Asphalt Mixtures Containing RAS: Effect of REOB on Laboratory Performance

Louay N. Mohammad
Sam Cooper, Jr.
Department of Civil and Environmental Engineering
LA Transportation Research Center
Louisiana State University

William H. Daly
Ioan I Negulescu
Sreelatha Balamurugan
Department of Chemistry
Louisiana State University

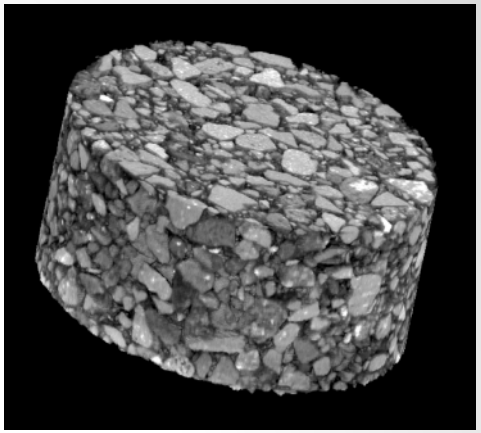
Gaylon Baumgardner
Paragon Services

FHWA Asphalt Binder Expert Task Group
Oklahoma City, Oklahoma
September 16, 2015

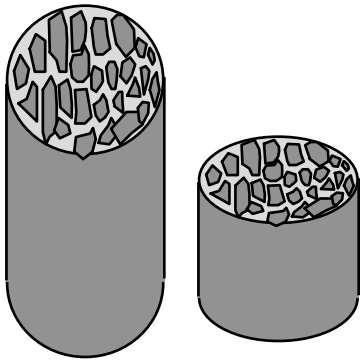
The Story!

- Background
- Objective/Scope
- Methodology
  - Mixture Experiment
    - High, Intermediate, Low Temperatures
  - Binder Experiment
    - Binder Fractionation by MW
    - SARA
- Results
- Summary

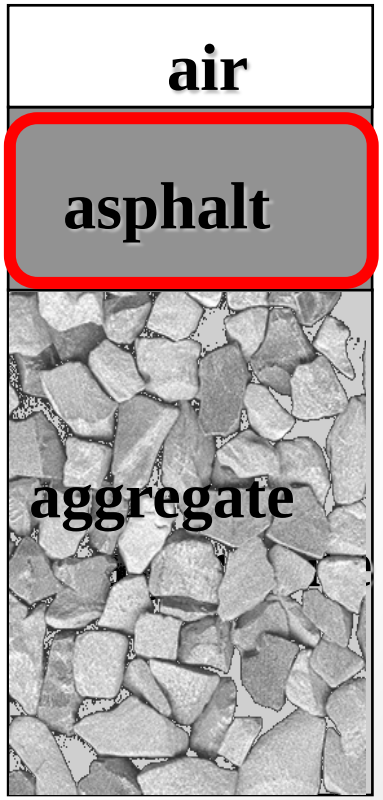
Asphalt Mixture Design: Concern



- **Optimum asphalt cement content**
  - **Quantity**
  - **NOT QUALITY**
  - **Recycled materials**
    - **Aged binders**



VOLUME *MASS*

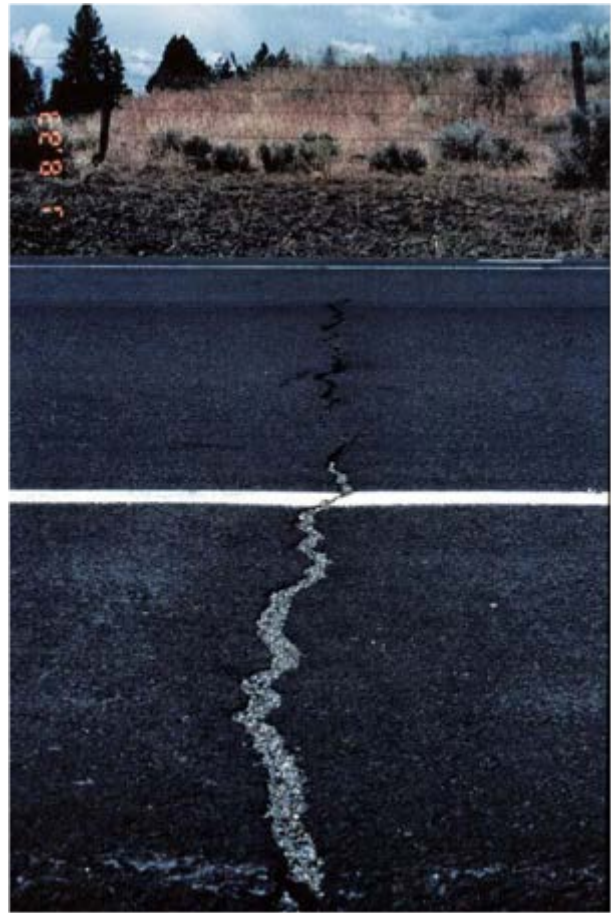


Total Volume

Total Mass

Objectives of Mixture Design

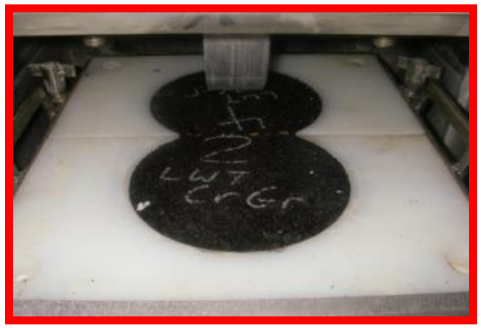
- **Perform**
  - permanent deformation
  - fatigue cracking – repeated load
  - low temperature cracking
  - moisture induced damage
- **Safety**
  - Resist skid
- **Constructable**
  - Workability

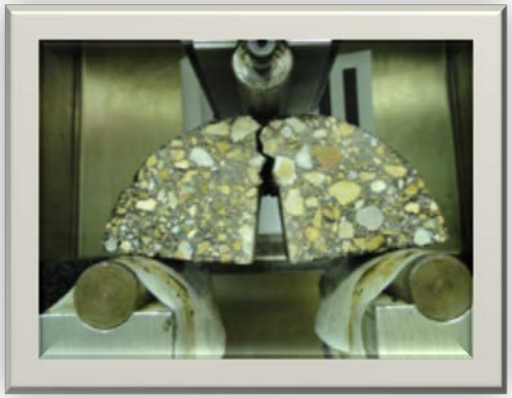


Objective – Mixture Experiment

- **Laboratory Performance at Low, intermediate, and high temperatures**
  - **Conventional mixtures**
  - **mixtures containing RAS**
    - **With and without REOB as a RA**
    - **Effect of REOB as RA**

Fatigue Cracking





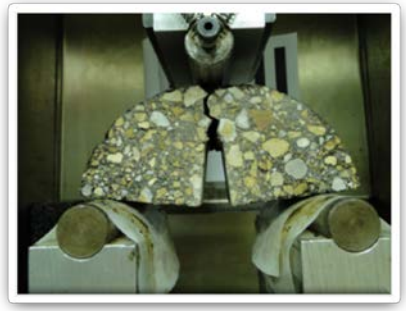
Scope

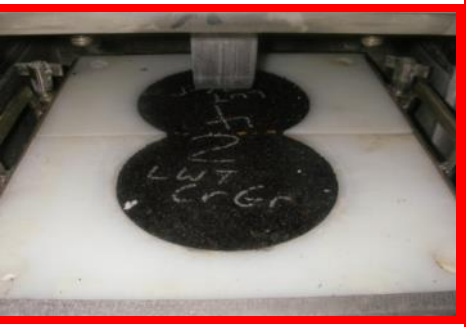
- 12.5 mm Asphalt Mixture
- RAS: Post-Consumer
- Binder: PG 70-22M

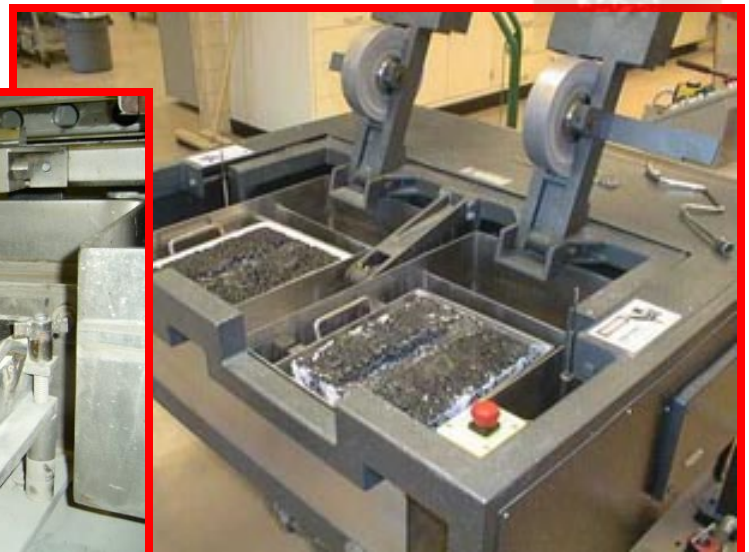
Mix ID	Mix Code	RAS	Recycling Agent
Mix 1	70CO	0	None
Mix 2	70PG5P_B	5	None
Mix 3	70PG5P_B5SK	5	5% REOB
Mix 4	70PG5P_B10SK	5	10% REOB
Mix 5	70PG5P_B15SK	5	15% REOB

Lab Performance Tests

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

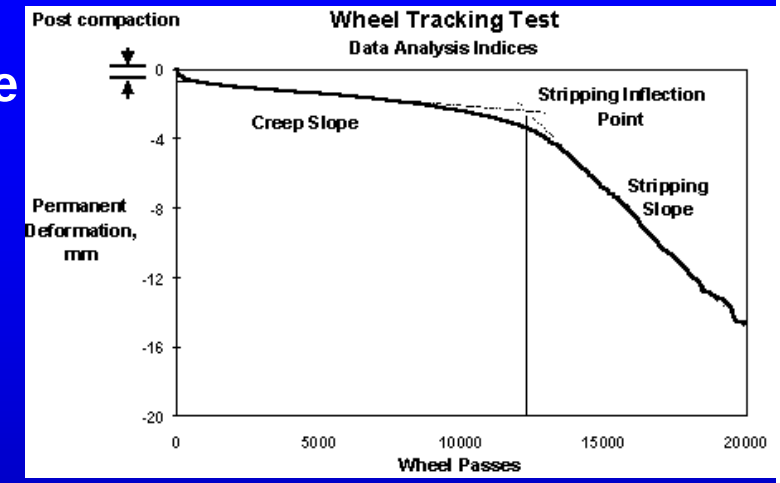






Loaded Wheel Tracking Test – 50ºC

- AASHTO T 324
- rolling steel wheel across the surface of a sample
- Specimen Geometry
  - Cylindrical: Core or SGC
  - Slab: 320- L, 260- W, and 80-mm thick
- Wet or dry
- Analysis
  - Deformation at 20,000 passes is recorded
  - Indices



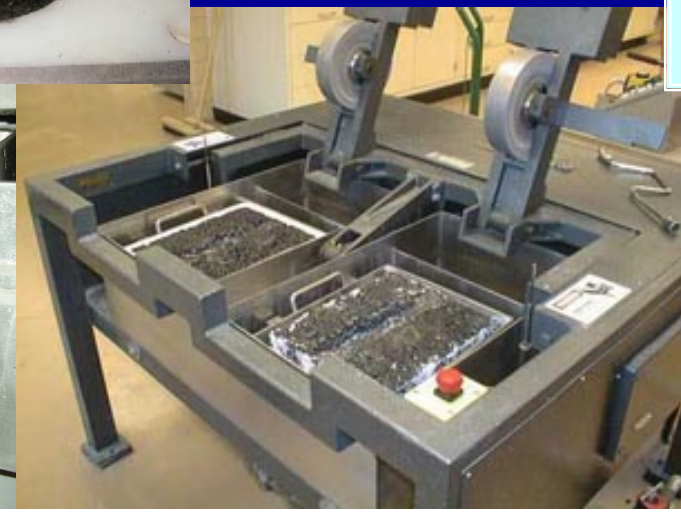
Wheel Diameter: 203.5 mm (8 inch)

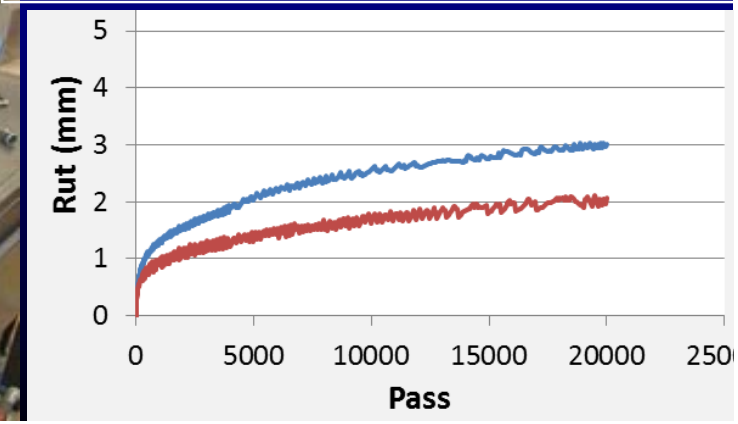
Wheel Width: 47mm (1.85 inch)

Fixed Load: 703 N (158 lbs)

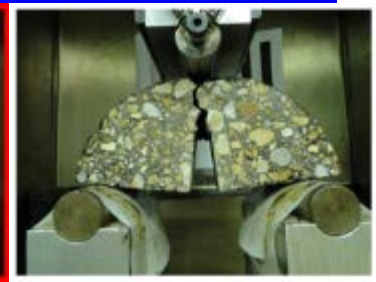
Rolling Speed: 1.1 km/hr

Passing Rate: 56 passes/min

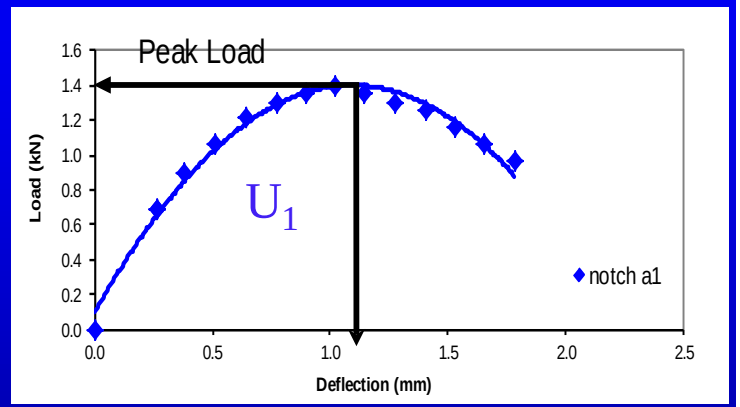




Semi Circular Bend (SCB) Test

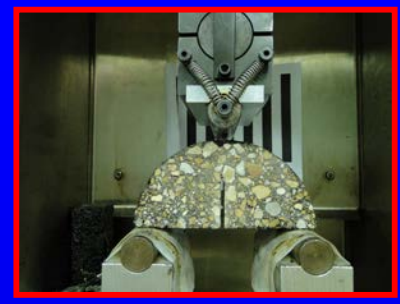


- LA DOTD TR 330
- Temperature: 25°C
- Half-circular Specimen
  - Laboratory prepared
  - Field core
  - 150mm diameter X 57mm thickness
  - simply-supported and loaded at mid-point
- Notch controls path of crack propagation
  - 25.4-, 31.8-, and 38.0-mm
- Aging: 5 days, 85°C
- Loading type
  - Monotonic
  - 0.5 mm/min
  - To failure
- Record Load and Vertical Deformation
- Compute Critical Strain Energy: Jc

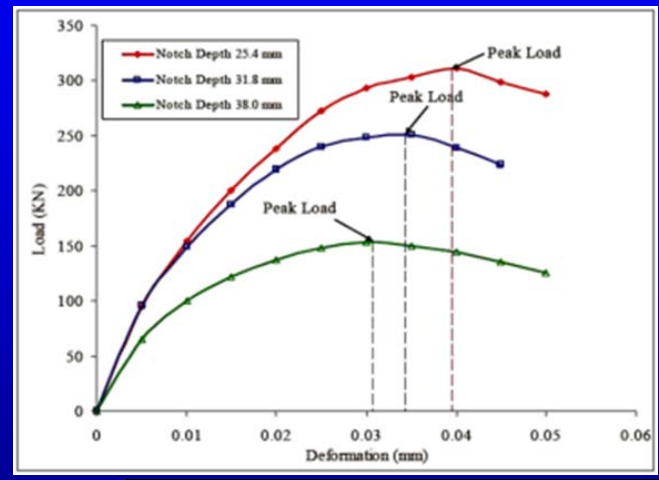


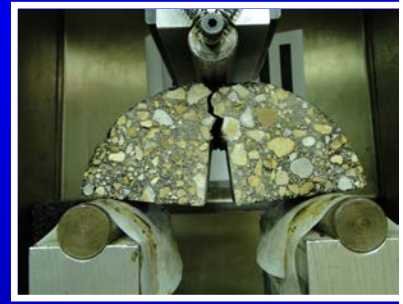
SCB Test – Analysis

- Calculate Energy at failure for each notch depth
- Plot U vs. a and determine slope (dU/da)
- Compute CSERR
  - Jc



$$J = -\frac{1}{B}\left(\frac{\partial U}{\partial a}\right)$$





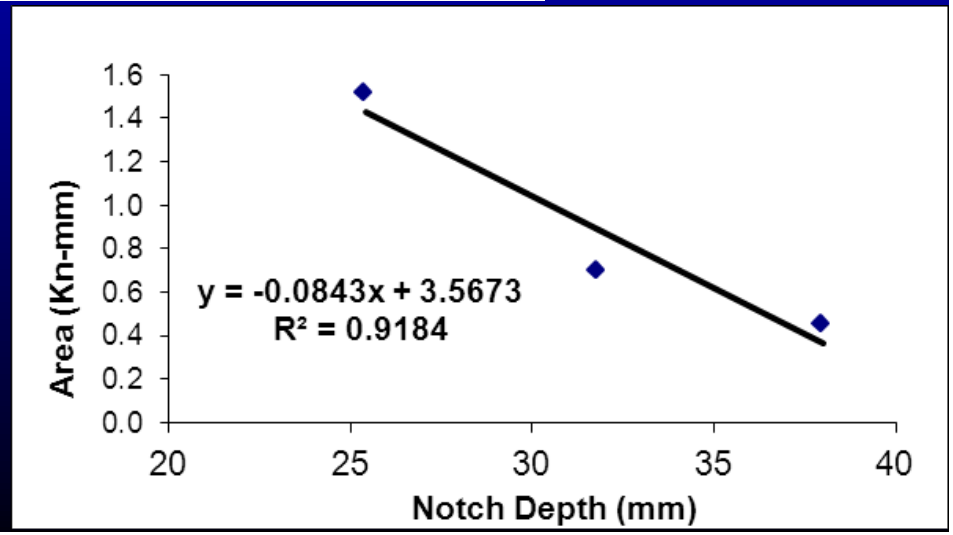
Jc= Critical Strain Energy Release Rate (kJ/m^2);

b = sample thickness (m);

a = notch depth (m);

U = strain energy to failure (kilo-Joule, kJ);

dU/da = change of strain energy with notch depth, KJ/m

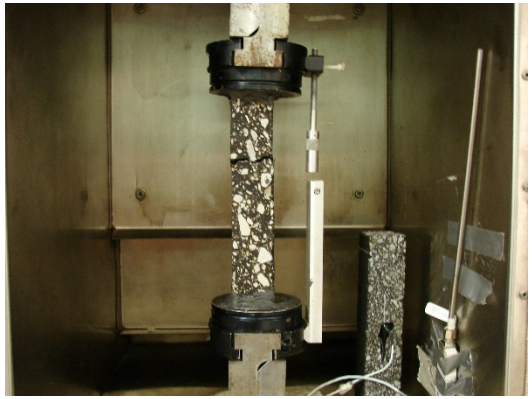


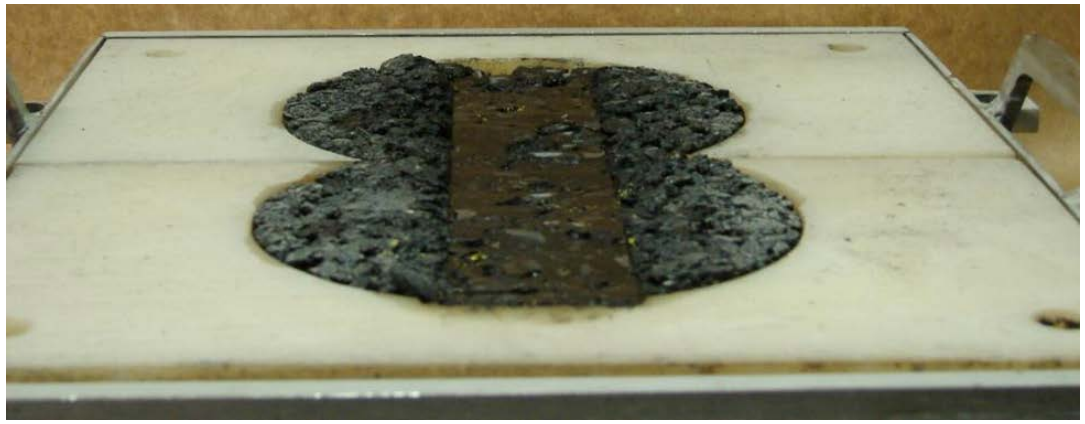
Thermal Cracking

Fatigue Cracking

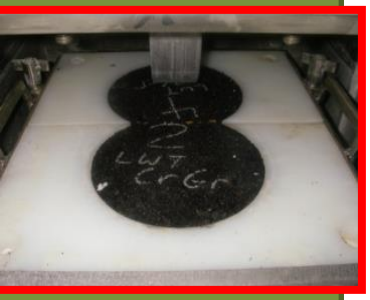
Permanent Deformation

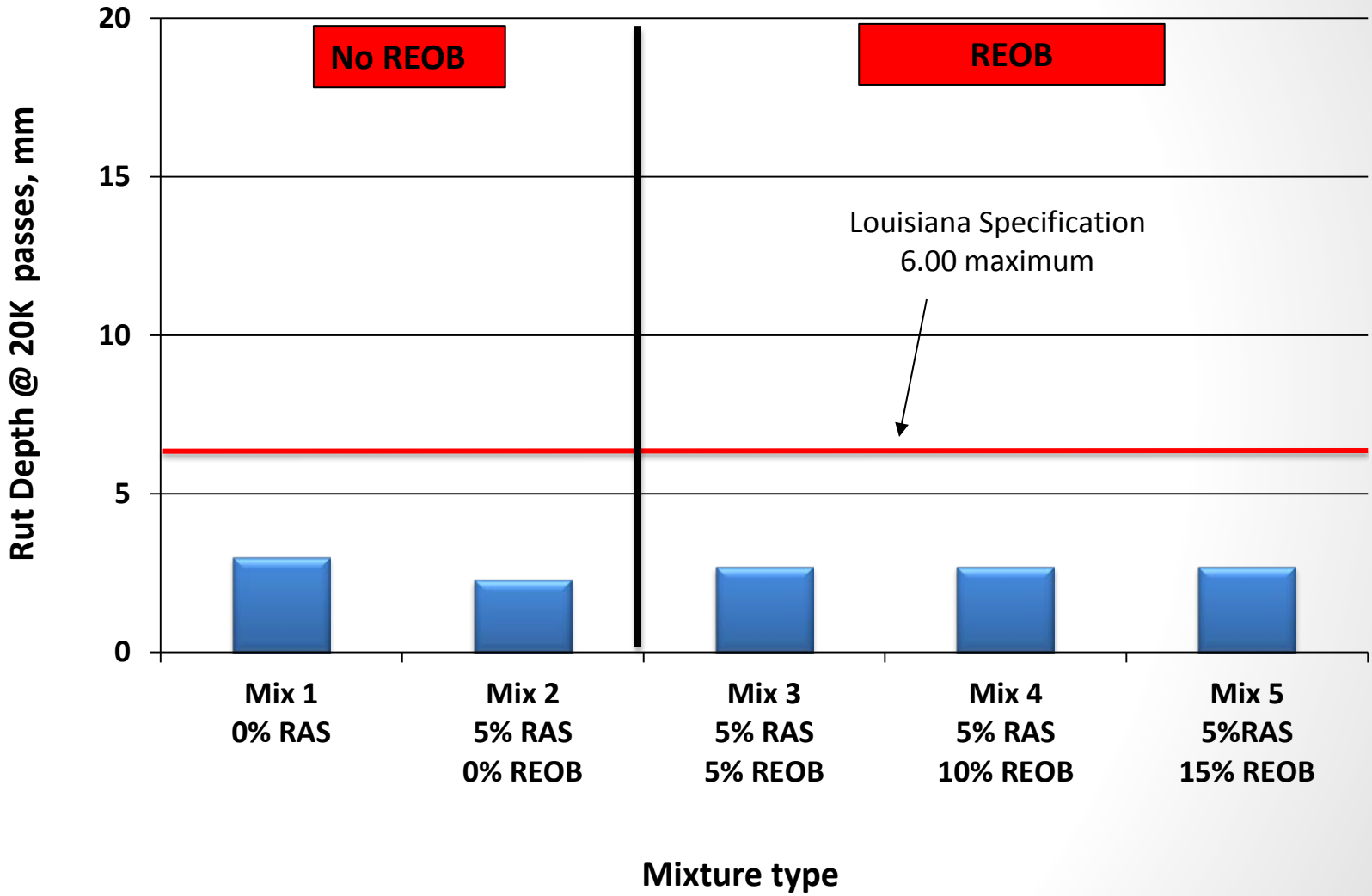
Results



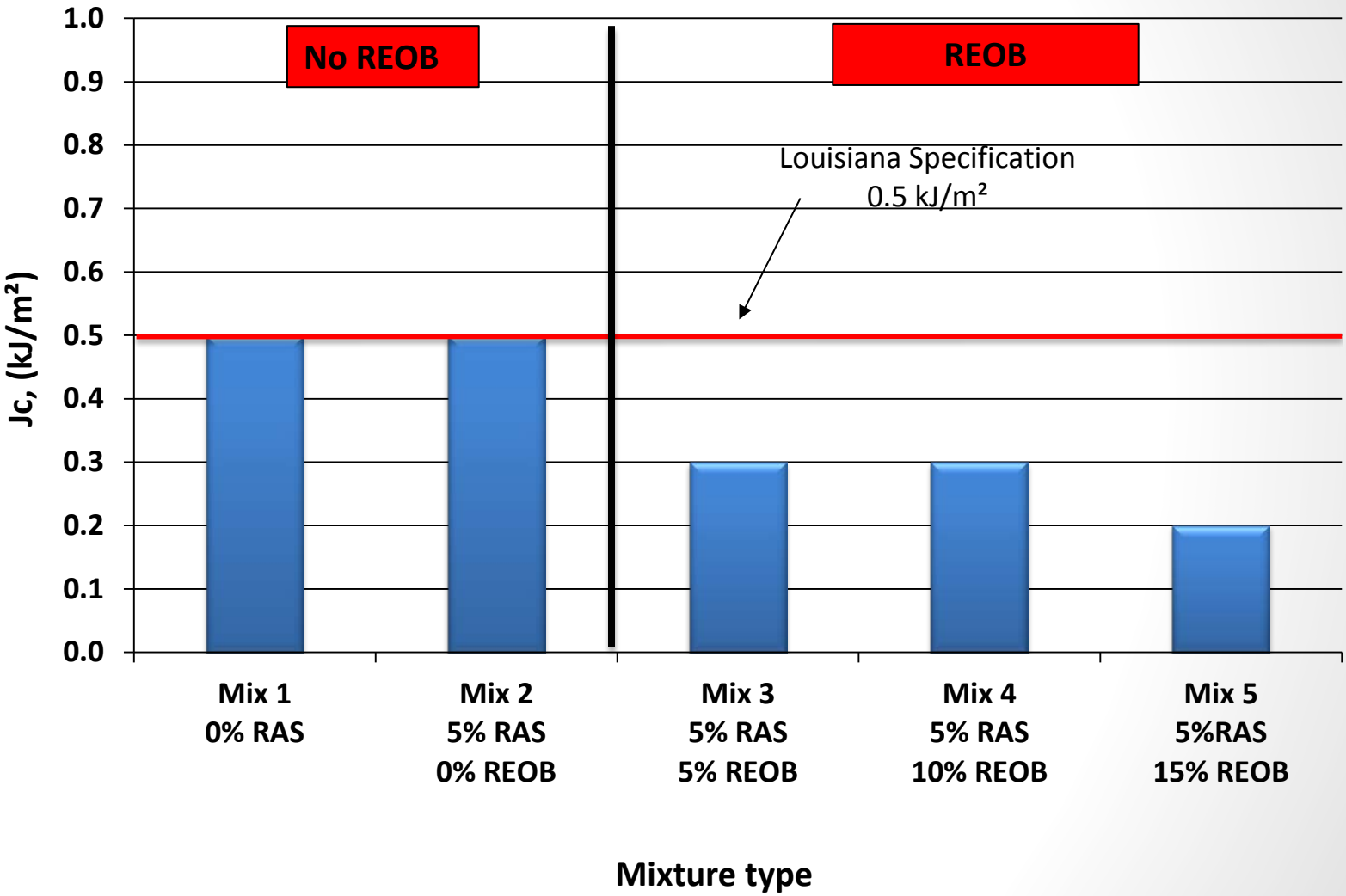


LWT Test Results 50°C

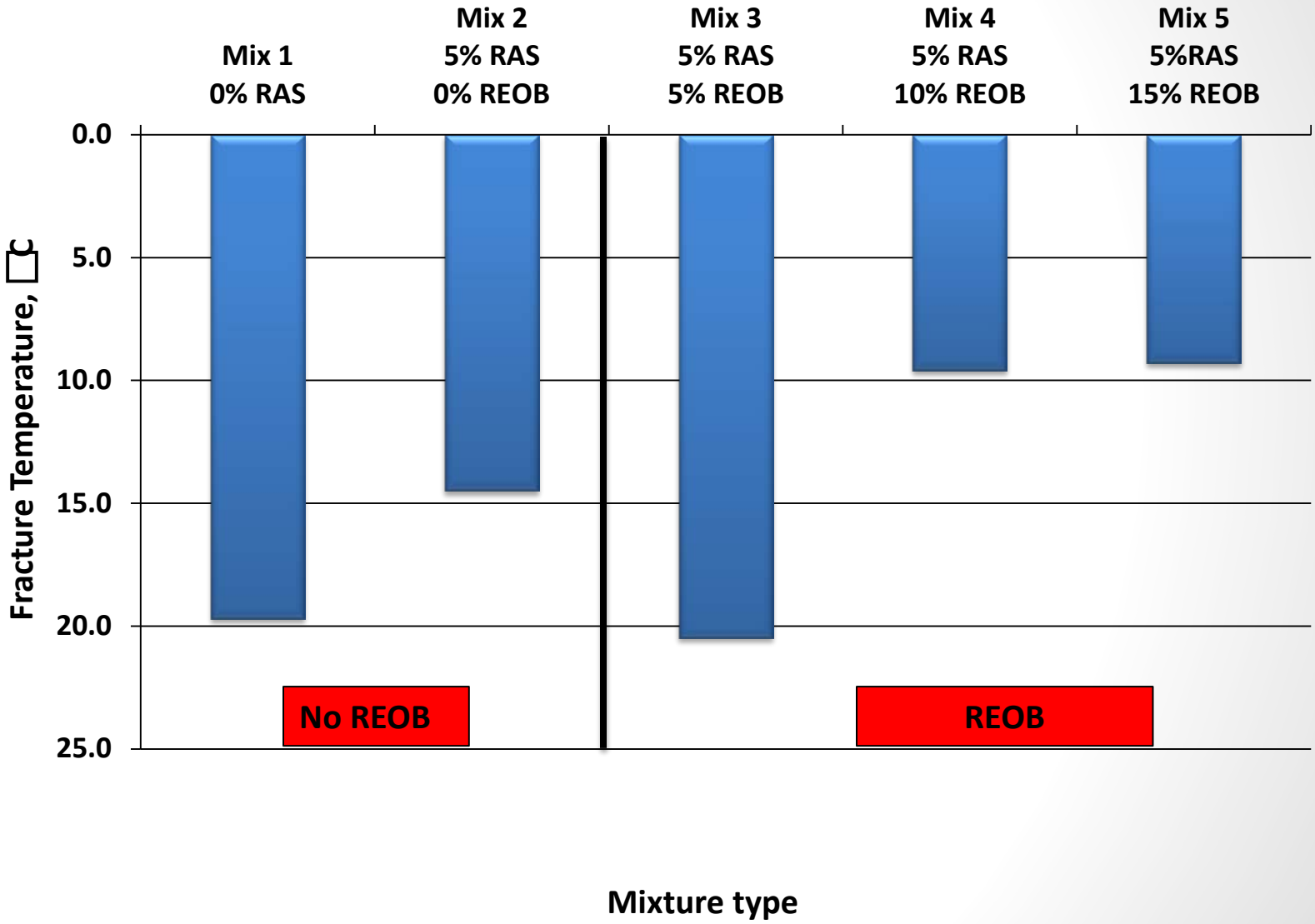




Semi Circular Bend Test Results 25°C



Thermal Stress Restrained Specimen Test Results



Summary of Performance *Mixes Containing RAS, RAS/REOB as Compared to Control Mixture*

Mixture	High Temp (LWT)	Intermediate Temp (SCB)	Low Temp (TSRST)
70PG5P_B	+	=	−
70PG5P_B5SK	+	−	=
70PG5P_B10SK	+	−	−
70PG5P_B15SK	+	−	−

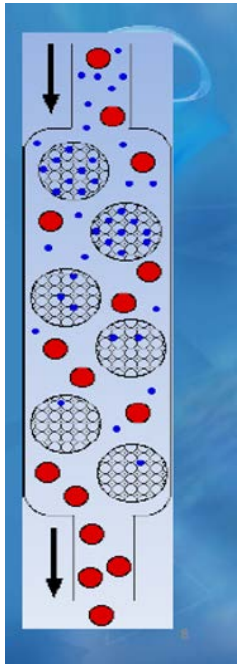
Objective / Scope

- Correlate the molecular structure of asphalt binders to fracture property of asphalt mixtures
  - Asphalt mixtures: Conventional
  - Asphalt mixtures: RAS with and without REOB

- Binder Experiment
  - Extracted from aged asphalt mixtures
    - 5 days, 85°C
  - Gel Permeation Chromatography (GPC)
  - Saturates (S), aromatics (Ar), and resins (R) Analysis (SARA)

Scope – Binder Experiment

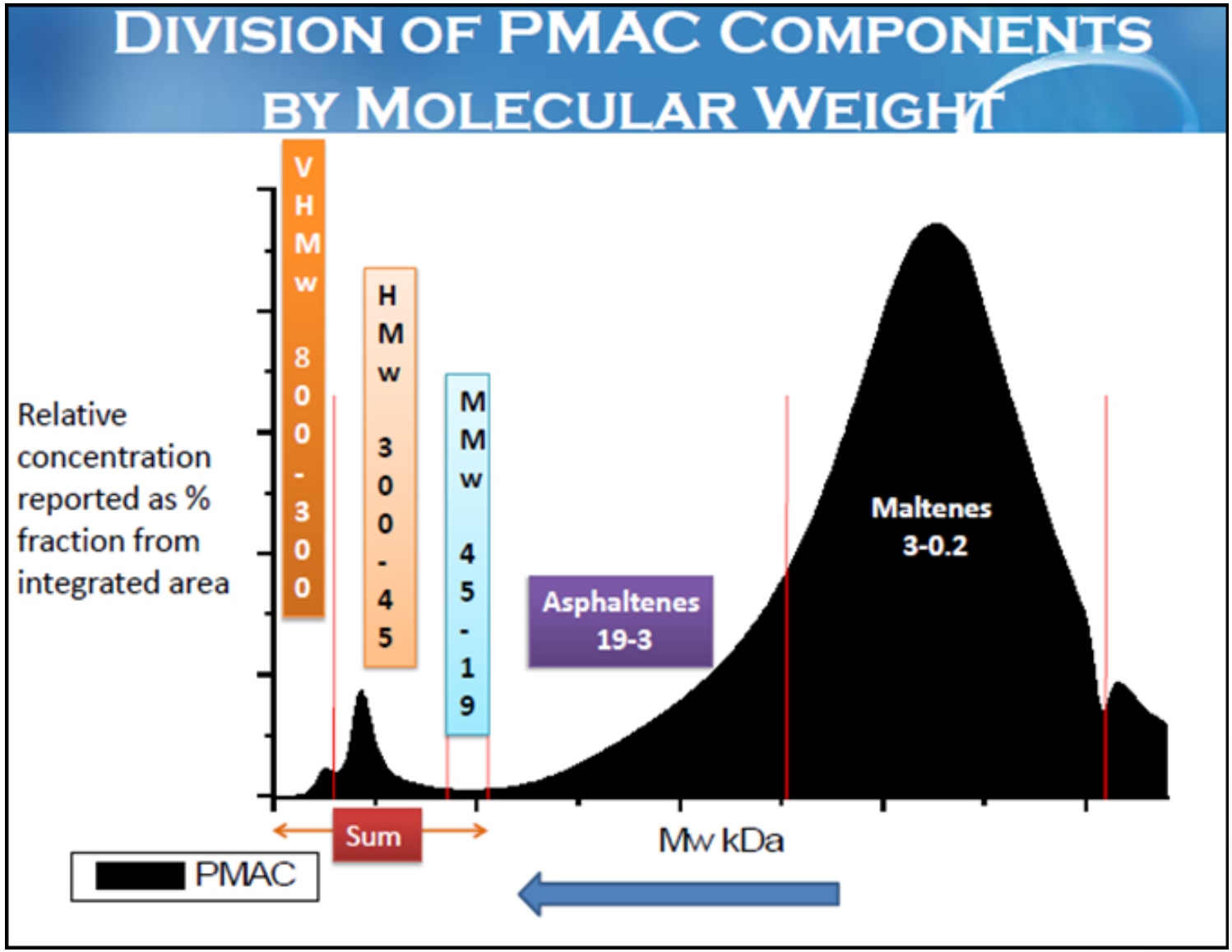
- Gel Permeation Chromatography **(GPC)**



GPC
Analysis Principle

GPC Instrument from DOTD Asphalt Lab

Quantification *of GPC Curves by Integration*

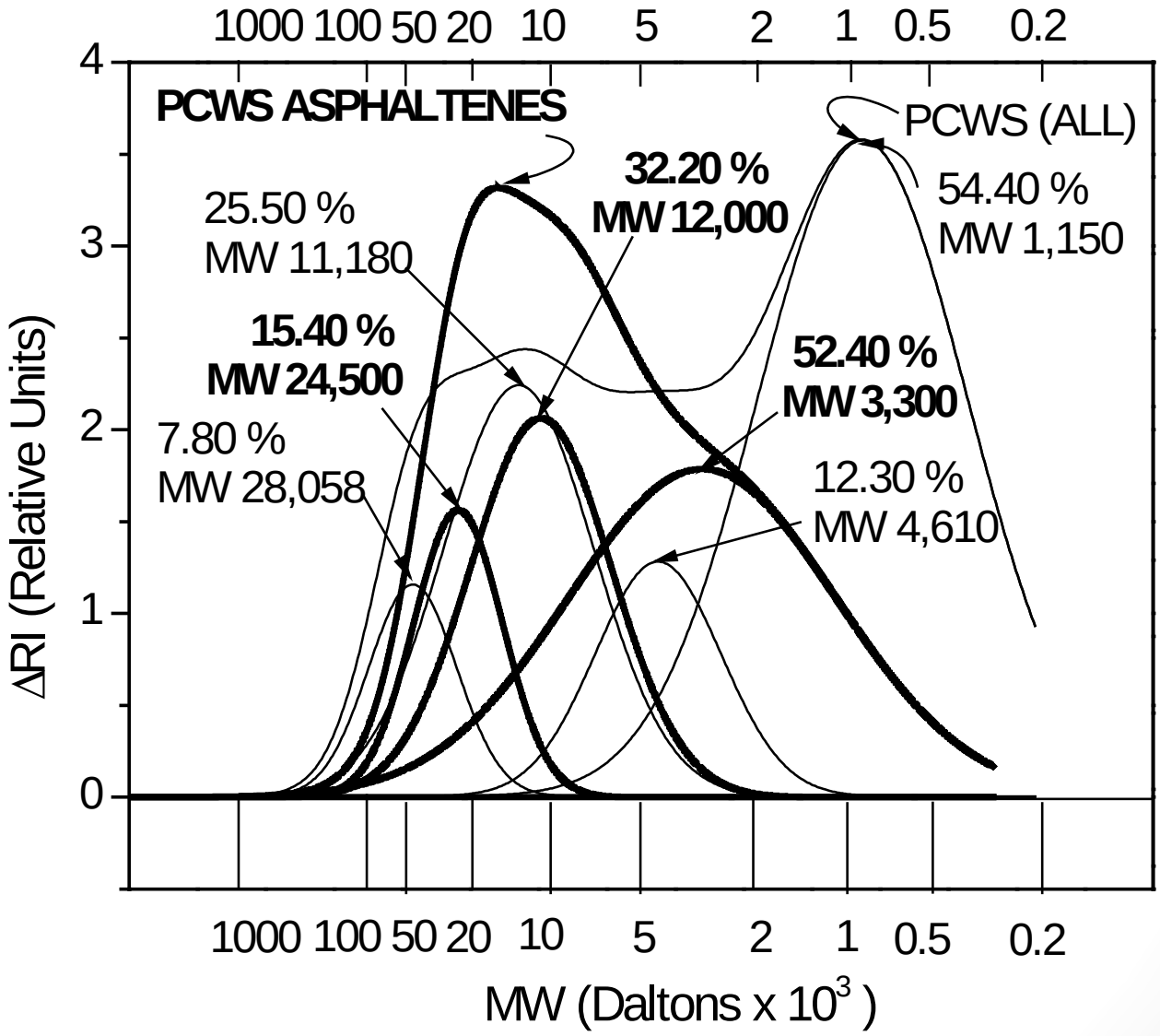


Scope – Binder Experiment

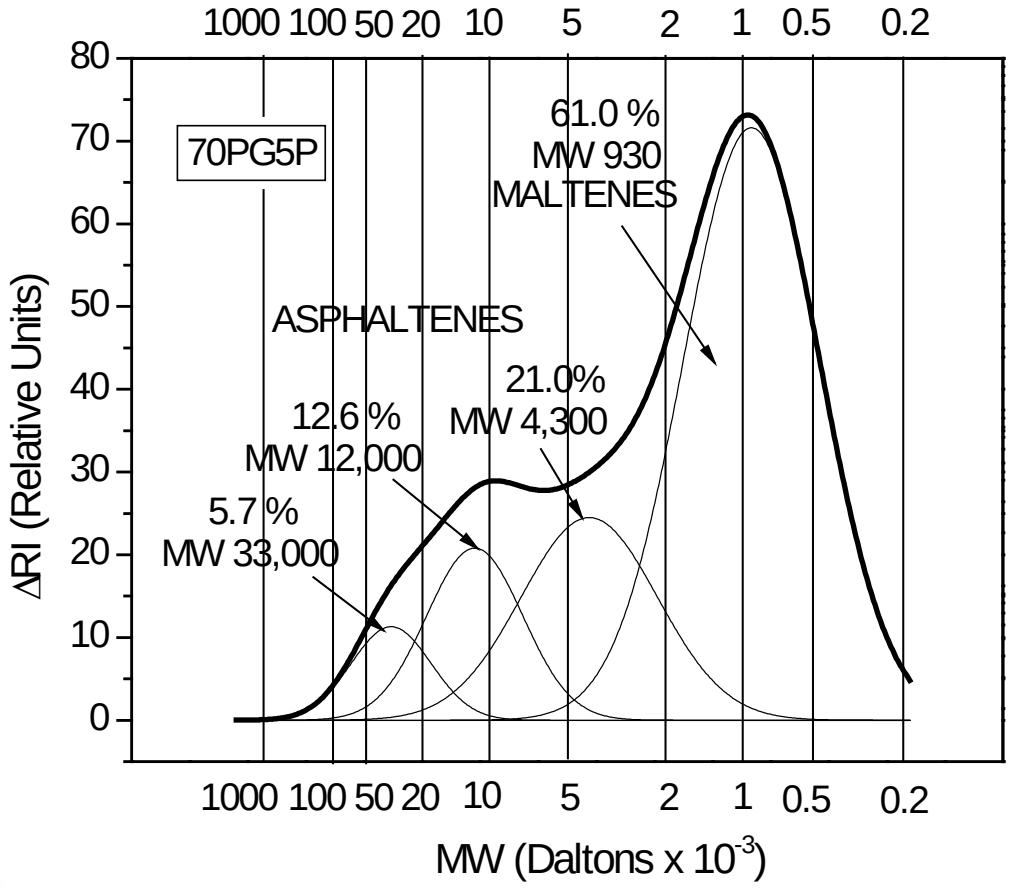
Analysis of Asphalt Binder Composition (***SARA***)*

- Each binder was deasphaltened to yield *asphaltenes* (As) and *maltenes* which are dissolved in the n-heptane soluble portion.
- The *maltenes* were further fractionated in *saturates* (***S***), *aromatics* (***Ar***), and *resins* (***R***). n-Pentane was used to elute the saturates, and a 90/10 toluene/chloroform mixture was used to elute the aromatics.
- The resins were not eluted and remained at the origin.

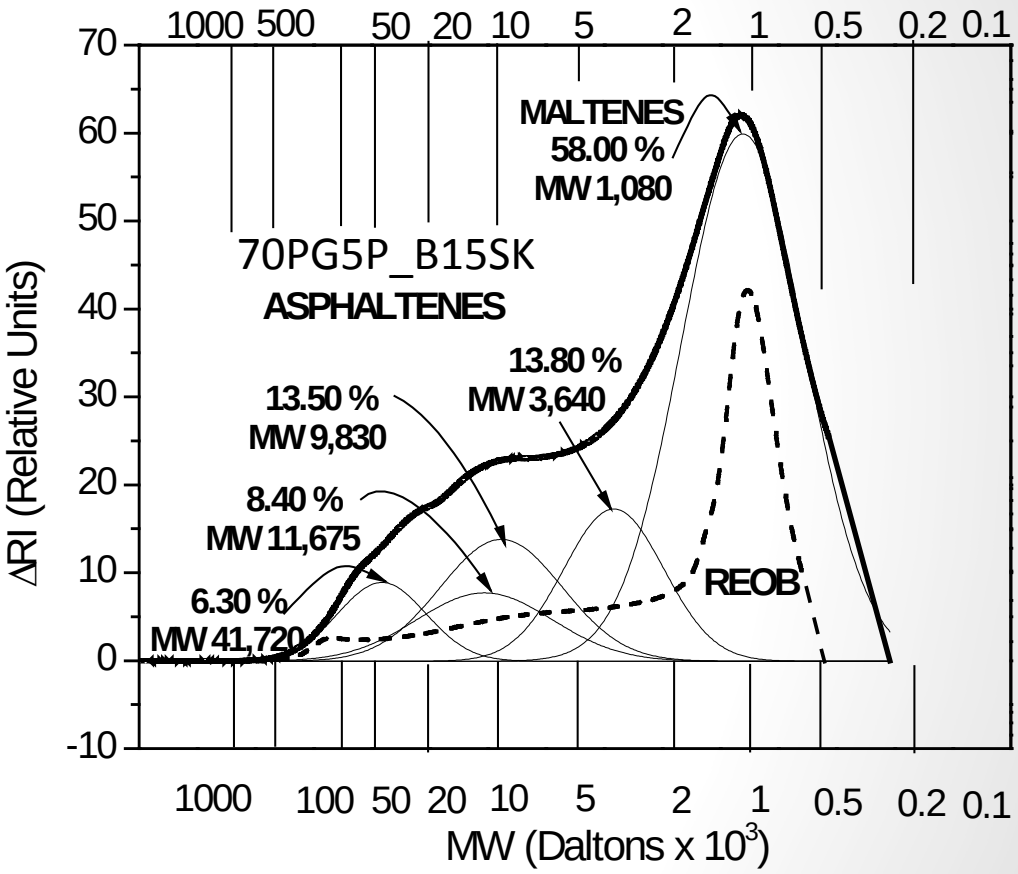
Comparative deconvolution of GPC traces of molecular weight species from PCWS and of n-heptane precipitated asphaltenes (PCWS Asphaltenes).



MW distribution of molecular species of 70PG5P and 70PG5P_B15SK binders extracted from mixtures containing 5% PCWS (A) and 5% PCWS & 15% REOB (B) , respectively



A

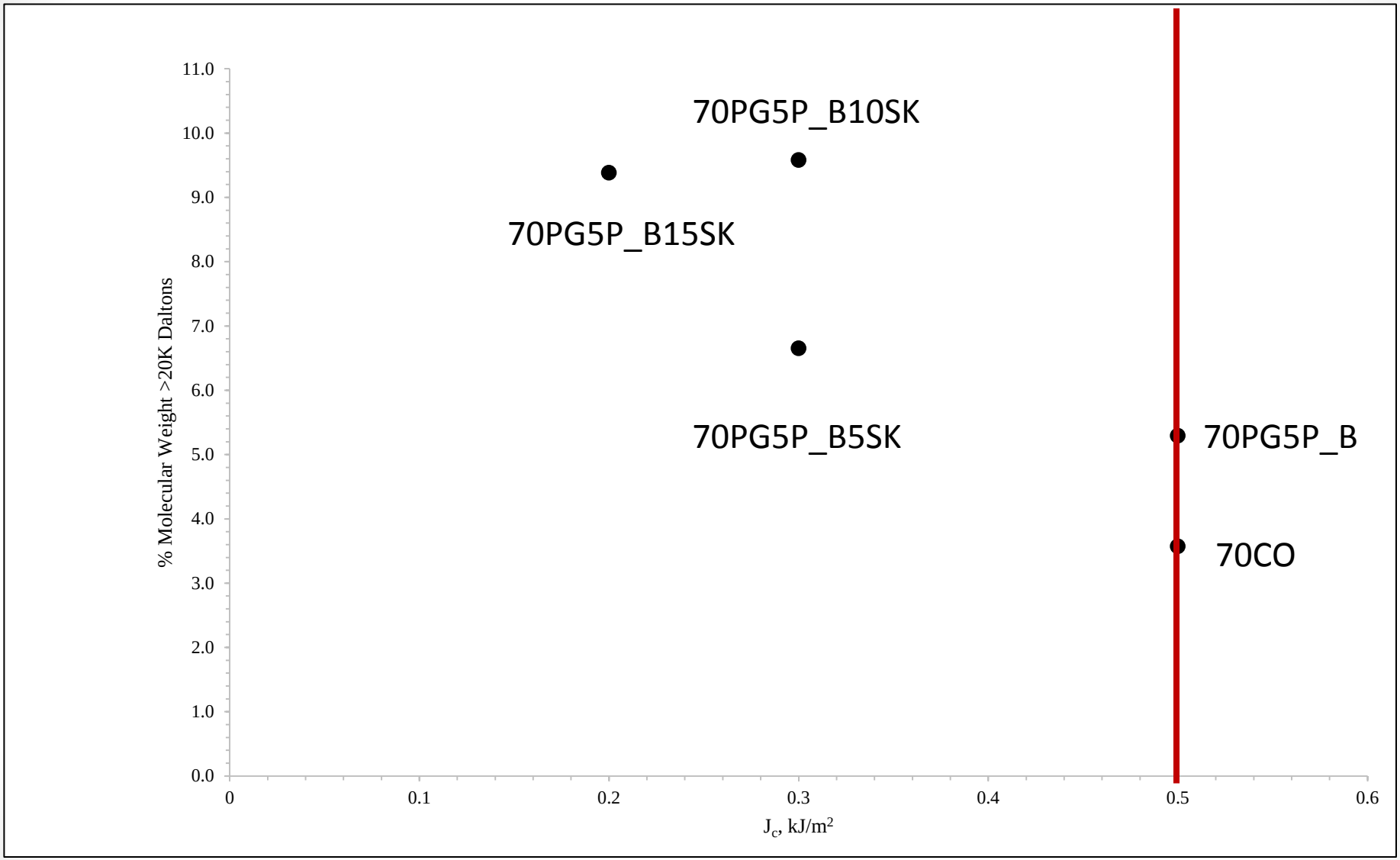


B

Chemical Composition of Extracted Mixture Binders.

Mix Designation	SARA Analysis, %					DECONV ASPH, %	HMW, %	DECONV MALT, %	J_c, kJ/m^2
	Asphaltenes	Resins	Aromatics	Saturates	Sum resins, aromatics, & saturates				
70CO	23.2	32.7	42.4	1.7	76.8	30.0	1.0	70.0	0.5
70PG5P_B	22.3	25.5	47.2	5.0	77.7	41.6	5.2	58.4	0.5
70PG5P_B5SK	20.6	26.9	45.4	7.1	79.4	33.5	4.5	66.5	0.3
70PG5P_B10SK	22.3	25.2	47.3	5.2	77.7	42.1	3.2	57.9	0.3
70PG5P_B15SK	24.4	29.3	40.2	6.1	75.6	42.0	6.3	58.0	0.2

Comparison of Jc values versus the content of asphalt fractions with MW>20K Daltons



Conclusion – Mixture Experiment

- In general, mixtures with 5% RAS/No RA exhibited similar performance as conventional mixture
- High Temperature
  - LWT Rut depth
  - conventional mixtures = mixtures containing RAS and REOB RA.
- Intermediate Temperature
  - SCB JC
  - conventional mixtures was similar to mixtures containing RAS and no RA
  - Jc decreased as the % REOB RA increased
- Low Temperature
  - In general , fracture temperature decreased with an increase in % REOB RA
    - Except 5% REOB

Conclusion – Binder Experiment

- Concentration of RAS asphaltenes exceeds 40%
  - 25% of these are highly aggregated with apparent MW approaching 100K
- Addition of REAO RA did not significantly dissociated HMW associated asphaltenes
  - Evident SCB Jc values
- Extraction of RAS binder increased with an increase in %REOB RA
  - Increased availability factor

Conclusion – Binder Experiment

- SARA asphaltenes analysis by precipitation did not capture the total amount of associated asphaltenes in the binder as measured by GPC. Some associated asphaltenes may remain in the resin fraction

- Asphaltenes component from the SARA was considerably smaller than the asphaltenes determined from deconvoluted GPC chromatograms


LSU
LOUISIANA STATE UNIVERSITY
Photo: Jim Zietz, Office of Public Affairs

THANK YOU