Concrete Pavement Preservation and Preventive Maintenance (A Webinar Series)

• Part 1 – The Essentials: From Pavement Evaluation to Strategy Selection - March 15

• Part 2 – Partial- and Full-Depth Repair Methods

• Part 3 – Tips and Techniques for Specialized Repair and Construction Methods – September 14
  – Includes Slab Stabilization, Slab Jacking, Retrofit Edge Drains, Dowel Bar Retrofit, Cross-Stitching and Slot Stitching

• Part 4 – Concrete Pavement Surface Restoration and Joint/Crack (Re)Sealing – October 6
  – Includes Diamond Grinding and Grooving

• Part 5 – Pavement Maintenance and Preservation Using Concrete Overlays – October 25
Webinar Part 1 - Highlights

• What is Pavement Preservation?
  – Network level, long-term strategy for enhancing pavement performance
  – Focus on extending pavement life and restoring functional condition
  – Goals accomplished with a collection of preventive maintenance treatments and a few minor rehabilitation and routine maintenance treatments

• What is Preventive Maintenance?
  – Planned strategy of cost effective treatments
  – Applied to structurally sound pavements with significant remaining life
  – Maintain or improve functional condition
Webinar Part 1 - Highlights

- **Pavement Evaluation**
  - Determine causes of deterioration
  - Develop appropriate alternatives
  - Provides quantitative information for quantity estimates, LCCA
  - As-built info, distress surveys, NDT, sampling

- **Strategy Selection**
  - Treatment-Distress Matrix
  - Concurrent Treatment Sequencing
Partial-Depth Repairs
Introduction

• Definition:
  \[\text{Removal and replacement of small, shallow areas of deteriorated PCC at spalled or distressed joints.}\]

• Criteria for application:
  • Distress limited to upper 1/3 – 1/2 of slab
  • Existing load transfer devices are functional
Benefits

• Restores slab integrity
• Improves ride quality
• Extends the service life
• Restores a well-defined uniform joint sealant reservoir
Good Candidate Projects

• Spalls caused by:
  – Incompressibles in joints
  – Localized areas of weak material
  – Joint inserts

• Surface deterioration caused by:
  – Reinforcing steel too close to surface
  – Poor curing or finishing practices

• Recommended evaluation procedures:
  – Distress surveys
  – Sounding
Poor Candidate Projects

- Spalls due to dowel bar misalignment
- Spalls at working cracks due to shrinkage, fatigue, or vertical movement
- Spalls due to D-cracking or reactive aggregate
Good candidate?
Good candidate?
Good candidate?
Good candidate?
Partial-Depth Repair Types

- Type 1 - Joint "V" Milled
- Type 2 - Crack "V" Milled
- Type 2 - Transverse Joint "V" Milled
- Type 2 - Longitudinal Joint "V" Milled
- Type 1 - Spot Repair Saw and Chip
- Type 3 Bottom Half

Fig. 5.1 on p. 5.2
Design Considerations

- Sizing of repair
- Material selection
- Bonding agent
Sizing of Repair

- Greater than 3 inches beyond spall
- Combine spalls if closer than 24 inches
- Cementitious:
  - 4 inch x 10 inch
  - 2 inch depth
- Proprietary:
  - Refer to manufacturer’s instructions
Material Selection Factors

• Allowable lane closure time
• Ambient temperature
• Material and placement cost
• Material properties (shrinkage, CTE, bond strength)
• Compatibility between repair material and existing pavement
• Size and depth of repair
• Performance capabilities
Repair Material Selection

- Repair materials for partial-depth repairs are generally classified cementitious, polymeric, or bituminous.
- Concrete mixes along with a wide variety of rapid-setting and high-early-strength proprietary materials have been developed.
  - *High-quality portland cement concrete is generally accepted as the most appropriate material for the repair of existing concrete pavements.*
  - *Concrete mix requires use of small-sized, coarse aggregate, usually less than 1/2 in.*
Material Selection – Repair Material

- MnDOT Cementitious 3U18 Material Recommended for Use in Partial-Depth Repairs
  - 850 lbs Type I Cement
  - 295 lbs of water
  - 1,328 lbs of coarse aggregate
  - 1,328 lbs of sand
  - Target W/C of 0.35
  - Type E Water Reducing and Accelerator
  - 6.5% air

- ~2500 psi strength in 18 hours
- Used successfully for 30+ years
Material Selection – Repair Material

• Cementitious 3U18 Recommended for Use in Partial-Depth Repairs
  – Maximum 1 in. slump (measured after allowing to set 5 minutes after mixing)
  – Cure time of 18± hours
  – Aggregate gradation of
    o 100% passing the 3/8 in. sieve
    o 55% - 95% passing the #4 sieve
    o Not more than 5% shall pass the #50 sieve
Bonding Agent

• Intended to enhance bond between repair material and existing pavement.
  – Can reduce bond if not installed properly
• Required for many cementitious repair materials.
  – Some agencies allow clean, SSD surface in lieu of bonding agent
• Manufacturer’s instructions should be consulted for proprietary mixes
Bonding (Grout) Agent

• Sand-cement grouts have proven adequate when properly used as bonding agents with concrete repair materials.
  – 2 parts Type I cement
  – 1 part water (more or less, as needed to develop a creamy consistency)
  – 1 part sand
Bonding (Grout) Agent: Kansas DOT Approach

- Use a more watery mix which helps cool and pre-wet the existing concrete pavement before placement.
  - 1 part Type I cement
  - 3 parts water
Construction Steps

1. Repair dimension selection
2. Concrete removal
3. Repair area preparation
4. Joint preparation
5. Bonding agent application
6. Patch material placement
7. Curing
8. Diamond grinding (optional)
9. Joint resealing
1. Repair Dimension Selection

Sounding
1. Repair Dimension Selection

Marking
1. Repair Dimension Selection

Recommendations for Cementitious

Min. Patch Length 10 in
Min. Patch Width 4 in
2. Concrete Removal

• Methods
  – Saw and Patch
    ➢ Saw perimeter and light jackhammer breakout
  – Chip and Patch
    ➢ Light jackhammer breakout (no sawing)
  – Mill and Patch
    ➢ Removal of deteriorated concrete through cold milling
2. Concrete Removal

Sawing
2. Concrete Removal
Chipping
2. Concrete Removal

Cold Milling

Transverse Milling (small head, moves along joint)

Longitudinal Milling (wide head, pick up & move over)

Fig. 5.13 on p. 5.15
2. Concrete Removal

Cold Milling

Milling Along the Joint

Milling Across the Joint
2. Concrete Removal

Cold Milling Heads

<table>
<thead>
<tr>
<th>“V” Shape Milling Head and Pattern</th>
<th>Rock Saw and Rounded Pattern</th>
<th>Vertical Edge Mill Head and Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="V Shape Milling Head" /></td>
<td><img src="image2" alt="Rock Saw and Rounded Pattern" /></td>
<td><img src="image3" alt="Vertical Edge Mill Head" /></td>
</tr>
</tbody>
</table>

- “V” Shape Milling Head and Pattern
  - 30 to 60 degrees

- Rock Saw and Rounded Pattern

- Vertical Edge Mill Head and Pattern
3. Repair Area Preparation

Sandblasting
3. Repair Area Preparation

Air Blasting

- Air blasting to remove dust and debris (90 psi minimum)
- Free of oil and moisture
- Direct away from patches
4. Joint Preparation

Fig. 5.18 on p. 5.19
Placement of Compression Relief
(Waxed Cardboard)

- Often more easily fits the irregular nature of random cracks.
- Has the ability to maintain its rigidity for the concrete placement.
- Hold in place during concrete vibration so that it doesn’t float.

Concrete placement for Type 1 repair using waxed cardboard

Type 2B – Crack Repair
5. Bonding Agent Application

Cement Grout

Epoxy
6. Patch Material Placement

- Batch small quantities
- Temperature restrictions
  - Typically require <40°F at placement with forecast temps above 40°F)
- Some epoxy materials placed in lifts
- Overfill patch area by ~1/8 inch (3 mm)
- Consolidate material with small spud vibrator or other appropriate means
- Screed and hand trowel (center to edge)
6. Patch Material Placement
6. Patch Material Placement

Consolidation

Finish Towards Edges
6. Patch Material Placement

Sealing Edges and Runouts
7. Curing

- Prevent moisture loss
- White-pigmented curing compound commonly used
- Opening to traffic
  - Mix- /temperature-dependent
  - Common values: 1600 to 1800 psi
Re-establish Joint/Crack

- Type 1 and Type 2A joints have been successfully sawed.
- Fresh concrete can also be tooled prior to sawing.
- Joint reservoir must be wider than the crack under the repair.

Tooling of the joint

Sawing following tooling of the joint
8. Diamond Grinding (optional)
9. Joint Resealing
Completed Repairs
Examples of Long-Lasting Partial-Depth Repairs

20 year old Type 2A longitudinal and transverse partial-depth repairs in Hopkins, MN

Close up of partial-depth patch in Hopkins, MN done in 1991 and picture taken 2011
Key Factors For Success

- Proper selection of candidate projects
- Proper material selection
- Identification of repair boundaries
- Use of joint/crack reformers
- Achieving good bond
  - Clean and dry repair area
  - Sandblasting sidewalls
  - Proper application of bonding agent followed by timely placement of repair material
- Proper placement and curing
Troubleshooting

• Problem

  Deterioration found to extend beyond the original repair boundaries

• Solutions?
Troubleshooting
What is wrong here?
Troubleshooting
What is wrong here?
Troubleshooting
Construction Quality Problems

• Problem

*Patch material flows into joint*

• Potential causes? Solutions?
Troubleshooting
What is wrong here?
Additional Resource

Full-Depth Repairs
Introduction

- **Definition**
  
  *Cast-in-place concrete repairs that extend the full-depth of the existing slab*

- **Benefits**
  - Restore rideability
  - Restore structural integrity
Applications

• Address structural deterioration
  – Deteriorated cracks
  – Corner breaks
  – Shattered slabs and blowups
  – Punchouts (CRCP)

• Address joint deterioration
  – Severe spalling
  – Joint lockup

• Utility cut repairs

• Prepare pavement for overlay
Limitations

• Does not address structural inadequacy
• Not a long-term solution for material-related distresses (ASR, D-cracking)
• Not cost-effective for widespread deterioration
• Potentially an expensive cost item
Design and Materials Considerations

- Repair boundaries
- Repair materials
- Load transfer design
Repair Boundaries

• Encompass all deterioration
• Typically use full lane-width repairs
• Length $\geq 6$ ft
• Provide intermediate joint for long repairs ($>15$ ft)
• Independent repairs in adjacent lanes
• Combine repairs when there is less than 8 – 10 ft between them
• Maintain minimum distance between repair and existing joints and cracks.
Repair Boundaries
Example Repairs in JPCP

Before

After

L, M, H = Low-, Medium-, High-Severity

NOTES
a – Minimum length is 1.8 m (6 ft)
b – Check distance between patches and nearby joints
c – Replace the entire slab if there are multiple intersecting cracks

Fig. 6.2 on p. 113
Selecting Repair Boundaries
Potential Extent of Deterioration at Joint

Fig. 6.1 on p. 6.4
CRCP Pavements
Repair Recommendations

Replace as a single area

a ≥ 1.8 m (6 ft) tied steel
a ≥ 1.2 m (4 ft) welded or mechanical connection
b ≥ 0.46 m (1.5 ft)

Fig. 6.4 on p. 6.7
Selecting Repair Materials

• Based largely on required opening times
  – Conventional PCC mixes most common
  – Proprietary materials and specialty cements available

• Various materials can be used within a project to meet opening requirements
Load Transfer Design

Dowel Bars

- Critical to long-term performance
- Dowel characteristics:
  - Diameter: Typically D/8
  - Length: Typically 18 in
  - Corrosion-resistant (epoxy common)
  - Debonding medium
Load Transfer Design

Example Layout

Traffic Direction

Mid-depth slab

12 ft

2 ft

1 ft typical

Smooth dowels 1.5 inch dia.

6 ft minimum

Fig. 6.5 on p. 116
Construction Steps

1. Concrete sawing
2. Concrete removal
3. Repair area preparation
4. Restoration of load transfer
5. Treatment of longitudinal joints
6. Concrete placement/finishing
7. Curing and opening to traffic
8. Diamond grinding and joint sealing
1. Concrete Sawing

- Full-depth, diamond-bladed sawing
- Limit traffic loading on sawed pavement to avoid pumping
- Maintain straight edge along shoulder side
2. Concrete Removal
Breakup and Cleanout

- Simple and straightforward
- May disturb base and underlying utilities

- Relatively slow
2. Concrete Removal
Liftoout Method (preferred)

- Minimizes disturbance
- High productivity
- Requires heavy lifting equipment
3. Repair Area Preparation
4. Restoration of Load Transfer

Schematic of Dowel Bar Installation

**Grout-retention disk (optional)**

**Existing slab**

**Repair area**

**Subbase**

- $d = \text{dowel diameter}$
- $a = 1/8 \text{ in for epoxy}$
- $a = 1/4 \text{ in for cement grout}$

**Subgrade Soil**

Hole dia. = $d + a$

Fig. 6.13 on p. 124
Load Transfer Design

Dowel Bars

• Critical to long-term performance
• Dowel characteristics:
  – Diameter: Typically D/8 (or more)
  – Length: Typically 457 mm (18 in)
  – Corrosion-resistant (epoxy common)
  – Bond-breaking agent
Load Transfer Design

Example Layout

Traffic Direction

Mid-depth slab

3 - 5 dowels/wheel path (typical)

Smooth dowels
38 mm (1.5 in) dia.

3.7 m (12 ft)

0.6 m (2 ft)

0.3 m (1 ft) typical

1.8 m (6 ft) minimum

Fig. 6.5 on p. 116
Restoration of Load Transfer
Drilling Recommendations

• Dowel holes drilled at mid-depth (typically) of existing slab at specified spacings

• Dowel holes drilled slightly larger than dowel diameter

• Use gang drills for better alignment and increased productivity
# MnDOT: Multiple Projects Tested

<table>
<thead>
<tr>
<th>Road</th>
<th>MP</th>
<th>2010 ADT</th>
<th>2010 %Trucks</th>
<th>Dowels per lane</th>
<th>FWD LTE Range</th>
<th>CPR Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-90</td>
<td>138-145</td>
<td>7,668</td>
<td>25.4</td>
<td>6</td>
<td>5-83%</td>
<td>2009</td>
</tr>
<tr>
<td>I-90</td>
<td>185-193</td>
<td>11,416</td>
<td>11</td>
<td>11</td>
<td>86-95%</td>
<td>2010</td>
</tr>
<tr>
<td>I-94</td>
<td>157-194</td>
<td>43,500</td>
<td>10.3</td>
<td>6</td>
<td>25.7-46.4%</td>
<td>2009</td>
</tr>
<tr>
<td>I-94</td>
<td>209-217</td>
<td>100,725</td>
<td>9.5</td>
<td>8</td>
<td>19-80%</td>
<td>2010</td>
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<tr>
<td>MN23</td>
<td>112-124</td>
<td>3,290</td>
<td>12.9</td>
<td>8</td>
<td>97-97.5%</td>
<td>2011</td>
</tr>
<tr>
<td>MN77</td>
<td>1-5</td>
<td>65,000</td>
<td>2.2</td>
<td>11</td>
<td>31-95%</td>
<td>2007</td>
</tr>
</tbody>
</table>

- Visual examination of the cores
- FWD Testing
  - Does LTE tell us what we need to know?
  - Michigan DOT suggested looking at deflection....
2013 Construction Season

- MnDOT randomly cored every CPR project in 2013
- One Contractor took initiative to core and check their own workmanship
- Most effective cause for Contractor to change was when MnDOT cored each project – even when Contractors were working on multiple projects
Dowel Bar Installation Recommendations

• Blow debris and dust from holes
• Place grout or epoxy in holes
• Insert dowel into hole with slight twisting motion
• Install grout retention disks (optional)
• Apply bond-breaker to protruding dowel ends
Restoration of Load Transfer

Cleaning Holes (Air Blasting)
Restoration of Load Transfer
Injecting Anchoring Material
Restoration of Load Transfer
Dowel Bar Placement

1

2

3
Restoration of Load Transfer
Area Prepared with Dowels in Place
CRCP
Restoring Longitudinal Steel

• Most agencies maintain continuity of longitudinal steel through repair
  – Longitudinal reinforcement in existing pavement exposed using 2 sets of sawcuts
    ➢ Partial-depth at each end of repair area
    ➢ Full-depth inside of partial-depth cuts
  – New steel affixed via either:
    ➢ Tied splices
    ➢ Welded splices
    ➢ Mechanical connection
CRCP Pavements
Sawcut Locations and Repair Details

Fig. 6.6 on p. 6.11
CRCP Pavements
Exposed Steel

Fig. 6.11 on p. 6.18
CRCP Pavements
Restoring Continuity of Reinforcing Steel
5. Treatment of Longitudinal Joints

Bondbreaker Board
6. Concrete Placement

- Consolidation and level finish are critical
- Vibrate along edges of repair and in vicinity of dowel bars
- Don’t use vibrators to move concrete
- Avoid addition of extra water
- Texture surface to match existing pavement
6. Concrete Placement

- Consolidation and level finish are critical
- Vibrate along edges of repair and in vicinity of dowel bars
- Don’t use vibrators to move concrete
- Avoid addition of extra water
- Texture surface to match existing pavement
Concrete Placement

Finishing

Fig. 6.15 on p. 125
Concrete Placement

Texturing
7. Curing and Opening to Traffic

- White-pigmented curing compound
- Apply immediately after texturing
- Uniform coverage
Opening To Traffic

- Typical ranges:
  - Compressive: 2,000 – 3,000 lb/in²
  - Flexural (3rd Point): 290 – 400 lb/in²
  - Dowel bearing stress considerations: 2,000 – 2,500 lb/in²
### Opening Strength Matrix

<table>
<thead>
<tr>
<th>Slab Thick, in</th>
<th>Strength for Opening to Traffic, psi</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length &lt; 10 ft</td>
<td>f’c</td>
<td>MR (3^rd)</td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>3000</td>
<td>490</td>
</tr>
<tr>
<td>7.0</td>
<td></td>
<td>2400</td>
<td>370</td>
</tr>
<tr>
<td>8.0</td>
<td></td>
<td>2150</td>
<td>340</td>
</tr>
<tr>
<td>9.0</td>
<td></td>
<td>2000</td>
<td>275</td>
</tr>
<tr>
<td>10.0+</td>
<td></td>
<td>2000</td>
<td>250</td>
</tr>
</tbody>
</table>

Table 6.6 on p. 119
8. Diamond Grinding & Sealing

Diamond Grinding

Joint Sealing
Precast Concrete Repairs
Heavy Traffic = Short Work Windows

145,000 vpd
I-287, Tarrytown, NY

200,000 vpd
I-15, Ontario, CA

180,000 vpd
I-66, Fairfax, VA

Requires Rapid, Durable Repair/Reconstruction!

Source: The Fort Miller Co., Inc.
Precast Concrete Slabs

Prefabricated panels used for repair or reconstruction of roadway pavements

- **Advantages:**
  - Good quality concrete
  - Improved curing
  - Minimal weather impacts
  - Rapid opening

- **Application:**
  - Heavily trafficked roads
  - Intersections
  - Ramps
  - Bridge approach slabs
Load Transfer System Options
Repair Panel Leveling Options

- Embedded Leveling Bolt - Generic
- Precision Grade-Supported
- Shim Supported (with grout injection)
- Urethane or Grout Injection
Many Uses

Tappan Zee Bridge Toll Plaza

Santa Monica, California Bus Pad

New York City Intersection

LaGuardia Airport (New York)
Lane Miles of Jointed Precast Slab Installations (June 2013) (All Systems, U.S. & Canada)
Troubleshooting
(a.k.a. “What could possibly go wrong?!?”)
Troubleshooting

What is wrong here?
Troubleshooting
What is wrong here?
Troubleshooting

What is wrong here?
Troubleshooting

What is wrong here?
Additional Resource

Acknowledgments

- American Concrete Pavement Association (ACPA)
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- Jeff Uhlmeyer/Washington State DOT
- John Donahue/Missouri DOT
- Kurt Smith/Applied Pavement Technology, Inc.
- Maria Masten/Minnesota DOT
- National Precast Concrete Association
- The Fort Miller Company, Inc.
- U.S. Federal Highway Administration (FHWA)
- Shiraz Tayabji/Applied Research Associates, Inc. (ARA)
Thank You For Your Attention!

Questions?