Polymer Overlays of New Bridge Decks

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Kansas Polymer Overlays

- Epoxy Polymer Overlays
  - 2 part epoxy
  - Flint aggregate
- Epoxy protects the bridge deck from water and chloride intrusion
- Flint provides abrasive surface
- Typically used as a bridge preservation strategy
Overlay Placement

Pictures courtesy of Dave Meggers
Overlay Placement

Pictures courtesy of Dave Meggers
Typical Overlay Schedule as a Repair

- **Assessment**
- **Start Work**
Typical Overlay Schedule as a Repair

CONDITION

TIME

Assessment

Start Work

Good

Poor
Typical Overlay Schedule as a Repair

- Assessment
- Start Work
Typical Overlay Schedule as a Repair

Good

Assessment

Start Work

TIME

CONDITION

Poor

Poor
Project Statement

- Polymer overlays have been used in Kansas for over a decade on existing bridges
  - Now being specified on new construction
    - How long after wet curing should pass for adequate bond?
- Current KDOT specification call for 14 days wet cure followed by 21 days dry cure
  - Several weeks delay
Utah

- 14 day wet cure, 28 days after placement
- Some manufacturer's do moisture tests of the concrete decks to make sure it's cured and dry
- No additional special provisions, spec. 03372
“We are like Utah, we wait for the deck to go through one winter prior to placing the epoxy overlay. The epoxy overlays are able to bridge over cracks. Thus by letting the deck go through a cold cycle, we are confident that most cracking has occurred. If the epoxy overlay is placed prior to cracking, we are fairly confident that the deck cracking will reflect up through the epoxy overlay.”

- Tom Macioce, P.E. Chief Bridge Engineer, PA DOT
Virginia

- Waited 28 days and used curing compound.
- “Research indicates that the highest bond strengths can be achieved by waiting 28 days for most of the mix water to react with the cement.”
- “We wait for the concrete to age 28 days. If we want to do the overlay earlier we construct test patches and test for bond strength and if we get > 250 psi and failure in the concrete we allow placement of the overlay.”
  - Michael Sprinkel, P.E. Associate Director, VDOT
Wisconsin

- 14 day wet cure, 28 days after placement

“The polymer overlay spec requires the moisture content in the deck to be less than 4.5% when measured by an electronic moisture meter and cannot show visible moisture after 2 hours when measured in accordance to ASTM D4263.”

- William Dreher, P.E. Structures Design Chief, WisDOT

- ASTM D4263—plastic sheet method
Other DOT’s

- Illinois - 7 day wet cure, 28 days after placement
- New York - same as required strength
- Most DOT’s did not place polymer overlay on new bridge decks by design
Test Program

Slab Dimensions

18”

6”

12”
## Mix Designs

<table>
<thead>
<tr>
<th>Low-Cracking</th>
<th>25% Fly Ash</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 550 lb Cement</td>
<td>• 550 lb Cement</td>
<td>• 550 lb Cement</td>
</tr>
<tr>
<td>• w/c = .4445</td>
<td>• 25% Fly Ash</td>
<td>• w/c = .5</td>
</tr>
<tr>
<td>• 60% Coarse Aggregate</td>
<td>• w/c = .5</td>
<td>• 60% Coarse Aggregate</td>
</tr>
<tr>
<td>□ ¾” Limestone</td>
<td>• 60% Coarse Aggregate</td>
<td>□ ¾” Limestone</td>
</tr>
<tr>
<td>• 40% Fine Aggregate</td>
<td>• 60% Coarse Aggregate</td>
<td>• 40% Fine Aggregate</td>
</tr>
<tr>
<td>• 800 mL/kg cement of Water Reducer</td>
<td>• 40% Fine Aggregate</td>
<td>• 600 mL/kg cement of Water Reducer</td>
</tr>
<tr>
<td></td>
<td>• 0 mL/kg cement of Water Reducer Needed</td>
<td></td>
</tr>
</tbody>
</table>
### Slab Matrix (180 slabs)

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>Wet Cure @ 100% RH 14 Days (60 per)</th>
<th>Dry Cure @73°F, 50% RH (45 per)</th>
<th>Epoxy (30 per)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control w/c = .5</td>
<td>40°F</td>
<td>3</td>
<td>E-Bond 526 (1)</td>
</tr>
<tr>
<td>Low-Cracking</td>
<td>73°F</td>
<td>7</td>
<td>Pro-Poxy (2)</td>
</tr>
<tr>
<td>25% Fly Ash</td>
<td>100°F</td>
<td>14</td>
<td>Flexolith (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21</td>
<td>Sikadur (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mark 154 (5)</td>
</tr>
</tbody>
</table>
Testing Procedure - Concrete Placement

- Placing concrete
  - Forms made to accommodate “handles” along the bottom of the short edge
  - Thermocouple wire is placed 1 in below the surface
Testing Procedure - Curing

- Cure concrete
  - Wet cure for 14 days in 40, 73, or 100°F
  - Remove from wet cure and wrap slab in plastic
  - Place in 73°F, 50% RH room to dry cure
Overlay Placement

- Sand Blast Surface
  - KDOT specifies a surface roughness of 6-7 according to ICRI
  - Only a 3-5 was obtainable with equipment
- Moisture Test
  - Take 6 moisture readings across the surface
- Place 1st and 2nd course of overlay

http://shotblastinc.com/bridge-shot-blasting/
Testing Procedure - Post Curing Day 1

- Sand Blast Surface
- Moisture Test
  - Take 6 moisture readings across the surface
- Place 1st and 2nd course of overlay
Overlay Placement - 1st Layer
Overlay Placement - 2\textsuperscript{nd} Layer
Testing Procedure - After Curing Day 2

- Drill 8 cores to 1/2 inch deep in concrete
- Place adhesive and mount pull-off caps
- Fill cores with silicone caulk
Mount Pull-Off Caps
Testing Procedure - After Curing
Day 3

• Heat slabs with heat lamps to 122-125°F at 1 inch below surface
• Once slabs reach internal temperature of 122-125°F, perform “hot” pull-off tests
• Allow slabs to return to room temperature and perform “cold” pull-off tests
Heat Slabs
Testing Procedure - After Curing
Day 3

- Cylinders tested for compressive strength
  - 2 at 14 day wet cure
  - 2 per slab at pull-off
Moisture Readings
<table>
<thead>
<tr>
<th>Dry Cure Time (Days)</th>
<th>Overall Moisture %</th>
<th>Percentage Decrease from Previous</th>
<th>Percentage Decrease from Previous (Per Day)</th>
<th>Percentage Decrease from 3 Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3.576</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3.556</td>
<td>-0.55%</td>
<td>-0.14%</td>
<td>-0.55%</td>
</tr>
<tr>
<td>14</td>
<td>3.441</td>
<td>-3.22%</td>
<td>-0.46%</td>
<td>-3.76%</td>
</tr>
<tr>
<td>21</td>
<td>3.433</td>
<td>-0.25%</td>
<td>-0.04%</td>
<td>-3.99%</td>
</tr>
</tbody>
</table>
Moisture Readings: Concrete Type

Moisture %

Dry Cure (Days)

3 7 14 21

CONTROL
LOW-CRACKING
FLY ASH
Moisture Readings: Pre and Post Sand Blasting for Fly Ash Concrete

FLY ASH PRIOR TO SAND BLASTING

Moisture %

Dry Cure (Days)

FLY ASH PRIOR TO SAND BLASTING
Moisture Readings: Pre Sand Blasting for the Fly Ash Concrete Categorized by Wet Cure Temperature

Moisture %

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Moisture Readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>40°F</td>
<td>3</td>
</tr>
<tr>
<td>73°F</td>
<td>7</td>
</tr>
<tr>
<td>100°F</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>21</td>
</tr>
</tbody>
</table>

Dry Cure (Days)
Additional Testing

- Batched smaller concrete specimen to dry at 200°F
- Compare moisture meter readings to moisture content determined by weight
Moisture Contents of Heat Dried Specimen

- Specimen 2: Moisture by Weight
- Specimen 4: Moisture by Weight
- Specimen 2: Moisture Meter
- Specimen 4: Moisture Meter
Additional Testing

- Slabs drying for 21 days were subjected to moisture meter readings throughout drying period
  - Moisture readings taken same from procedure earlier
  - Show what individual slabs looked like during drying
Time Progression of Moisture Readings for Selected Slabs

- F-100-21-2
- F-70-21-2
- F-40-21-2
- F-100-21-3
- F-70-21-3
- F-40-21-3
- F-100-21-4
- F-70-21-4
- F-40-21-4
Pull-off Results
Note on Slab Labels

- **C-40-7-1**
  - **1<sup>st</sup> value** refers to Concrete Type
    - C (control), L (low-cracking), F (fly ash)
  - **2<sup>nd</sup> value** refers to wet cure temperature
    - 40°F, 73°F, or 100°F
  - **3<sup>rd</sup> value** refers to dry cure time in days
    - 3, 7, 14, or 21 days
  - **4<sup>th</sup> value** refers to epoxy used for overlay
    - 5 different epoxy brands used
Note on Slab Labels

- Hot and Cold pull-offs
  - “hot” pull-offs
    - Pull-offs performed when internal temperature of concrete is 122-125°F
  - “cold” pull-offs
    - Pull-offs performed after 24 hours when internal temperature of concrete has returned to room temperature (~73°F)
Types of Failures

- There are five types of failures:
  - Type 1 – Failure in the concrete at a depth greater than or equal to \( \frac{1}{4} \) inch over more than 50% of the test area.
  - Type 2 – Failure in the concrete at a depth less than \( \frac{1}{4} \) inch over more than 50% of test area.
  - Type 3 – Separation of the polymer overlay from the concrete surface.
  - Type 4 – Failure within the polymer overlay.
  - Type 5 – Failure of the test adhesive.

- Taken from KDOT's KT-70
Pull-offs Test Results

Dry Cure Time (Days)

<table>
<thead>
<tr>
<th></th>
<th>Hot Temperature</th>
<th>Room Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry Cure Time (Days)</td>
<td>Hot Temperature</td>
<td>Room Temperature</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td></td>
<td>Pull-off (psi)</td>
<td>Percentage increase from previous</td>
</tr>
<tr>
<td>3</td>
<td>165</td>
<td>-2.1%</td>
</tr>
<tr>
<td>7</td>
<td>187</td>
<td>13.8%</td>
</tr>
<tr>
<td>14</td>
<td>231</td>
<td>23.1%</td>
</tr>
<tr>
<td>21</td>
<td>236</td>
<td>2.2%</td>
</tr>
</tbody>
</table>
Hot Pull-offs: Concrete Type

Days after Wet Cure

- CONTROL
- LOW-CRACKING
- FLY ASH
Room Temperature Pull-offs: Concrete Type

- CONTROL
- LOW-CRACKING
- FLY ASH

Pull-off (psi) vs. Days after Wet Cure
Hot Pull-offs: Wet Cure Temperature

Days after Wet Cure

- 40°F
- 73°F
- 100°F
Room Temperature: Wet Cure Temperature

- 40°F
- 73°F
- 100°F

Days after Wet Cure

- 3
- 7
- 14
- 21

Pull-off (psi)
Hot Pull-offs: Epoxy Type
Room Temperature Pull-offs: Epoxy-Polymer Overlay

<table>
<thead>
<tr>
<th>Days after wet cure</th>
<th>E-Bond 526</th>
<th>Pro-Poxy Type III DOT</th>
<th>Flexolith</th>
<th>Sikadur 22 Lo Mod</th>
<th>Mark 154</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
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<td></td>
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<tr>
<td>14</td>
<td></td>
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<td></td>
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<tr>
<td>21</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Additional Testing

- Epoxy Tension Test
- Check for epoxy softening at higher temperatures
  - Pull-off test results conducted at 73°F twice the strength of tests conducted at 122°F
<table>
<thead>
<tr>
<th>Test</th>
<th>Force (lbf)</th>
<th>Comments</th>
<th>Force (lbf)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>3240</td>
<td></td>
<td>3127</td>
<td></td>
</tr>
<tr>
<td>Test 2</td>
<td>2678</td>
<td></td>
<td>1644</td>
<td>Not full coverage</td>
</tr>
<tr>
<td>Test 3</td>
<td>2685</td>
<td>Not full coverage</td>
<td>2940</td>
<td></td>
</tr>
<tr>
<td>Test 4</td>
<td>2855</td>
<td></td>
<td>2415</td>
<td></td>
</tr>
<tr>
<td>Test 5</td>
<td>3018</td>
<td></td>
<td>-</td>
<td>Broke prior to testing</td>
</tr>
<tr>
<td>Average of all tests</td>
<td>2895</td>
<td></td>
<td>2532</td>
<td></td>
</tr>
<tr>
<td>Average of tests with full coverage</td>
<td>2948</td>
<td></td>
<td>2827</td>
<td></td>
</tr>
</tbody>
</table>
Moisture Conclusions

- Moisture readings taken prior to sand-blasting decreased significantly with time.

- Moisture readings taken after sand-blasting decreased only slightly with time.

- Greatest moisture decrease occurred between 7 and 14 days.
Moisture Conclusions (cont.)

- Concrete surface dried out initially
- Moisture from within the concrete replenished the moisture on surface during drying
- The surface moisture is not the only reading needed
Pull-off Test Conclusions

• Pull-off results were nearly double when tested at $73^\circ \pm 5^\circ$ than at $122^\circ$

  ▫ $122^\circ$ pull-off tests showed much higher strength gain when given extra time (>40% gain)

  ▫ $73^\circ \pm 5^\circ$ pull-off tests showed smaller strength gains (<10%)
Pull-off Test Conclusions (cont.)

• Pull-off test results did not correlate well with the moisture readings
  ▫ As noted previously, internal moisture replenished surface moisture
  ▫ Pull-off test results affected by more than just the surface moisture readings
Recommendations

- Place overlay between 10 and 14 drying days
  - Pull-off strength increased most between 7 and 14 days
  - Moisture decreased the most between 7 and 14 days

- Surface moisture was unable to predict pull-off strength
  - More tests to see how internal moisture in concrete dries
Thank you all for coming!

Questions?