Reflective Cracking Control

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Causes of Cracks

- Fatigue
- Thermal
  - Concrete, flexible, and composite pavements
- Surface stresses
- Lack of bearing support
  - Under-design, poor drainage, or settlement
- Exiting discontinuities
  - Cracks, joints, widening
Reflective Cracking

- A major distress in HMA overlays
- Environmental and tire loading
- Premature cracking within 2-3 years
- Transverse and longitudinal directions
# Reflective Cracking Mechanisms

<table>
<thead>
<tr>
<th>Cause</th>
<th>Result</th>
<th>Type</th>
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<tbody>
<tr>
<td>Tire Loading</td>
<td>Crack opening, Shear failure</td>
<td>Mode I, Mode II, Mixed mode</td>
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<tr>
<td>Seasonal Variation</td>
<td>Crack opening</td>
<td>Mode I</td>
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</tbody>
</table>

**Mode I (Opening)** 

**Mode II (Sliding)** 

**Mode III (Tearing)**
Main Causes: Traffic

- Shear failure (Mode II, Mixed mode)
- Crack opening (Mode I)

Bending stress

Shear stress
Crack Development

Horiz. Propag.  
Vertic. Propag.

Bonded Interface  
Debonded Interface
Single or Double RC (Thin Overlay)

Scarpas et al. 2000
Zhou and Sun 2002
Crack Control Expectation

- Delay cracking occurrence
- Reduce number of cracks
- Control crack severity
- Provide other benefits:
  - Reduce overlay thickness
  - Enhance waterproofing capabilities
Control Measures

- **Typical Solution**
  - **Pre-Overlay Treatment:**
    - Crack and seat, Break and seat, Rubblization
    - Slab stabilization/ load transfer restoration
    - Sawing and sealing joints
  - **HMA Overlay**
  - **Overlay Systems**
    - Improved mix
    - Joint filling/ stabilization
    - Leveling course
    - **Interlayer systems:**
Interlayer Systems

- **Cost-effective technique (!)**
- **Reinforcement:**
  - Stiff materials to compensate lack of HMA’s tensile strength
- **Strain tolerant (Stress relief):**
  - Soft materials to dissipate strain energy by deforming itself
- **Modified HMA:**
  - “Tough” materials to resist cracking
Interlayer Systems

- Sand Asphalt
- SAMI
- Geotextile
- Geomembrane/ Geocomposite
- Grid/ Steel Netting
- 3D Grid
Fabric Interlayer

- Overlay
- Fabric Interlayer
- Old pavement
- Stress concentration
Stress-Absorbing Interlayer

Overlay
Membrane
Stress concen.
Old pavement
Shear Stress/Strain at Crack Tip Vicinity

Shear Stress (kPa) vs. Overlay Thickness (mm) for different overlay thicknesses with and without a membrane.

Shear Strain vs. Overlay Thickness (mm) for different overlay thicknesses with and without a membrane.

Overlay Thickness:
- 50.8 mm
- 76.2 mm
- 101.6 mm

Shear Stress:
- Without membrane
- With membrane

Shear Strain:
- Without membrane
- With membrane
STRATA

- 1” Thick Strain Tolerant Interlayer, 4.75mm mix, Standard HMA Construction

- UIUC ATLaS Project at ATREL – Full-Scale Validation
Steel Reinforcing Netting

Technology emerged in the early 1950s in the US and Canada, and was re-introduced in the early 1980s in Europe.
Steel Reinforcement Netting

- The first application in the US was in 1999 by Al-Qadi et al.
- Several states installed trials sections and some are being monitored for long-term performance
Reinforcing Composite

Interlayer Stress Absorbing Composite, ISAC
Optimum Thickness of Band-Aid

Debonding

High voids

Existing JCP

Over a joint  Offset from a joint

HMA overlay

Interlayer

Debonding

In Less than a Year
Drainage Layer
Lack of Performance

Control section

Sand mix interlayer treated section
## Overlay Interlayer Functions

<table>
<thead>
<tr>
<th></th>
<th>Reinf.</th>
<th>Resist High Strain</th>
<th>Waterproof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Asphalt</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SAMI (*)</td>
<td></td>
<td>XX</td>
<td>XX</td>
</tr>
<tr>
<td>Impregnated Nonwoven</td>
<td></td>
<td>X</td>
<td>XX</td>
</tr>
<tr>
<td>Grid Composite</td>
<td>X/XX</td>
<td>X</td>
<td>X/XX*</td>
</tr>
<tr>
<td>Steel Netting</td>
<td>XX</td>
<td>X*</td>
<td>X*</td>
</tr>
<tr>
<td>3D Grids</td>
<td>XX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tri-planar</td>
<td></td>
<td>X</td>
<td>XX</td>
</tr>
<tr>
<td>Strain Tolerant Layer</td>
<td>XX</td>
<td></td>
<td>XX</td>
</tr>
</tbody>
</table>

# Smoothness & Recycling!!
Interlayer System Assessment

Field Survey

Visual and video:
- Pavement surface cracks

Ground penetrating radar:
- Joint/patch locations

Forensic Investigation

Field coring:
- Various reflective crack patterns
- Interface failure phenomenon

Laboratory tests:
- Fundamental material properties affect reflective cracking

Life-Cycle Cost Analysis
Field Survey Methods

- **Surface Pavement Distress Survey**
  - Visual (Walk-on) survey
    - Severity (starting, low, medium, and high)
    - Extent (0.0 - 1.0)
  - Video survey
    - Faster and safer operation
    - Link to other distress survey

- **Nondestructive Testing**
  - Ground penetrating Radar (GPR) survey
    - Overlay thickness
    - Joint/patch location
Video Crack Survey

- A high resolution digital video camera: 4m x 3m
- Highway speed up to 30MPH

IL130 northbound (STA. 211+00 to STA. 212+00)
Video Crack Survey

- Crack detection
  - 165 out of 195 (84.2%) transverse cracks
  - Shift in severity distribution
GPR Survey

- Using a ground-coupled antenna
- ISAC identification/ accurate width measurement (0.9m)

Multiple strong reflections from a dowel bar
Weak reflection from PCC and HMA overlay
GPR Survey

- Using an air-couple antenna
- Detection of dowel bar at joints and patches

Strip reflection at PCC patch and HMA overlay
Strip reflection at HMA patch and PCC slab
Multiple reflections from a dowel bar
Reflective Cracking Identification


Video survey (2006)

GPR survey (2006)

Visual survey (2003) before overlay
Reflective Cracking Identification

Transverse RC from a joint

Longitudinal RC from patches
Transverse RC from patches
Non Reflective Crack
Double transverse RC from a joint
Reflective Crack Index

Reflective Cracking Appearance Ratio with joint-associated reflective cracking

\[ R_{RCA} = \frac{N_{RC}}{N_J} \]

Transverse Cracking Appearance Ratio with all transverse cracking

Including crack severity (Weight function, \( W_i \))

\[ R_{RCAW} = \frac{\sum_{i=1}^{4} [W_i \times (N_{RC})_i]}{N_J} \]

\[ R_{TCA} = \frac{N_{TC}}{N_S} \]

\[ R_{TCAW} = \frac{\sum_{i=1}^{4} [W_i \times (N_{TC})_i]}{N_S} \]
Reflective Crack Index

Reflective Cracking Index with $R_{RCAW}$: 100 (no RC) to 0 (all high-severity RCs)

\[ RCI = 100 \left[ 1 - \frac{R_{RCAW}}{3} \right] \]

Interlayer systems performance to retard reflective cracking
Forensic Investigation
Typical Reflective Crack Path

- SAF: Medium severity crack
- Starting severity cracks
- Around the strip

Directly over a joint

Edge of strip treatment

Strip type System B

Mattis, Champaign

US136 San Jose
Various RC Paths/Mechanisms

- Offset from a Joint
- Interface of wearing and leveling binder
- From PCC Joint
- From HMA Patch
- New
- Old
- Interface of old and new overlay
Interface Failure Types

Good bonding

PCC and HMA overlay

Interface failure

Due to lack of bond strength (tack coat) and/or moisture penetration

PCC and interlayer

Interlayer and HMA overlay
Life-Cycle Cost Analysis
## Overall Process

### Input
- **HMA Overlay**
  - Material price
  - Construction period
  - Lane configurations
- **Interlayer**
  - Material price
  - Construction period
  - Service life
- **Traffic**
  - AADT

### Analysis
- **Agency Cost**
  - Overlay cost
  - Interlayer cost
  - Salvage value
- **User Delay Cost**
  - Free flow cost
  - Forced cost
  - Salvage value
  - Default values

### Output
- **Agency Cost**
- **Grand Total Cost**
  - Agency cost
  - User delay cost
  - Net present value
- **Selection**
  - Cost-effective interlayer
CEISDP
(COST-EFFECTIVE INTERLAYER SYSTEM DECISION PROGRAM)
Version 0.8
Example (Output)

LCCA Output

- **Agency Cost**
  - System A (Area)
  - System A (Strip)
  - System B (Area)
  - System B (Strip)
  - ISAC
  - Sand mix

- **Total Cost**
  - Control
  - System A (Area)
  - System A (Strip)
  - System B (Area)
  - System B (Strip)
  - ISAC
  - Sand mix

- **Cost-Effective method**

- **Additional cost**

- **Remaining capacity**
Major Variables

- Joint spacing
- Interlayer system performance
- Interlayer cost

![Graph showing relative benefit (%)](image-url)
Considerations When Using Interlayer Systems to Abate Reflective Cracking

- Interlayer systems MAY NOT prevent crack movement
- Not all interlayer systems are the same! (reinforcement, strain tolerant, moisture barriers)
- Joints/cracks must be stable (Prepare Pavement!)
- Minimum overlay thickness needs to be identified
- Successful installation is a key for good performance:
  - No wrinkles
  - Pretensioning/ fixation
  - Interlayer system joints
  - Bonding issues
  - Overlay characteristics
Joint-associated reflective cracking can be successfully identified using ground-penetrating radar (GPR) and crack surveys.

Reflective crack indices are proposed to evaluate crack extent and severity.

Criteria to select an interlayer system:
- Performance ▶ Interlayer system assessment
- Cost ▶ Life-cycle cost analysis (LCCA)

Proper installation is very important!
Thank You?
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Chicago, Illinois
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www.ict.uiuc.edu/RILEM