Mitigation Strategies for Reflective Cracking in Pavements

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Introduction

• Reflection of existing cracks and joints from underlying PCC and asphalt pavement is known as **reflective cracking**
• One of the major modes of failure in rehabilitated pavements
• HMA overlays are not cost-effective against reflective cracking
• Various crack control methods have been introduced since 1970s → Mixed experiences
Mechanisms of Reflective Cracking

Tip of the joint or working crack

Void

Stress at the tip of the crack

Shearing stress
Research Objectives

• Conduct an in-depth literature review of research studies on reflective cracking
• Conduct a survey of the state practices to address reflective cracking
Topics in the Synthesis

• Types and effectiveness of reflection crack control treatments
• Performance and cost-effectiveness
• Selection criteria for different crack control strategies
• Knowledge gaps and unresolved questions
## Crack Control Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Functions</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galvanized Steel Netting</td>
<td>Reinforcement</td>
<td>3.00 – 5.00 $/yd²</td>
</tr>
<tr>
<td>Geogrid</td>
<td>Reinforcement</td>
<td>1.80 – 4.00 $/yd²</td>
</tr>
<tr>
<td>Geonet</td>
<td>Reinforcement</td>
<td>3.00 – 4.00 $/yd²</td>
</tr>
<tr>
<td>Glass-Grid</td>
<td>Reinforcement</td>
<td>4.00 – 7.00 $/yd²</td>
</tr>
<tr>
<td>Paving Fabric</td>
<td>Stress Relief</td>
<td>0.60 – 1.05 $/yd²</td>
</tr>
<tr>
<td>Geocomposite</td>
<td>Stress Relief</td>
<td>8.00 – 9.20 $/yd²</td>
</tr>
</tbody>
</table>
## Crack Control Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Picture</th>
<th>Functions</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMI</td>
<td></td>
<td>Stress Relief</td>
<td></td>
</tr>
<tr>
<td>Rubblization</td>
<td></td>
<td>Eliminates movement in concrete layer</td>
<td>5.00 – 6.00 $/yd²</td>
</tr>
<tr>
<td>NovaChip</td>
<td></td>
<td>Stress Relief</td>
<td>3.00 – 4.00 $/yd²</td>
</tr>
<tr>
<td>Strata</td>
<td></td>
<td>Stress Relief</td>
<td>4.00 – 5.00 $/yd²</td>
</tr>
<tr>
<td>Saw and Seal</td>
<td></td>
<td>Control reflective cracking by sawing overlay</td>
<td>1.00 - 2.00 $/ft.</td>
</tr>
</tbody>
</table>
LITERATURE REVIEW
GEOSYNTHETICS
Paving Fabrics (Shuler 2004)

- Investigated the use of paving fabrics in delaying reflective cracking:
  - 18 test sections were evaluated with eight treatment methods
  - Five years monitoring period
  - 4in. Overlay was applied after milling
  - Heavy traffic (20 million ESALs)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 Pound Petromat</td>
<td>A</td>
</tr>
<tr>
<td>120 Pound Petromat</td>
<td>B</td>
</tr>
<tr>
<td>Petrotac</td>
<td>C</td>
</tr>
<tr>
<td>ProGuard</td>
<td>D</td>
</tr>
<tr>
<td>Crack sealers without routing</td>
<td>F and H</td>
</tr>
<tr>
<td>Crack sealers with routing</td>
<td>E and G</td>
</tr>
</tbody>
</table>
Paving Fabrics  (Shuler… 2004)

- A number of treatments performed better than the control section
- Control section performed better in the passing lane
- Construction and repair costs were the least for the control section
**Glasgrid** *(Bischoff and Topel 2003)*

- Glasgrid was placed in 5-foot widths across transverse joints on top of JPCP
- Single and double strand grid
- 1.5 in. asphalt overlay - 10 years monitoring period
- Glasgrid was not effective in delaying reflective cracking

<table>
<thead>
<tr>
<th>Section</th>
<th>Years After Construction</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Strand</td>
<td></td>
<td>53</td>
<td>69</td>
<td>76</td>
<td>91</td>
<td>91</td>
<td>108</td>
</tr>
<tr>
<td>Single Strand</td>
<td></td>
<td>55</td>
<td>61</td>
<td>68</td>
<td>83</td>
<td>83</td>
<td>106</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>59</td>
<td>73</td>
<td>86</td>
<td>87</td>
<td>87</td>
<td>105</td>
</tr>
</tbody>
</table>
Glasgrid (Elseifi and Bandaru 2011)

- Evaluated the performance and cost-effectiveness of 13 in-service rehabilitated pavements constructed with Glasgrid
Factors Influencing Geosynthetics Performance

• Existing pavements
  – More successful with rehabilitated flexible pavements

• Movement at the joints
  – More successful with stable joints

• Traffic
  – More successful with light traffic

• Construction
  – Good bonding key to good performance (tack coat, …)
FRACTURED SLAB APPROACHES
Rubblization (Sebasta and Scullion 2007)

- Evaluated the performance of rubblization for concrete pavements:
  - Five field projects were evaluated and monitored
  - Prior and after construction evaluation was performed using GPR, FWD and DCP
  - Tests performed to identify areas of moisture accumulation and weak support beneath the slab
Rubblization (Sebasta and Scullion 2007)

- Two factors to consider in selecting rubblization:
  - Drainage conditions
  - Subgrade support beneath the slab
- Modulus of rubblized layer increased with age (from 114 to 323 ksi)
- The Illinois rubblization selection chart and a modified chart version were presented
LITERATURE REVIEW
AC INTERLAYER
NovaChip®

- Ultrathin bonded wearing course - NovaChip
- A thin (3/8 to 3/4in) gap graded HMA layer placed on top of a Novabond® membrane, which is a polymer-modified asphalt emulsion
- Pretreatment of existing joints is recommended (crack sealing)
NovaChip® (Russel et al. 2008)

• Conducted a field study in Washington State
• NovaChip used instead of 1-in dense HMA on top of a deteriorated flexible pavement
• NovaChip perform well for about six years
  – Service life around 8 to 9 years
• NovaChip on high traffic roads is limited
NovaChip (Russel et al. 2008)

• Evaluated cost effectiveness of NovaChip compared to HMA Class G:
  – Evaluated for low volume roads
  – Cost ranges from $3.00 to $4.00 per square yard
  – Cost of NovaChip® was comparable to dense HMA
    • Base cost of NovaChip was twice that of HMA

<table>
<thead>
<tr>
<th>Rehabilitation Type</th>
<th>Estimated Time Between Treatments (yrs.)</th>
<th>Annual Worth ($/Lane Mile)</th>
<th>Annual Worth ($/Square Yard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BST</td>
<td>6</td>
<td>2,700</td>
<td>0.28</td>
</tr>
<tr>
<td>HMA Class G</td>
<td>7</td>
<td>8,300</td>
<td>0.89</td>
</tr>
<tr>
<td>NovaChip</td>
<td>8 to 9</td>
<td>7,800 - 8,600</td>
<td>0.83 - 0.92</td>
</tr>
<tr>
<td>HMA Class A or ½ in Superpave</td>
<td>10</td>
<td>11,100</td>
<td>1.18</td>
</tr>
</tbody>
</table>
Saw and Seal

Mark Joint Locations

Seal Joints

Cut Joints

Clean Joints

Asphalt Paving

Within 3 days of Overlay

3mm wide by 25mm deep

Rubberized asphalt sealant
Saw and Seal \cite{Elseifi2011} (Elseifi et al. 2011)

- Evaluated the field performance of saw and seal treatment method to control reflective cracking
  - 15 in-service pavements with a service life of 6 to 14 years
- Assessed performance and cost-effectiveness of saw and seal treatment method
Results: Levels of Improvement

Level of Improvement (Years)

% of Sections

-VE  +VE
Results: Cost Analysis

Difference in Cost between Untreated and Sawed and Sealed sections
SAMI (Greene et al. 2012)

• Evaluated the performance of ARMI
  – Spray asphalt rubber binder (0.6 to 0.8 gsy)
  – Apply No. 6 stone (0.26 to 0.33 ft³ per square yard)
  – Roll the stone with a pneumatic tire roller

• APT and long term field performance
  – Five test lanes were designed and constructed
  – Composite Specimen Interface Cracking (CSIC) test was performed
SAMI (Greene et al. 2012)

- Sections without ARMI outperformed sections with ARMI
- Recommended not to consider ARMI as a primary treatment method against reflective cracking
  - ARMI increased the rutting when subjected to combination of slow moving load and high temperature
  - Sections without ARMI provided better performance in the CSIC test
STRATA® (Bischoff 2007)

- A polymer-rich dense fine aggregate mixture placed on the existing pavement and is then overlaid
- Recommended on structurally-sound pavement
STRATA® - (Bischoff 2007)

- Described the field evaluation of the STRATA system in Wisconsin
  - Two sections on I94 were evaluated
- First section:
  - One section with STRATA performed similarly to the control section
  - STRATA section performed the best with only 6% reflective after 4 years
- Second section:
  - One of the control section performed the best
- Bischoff recommended not using the STRATA system in Wisconsin
Chip Seal/Paving Fabric (Davis and Miner 2010)

- Evaluated the use of nonwoven paving fabrics under chip seal
- 33 field projects were analyzed
Chip Seal (Davis and Miner 2010)

• Results:
  – In warm climates (e.g., Texas and California), incorporation of fabric improved life of chip seal by 50-70%
  – In Michigan, test section with chip seal and paving fabric performed well compared to control section

• Shall not be used for roads with:
  – Vertical grades greater than 10%
  – ADT greater than 10,000
  – Severe freeze-thaw cycles
  – Poor drainage conditions

• Binder application rates:
  – 0.30 and 0.35 gal/yd² for cold climate
  – 0.25 and 0.30 gal/yd² for hot climate
Collective Evaluation (Powell 2012)

• Evaluated the field performance of pavement preservation treatments:
  – fog seals, crack seals, chip seals, overlay, ultra-thin bonded wearing course

• Crack sealing stopped the development of interconnected cracks observed in the control section
SURVEY OF THE STATE PRACTICES
Responses to Survey

Figure 1: States Response to Nationwide Survey

35 responses
Regular Actions

• Does your state take regular actions to address reflective cracking in HMA overlay?

• Majority (63%) of states take regular actions

• 37% of highway agencies do not take specific regular actions to address reflective cracking
Other Treatments

• Other treatment methods:
  – Cold-in-place recycling (CIR)
  – SMA
  – Rubber seals
  – Open-graded crack relief interlayer
Pre-Construction Repair

What pre-construction repair activities do you recommend prior to HMA overlay application?

- Patching, crack sealing (for both rigid and flexible pavements) and joint repair (for PCC pavements) are recommended by most respondents.
Recommendations

- The performance of a number of treatment methods has been mixed
- A number of treatment methods have predominantly shown benefits

<table>
<thead>
<tr>
<th>For Asphalt Pavements</th>
<th>Pros and Cons</th>
</tr>
</thead>
</table>
| Crack sealing and overlay | Pros: Low cost and suitable for asphalt pavements  
Cons: Reflective cracking may appear |
| Chip seal and open-graded interlayers | Pros: low cost and adequate control of reflective cracking |
| Full-depth reclamation | Pros: prevent reflective cracking, suitable for heavily trafficked pavements, environmental friendly  
Cons: Cost |
| Cold-in place Recycling | Pros: prevent reflective cracking  
Cons: not suitable for heavily cracked pavements |
# Recommendations

## For PCC Pavements

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<tr>
<th></th>
<th>Pros and Cons</th>
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</thead>
<tbody>
<tr>
<td>Saw and seal</td>
<td>Pros: Low cost and well-proven performance</td>
</tr>
<tr>
<td>Chip seal and open-graded interlayers</td>
<td>Pros: low cost and adequate control of reflective cracking, can be used with weak subgrade</td>
</tr>
<tr>
<td>Rubblization</td>
<td>Pros: Eliminates slab action and high probability for success&lt;br&gt;Cons: Cost, requires adequate subgrade support, side work cost</td>
</tr>
<tr>
<td>NovaChip</td>
<td>Pros: well-proven performance in some states, does not require adjustments to side structures&lt;br&gt;Cons: Little data on performance and cost</td>
</tr>
</tbody>
</table>
What’s Next?

• Objectives:
  – Assess cost-effectiveness of recommended treatments on in-service pavement sections across the STC
  – Develop guidelines for the control of reflective cracking

• Research Tasks:
  – Identify field sections
  – Collect construction and cost data from bids
  – Collect performance data from PMS in the STC states
  – Assess Cost-effectiveness of treatment methods
  – Develop software to assist in treatments’ selection
What’s Next?

• Treatment Methods:
  – Crack sealing and overlay
  – Chip seal interlayer
  – Open-graded interlayer
  – Cold-in-place recycling
  – Saw and seal
  – Rubblization
  – NovaChip
Main Outcome

Input:
- Pavement type
- Pavement distress
- Subgrade condition
- Pavement age
- Desired service life
- Level of investment

Output:
- Recommended treatment
- Expect service life
- Savings vs. regular overlay

Diagram:
- Cost vs. Treatment
- PCI vs. Age
QUESTIONS?