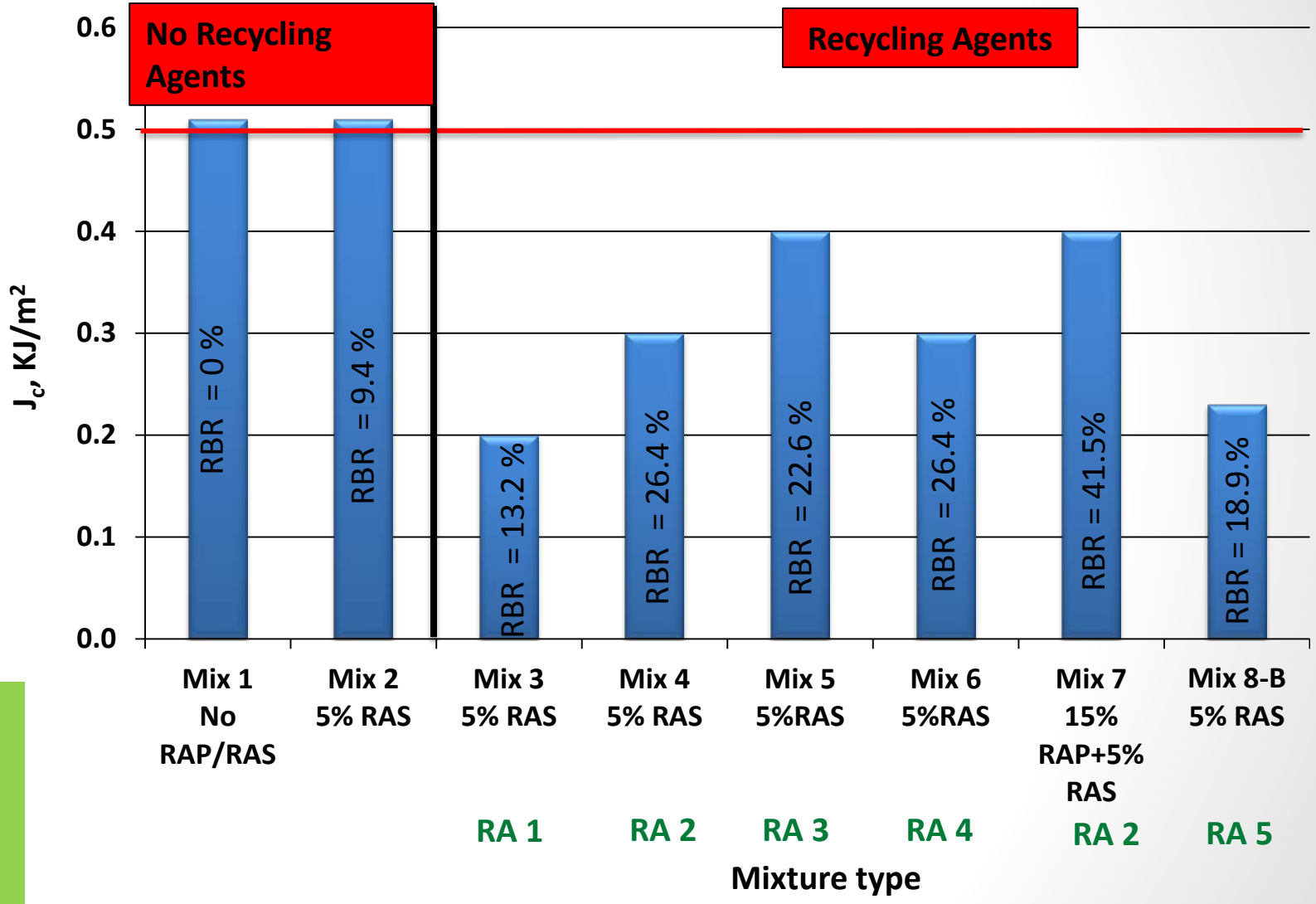


- Record Load and Vertical Deformation
- Compute Critical Strain Energy: Jc

Results

Semi-Circular Bend Test Results, 25°C

RAP and/or RAS



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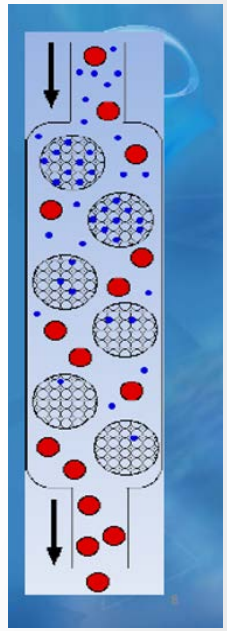
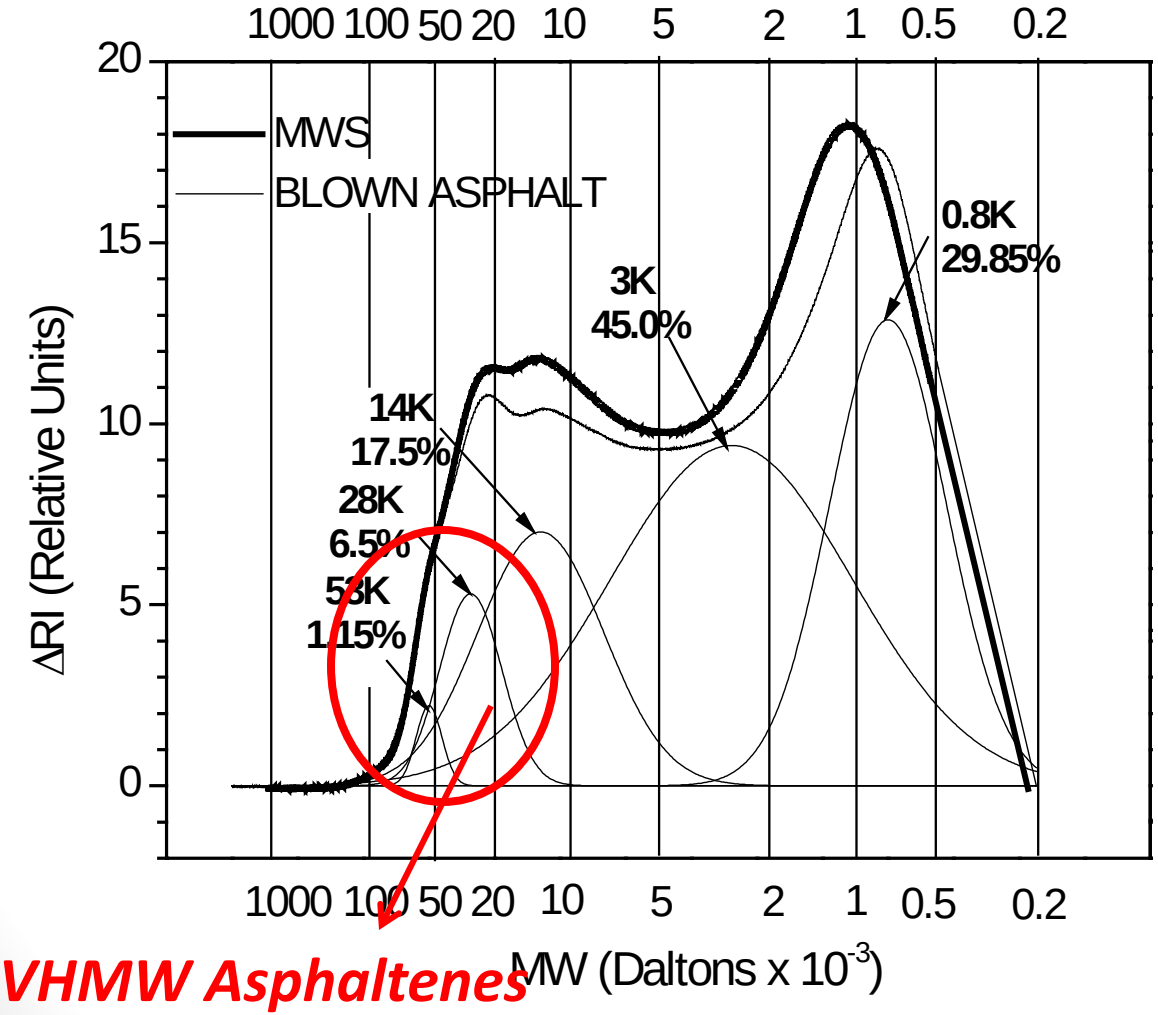
Objective / Scope – Binder Experiment

- Correlate the molecular structure of asphalt binders to fracture property of asphalt mixtures
  - Asphalt mixtures: Conventional
  - Asphalt mixtures: RAS with and without RAs
- Gel Permeation Chromatography (GPC)
- Fourier Transform Infrared Spectroscopy (FTIR)
- Binder extracted from aged HMA mixtures
  5 days, 85°C



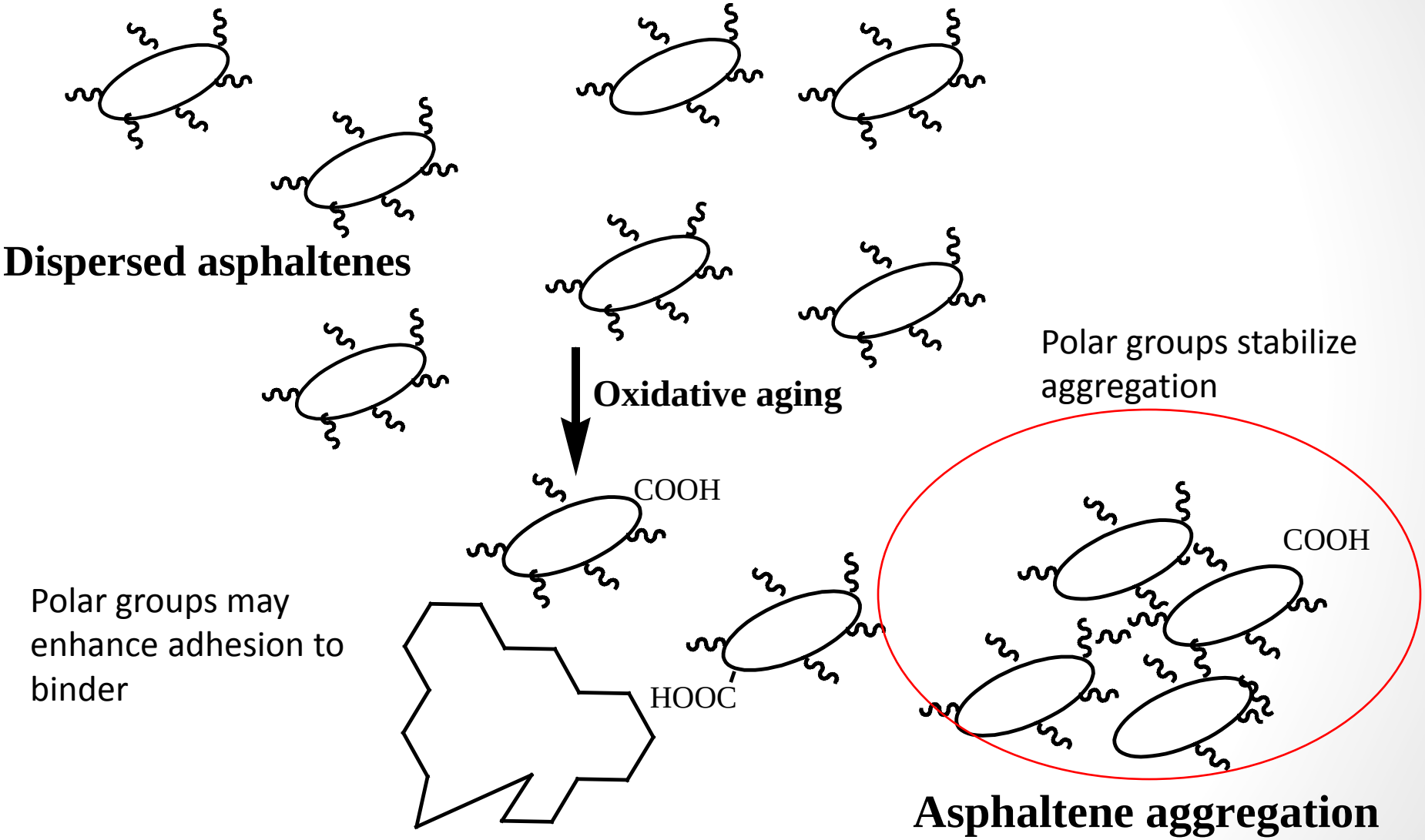
GPC data of Blown asphalt and MWS (RAS M) extracted binders



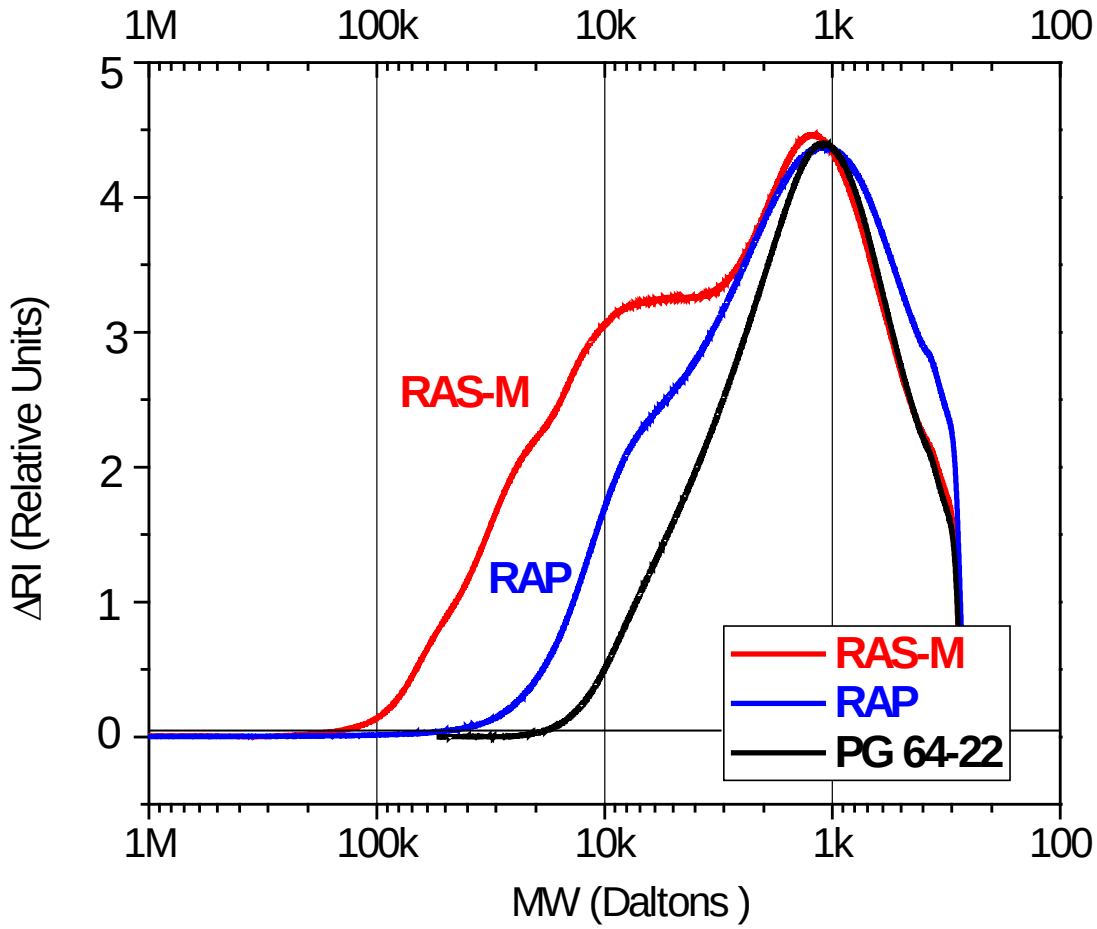
Binder of RAS M is practically identical to blown asphalt

VHMW Asphaltenes Associations

Oxidation of Asphalt Matrix

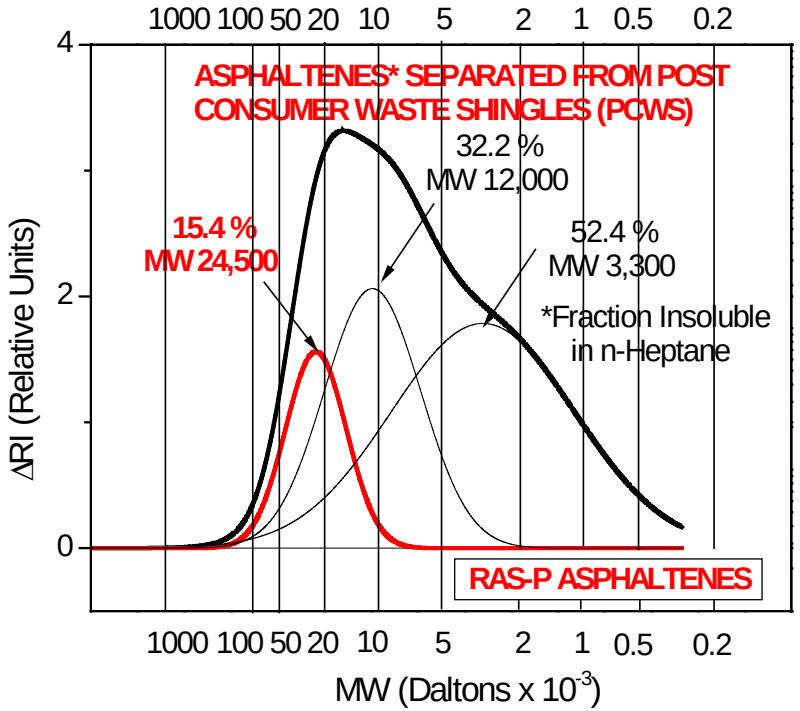


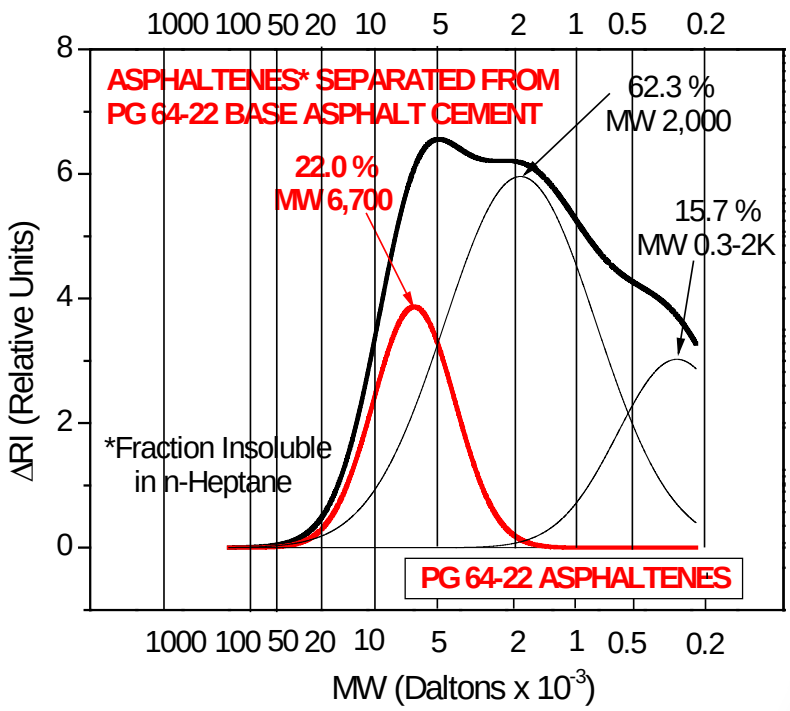
Typical MW Distributions of RAS, RAP and of PG 64-22



RAS M contributes with higher conc. of associated asphaltenes of much higher molecular weights than that of RAP

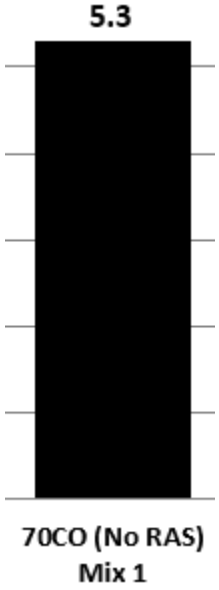
Typical MW Distributions of Asphaltenes Separated from RAS-P and from PG 64-22 Binder



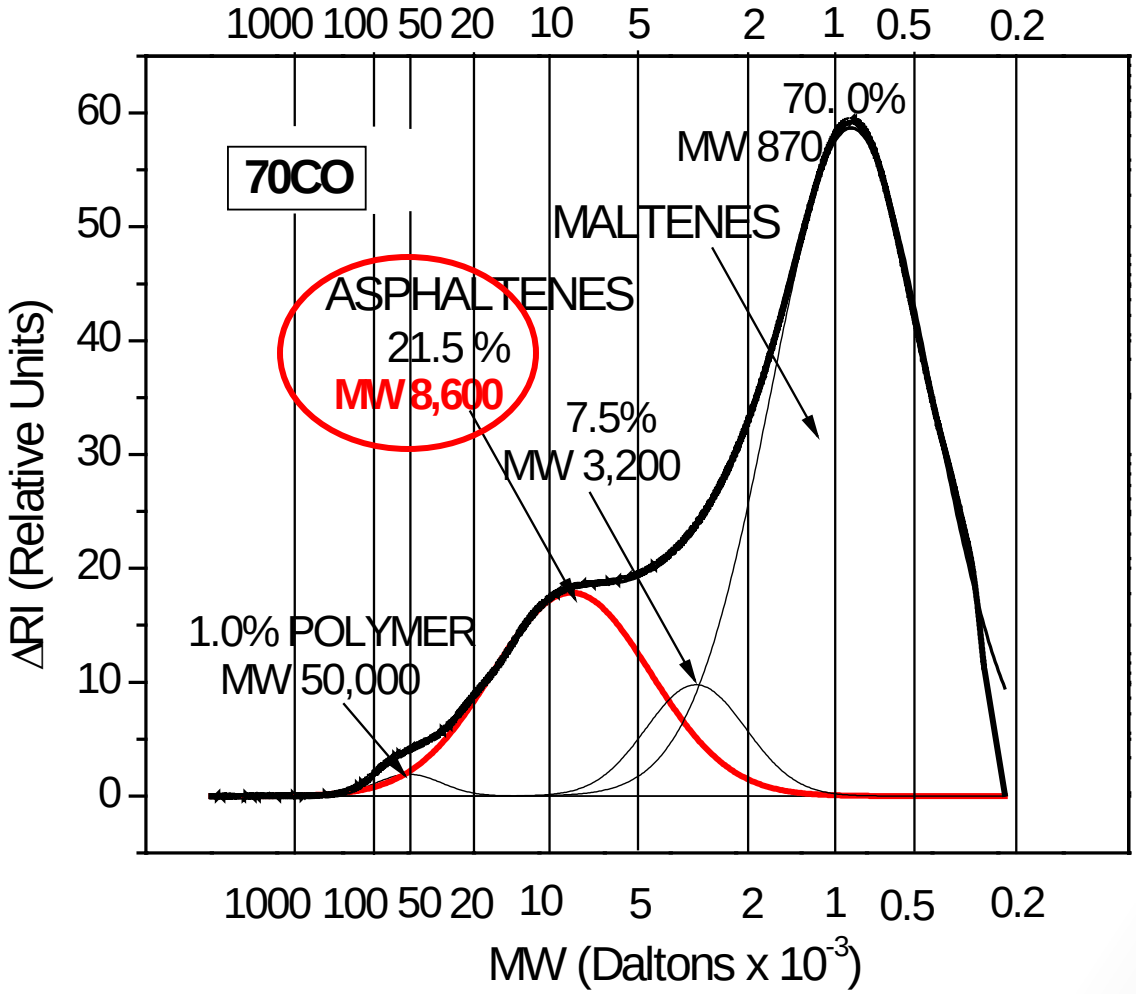


MW distribution of molecular species of extracted binder:

HMA mixture containing 0% RAS and PG70-22M binder

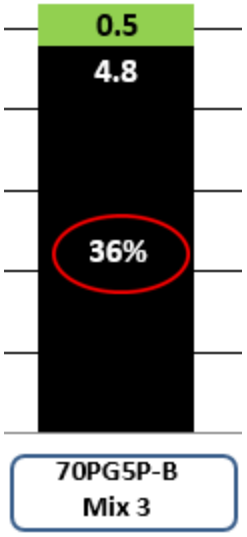


J_c = 0.5 kJ/m^2

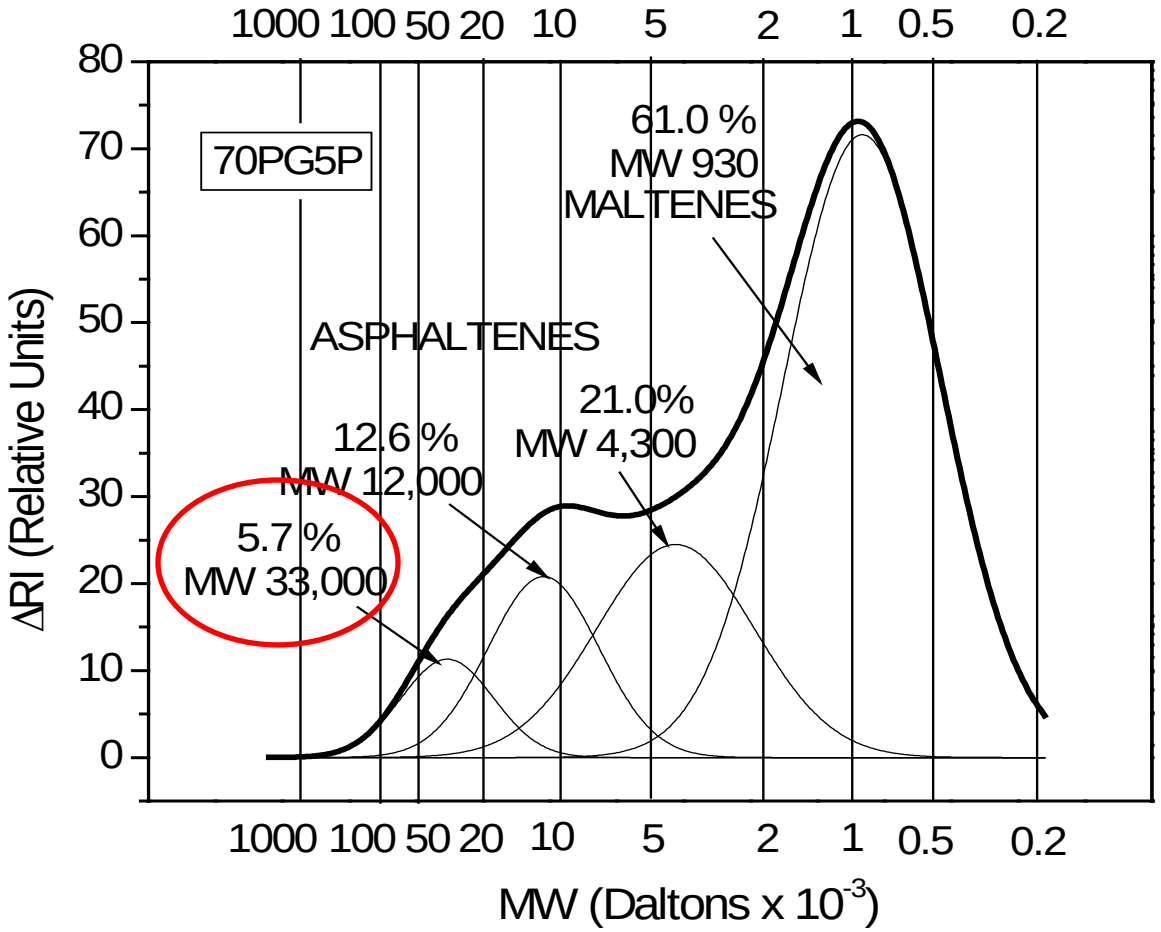


MW distribution of molecular species of extracted binder:

HMA mixture containing 5% RAS-P and PG70-22M binder

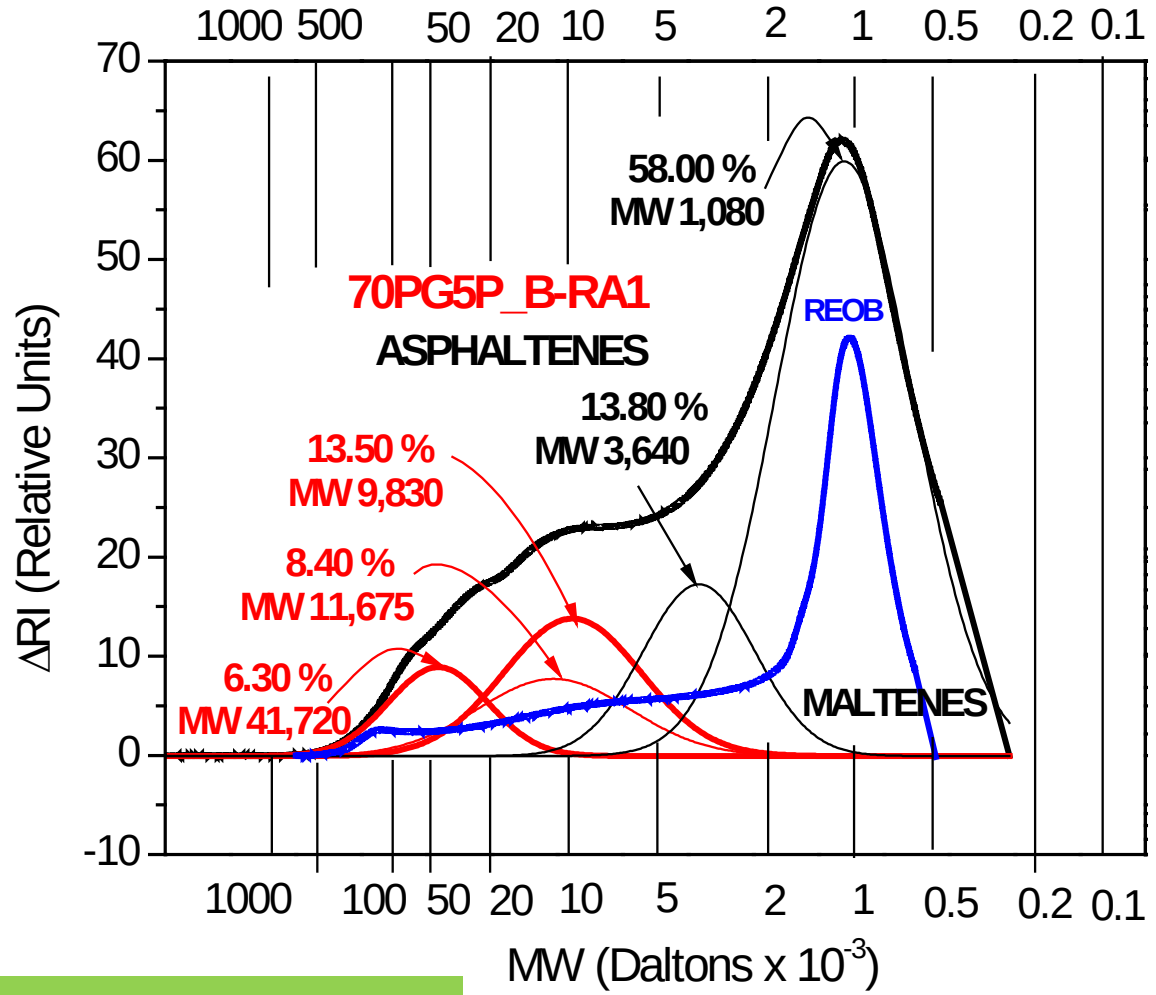


J_c = 0.5 kJ/m^2



Semi-Circular Bend Test Results, 25°C

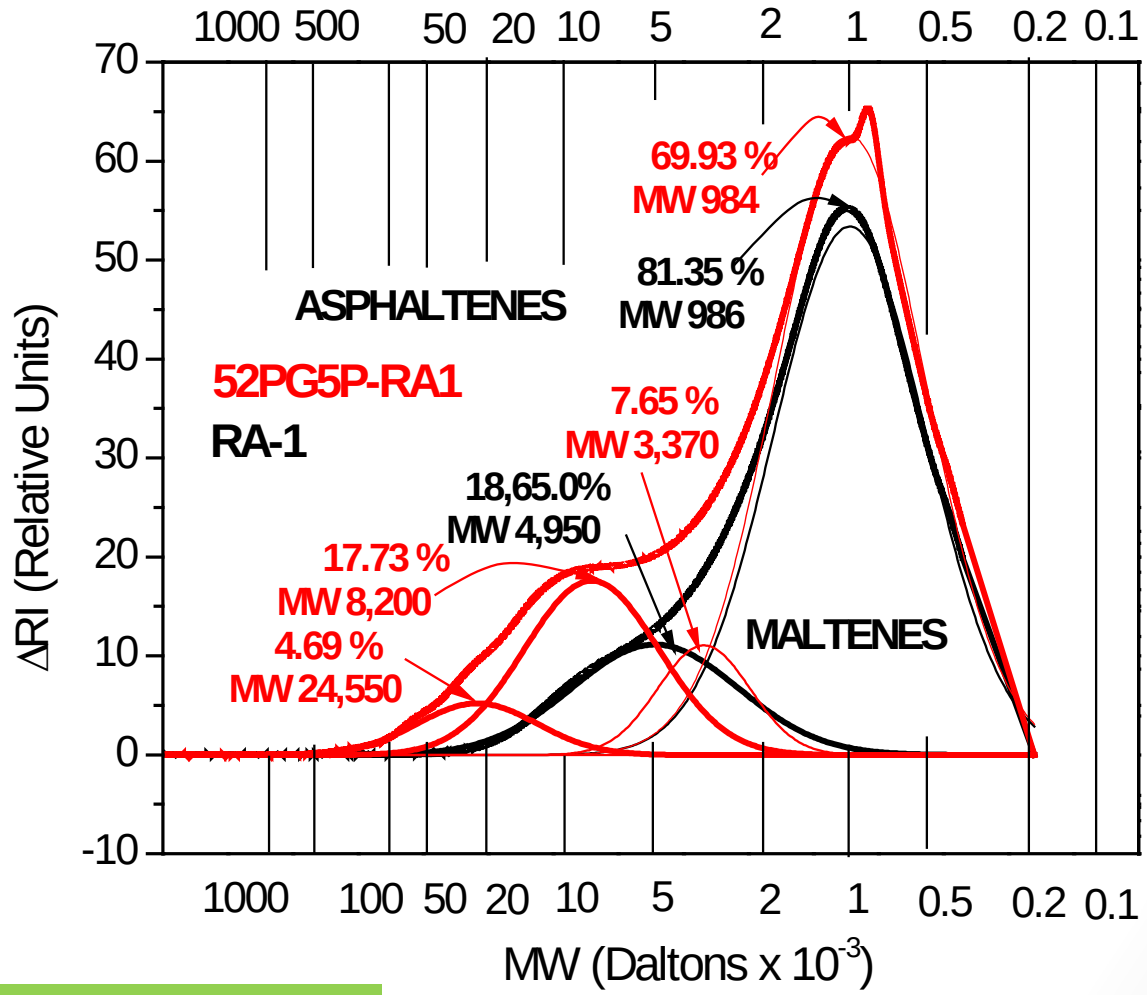
70PG5P_B-RA 1 (15% REOB)



$J_c = 0.23\ Kj/m^2$

Semi-Circular Bend Test Results, 25°C

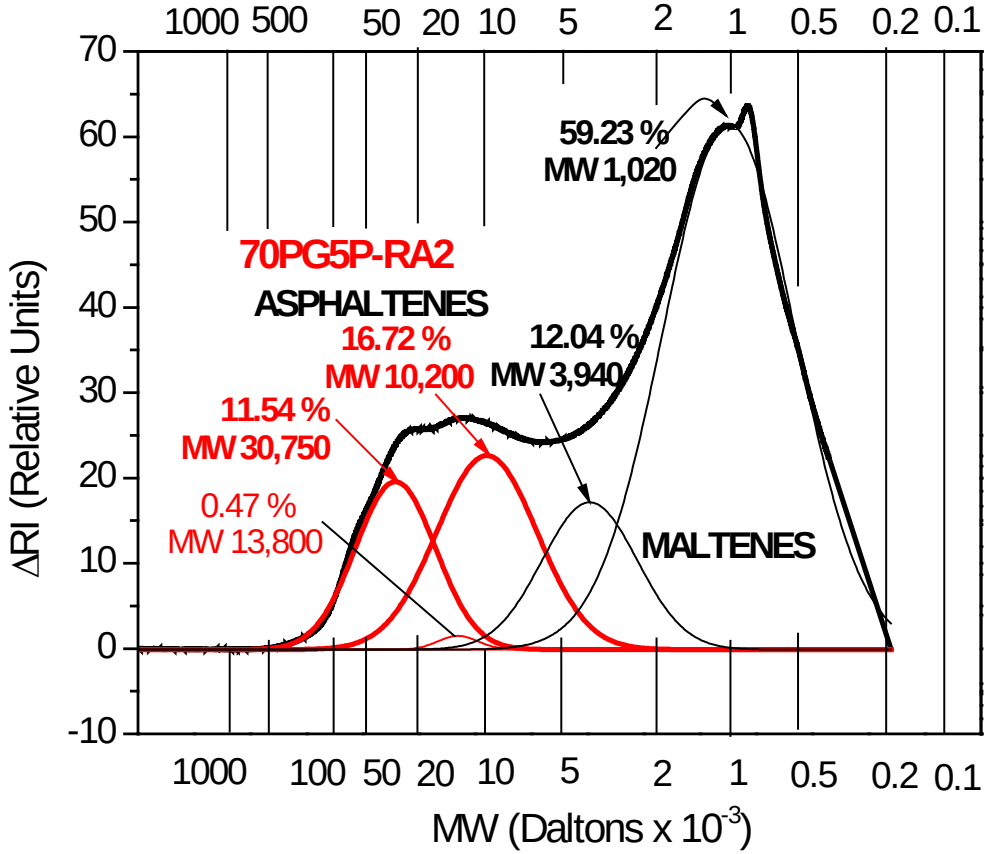
RAS - RA 1 (PG 52-28)

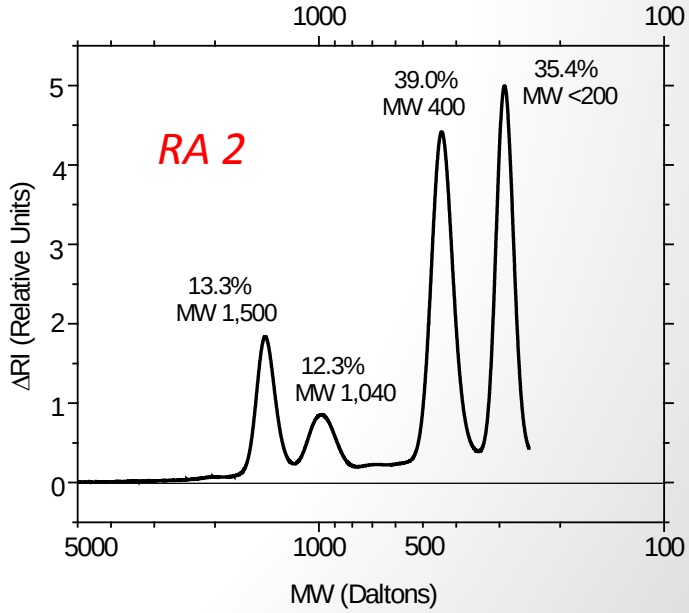


$J_c = 0.2\ Kj/m^2$

Semi-Circular Bend Test Results, 25°C

RAS – RA 2 (0.75% + 5%) V. D. O

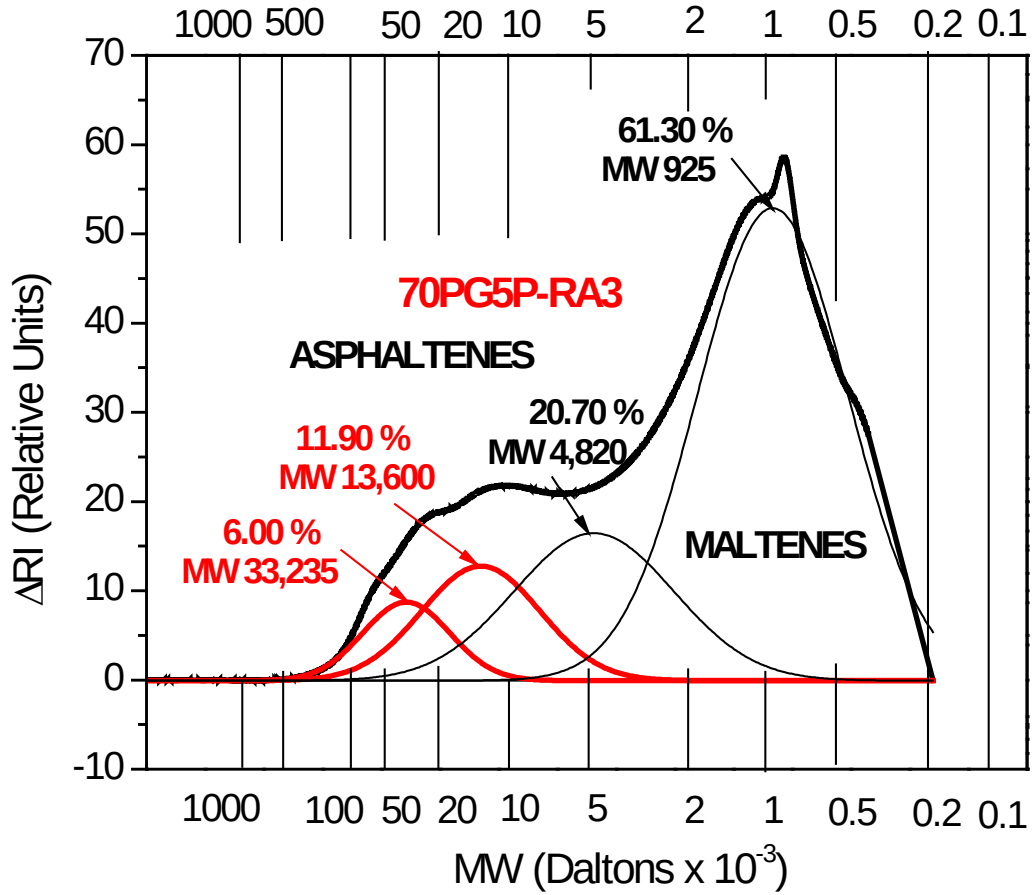




J_c = 0.3 Kj/m²

Semi-Circular Bend Test Results, 25°C

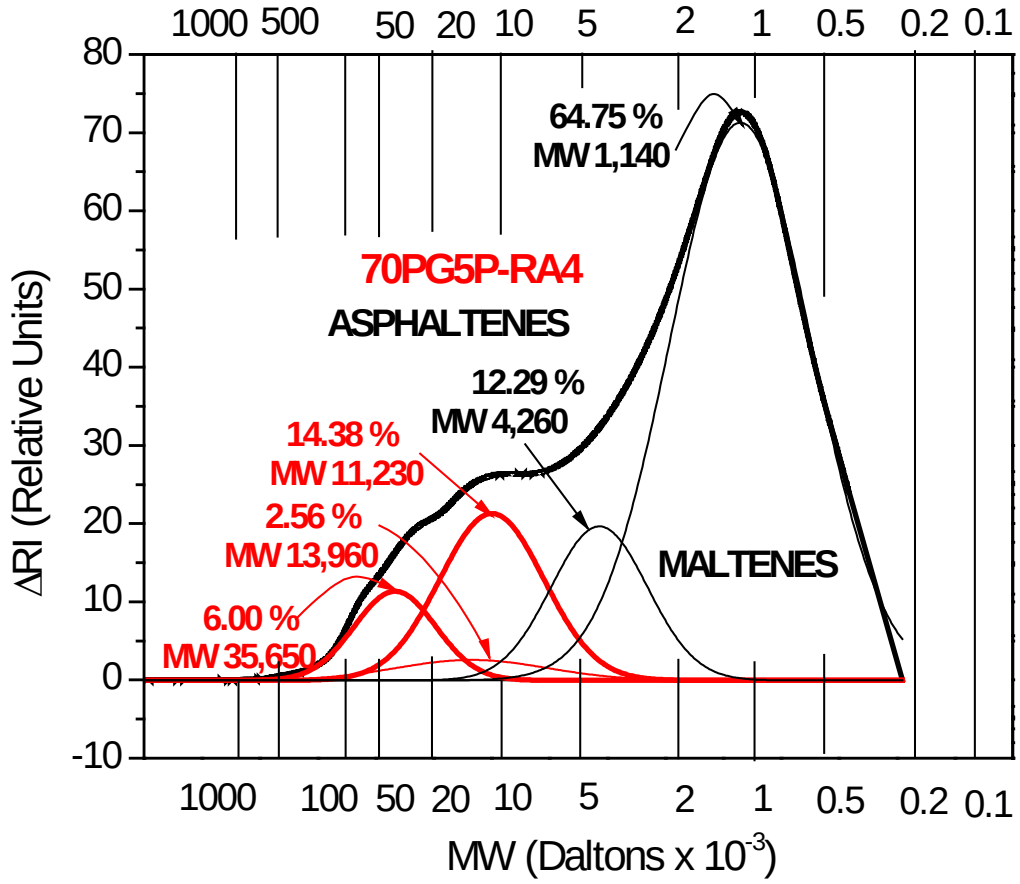
RAS – RA 3 (12% N.O.)



$J_c = 0.4\ Kj/m^2$

Semi-Circular Bend Test Results, 25°C

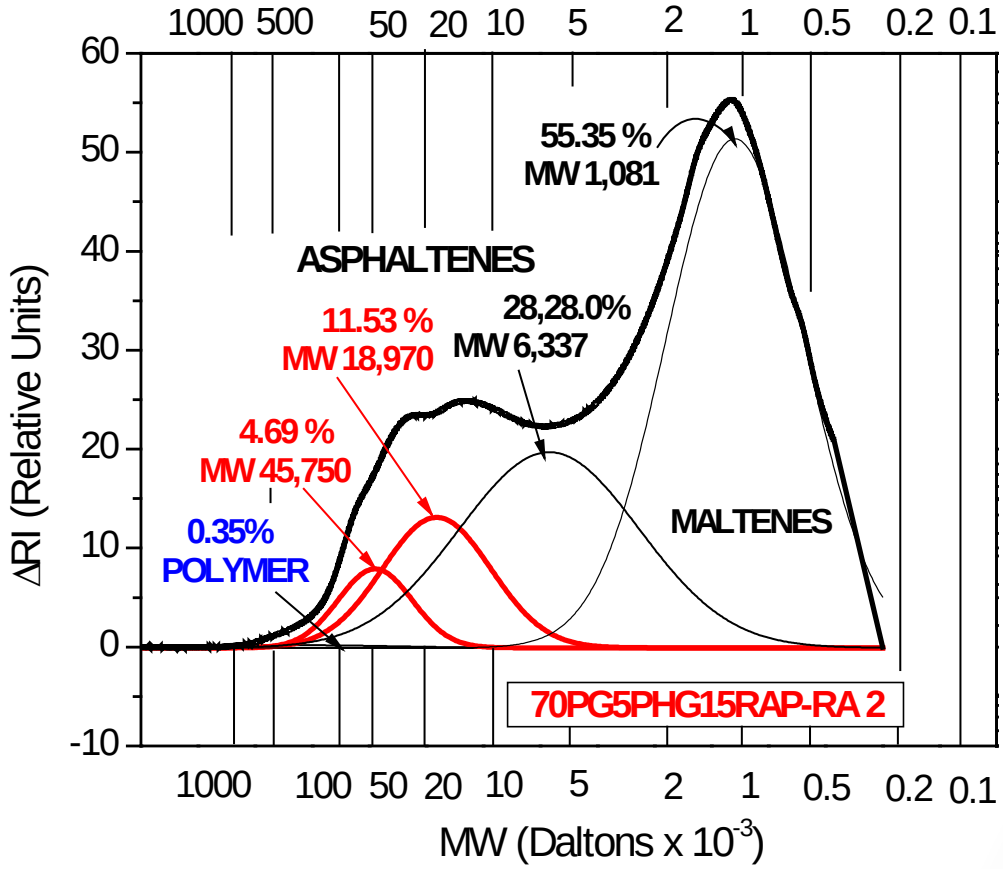
*RAS – RA 4 (*20% S.A.)



$J_c = 0.3\ Kj/m^2$

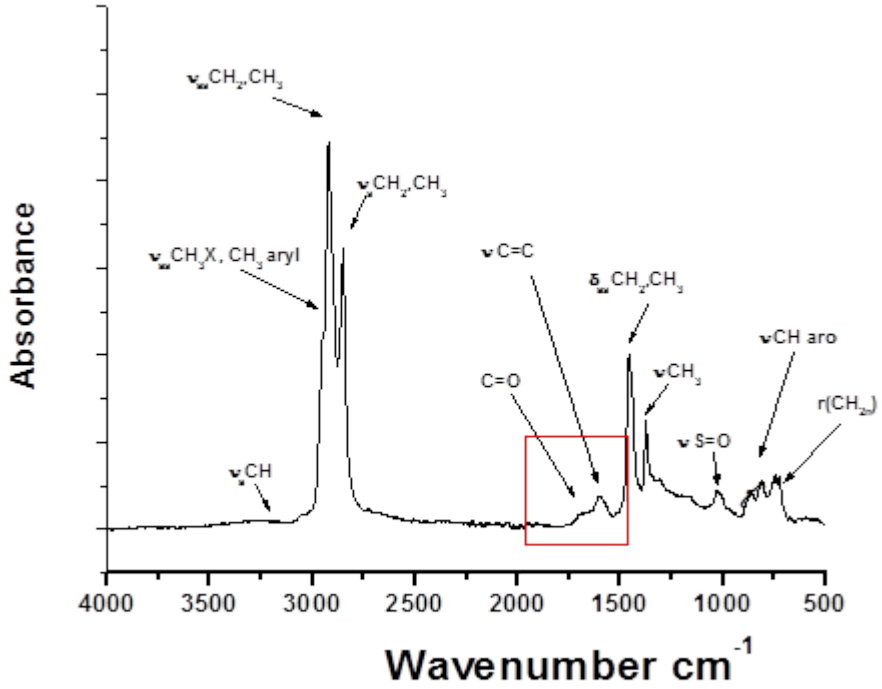
Semi-Circular Bend Test Results, 25°C

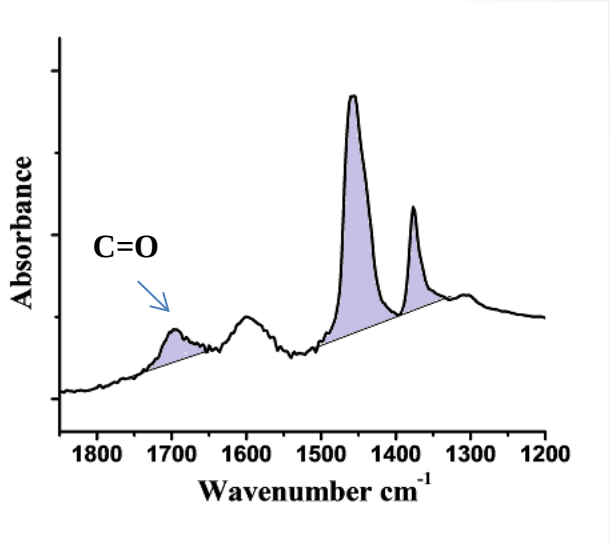
RAS & RAP – RA 2 (5% V. D. O.)



J_c = 0.4 Kj/m²

Estimation of Extent of Aging by FTIR





FTIR spectra of the aged samples show a peak around 1700 cm^{-1}, characteristic of C=O species. The carbonyl index was calculated from the band areas measured from valley to valley as shown above*:

$$\text{Carbonyl index (\%)} = \frac{\text{Area of the carbonyl centered around 1700 cm-1}}{\text{Area of the spectral bands between 1490 and 1320 cm-1}} \times 100$$

*J. Lamontagne et al., FUEL, 80(4), 483-48 (2001)

Correlation of VHMW, Carbonyl Index , and Jc

Mixture Type	Total VHMW % Polymer & Highly Associated Asphaltenes >20K	C=O Index x10^3	J_c KJ/m^2
70CO	1.0	6.8	05
70PG5P	5.7	21.2	0.5
52PG5P-RA 1	5.7	11.7	0.2
70PG5P-RA 2	11.5	17.1	0.2
70PG5P-RA 3	8.8	13.0	0.3

Remarks

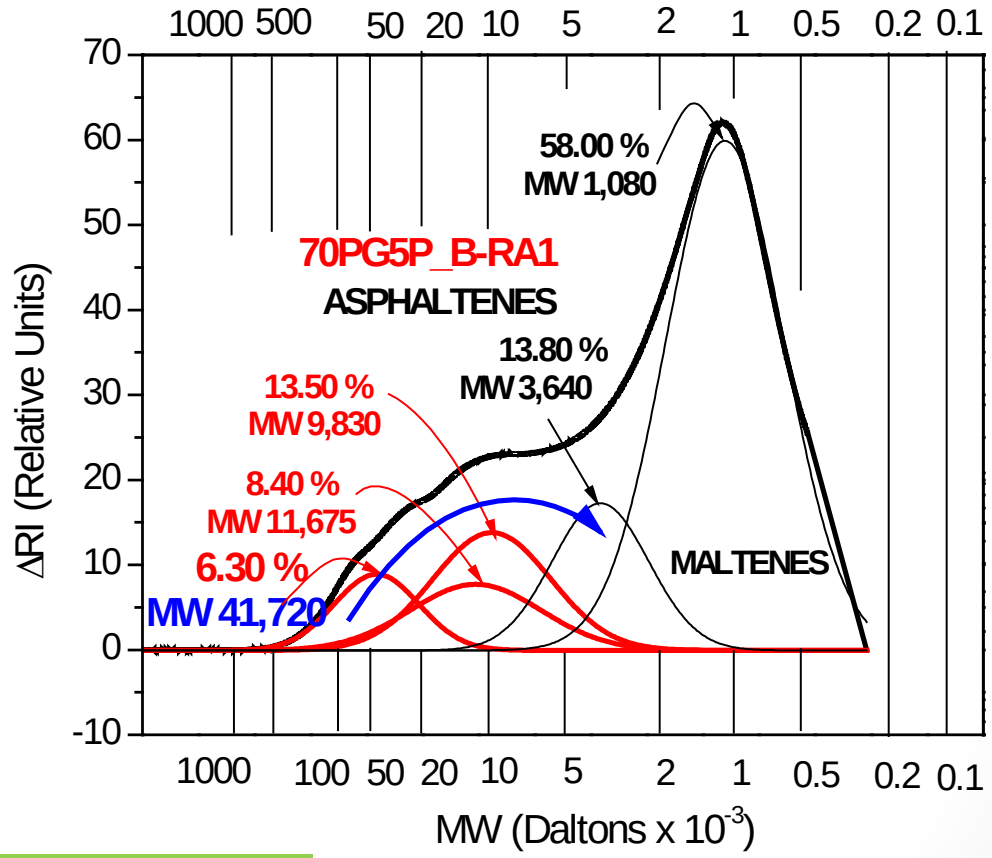
- **Effect of Recycling Agents**
  - **REOB and other RAs evaluated enhanced the extraction of the asphaltenes from the RAS.**
  - **Use of soft binder (RA 1) did not improve fracture properties.**
  - **Molecular fractionation through GPC of RAS samples confirmed the presence of associated asphaltenes in great concentrations.**
    - **High concentrations of HMW asphaltenes decrease the fracture resistance of the asphalt mixtures**
    - **Presence of SBS additives enhances the compatibility with the HMW asphaltenes.**
  - **C=O is not reliable indicator of intermediate fracture resistance performance.**
  - **Use of Recycling Agents evaluated in this study did not reduce the concentration of the highly associated asphaltenes**
    - **Did not improve the cracking resistance**

Thoughts!

- **Is 100% blending of available RAS binder desired?**
- **Consideration of Addition of *ADDITIVES* that enhance the compatibility with the HMW asphaltenes.**

Semi-Circular Bend Test Results, 25°C

70PG5P_B-RA 1 (15% REOB) & *Additive*



J_c = min 0.50 Kj/m²


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Photo: Jim Zietz, Office of Public Affairs

THANK YOU