Reflective Crack Mitigation Using an Asphalt Concrete Interlayer System
Topics

◆ What?
  ▪ The Problem
  ▪ The Solution: Reflective Crack Relief System
  ▪ Specifications

◆ Why?
  ▪ Advantages
  ▪ Project Results

◆ The Future?
What? The Problem

Before

Conventional HMA overlay 6 months later
What? The Problem

- Superpave didn’t address reflective cracking
- Many miles of pavement in poor condition
- Conventional HMA overlays not addressing need
- NCHRP 1-41: Models for Predicting Reflective Cracking in HMA Overlays (Texas A & M)
- Project 05-04 AAPTP: Techniques for Mitigation of Reflective Cracking on HMA Airfield Pavements
- TPF-5(146): Evaluation of Modified Performance Grade Binders in Thin Lift Maintenance Mixes, Surface Mix and a Reflective Crack Relief Layer Mix
Core from a 3 Year Old Overlay Over PCC

(New Jersey Rt. 10)

Path for water intrusion to base

HMA Overlay cracked through to PCC joint
The Solution
Reflective Crack Relief System

- Significantly delays reflective cracking
  - Improving surface
  - Protecting base
- Impermeable
  - Protects pavement from moisture damage
- Lengthens service life
- Recyclable
The Solution
Reflective Crack Relief System

Before

Control HMA overlay
Interlayer section

The crack stops here!

After
A Little History. . .

- 1995 - First trial in U.S.
- 1998-99 - Climatic trials in IA, IL, MO, & TX
- 1999 - Developed performance-based bending spec on mix for consistency
- 2000 - Placed performance-based projects in KS, KY, & MO
- >2001 - Process adapted for state specs & spread throughout U.S.
States with Reflective Crack Relief Interlayer System

Through 2006: 585 lane-miles (4.0 million yd$^2$) in 20 states
The Solution
Reflective Crack Relief System

**Interlayer**
- Thin (1") fine aggregate HMA
- Highly elastic PMAC
- Asphalt-rich, impermeable

**Overlay Recommendation**
- SBS modified SHRP+ spec, 98% reliability
- Minimum thickness to protect interlayer
The Solution
Reflective Crack Relief System

Minimum Overlay Thickness Recommendations

- 20 yr traffic
- <3 million ESALs = 1.5”
- 3-10 million ESALs = 2.5”
- 10-30 million ESALs = 3.0”
- >30 million ESALs = 3.5”

Thinner overlays possible with high stability interlayer option
Pavement Design Information

◆ Structural value

<table>
<thead>
<tr>
<th></th>
<th>Interlayer</th>
<th>Typical HMA Dense Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Coefficient</td>
<td>0.20</td>
<td>0.35-0.44</td>
</tr>
<tr>
<td>Flexural Modulus @ 20°C, psi</td>
<td>200,000</td>
<td>400,000</td>
</tr>
<tr>
<td>Resilient Modulus @ 20°C, psi</td>
<td>493,000</td>
<td>740,000</td>
</tr>
</tbody>
</table>
Fracture Energy
(Test Temp. = -20.0°C)

![Graph showing CMOD (mm) vs Load (kN) for 9.5mm PG64-22 and Interlayer with two curves indicating different behaviors at -20.0°C.]
Protects Pavement Base from Moisture Damage

**Permeability Tests on Field Samples**

- **Permeability (K) cm/sec**

  - Interlayer & Overlay
  - Fabric & Overlay
  - HMA
  - Clean Sands
  - Gravel

Surface Cracked, Interlayer Intact
Impermeable Interlayer Protects Pavement

Core after 3.5 years
Why Isn’t the Reflection Crack Over the Joint?

Stress distributed over larger area

Crack forms at weakest point in overlay

Stress concentrated at crack / joint

Overlay Interlayer PCC

Joint

Reflective Crack Relief Interlayer System

Typical Overlay
What Does That Mean for Performance?

Interlayer System

Overlay
Interlayer
PCC

CRACK OFFSET
Ride is better, structure is intact

Simple Overlay

CRACKED THROUGH TO BASE
Ride is worse, structure is compromised
Core Analyses

61 Interlayer cores at overlay cracks
- 51 not cracked through the interlayer
- 10 cracked into interlayer
  - Over undoweled patches / failing joints
- 41 cracks offset; others not checked
- No path for water intrusion

16 HMA cores at overlay cracks
- 15 cracked through to PCC joint
- Direct path for water intrusion

Cores from MO, WI, TX, KS, NJ, IL & IA projects
Interlayer Specifications

Materials

◆ Liquid AC Binder
  - Minimum PG
  - Elastic recovery
  - Separation

◆ Fine aggregate
  - Sand equivalency = 45+
  - Crushed & natural sands
  - Gradation:

<table>
<thead>
<tr>
<th>Sieve</th>
<th>% Passing</th>
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</thead>
<tbody>
<tr>
<td>3/8 inch (9.5 mm)</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>80 – 100</td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>60 – 85</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>40 – 70</td>
</tr>
<tr>
<td>No. 30 (600 μm)</td>
<td>25 – 55</td>
</tr>
<tr>
<td>No. 50 (300 μm)</td>
<td>15 – 35</td>
</tr>
<tr>
<td>No. 100 (150 μm)</td>
<td>8 – 20</td>
</tr>
<tr>
<td>No. 200 (75 μm)</td>
<td>6 – 14</td>
</tr>
</tbody>
</table>
## Mix Design Comparison

<table>
<thead>
<tr>
<th>Typical interlayer mix specs</th>
<th>Superpave mix specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGC design (Superpave Gyratory Compactor)</td>
<td>SGC design (Superpave Gyratory Compactor)</td>
</tr>
<tr>
<td>50 gyrations</td>
<td>*100 gyrations</td>
</tr>
<tr>
<td>0.5 – 2.5% air voids</td>
<td>4% air voids</td>
</tr>
<tr>
<td>16% min VMA</td>
<td>*15% min VMA</td>
</tr>
</tbody>
</table>

*Criteria for 9.5mm mixture, medium traffic.*
Design Specifications
Performance Based Specs: Reflective Crack Resistance

- Flexural Beam Fatigue Device, AASHTO T-321
- Tests mix’s ability to withstand repeated bending
- Data = number of loading cycles to failure (loss of strength)
- Run at 10x typical strain (deformation) to simulate reflective cracking caused by PCC joint movement
Performance Based Specification
Highly Crack Resistant

Cycles to Failure at 2000 microstrain

- Interlayer Specification: 100,000 cycles
- PG 76-28 HMA (PMAC): 6,000 cycles
- PG 64-22 HMA: 2,000 cycles

AASHTO T-321, at test temperature
Test temperature determined by project climate
Design Specifications
Performance Based Specs: Hveem Stability

- Resistance to rutting during construction
- 18.0 minimum Hveem stability
- Alternative: maximum 10 mm rut depth using Asphalt Pavement Analyzer (APA)

AASHTO T-246
High Stability Interlayer

Design for:
- Thinner overlays
- Highly loaded pavements and thickness restrictions
  - City streets with curb & gutter restrictions
  - Airports
- Higher stability specification
  - Stronger aggregate structure
  - Increased rut resistance
  - Same fatigue resistance

<table>
<thead>
<tr>
<th>Hveem Stability</th>
<th>Interlayer</th>
<th>High Stability Interlayer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Traffic Loading, ESALs</td>
<td>Overlay Thickness Recommendations</td>
<td></td>
</tr>
<tr>
<td>&lt; 3,000,000</td>
<td>1.5”</td>
<td>1.0”</td>
</tr>
<tr>
<td>3,000,000 – 10,000,000</td>
<td>2.5”</td>
<td>2.0”</td>
</tr>
<tr>
<td>10,000,000 – 30,000,000</td>
<td>3.0”</td>
<td>2.5”</td>
</tr>
<tr>
<td>&gt; 30,000,000</td>
<td>3.5”</td>
<td>3.0”</td>
</tr>
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</table>

High stability Interlayer
Rock County Airport, WI
Breathable Interlayer

- Designed for
  - Blister prone conditions
  - Why blisters occur
    - pV=nRT (ideal gas law)
  - Stability and fatigue specification are the same
  - Specification changes in gradation and air voids
Pavement Preparation

- Moderate & severe distresses repaired by doweled, full-depth patch
- Level profile (mill or level with HMA)
- Surface swept
- Tack under & over the interlayer
Construction Specifications

- Surface preparation
- Test strip recommended
- Specified temperatures
  - Mixing
  - Laydown
  - Compaction
- Typical target density = 96% min. of Gmm
- QC on mix & binder
Construction Recommendations

◆ Compaction:
  - 2 to 3 static steel wheeled rollers
  - First roller close to paver
  - Typically 5-6 passes

Normandy Drive, Ft. Riley, KS

LA I-20

Density Gauge
Construction Recommendations

- Recommend overlay interlayer immediately, but...
  - Designed to accommodate construction traffic
  - Max 5 days traffic after placement
Field Performance Analysis

- **Crack counting**
  \[
  \text{% reflective cracking =} \frac{\text{length of cracks measured}}{\text{length of cracks before overlay}}
  \]

- **Core analysis**
  Cores from Interlayer and control sections
Performance After 6 Years
US 36 Cameron, Missouri

HMA overlay with interlayer

HMA overlay without interlayer

Difference in crack severity
Performance After 6 Years
US 36 Cameron, Missouri

HMA overlay with interlayer

HMA overlay without interlayer

Difference in longitudinal cracking from older PCC widening
Performance After 6 Years
US 36 Cameron, Missouri

% Reflective Cracking

- Interlayer System
- Control

- March, 2001
- Feb, 2002
- April, 2003
- Feb, 2004
- Aug, 2005
- May, 2006
IA-9 Decorah, Iowa Construction
Performance After 4 Years
IA-9 Decorah, Iowa

HMA overlay with interlayer  
HMA overlay without interlayer
Performance After 4 Years
IA-9, Decorah Iowa

% Reflective Cracking

- Interlayer System
- Control

0% 0% 0% 4% 17% 29%

Reflective Cracking Delay
After 2 Years (2002 Projects)

% Reflective Cracking

- Interlayer Section
- Control Section

Variables: joint spacing, climate, traffic, etc.

Project Location:

- Lapham Blvd, Milwaukee
Reflective Cracking Delay After 3-4 Years (2001 Projects)

% Reflective Cracking

- IA Rt9: 17% Interlayer Section, 29% Control Section
- VA Rt17: 57% Interlayer Section, 76% Control Section
- China - Wu Shi Hwy: 6% Interlayer Section, 22% Control Section
- IA BusRt151: 1% Interlayer Section, 20% Control Section
- WI I94: 10% Interlayer Section, 14% Control Section
- KY I64*: 0% Interlayer Section, 0% Control Section
- MO US36*: 54% Interlayer Section, 89% Control Section

Project Location

*after 5 winters (2000 projects)
Variables: joint spacing, climate, traffic, etc.
Project Performance Summary

% Reflective Cracking

Interlayer improves overlay performance

Data represents 15 projects built with control sections, up to 5 years old
Project Performance Summary

Average 67% improvement* in reflective cracking

◆ on Interlayer projects
  (avg. 5% reflection cracking/year)

◆ over control sections
  (avg. 18% reflection cracking/year)

Interlayer improves overlay performance

*Data represents 15 projects built with control sections, up to 5 years old
Summary
Reflective Crack Relief Interlayer System Advantages

- Significantly delays reflective cracking
  - Improving surface
  - Protecting base
- Impermeable
- Lengthens service life
- Recyclable
The Future of the Reflective Crack Relief Interlayer

*Grant Opportunities for Academic Liaison with Industry*
Integrated Approach

Lab Testing

Computer Simulation

Fracture Mechanics

Field Data and Performance

Bulk Material Response
Field Investigation Projects

1. State Highway (IA-9) near Decorah, IA
2. US-36 near Cameron, MO
3. State Highway (LA-34) near Monroe, LA

Each project consists of:

- Control Section(s)
- Treated Section(s)

- Projects have been visited at least once annually for crack count and visual distress identification
Project Locations (Climatic)

Average Temperature (°F)
NOV 7 - 13, 2004

CLIMATE PREDICTION CENTER, NOAA
Computer generated contours
Based on preliminary data
### Interlayer Section
- **Surface Course**: 2.40-in. (60 mm)
- **Binder Course**: 2.30-in. (58 mm)
- **Interlayer**: 1.00-in. (24 mm)
- **Existing Old Pavement**

### Control Section
- **Surface Course**: 2.00-in. (51 mm)
- **Binder Course**: 2.10-in. (53 mm)
- **Existing Old Pavement**
Critical Loading Conditions:

- Simulations performed to evaluate the loading conditions in field which yield most cracking

- Thermal Only:
  - Single Event (15 Hrs)
  - 5-Day Event

- Thermal – Mechanical loading:
  - Tire load at coolest temperature
  - Multiple tire loads at coolest temperature
  - Tire loads at uniform interval over 5-Day cooling
  - Tire overload scenario
US36: Thermal-Mechanical Loading

- Simulation results for single event cooling cycle with single tire load application is presented

- Coolest event: Jan 25 – 26, 2003

- Single 9-kip tire load applied at coolest pavement surface temperature (4:00 am)
Temperature Profile: Coolest Event

Temperature (C)

Depth (cm)

2:00 PM 4:00 PM 6:00 PM 8:00 PM 10:00 PM 12:00 AM 2:00 AM 4:00 AM 6:00 AM

Surface

0600 Hrs 1400 Hrs

Binder
US36, Control Section – Single Tire

- PCC
- Subgrade
- Control Interlayer
- Surface Course
- Binder Course
- Interlayer

Softening (Micro-cracking/Damage)

Cracking
Current Studies

- An accelerated pavement testing study is currently under way
- A number of modeling variables will be calibrated and optimized using this accelerated pavement cracking study
- Laboratory testing for mode-II fracture testing of asphalt concrete is being developed
- More field sites may be studied in a follow-up project
Thank you.

Questions?