Laboratory Performance Asphalt Mixtures Containing High RAP Content with Crumb Rubber Additives

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Sustainable Materials for Pavement Infrastructure: Use of Waste Tires in Asphalt Mixtures
September 5, 2012
Baton Rouge, Louisiana
My Story

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

- Meeting the needs of the present without compromising the future
  - 1987 United Nation conference
  - World Commission on Environment and Development (WCED)
- “Do onto future generations as you would have them do onto you"
  - Golden Rule
- "Sustainable means using methods, systems and materials that won't deplete resources or harm natural cycles"
  - Rosenbaum, 1993
Sustainable Development

- **Economical Sustainability**
  - Balanced cost-revenue relationship
    - LCA
    - Managing Resources

- **Environmental**
  - Friendly to the ecosystems
  - Minimum harm to the surroundings
  - Recycling
    - minimize the use of natural resources
  - Renewable sources of energy
    - reduce energy consumption,
    - reduce greenhouse gas emissions

- **Materials Performance**
  - Better or similar performance
  - Meet people’s needs
  - ensure a high level of user comfort

- Three aspects must be considered altogether
Sustainability
Materials/Technology

- Recycled Materials
  - Waste Tires
Background

- LDOTD asphalt cement specification requires elastomeric type of polymer modifier
  - Styrene Butadiene Styrene (SBS)
  - enhanced performance
    - rutting and fatigue cracking

- Shortage in SBS
  - 2008
  - 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 asphalt industry
  - Use of recycled materials
  - Direct impact on cost and the environment
  - GREEN & LEED
    - Leadership in Energy and Environmental Design

- NCHRP 10-91 [RFP]
  - Guidebook for Selecting and Implementing Sustainable Highway Construction Practices
  - … identify effective sustainability practices that can be implemented during the construction of highway projects…”
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 Component 1
- 80% 30 Mesh CR
- 20% Asphaltenes

CR Component 2
- 80% 30 Mesh CR
- 20% De-metalized Oil

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

- RAP
- CR/Eng. Additives
- Oven, 163°C
- Superheated Agg/RAP
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
- $V_A = 7.0\% \pm 0.5$
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 $\phi = \frac{T_i}{T_p} \times 360^\circ$

<table>
<thead>
<tr>
<th>Frequency (HZ)</th>
<th>25, 10, 5, 1, 0.5, 0.1</th>
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<tbody>
<tr>
<td>Temp. (°C)</td>
<td>-10, 4.4, 25, 38, 54.4</td>
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</table>
Fracture Property – 25C
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
Fracture Property – 25C
Semi-Circular Bend (SCB) Test

150mm x 57mm
High Temperature Property – 50C Loaded Wheel Tracking Test

- AASHTO T 324
- 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
Moisture Susceptibility Test Results -- %TSR
No Antistrip Additives

Dry ITS: 140Psi-150Psi
Fracture Property – 25C
Semi-Circular Bend (SCB) Test

Mix Type

76CO  76CRM  76RAP15  64RAP40

$J_c$ (Kj/m$^2$)

0.2  0.4  0.6  0.8  1.0  1.2

Mix Type
Correlation – TSR vs Jc

\[ y = 31.06x + 51.94 \]

\[ R^2 = 0.60 \]
Complex Modulus Test Results –
$E^*$ Ratio to PG 76-22M
Correlation -- Fatigue Factor vs $J_c$

$y = -81.17x + 375.93$

$R^2 = 0.52$
High Temperature Property – 50C, Wet Loaded Wheel Tracking Test Results

Mix Type

Rut Depth @ 20k cyc, mm

Mix Type

76CO 76CRM 76RAP15 64RAP40
Summary

- Addition of CR additives had a positive influence on the asphalt cement binder and provide

**Moisture Susceptibility**
- Mixtures 76CO, 76RAP15, 64RAP40
- 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
Future Research

- Innovations that will maximize the use of CRM asphalt mixtures in flexible pavements.
  - Dry process feed systems;
  - Engineered asphalt-rubber system processed from waste tires that can be used in dry process for several applications such as:
    - Warm mix asphalt mixture;
      - Environmental and economical benefits
    - Allowing the use of higher percentages of RAP; and
    - Modifications of binder properties to improve the mixture resistance to moisture damage.

- Pavement thickness equivalency
  - between conventional mixes and CRM asphalt mixes
  - ensure cost competitiveness of these mixes.