Laboratory Mechanistic Evaluation of HMA Mixtures Containing High RAP Content with Crumb Rubber Additives

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My Story

- Background
- Objectives
- Scope
- Methodology
- Discussion of Results
- Conclusions

Background

- Recent increase in crude oil prices
  - "Golden Ages"
  - Asphalt cement prices all time high
  - Increase in asphalt mixtures
- Develop innovative technology
  - Sustainability
    - decrease material costs
    - no compromise in performance
  - Incorporate waste and recycled materials in asphalt mixture
    - crumb rubber from *waste tires*
    - *Reclaimed Asphalt Pavement*

Background

- LDOTD asphalt cement specification requires
  - elastomeric type of polymer modifier
    - Styrene Butadiene Styrene (SBS)
  - enhanced performance
    - rutting and fatigue cracking
- Shortage in SBS
  - reported by several polymer suppliers
- Potential to utilize crumb rubber from *waste tires*
  - absorption properties
    - carry engineered additives
  - Improve performance
    - revitalize aged binders
      - fatigue cracking

Background

- Most State Specification
  - Limit the % of RAP allowed in flexible pavement layers
    - HMA mixture
  - asphalt binders *hardened and oxidized*
  - causing premature cracking in pavements
- What is the solution to Increase Use of RAP?
  - soften the asphalt cement binder of RAP materials
    - engineered additives
  - crumb rubber from waste tires in *dry process*
    - Carrying agent of engineered additives
  - will enable the use of higher % RAP

Background

- Method of sustainability in the HMA industry
  - Use of recycled materials
  - Direct impact on cost and the environment
  - GREEN & LEED
    - Leadership in Energy and Environmental Design

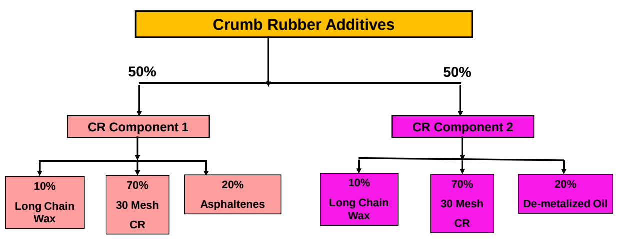
Objectives

- **Fundamentally characterize the laboratory performance**
  - **Conventional HMA mixtures**
  - **Mixtures containing high RAP content and waste tire crumb rubber/engineered additives**
    - **Dry process**

Scope

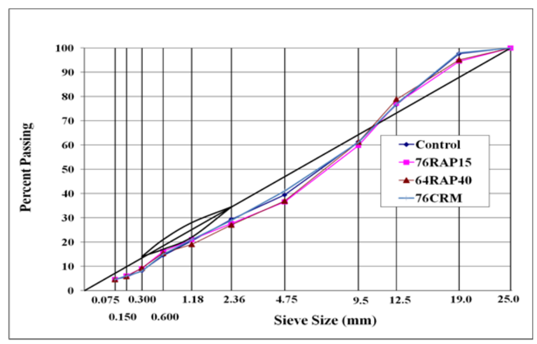
- **Four 19.0 mm Level 2 HMA mixtures**
  - **Siliceous limestone aggregates**
    - **commonly used in Louisiana**
  - **Mixture 1: Conventional one, 76CO**
    - **No RAP**
    - **Binder: PG 76-22M**
    - **control mixture**
  - **Mixture 2: 76CRM**
    - **No RAP**
    - **Binder: PG 64-22 + 30 mesh CR & engineered additives: *wet blend***
      - **PG 76-22M**
  - **Mixture 3: 76RAP15**
    - **15% RAP**
    - **Binder: PG 76-22M**
  - **Mixture 4: 64RAP40**
    - **40% RAP**
    - **Binder: PG 64-22**
      - **30 mesh CR & engineered additives: *dry blend***

Crumb Rubber/Engineered Additives (Dry Process)



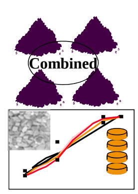
CR Supplied by: Mr. John Osborn of Elastomeric Concentrates, LLC

Aggregate Structure



Mixture Design

- Selection of Materials
  - Binder
    - PG 64-22, 76-22M
    - Extraction from RAP
    - Verification of the asphalt binder grade
  - Aggregates
    - No. 67, No. 78, No. 11, Coare Sand
    - RAP, CR
- Aggregate Structure Selection
  - combined in typical percentages
- Determination of Optimum Asphalt content
  - Superpave design will be performed
  - AASHTO TP28
    - Standard Practice for Designing Superpave HMA
  - Section 502 of the 2000 Louisiana Standard Specifications for Roads and Bridges
    - Volumetic (VTM, VMA, VFA)
    - Densification ((%G_{mm} at N_{ini}, %G_{mm} at N_{final})



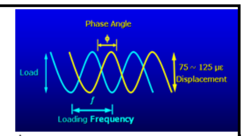
Asphalt Mixture Preparation

Laboratory Materials Characterization

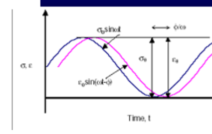
Binder
- PG grading

Mixture
- Permanent Deformation
  - Loaded Wheel Test
  - Dynamic Modulus Test
- Fracture/Durability
  - Semi Circular Bend Test
  - Moisture Susceptibility
    - Lottman Test
- Triplicate
- V_A = 7.0% ± 0.5

Dynamic Modulus |E*| Test



- IPC SPT (AMPT)
- AASHTO TP-62
- Sinusoidal axial compressive stress is applied to a specimen
  - temperature and frequency
- Dynamic modulus $|E^*| = \frac{\sigma_0}{\varepsilon_0}$
- Phase Angle $\phi = \frac{T_i}{T_p} \times 360°$



Frequency (HZ)	25, 10, 5, 1, 0.5, 0.1
Temp. (°C)	-10, 4.4, 25, 38, 54.4

Laboratory Sample Preparation -- |E*|

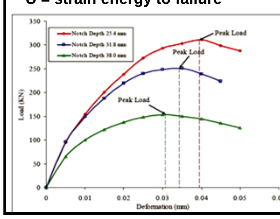
Semi-Circular Bend (SCB) Test

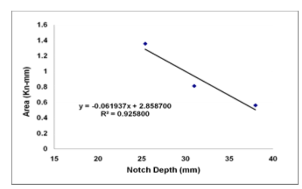
- The critical value of fracture resistance

$$J_c = -\left(\frac{1}{b}\right)\frac{dU}{da}$$

Loading rate: 0.5 mm/min
Notch Depth (mm): 25.4, 31.8, 38.0
Test temperature: 25 °C
Dimension: 150mm dia by 57mm wide

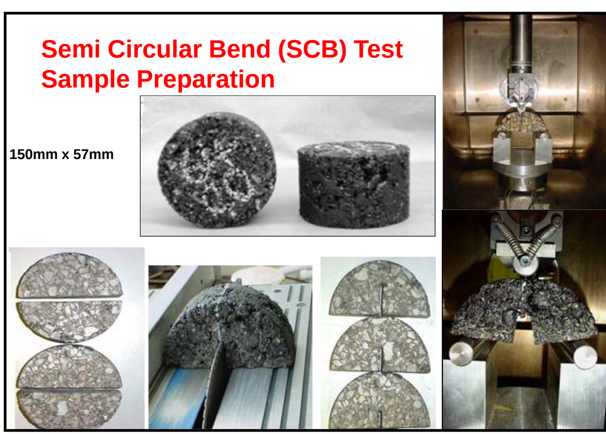
b = Sample Thickness,
a = notch depth,
U = strain energy to failure





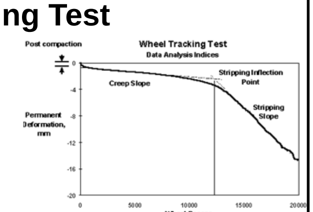
Semi Circular Bend (SCB) Test Sample Preparation

150mm x 57mm



Loaded Wheel Tracking Test

- AASHTO T 324-04
- Damage by rolling a steel wheel across the surface of a sample
  - Cylindrical, Slab
- 50 °C, Wet or dry
- Deformation at 20,000 passes is recorded

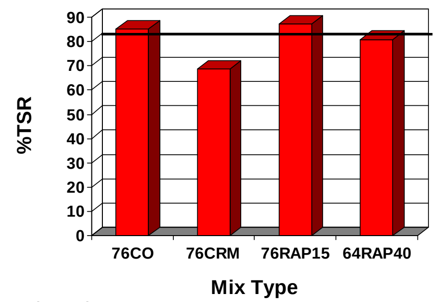


Wheel Diameter: 203.5 mm (8 inch)
Wheel Width: 47mm (1.85 inch)
Fixed Load: 703 N (158 lbs)
Rolling Speed: 1.1 km/hr
Passing Rate: 56 passes/min

Asphalt Cement Binder Characterization

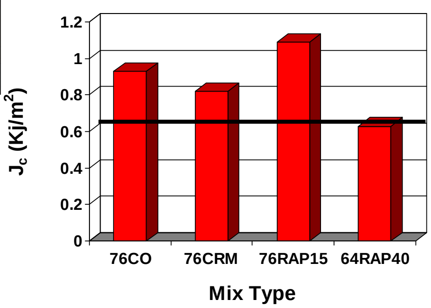
- PG Grading
  - Conventional Asphalt Cements
    - PG 76-22M
    - PG 64-22
  - PG 64-22 + 30 mesh CR & engineered additives
    - PG 76-22
    - wet blend
  - PG 64-22 + 30 mesh CR & engineered additives
    - dry blend:64RAP40
    - extracted binder
    - PG 70-28

Moisture Susceptibility Test Results -- %TSR No Antistrip Additives

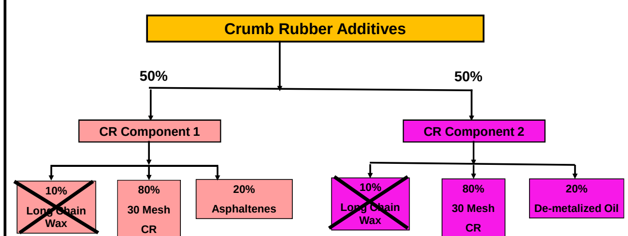


Dry ITS: 140Psi-150Psi

Semi-Circular Bend Test Results, 25C



Crumb Rubber/Engineered Additives (Dry Process)



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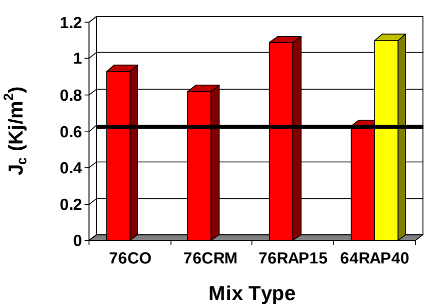
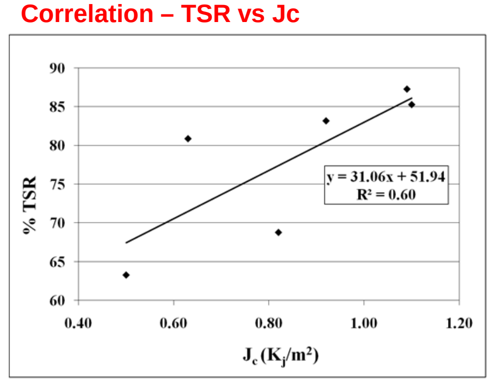
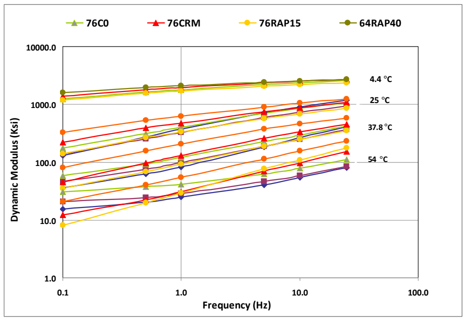
Semi-Circular Bend Test Results, 25C



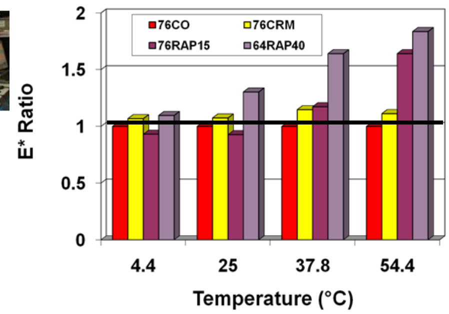
Correlation – TSR vs Jc



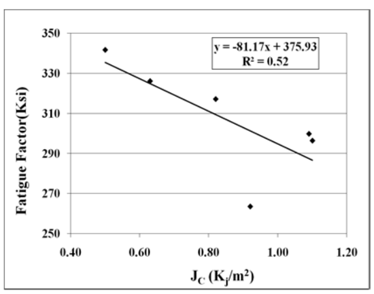
Complex Modulus Test Results -- Isotherms



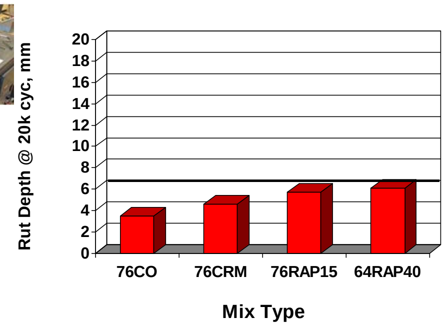
Complex Modulus Test Results – E* Ratio to PG 76-22M



Correlation -- Fatigue Factor vs J_c



Loaded Wheel Track Test Results – 50C, Wet



Conclusion

- **Addition of CR additives had a positive influence on the asphalt cement binder**
  - **Extracted 64RAP40 Binder graded as PG 70-28**
- **Moisture Susceptibility**
  - **Mixtures 76CO, 76RAP15, 64 RAP40**
  - **Passed with %TSR**
- **Intermediate Temperature**
  - **Critical Strain Energy, Jc from SCB test**
  - **Met the minimum value of 0.6 for fracture resistant mixtures**
- **High Temperature**
  - **Mixture performed well, < 6mm**
- **Fair Correlations**
  - **%TSR vs. Jc**
  - **E* fatigue factor vs. Jc**

Conclusion

- **The use of crumb rubber is a promising technology**
  - **significant potential to enhance pavement performance**
  - **satisfying current market needs with respect to supporting the recycling of waste tires**
  - **improving the performance characteristics**
    - **crumb rubber and engineered additives.**

THANK YOU