Characterization of Fracture Resistance of RPMAC Mixtures Using a Semi-Circular Bend Fracture Tests
Objective and Scope

- Evaluate the fracture resistance of Superpave mixtures containing RPMAC using the SCB test
- 19 mm Superpave mixture
- 4 binder blends
  - Blend 1: 100% PG 70-22M
    » SBS elastomeric polymer modified asphalt cement (PMAC)
  - Blend 2: 80% PG 70 - 22M + 20 % RPMAC
  - Blend 3: 60% PG 70 - 22M + 40 % RPMAC
  - Blend 4: 40% PG 70 - 22M + 60% RPMAC
**LTRC Semi-Circular Bend (SCB) Test**

- **Sample Geometry**
  - 150mm X 57mm
  - Four specimens

- **Three notch depths**
  - 25.4 mm
  - 31.8 mm
  - 38 mm

- **Test temperature**
  - 25 °C
**SCB Test Results**

### Graph

- **Equations:**
  - $y = -0.314x + 1.51$  
  - $y = -0.017x + 0.97$  
  - $y = -0.28x + 1.36$  
  - $y = -0.037x + 1.83$

- **$R^2$ Values:**
  - 0.8988  
  - 0.8225  
  - 0.9906  
  - 0.9954

### Table

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

- Semi-circular bend test provides a simple means to obtain fracture resistance characterization of asphalt mixtures.
- SCB provides stable testing configuration.
- The critical fracture resistance values (Jc) from the SCB tests were fairly sensitive to changes in binder stiffness.
- Increased percentages of RPAMC in the mixtures exhibited higher Jc.
- Semi-circular bend test can be used as a valuable correlative tool in predicting fatigue crack growth of asphalt mixtures.
**Future Work**

- Perform an extensive testing program
  - specimen geometry
  - environmental conditions
  - on the values of $J_{ic}$ obtained using the semi-circular bend specimen.

- Produce a standardized method by which $J_{ic}$ can be used as a material parameter to rank the static fracture resistance of asphalt mixtures
Influence Of Asphalt Tack Coat Materials On The Interface Shear Strength
Objective

- Evaluate the current practice of using tack coats through controlled laboratory shear tests
- Evaluate the influence of tack coat types, application rates, and test temperatures on interface shear strength
- Recommend optimum tack coat type and application rate
Scope

- 19 mm Mix

Tack Coat Materials

<table>
<thead>
<tr>
<th>Emulsions</th>
<th>Application Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>l/m²</td>
</tr>
<tr>
<td>CRS-2P</td>
<td>0.00</td>
</tr>
<tr>
<td>SS-1</td>
<td>0.09</td>
</tr>
<tr>
<td>CSS-1</td>
<td>0.23</td>
</tr>
<tr>
<td>SS-1h</td>
<td>0.45</td>
</tr>
<tr>
<td>PG 64-22</td>
<td>0.90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asphalt Cements</th>
<th>Application Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64-22</td>
<td></td>
</tr>
<tr>
<td>PG 76-22M</td>
<td></td>
</tr>
</tbody>
</table>

- Triplicate samples
- 156 samples

<table>
<thead>
<tr>
<th>Test Temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>55</td>
</tr>
</tbody>
</table>
Sample Preparation

Shear
**Test Procedure**

Shear Stress vs Displacement

Test Temperature 55°C

Shear Stress (kPa)

Displacement (mm)
Variation of Shear Strength Versus Application Rate at 25°C

Shear Strength (kPa)

Application Rate (l/m²)

- PG 64-22
- PG 76-22M
- CRS-2P
- SS-1
- CSS-1
- SS-1h
Variation of Shear Strength Versus Application Rate at 55ºC

Shear Strength (kPa)

Application Rate (l/m²)

PG 64-22
PG 76-22M
CRS-2P
SS-1
CSS-1
SS-1h
Maximum Interface Shear Strength

Test Temperature 25°C

Tack Coat Type

Max Shear Strength (Kpa)

PG 64-22
PG 76-22M
CRS-2P
SS-1
CSS-1
SS-1h

0.09 l/m²
0.23 l/m²
Maximum Interface Shear Strength

Test Temperature 55°C

Max Shear Strength (Kpa)

- PG 64-22
- PG 76-22M
- CRS-2P
- SS-1
- CSS-1
- SS-1h

Tack Coat Type

- 0.09 l/m²
- 0.23 l/m²
- 0.45 l/m²
- 0.90 l/m²
Summary and Conclusions

- Controlled laboratory simple shear tests
  - optimum application rate
- The influence of **tack coat types, application rates, and test temperatures** on the interface shear strength
- Among the six different tack coat materials used, CRS 2P emulsion was identified as the best performer
- Optimum application rate for CRS 2P emulsion was 0.09 l/m² (0.02 gal/yd²)
- At 25°C, increasing the tack coats application rates generally resulted in a decrease in interface shear strength
- At 55°C, the interface shear strength was not sensitive to the application rate
- CRS 2P at the optimum application rate provided only 83 percent of the monolithic mixture shear strength
- Suggests that the construction of flexible pavements in multiple layers introduces weak zones at these interfaces
Recommendations

Further Research is Recommended to

- Validate laboratory interface strength measurements by conducting similar simple shear tests on field cores;
- Examine the variation of interface strength under fatigue;
- Evaluate the influence of tack coats at interfaces between: an asphalt concrete and a Portland cement concrete layer, and between a new construction surface and an old one; and
- Determine optimum application temperature and curing period for different tack coat types.
Variability of Air Voids and Mechanistic Properties of Plant Produced Asphalt Mixtures
Objectives

- Evaluate the variability of Air Voids of Plant Produced Mixtures
- Compare different methods of air void measurements
- Characterize SGC samples and field cores
- Assess the in-situ test measurements
**Scope**

- Two overlay rehabilitation Projects
  - I-10 Egan
    - 25.0 mm Superpave Mixture, Binder Course
    - 12.5 mm Superpave Mixture, Wearing Course
  - I-10 Vinton
    - SMA mixture
- Test Sections
  - 6: I-10 Egan
  - 1: I-10 Vinton

<table>
<thead>
<tr>
<th>Egan</th>
<th>Vinton</th>
</tr>
</thead>
<tbody>
<tr>
<td>2” SMA (12.5mm)</td>
<td>2” 12.5mm-Superpave</td>
</tr>
<tr>
<td>7” 25mm-Superpave</td>
<td>7.5” 25mm-Superpave</td>
</tr>
<tr>
<td>10” Rubblized PCC</td>
<td>10” Rubblized PCC</td>
</tr>
<tr>
<td>Silty Clay Subgrade (AASHTO A-6)</td>
<td>Silty Clay Subgrade (AASHTO A-6)</td>
</tr>
</tbody>
</table>
Testing Program

- Test section
  - Collect sufficient loose mixtures from the paver
  - Mixture composition analysis
  - Compacted Samples
    » Air voids
    » Mechanistic tests
In-Situ Test Devices

PQI model 301
TransTech System, Inc.

FWD
Dynatest 800 model

LFWD – PRIMA 100 model
Carl Bro Company, Denmark
Laboratory Testing Program

Air voids

- Cores and SGC samples
- Conventional
  - AASHTO T166
- Vacuum Sealing Method
  - CoreLok
  - ASTM D 6752
Laboratory Testing Program

Mechanistic Tests

- Indirect Tensile Strength Test
  - 25°C
  - Each test section:
    » One Core and SGC sample
    » Six
  - Analysis: ITS

- FSCH
  - AASHTO TP7
  - 48°C and 60°C
  - Each test section:
    » One Core and SGC sample
    » Six
  - Analysis: $G^*$ and $\delta$
Relationship of Air Voids Test Methods
(Conventional vs CoreLok)

\[ y = 1.05x \]

\[ R^2 = 0.92 \]
Relationship of Air Voids Test Methods
(PQI vs. Conventional / CoreLok)

\[ y = 1.05x \quad R^2 = 0.59 \]

\[ y = 1.01x \quad R^2 = 0.49 \]
ITS Test Results – Cores vs SGC

- SMA
- Super WC
- Super BC

<table>
<thead>
<tr>
<th>Core</th>
<th>SGC</th>
<th>Core</th>
<th>SGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA</td>
<td></td>
<td>Super WC</td>
<td></td>
</tr>
<tr>
<td>Super BC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IDT Strength vs Air Voids

\[ y = -13.9x + 251.1 \]
\[ R^2 = 0.74 \]

\[ y = -13.6x + 277.9 \]
\[ R^2 = 0.47 \]
**Variation of G* - I 10 Egan**

**12.5 mm Mixture - 48 C**

- **SGC**
  - Mean = 25992 psi
  - SD = 3604 psi
  - CV = 14%

- **Core**
  - Mean = 14758 psi
  - SD = 1310 psi
  - CV = 9%
FSCH Test Results, $G^*(10\text{Hz})$ at 48 °C
Complex Shear Modulus ($G^*_{10Hz}$)  
(SGC vs. Core) 

$y = 1.57x$  
$R^2 = 0.88$
Variation of FWD Results - I 10 Egan
25 mm Mixture

![Graph showing FWD deflection results for different sections (S-1 to S-6) with symbols d1, d1-d6, and d7 representing varying deflection values.](image-url)
$y = -1.38x + 397.3$

$R^2 = 0.80$
Conclusions

Air Voids

- Binder course mixtures had the highest air voids variation as measured by all three methods, followed by the wearing course and SMA mixtures.
- CoreLok air voids variation were slightly than the conventional methods.
- Strong correlation between air voids measured using Conventional and CoreLok methods.
- Correlations between PQI measured air voids and other two methods (CoreLok and AASHTO T-166) are fair.
Conclusions
Mechanistic Tests

- Binder course mixtures had the highest ITS & G* variations followed by the wearing course and SMA mixtures
- Cores showed better correlations to air voids than SGC samples
- Cores and SGC samples showed similar variations - ITS, G*
- The ITS and G* of SGC samples were higher than cores
- Good correlation was observed between the G* of the cores and SGC samples
Conclusions

Mechanistic Tests

- Good correlations were observed between $E_{LFWD}$ and FWD deflections d1 and d1-d6
- LFWD test may be used as an alternative to FWD testing in pavement structure evaluation
Louisiana Experience With Foamed Recycled Asphalt Pavement Base Materials
The Project Statement

- Route: US 190, Baton Rouge, Louisiana
- CRCP concrete pavement design called 8" stone base
- Field jobs include the removal of the existing asphalt overlay and original concrete pavements (RAPs and waste concretes)

Question:
1. What’s the strength of the foamed asphalt treated RAPs?
2. Can it be used in place of the designed stone base?
Objective

- Assess the potential use of foamed asphalt (FA) treated RAP as a base course material in lieu of a crushed lime stone base
Scope

- Laboratory foamed asphalt (FA) RAP mixture design

- Field Evaluation: In-situ test device
  - Dynamic cone penetrometer (DCP)
  - Humboldt Stiffness Geoguage (HSG)
  - Falling Weight Deflectometer (FWD)
  - Light Falling Weight Deflectometer (LFWD)
  - Dynaflect
Foamed Asphalt Mixture Design

- Wirtgen Cold Recycling Manual
Optimum FA Content: 2 percent
**Field Test Section**

- **Test Section Layout - US Highway 190**

<table>
<thead>
<tr>
<th>Section A</th>
<th>Section B</th>
<th>Section C</th>
</tr>
</thead>
<tbody>
<tr>
<td>8&quot; Stone base</td>
<td>8&quot; F.A.* RAP** base</td>
<td>4&quot; F.A. RAP base</td>
</tr>
<tr>
<td>8&quot; Lime treated subbase</td>
<td>8&quot; Lime treated subbase</td>
<td>4&quot; F.A. RAP+25% crushed concrete</td>
</tr>
<tr>
<td>Subgrade</td>
<td>Subgrade</td>
<td>Subgrade</td>
</tr>
</tbody>
</table>

* F.A. Foamed Asphalt
** RAP Recycled Asphalt Pavement
Field Testing

c) FWD

b) Geoguage
d) Dynaflect
e) LFWD

a) DCP
Comparison Of FA Treated Bases

- Base A: Crushed Lime Stone
- Base B: Foam Asphalt with 100% RAP
- Base C: Foam Asphalt with 75% RAP & 25% Crushed Concrete
Construction Cost and Economics

- Breakdown unit cost for the US 190 foamed asphalt RAP base job.

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP and Crushed Concrete materials</td>
<td>1.65 $/m^2 (unit price of 4 $/ton)</td>
</tr>
<tr>
<td>2% Asphalt Cement (PG 58-22)</td>
<td>2.39 $/m^2</td>
</tr>
<tr>
<td>1.5% Cement</td>
<td>0.92 $/m^2</td>
</tr>
<tr>
<td>Average Placement Cost</td>
<td>1.20 $/m^2</td>
</tr>
<tr>
<td><strong>Total Construction Cost</strong></td>
<td><strong>6.16 $/m^2</strong></td>
</tr>
</tbody>
</table>
Summary and Conclusions

- A pilot Study on the performance of FA stabilized RAP
- Three base materials:
  - Stone, FA stabilized, FA/CC stabilized
- Field test sections were constructed
- Set of in-situ test devices
- All five in-situ test devices were sensitive to the difference of base materials
- FA treated RAP showed higher in-situ stiffness values and structure numbers than those of lime stone base layer
- No significant difference in the measured field stiffness
  - 100 percent RAP
  - 75 percent RAP and 25 percent crushed concrete.
- The addition of 1.5 percent of Portland cement resulted in a higher soaked ITS
- Similar observation was noted form field strength tests
- Cost effectiveness
1998 Superpave

Comparison of Laboratory and Field
Densification of Level 3 WC from Traffic

- US 90 GB
- US 61 (0045)
- US 90 WBE
- I-20 BC
- US 61 (0044)
- Avg. all jobs

% Air Voids vs. Months

0 5 10 15 20 25 30 35 40 45 Months
Field Performance of Superpave

- IRI measured with Laser Profilograph
  - All jobs Excellent (< 80)

- Rut measured
  - Maximum measurement after 5 years of traffic = 0.15”