Concrete Bridge Deck Crack Sealant Evaluation and Implementation

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Presentation Outline

- Research Project (2009-2014)
  - Project Background
  - Test Sections & Products
  - Performance
  - Conclusions & Recommendations

- Next Steps
Project Goal & Approach

- Select test bridge(s) and apply sealants and monitor performance.
- Installed by Vendors with the surface preparation and method(s) of their choice.
- Sealant performance was evaluated through a combination of field permeability testing, visual observations, and coring and petrographic examination.
- Conclusions and recommendations of products for consideration on the Approved Products List (APL)
Project Timeline

- Very Dynamic Project Team
  - Two Consultant PIs
  - Three MnDOT PMs
Selected Test Bridge Site

- Built in 1986
- Two lanes of through traffic
- Cast-in-place PCC deck with low-slump PCC wearing
- Approximately a four percent grade increasing from the south to the north
- 13,900 AADT (2010) with 270 HC vehicles (1.9%)
- Had been sealed but ~2002
Test Sections, Pt 1
Test Sections, Pt 2
Surface Preparation (9/8/11)
Sealant Application (9/8/11)
Evaluation: Permeability

- The NCAT Permeameter was selected by the project team as the best method to qualitatively evaluate sealant performance.
- It was tested pre- and post-sealing and after one winter.
- It was not measured again because of traffic control needs, time consuming, and large variability.
Coring was performed after the second winter and the cores were photographed and subjected to a petrographic evaluation.
Evaluation: Petrographic Analysis

- The observed depth of sealant penetration was highly variable and likely is dependent on the presence of:
  - debris
  - original crack width
  - deck temperatures during application

- The predominant failure mode observed under magnification was detachment from the crack face and not within the sealant materials.
Examples
Evaluation: Visual Observations

- Braun Intertec and MnDOT Bridge Office staff performed visual observations each spring over a three year period.
- Each test location was qualitatively rated for sealant effectiveness:
  - **Effective (3):** Sealant fully intact or essentially intact with a hairline crack
  - **Semi-effective (2):** Sealant mostly intact, but exhibiting small cracks, holes or debonding
  - **Ineffective (1):** No evidence of sealant or some sealant present but larger cracks and/or holes present.
Comparative Visual Observations
CONCLUSIONS & RECOMMENDATIONS
Summary

- 12 crack sealant products were applied on the Smith Avenue High Bridge in St. Paul and evaluated over three winters from 2011-14.
- Visual observations and characterization of performance (effective, partially effective, and ineffective) provided evidence that approximately 67 percent of test sections were performing effectively after one winter but only 4 percent after two winters.
- After three winters, 58 percent of the test locations were visually characterized as ineffective and 42 percent as partially effective.
- Overall, product performance significantly reduced over the third winter and was primarily due to major loss of sealant and surface sand materials.
General Recommendations

- Based on numerous factors, **four epoxy** and **three methacrylate** products were recommended for consideration on MnDOT’s Approved Products List (APL).
- Each product recommendation contains the surface preparation and application method conditions under which they were applied.
- It was also recommended that MnDOT look into increasing the frequency of its routine crack sealing maintenance program from the current five-year cycle.
- A Field Guide for bridge practitioners was also prepared as part of this project with best practices learned from this project and literature review of other State DOTs.
# Evaluation/Ranking Criteria

<table>
<thead>
<tr>
<th>Evaluation Category</th>
<th>Factor</th>
<th>Rank 1 (Worst)</th>
<th>Rank 2</th>
<th>Rank 3 (Best)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>Meet MnDOT Req</td>
<td>--</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>Highest Cost</td>
<td>Intermediate Cost</td>
<td>Lowest Cost</td>
</tr>
<tr>
<td>Application</td>
<td>Surface Prep</td>
<td>Shot Blast</td>
<td>Sand Blast</td>
<td>Air</td>
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<tr>
<td></td>
<td>Crack Prep</td>
<td>Route</td>
<td>Pretreat</td>
<td>None</td>
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<tr>
<td></td>
<td>Application Type</td>
<td>Flood</td>
<td>Bottle</td>
<td>Pump</td>
</tr>
<tr>
<td></td>
<td>No. Of Applications</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Level of PPE</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Odor</td>
<td>Strong</td>
<td>Moderate</td>
<td>Weak</td>
</tr>
<tr>
<td>Petrography</td>
<td>Penetration</td>
<td>Bottom Third</td>
<td>Middle Third</td>
<td>Top Third</td>
</tr>
<tr>
<td></td>
<td>Sealant Cracked?</td>
<td>No Sealant Present</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Sealant Detached?</td>
<td>No Sealant Present</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Visual Observations</td>
<td>Visual_1yr</td>
<td>Ineffective</td>
<td>Semi-Effective</td>
<td>Effective</td>
</tr>
<tr>
<td></td>
<td>Visual_2yr</td>
<td>Ineffective</td>
<td>Semi-Effective</td>
<td>Effective</td>
</tr>
<tr>
<td></td>
<td>Visual_3yr</td>
<td>Ineffective</td>
<td>Semi-Effective</td>
<td>Effective</td>
</tr>
<tr>
<td>Permeameter</td>
<td>HL_post*</td>
<td>&gt;15</td>
<td>&gt; 3 to 15</td>
<td>3 or less</td>
</tr>
<tr>
<td></td>
<td>HL_1yr*</td>
<td>&gt;15</td>
<td>&gt; 3 to 15</td>
<td>3 or less</td>
</tr>
</tbody>
</table>
## Recommended Epoxy Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Surf Prep</th>
<th>Application</th>
<th>Additional Details</th>
<th>1 year</th>
<th>2 years</th>
<th>3 years</th>
<th>Petrography</th>
<th>Estimated Service Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>TK-2110</td>
<td>Air Blown</td>
<td>Flood</td>
<td>--</td>
<td>E</td>
<td>SE</td>
<td>SE</td>
<td>Free of cracks. Not detached.</td>
<td>3 to 4+ years</td>
</tr>
<tr>
<td>Paulco TE-2501</td>
<td>Air Blown</td>
<td>Bottle</td>
<td>3 applications</td>
<td>E</td>
<td>SE</td>
<td>SE</td>
<td>Free of cracks. Not detached.</td>
<td>3 to 4+ years</td>
</tr>
<tr>
<td></td>
<td>Air Blown</td>
<td>Bottle</td>
<td>3 applications</td>
<td>E</td>
<td>SE</td>
<td>SE</td>
<td>Free of cracks. Not detached.</td>
<td>3 to 4+ years</td>
</tr>
<tr>
<td>Dural 50 LM</td>
<td>Air Blown</td>
<td>Flood</td>
<td>Pre-treated cracks</td>
<td>E</td>
<td>SE</td>
<td>I</td>
<td>Free of cracks. Not detached. Does not &quot;bridge&quot; crack.</td>
<td>2 to 3 years</td>
</tr>
<tr>
<td>Epoxideal GS</td>
<td>Air Blown</td>
<td>Flood</td>
<td>--</td>
<td>E</td>
<td>SE</td>
<td>I</td>
<td>Free of cracks. Detached.</td>
<td>2 to 3 years</td>
</tr>
</tbody>
</table>
# Recommended MMA Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Surf Prep</th>
<th>Application</th>
<th>Additional Details</th>
<th>Visual Observations*</th>
<th>Petrography</th>
<th>Estimated Service Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBP 204 P</td>
<td>Air Blown</td>
<td>Flood</td>
<td>--</td>
<td>E</td>
<td>Free of cracks. Detached.</td>
<td>3 to 4+ years</td>
</tr>
<tr>
<td>T-70-MX-30</td>
<td>Air Blown</td>
<td>Flood</td>
<td>--</td>
<td>E</td>
<td>Free of cracks. Detached.</td>
<td>3 to 4+ years</td>
</tr>
<tr>
<td>Degadeck CSP</td>
<td>Air Blown</td>
<td>Flood</td>
<td>Pre-treated cracks</td>
<td>E</td>
<td>Free of cracks. Detached.</td>
<td>3 to 4+ years</td>
</tr>
</tbody>
</table>
Guide: Product Selection

- Lower viscosities will logically penetrate narrower cracks more easily.

<table>
<thead>
<tr>
<th>Product</th>
<th>Viscosity (cps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1</td>
</tr>
<tr>
<td>MMA/HMWM Resin Sealers</td>
<td>&lt; 25</td>
</tr>
<tr>
<td>Corn Oil</td>
<td>~65</td>
</tr>
<tr>
<td>Epoxy Sealers (high strength)</td>
<td>&lt; 125</td>
</tr>
<tr>
<td>Maple Syrup</td>
<td>~150</td>
</tr>
<tr>
<td>Epoxy Sealers (high elongation)</td>
<td>&lt; 250</td>
</tr>
<tr>
<td>Honey</td>
<td>~2,000+</td>
</tr>
</tbody>
</table>

cps = centipoise
Guide: Product Selection

<table>
<thead>
<tr>
<th>Average Crack Width Range (in)</th>
<th>Isolated (&lt;0.005%)</th>
<th>Occasional (0.005% to &lt; 0.017%)</th>
<th>Moderate (0.017% to &lt; 0.029%)</th>
<th>Extensive (&gt; 0.029%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.004</td>
<td>No Treatment</td>
<td>No Treatment</td>
<td>No Treatment</td>
<td>MMA/HMWM</td>
</tr>
<tr>
<td>0.004 to &lt;0.008</td>
<td>No Treatment</td>
<td>No Treatment</td>
<td>Epoxy or MMA/HMWM</td>
<td>Investigate</td>
</tr>
<tr>
<td>0.008 to &lt;0.012</td>
<td>No Treatment</td>
<td>Epoxy or MMA/HMWM</td>
<td>MMA/HMWM</td>
<td>Investigate</td>
</tr>
<tr>
<td>0.012 to &lt;0.016</td>
<td>Epoxy or MMA/HMWM</td>
<td>MMA/HMWM</td>
<td>MMA/HMWM</td>
<td>Investigate</td>
</tr>
<tr>
<td>0.016 to &lt;0.020</td>
<td>Epoxy or MMA/HMWM</td>
<td>Investigate</td>
<td>Investigate</td>
<td>Remove and Replace</td>
</tr>
<tr>
<td>0.020 to &lt;0.024</td>
<td>Epoxy</td>
<td>Investigate</td>
<td>Investigate</td>
<td>Remove and Replace</td>
</tr>
<tr>
<td>0.024 to &lt;0.028</td>
<td>Epoxy</td>
<td>Investigate</td>
<td>Investigate</td>
<td>Remove and Replace</td>
</tr>
<tr>
<td>&gt;0.028</td>
<td>Investigate</td>
<td>Investigate</td>
<td>Investigate</td>
<td>Remove and Replace</td>
</tr>
</tbody>
</table>
Guide: Application Method

- Crack Chasing refers to applying the product directly onto cracks with bottle/gun/pump.
  - This method only seals visible cracks
    - Crack size is approximately visible with the naked eye while standing.
  - Generally applicable for low crack density
  - More time consuming than flood coats
Guide: Application Method

- Flood sealing refers to pouring/spraying product onto the deck and spreading the material over the entire deck surface with squeegees and/or brooms.
  - This method seals every crack.
  - It is generally applicable for high crack density.
  - Less time consuming than crack chasing but requires significantly more sealant product.
Guide: Application Method

- Based on observed application times for the various products in this research project, typical product coverage rates, material costs, and estimates for costs of resources (labor and equipment), it appears to be most efficient to use the crack chasing method when the nominal crack spacing is approximately 2 to 3 feet or greater.
NEXT STEPS
Research Implementation

- In Progress
  - Bridge Maintenance Manual
  - Training
  - Approved Product List
Bridge Maintenance Manual

- Incorporate Crack Sealing Guidance Document
  - Provide guidance to bridge maintenance crews
  - Identify equipment, materials and best practices to perform the work
Training

- E-learning Module
- Combination of text, photos, videos and interactive activities

- Topic 1: The Importance of Crack Sealing
- Topic 2: Equipment and Materials
- Topic 3: Site Preparation and Best Practices
Approved Products List

- **Bridge and Surface Crack Sealer**
  - Updated the material qualification process and requirements
  - Added a performance evaluation component
    - Two year evaluation period
    - MnDOT will evaluate adhesion and cohesion failure after each winter season to determine percentage of total failure
    - Petrographic analysis performed by an independent lab following second season
Still to Come…

- Summer 2015
  - MnDOT Evaluation of Crack Sealant Products (after fourth winter)
Thank You!

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Full report available here:
www.dot.state.mn.us/research/TS/2014/201434.pdf