Investigation of the Use of Recycled Polymer Modified Asphalt in Asphaltic Concrete Pavements

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Presentation Outlines

- **Background**
- **Objective**
- **Laboratory Testing**
- **Discussion of Test Results**
- **Conclusions**

Background

- **Polymers modification of asphalt binders**
  - **increases fatigue life of mixture**
  - **reduces the extent of permanent deformation**
  - **improves thermal cracking resistance**
  - **improves moisture sensitivity and reduces age hardening**
  - **Initial success prompted LA DOTD and other states to require that polymers be incorporated into asphaltic pavements.**

Background

- **Late 1980s: PMAC pavements were built**
- **1994: LDOTD adopted the use of PMAC in most of its HMA pavements**
- **Rehabilitation stage**
- **Residual polymer additives**
  - **Concentration**
  - **Characterization**
  - **Contribution**
- **Evaluate the fundamental characteristics of recycled polymer modified asphalt pavements**

Objective is to answer the question, can you recycle polymer modified asphalt?

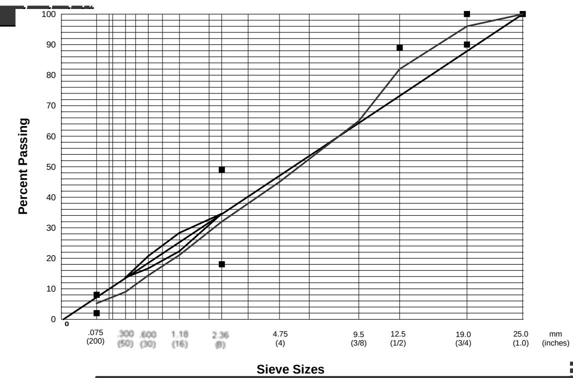
- **Characterize the rheological properties**
  - **virgin polymer modified asphalt cement (PMAC)**
  - **field aged PMAC (RPMAC)**
  - **Blends**
- **Evaluate mixture performance properties containing various percentages of RPMAC**

Materials (a) Binder Types

- **A SBS elastomeric polymer-modified asphalt cement (PMAC)**
  - **AC-30 + 3% SBS by weight.**
  - **meeting Louisiana DOTD specifications for PG 76-22**
- **A reclaimed PMAC binder (RPMAC)**
  - **eight year old PMAC binder wearing course from Highway US 61**
- **4 binder blends**
  - **Blend 1: 100% PMAC**
  - **Blend 2: 80% PMAC + 20 % RPMAC**
  - **Blend 3: 60% PMAC + 40 % RPMAC**
  - **Blend 4: 40% PMAC + 60% RPMAC**

Materials – (b) Asphalt Mixtures

- **Four 19 mm-Superpave Mixtures with different binder types but same crushed limestone aggregate and gradation**
- **Aggregate Structure**
  - **25% No. 67 LS**
  - **25% No. 78 LS**
  - **45% No. 11 LS**
  - **5% Sand**



19 mm Superpave Volumetric Properties

	Properties	Spec
%AC	4.2	
%AV	3.8	3 – 5
%VMA	13.7	> 13
$\%G_{mm}$, Ni	85.5	< 89
$\%G_{mm}$, Nf	97.5	> 89
Aggregate Properties		
FAA	48	45%, min
SE	74	45%, min
F & E	2	10%, max
CAA	100	95/100

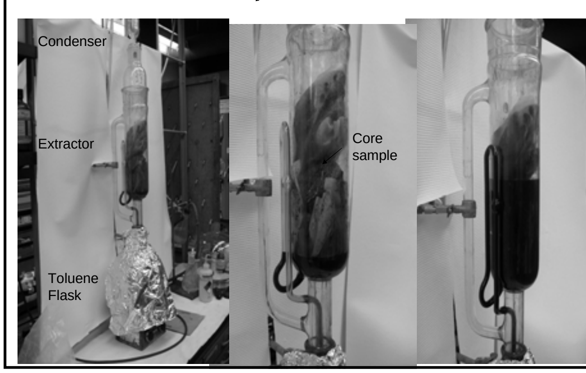
Gyrations	
N_i	9
N_d	125
N_f	205

Asphalt Binder Test and Results

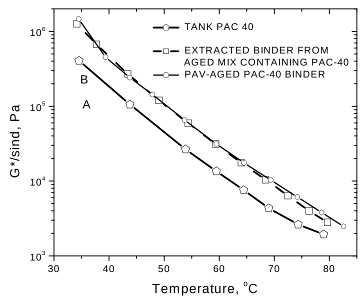
Asphalt Binder Tests

- **Binder Tests**
  - **Extraction**
  - **Dynamic Shear Rheometer (DSR)**
  - **Bending Beam Rheometer (BBR)**

Extraction process: Soxhlet Extraction Apparatus



Material characterization - DSR



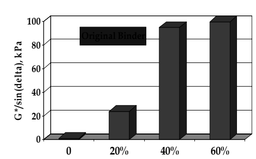
Thermal Transitions of Asphalt Binder

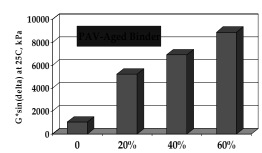
SAMPLE	Tg °C
AC-30	<-20
PMAC	-22
PAV-PMAC	-11.0
US61 Binder	4.5
20% US61	-0.5
40% US61	-3.1
60% US61	3.8

Binder Test Results (Table)

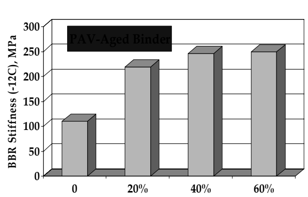
Test	Property	Test Results: Original PMAC	20% RPMAC	40% RPMAC	60% RPMAC	PG Criteria
Original Binder						
Dynamic Shear, 10 rad/s	G*/sin δ, kPa (76°C)	1.03	23.8	94.8	99.7	1.0 kPa, Min
Pressure Aging Vessel (PAV) Aged Binder						
Dynamic Shear, 10 rad/s	G*sin δ, kPa (25°C)	1056	5230	6911	8889	5000 kPa, Max.
Bending Beam	Stiffness,MPa S (-12°C)	110	219	246	249	300 MPa, Max.
	M value (-12°C)	0.39	0.271	0.246	0.229	0.300, Min.

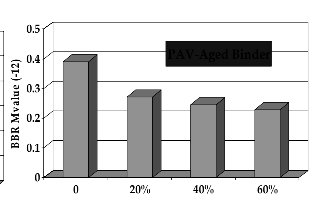
DSR Test Results





BBR Test Results





Mixture Test Results

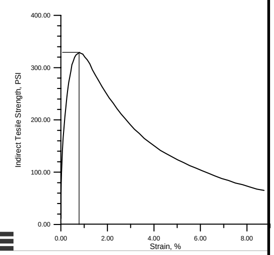
Mixture Performance Tests

- Repeated Shear at Constant Height (RSCH), 60C
- Indirect Tensile Creep (ITC) test, 40C
- Indirect Tensile Strength (ITS) test, 25C
- Semi-Circular Bend (SCB) test, 25C

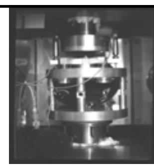
Indirect Tensile Strength Test

- **Test Protocol**
  - Cylindrical Specimen: 100mm x 63.5mm
  - 50.8 mm/min vertical deformation rate
  - Temperature: 25C
  - Analysis: ITS

$$\text{ITS} = \frac{2 \cdot P_{ult}}{\pi \cdot t \cdot D}$$



Indirect Tensile Creep Test

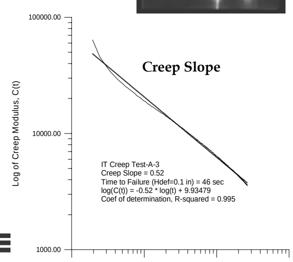


- **Test Protocol**
  - Cylindrical Specimen: 100mm x 63.5mm
  - Creep Load: 1112.5 N (250lb) Compressive load
  - Creep Time: 60 min. or failure
  - Temperature: 40C
- **Creep Slope**

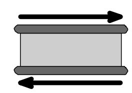
Creep Modulus $C(T) = \frac{3.59\,P}{t \cdot \delta V(T)}$

Where:

C(T)– creep modulus at time T, MPa,
P – applied vertical load, N,
t – sample thickness, mm, and
δV(T)– vertical deformation at time T, mm.



Repeated Shear at Constant Height

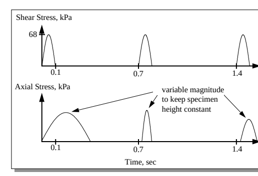


- **Test Protocol (AASHTO TP7)**
  - Cylindrical Specimen: 150mm x 50mm
  - Stress-controlled test
  - Haversine load: 68kpa, 0.1s load time, and 0.6s rest time
  - Up to 5000 cycles
  - Temperature: 60C
- **Cumulative Permanent Shear Strain**

Where: $\gamma_{12} = \delta_h / d$

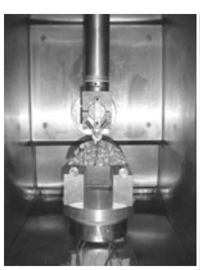
δ_h - the cumulative permanent shear displacement at 5,000 cycles

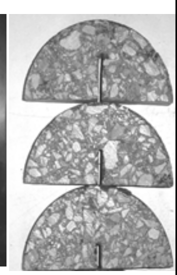
d - the distance over which shear deformation is measured or gage length.



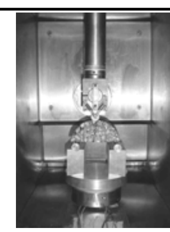
Semi-Circular Bend (SCB) Test

- **Sample Geometry**
  - 150mm X 57mm
  - Four specimens
- **Three notch depths**
  - 25.4 mm
  - 31.8 mm
  - 38 mm

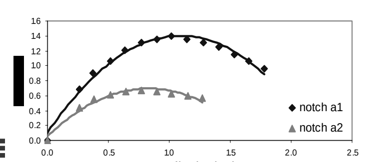


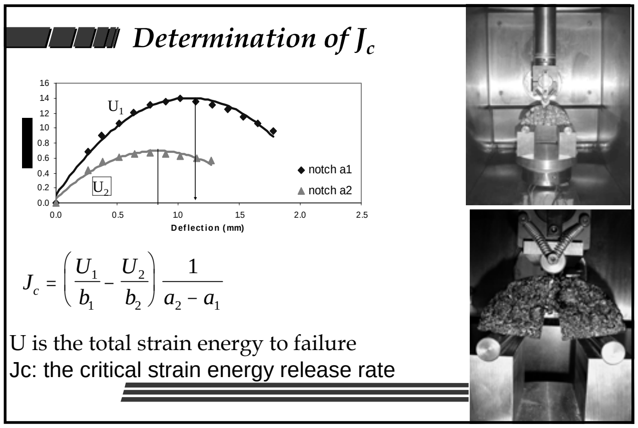


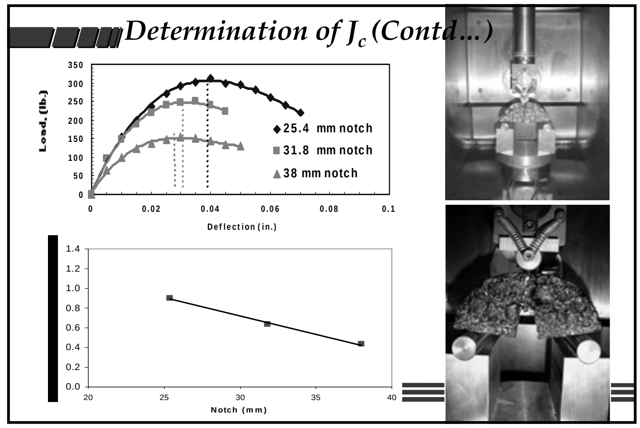
SCB Test (Contd…)

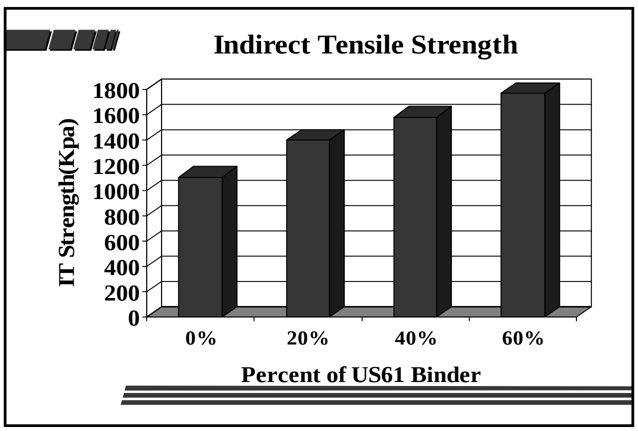


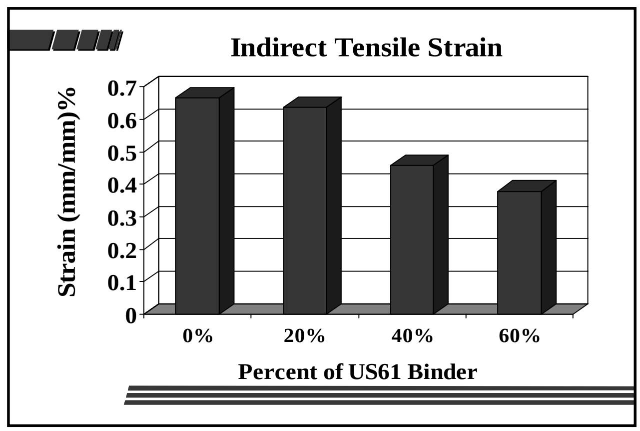
- **Loading rate**
  - 0.5 mm/min
- **load and deformation are recorded**
- **Test temperature**
  - 25 °C
- **Triplicate**

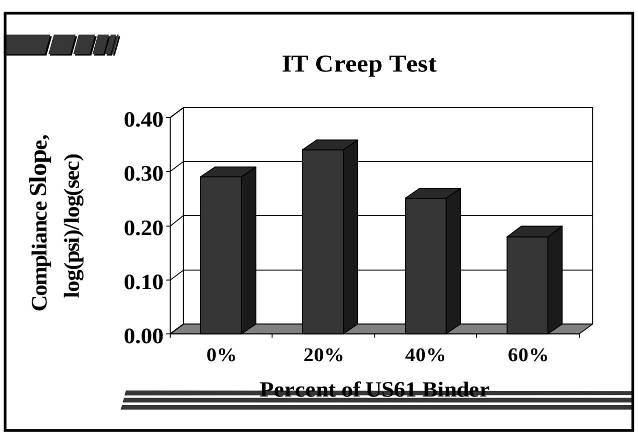


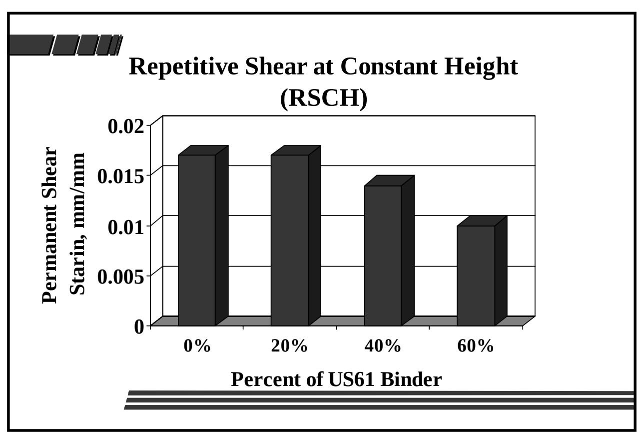

Determination of J_c
U_1
U_2
notch a1
notch a2
Deflection (mm)
$J_c = \left(\frac{U_1}{b_1} - \frac{U_2}{b_2}\right)\frac{1}{a_2 - a_1}$
U is the total strain energy to failure
Jc: the critical strain energy release rate


Determination of J_c (Contd…)
Load (lb.)
25.4 mm notch
31.8 mm notch
38 mm notch
Deflection (in.)
Notch (mm)

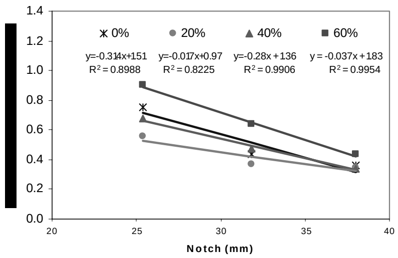

Indirect Tensile Strength
IT Strength(Kpa)
0%
20%
40%
60%
Percent of US61 Binder


Indirect Tensile Strain
Strain (mm/mm)%
0%
20%
40%
60%
Percent of US61 Binder

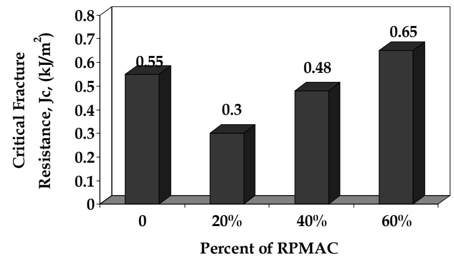

IT Creep Test
Compliance Slope, log(psi)/log(sec)
0%
20%
40%
60%
Percent of US61 Binder


Repetitive Shear at Constant Height (RSCH)
Permanent Shear Starin, mm/mm
0%
20%
40%
60%
Percent of US61 Binder

SCB Test Results



Jc vs. Percent of RPMAC



Comparison of the Critical Jc for various asphalt mixtures

	0%	20%	40%	60%	PG70 -28	CRA PG70-22	AC-5 + 9% SEBS	AC-5 + 2% Elvaloy
J_c (kJ/m²)	0.55	0.30	0.40	0.65	0.54	0.65	0.42	0.40
	Current RPMAC Study				Mull et al., 2002		Bhurke et al., 1997	

Summary and Conclusions

- Use of RPMAC in HMA was investigated
- Field aged binder was extracted from 8 year HMA WC mixture
- Blends: 0-, 20-, 40-, 60-percent RPMAC
- Procedures were developed to separate the PMAC into its asphalt resin and polymer additive components
- Impact of the extraction and recovery process on binder properties has been found to be minimal

Summary and Conclusion

- US61 binder exhibited higher extent of oxidation than the PAV-aged PMAC
- Increasing of the percentages of US61 binder in mixtures increased the *rutting resistance*, as evidenced by RSCH, APA and IT Creep test results.

Conclusion

- SCB test provides a simple means to obtain fracture resistance characterization of asphalt mixtures
- The critical Jc values are found fairly sensitive to changes in binder stiffness.
- As more RPMAC added, its stiffening effect overcame that of the new control modified binder. This has resulted in an increase in the values of strain energy to the failure, U, and the critical value of fracture resistance, Jc, which represents an improved fracture resistance of the RPMAC mixtures.

Summary and Conclusion

- It appears that the 60% RPMAC mixtures have a better fracture resistance than 0%, 20% and 40% RPMAC mixtures
- Similarly, the 0% RPMAC mixtures seems to have a better fracture resistance than 20% and 40% RPMAC mixtures
- The ranking order based on Jc values is different from that based on ITS test results.

Future Work

- Produce blends with softer binders
  - Sufficient polymer impact
- Validate blending charts
- Durability

Acknowledgement

- Louisiana Education Quality Support Fund
- Louisiana DOTD
- Koch Materials

Thank You

Possible Explanation

- The sudden drop of the J_c value from 0% to 20% could be due to,
  - the RPMAC at low concentrations may be incompatible with the controlled elastomeric modified binder – PMAC
  - discontinuity in binder blend could be created, which can weaken the adhesive and cohesive properties of the binder and promoted the crack propagation in the mixtures.
- As more RPMAC added, its stiffening effect overcame that of the new control modified binder, which is accompanied by an increase in the maximum sustained load and slight decrease in the deflection at maximum load.
- The increased load and small decrease in deflection will result in an increase in the values of strain energy to failure, U, and eventually a higher Jc value.