Concrete Pavement Preservation Fundamentals

National Concrete Pavement Technology Center
Iowa’s Lunch–Hour Workshop
In cooperation with the Iowa DOT
and the Iowa Concrete Paving Association
Investment

Protect the Investment
Review your Pavements
Plan for Preservation
Do it Correctly
Service Life

SHORT-TERM PAVEMENT

INVESTMENT

PAVEMENT CONDITION

Excellent
Good
Fair
Poor
Deteriorated

YEARS

0 5 10 15 20 25 30 35 40 45
Preservation

- Work planned & performed to improve or sustain the condition of the transportation facility to a good condition¹ (keep good roads good)
- Generally do not add capacity or structural value, but restore the overall condition¹
- Extending life and restoring functional condition
- Collection of maintenance and minor rehabilitation

Preventative Maintenance

- Maintain (or improve) the condition of the transportation system to a functional state of operation¹
- Part of asset management (routine & preventive maintenance)¹
- Applied to structurally sound pavements with significant remaining life

¹Source: FHWA Guidance on Highway Preservation and Maintenance
Maintenance vs. Preservation

Extend performance with proper Materials, Design & Construction

Goal of extending service life without distresses

Pavement Preservation

Good

Excellent

Good

Fair

Common Preservation Action

Poor

Deteriorated

Failed

Rehabilitation

Minor Rehabilitation

Major Rehabilitation

Reconstruction

Time

Poor

Design Phase – Consider future preservation & rehab

Implement timely & less costly preservation techniques

Timely (more costly) techniques

Unbonded Concrete Overlays

Bonded Concrete Overlays
## Trigger/Limit Values for Preservation (JPCP)

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>Trigger Value</th>
<th>Limit Value</th>
<th>Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans. Cracking</td>
<td>1.5-2.5% of slabs cracked</td>
<td>5-15% of slabs cracked</td>
<td>Partial, Full, Dowel Bar Repairs</td>
</tr>
<tr>
<td>Joint Deterioration</td>
<td>2.0-4.0% of joints</td>
<td>15-20% of joints</td>
<td>Partial-Depth Repair</td>
</tr>
<tr>
<td>Joint Faulting</td>
<td>1/8 inch</td>
<td>3/8 – 1/2 inches*</td>
<td>Dowel Bar Retrofit</td>
</tr>
<tr>
<td>Roughness</td>
<td>90 in/mi</td>
<td>170 in/mi*</td>
<td>Diamond Grinding</td>
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</table>

* CP Tech Center  
Values Adapted from Table 3.2 Preservation Guide
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Expected Performance (Treatment Life), Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Concrete joint resealing</td>
<td>8 - 15</td>
</tr>
<tr>
<td>* Concrete crack sealing</td>
<td>8 - 15</td>
</tr>
<tr>
<td>Diamond grinding</td>
<td>8 to 15</td>
</tr>
<tr>
<td>Diamond grooving</td>
<td>10 to 15</td>
</tr>
<tr>
<td>* Partial-depth concrete patching</td>
<td>12 - 20</td>
</tr>
<tr>
<td>* Full-depth concrete patching</td>
<td>15 - 25</td>
</tr>
<tr>
<td>* Dowel bar retrofit</td>
<td>15 - 20</td>
</tr>
</tbody>
</table>

* CP Tech Center (adapted from Preservation Guide)
Q3: Full Depth Repairs: What is your Agency's expected life of full depth repair?
Q5: Partial Depth Repairs: What is your Agency's experience doing partial depth repairs?

Routine (many projects)
Some (Less than 5 projects)
None (never tried)

2017 Survey
Q7: Partial Depth Repairs: What is your Agency's expected life of partial depth repair?
Q9: Dowel Bar Retrofits: Does your Agency have any experience doing dowel bar retrofit repairs?

- **Routine (many projects)**: States with many projects.
- **Some (Less than 5 projects)**: States with less than 5 projects.
- **None (never tried)**: States with no experience.

2017 Survey
Q10: Dowel Bar Retrofits: What is your Agency's expected life of dowel bar retrofit repair?

2017 Survey
Concrete Pavement Preservation Guide 2014

- Contains 12 Chapters on Preservation Techniques
- Focus on Repair Techniques (How to do it)
Distress Assessments & Solutions

DIVISION 1 – FULL DEPTH CONCRETE PAVEMENTS

- Surface Defects
- Surface Delamination
- Material Related Cracks
- Transverse & Diagonal Cracking
- Longitudinal Cracking
- Corner Cracking
- Spalling
- Faulting
- Joint Warping and Curling
- Blowups
- Settlement and Heaves
- Subgrades & Base Support Conditions
- CRCP

DIVISION 2 – CONCRETE OVERLAYS

- Concrete Overlays, BCOA, BCOC, UBCOA, UBCOC
- Laboratory & Field Testing

Google: CP Tech Center Distress Manual (pdf & ePub)

Full Depth Pavements

Ch 2. Surface Defects

Ch 3. Surface Delamination

Ch 4. Material-Related Cracks

Ch 5. Transverse/Diagonal Cracking
Full Depth Pavements

Ch 6. Longitudinal Cracking

Ch 7. Corner Cracking

Ch 8. Spalling

Chapter 9. Faulting
Full Depth Pavements

Ch 10. Joint Curling and Warping

Ch 11. Blowups

Ch 12. Subgrades and Base Support

Ch 13. CRCP
This chapter will help quickly identify where in Division 2 of this manual you can find more detailed guidance on distresses in concrete overlays (causes and solutions). A brief overview of each chapter is provided along with a description of the overlay type being addressed.
Concrete Overlay Distress Manual

Chapters

Ch 15. Bonded Concrete Overlay on Asphalt (BCOA)

Ch 16 Bonded Concrete Overlay on Concrete (BCOC)

Ch 17. Unbonded Concrete Overlay on Asphalt (UBCOA)

Ch 18. Unbonded Concrete Overlay on Concrete (UBCOC)
Ch. 15 Concrete Overlay on Asphalt (BCOA)

Interior Structure/Unbonded Cracks

Longitudinal lane-shoulder joint spall due to shoulder heave

Compression-transverse joint due to slab expansion & adjacent joints not opening

Transverse joint faulting

Panel migration/slippage

Mult. Longitudinal cracking in wheel path
Ch 16. BONDED CONCRETE OVERLAY ON CONCRETE (BCOC)

- Reflective crack over transverse crack
- Multiple panel cracks near panel end due to debonding
- Longitudinal crack-overlay fatigue after debonding
- Late sawing/or saw cut not directly over existing joint/crack
- Wheel path cracking-debond & fatigue cracking of overlay
- Reflective crack-not cutting a joint over existing crack
Ch. 17 UNBONDED CONCRETE OVERLAY ON ASPHALT (UBCOA)

Longitudinal cracking in wheel path with tied & widened shoulders

Faulting & panel movement of UBCOA due to deformation of the underlying HMA

Diagonal longitudinal crack over widened section

Cracking- misaligned dowels; paint marks dowel basket

Mid-panel cracking

Blowups
Ch 18 UNBONDED CONCRETE OVERLAY ON CONCRETE (UBCOC)

Longitudinal cracking in wheel path with tied & widened shoulders (UBCOC)

Transverse joint faulting of UBCOC

Longitudinal cracking in wheel path in UBCOC

Transverse reflective cracking of UBCOC

UBOC Mid-panel cracking

Cracking due to misaligned dowels, (yellow oval shows the exposed end of dowel)
COMMON DISTRESS TYPES
## Longitudinal and Transverse Cracking – Causes and Prevention

<table>
<thead>
<tr>
<th>Causes</th>
<th>Prevention</th>
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<tbody>
<tr>
<td>Excessive slab length</td>
<td>Follow guidelines, saw to adequate depth</td>
</tr>
<tr>
<td>Late sawing</td>
<td>Maximize sawing window, increase labor/equip forces</td>
</tr>
<tr>
<td>Inadequate saw depth</td>
<td>Check blades, saw to $T/4$ on transverse joints ($T/3$ on longitudinal and CD joints)</td>
</tr>
<tr>
<td>Non-Uniform support volume changes</td>
<td>Uniform drainage, compact &amp; subgrade soils, chemically stabilize subgrade if needed</td>
</tr>
<tr>
<td>Traffic loading</td>
<td>Use proper thickness, keep construction traffic away from edges</td>
</tr>
<tr>
<td>Defect</td>
<td>Orientation</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Plastic Shrinkage</td>
<td>Any</td>
</tr>
<tr>
<td>Uncontrolled Crack</td>
<td>Transverse</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncontrolled Crack</td>
<td>Transverse</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncontrolled Crack</td>
<td>Transverse</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Spalled sawcut or uncontrolled crack</td>
<td>Transverse</td>
</tr>
<tr>
<td>Uncontrolled Crack</td>
<td>Longitudinal</td>
</tr>
<tr>
<td>Uncontrolled Crack</td>
<td>Longitudinal</td>
</tr>
<tr>
<td>Uncontrolled Crack</td>
<td>Longitudinal</td>
</tr>
<tr>
<td>Spalled sawcut or uncontrolled crack</td>
<td>Longitudinal</td>
</tr>
<tr>
<td>Uncontrolled Crack</td>
<td>Diagonal</td>
</tr>
<tr>
<td>Uncontrolled Crack</td>
<td>Multiple per panel</td>
</tr>
</tbody>
</table>
## Spalling - Causes

<table>
<thead>
<tr>
<th>Distress</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spalling (Material or Chemical)</td>
<td>Heavy application of Magnesium &amp; Calcium Chlorides</td>
<td>Deicing chemicals react with Calcium Hydroxide (CH) causing flaking of hardened paste</td>
</tr>
<tr>
<td></td>
<td>Freeze Thaw Damage</td>
<td>Damage to the paste of the concrete from:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Poor air entrainment system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Saturated concrete joints/cracks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Chemical breakdown of the concrete from calcium and magnesium chloride (Calcium Oxychlorides)</td>
</tr>
<tr>
<td></td>
<td>Thermal Expansion</td>
<td>High coefficient of thermal expansion (CTE) of the aggregate results in higher compressive stresses at the joint or crack.</td>
</tr>
<tr>
<td></td>
<td>Infiltration</td>
<td>Infiltration of incompressibles into poorly sealed or unsealed joints.</td>
</tr>
<tr>
<td></td>
<td>Compression Shear</td>
<td>Compression shear from deflection of the slab, lack of load transfer, or lack of subgrade support</td>
</tr>
<tr>
<td></td>
<td>Chipping/Fraying</td>
<td>Early sawing of the joint which chips or frays the edges of the joint.</td>
</tr>
<tr>
<td></td>
<td>Moving Dowels</td>
<td>Dowel bar movement from misaligned dowels.</td>
</tr>
</tbody>
</table>

### Joint Deterioration/Spalling

### Air Distribution

### Super Air Meter
How do we get low permeability?

Use SCMs to tie up CH

\[
\text{Cement} + \text{Water} = \text{C-S-H} + \text{CH}
\]

\[
\text{SCM} + \text{Water} + \text{CH} = \text{more C-S-H}
\]
COMMON REPAIR METHODS
Partial-Depth Repair

Key Factors for Success

• Proper selection of candidate projects
• Proper material selection
• Identification of repair boundaries
• Use of joint/crack reformers
• Achieving good bond
• Proper placement and curing
Partial-Depth Repair

1. Vertical saw cut (typical). Apply tack coat to sides and bottom.
2. Taper the sides of the removal area 30 to 60 degrees from vertical. Apply cement grout to sides and bottom.
3. Saw and seal existing joint.
4. Extend patch limits at least 3 inches beyond distressed area.
5. When milled removal is allowed, sawed vertical edges are not required. Apply cement grout to milled area.

**PCC PATCH ACROSS JOINT**

- Initial Saw Cut
- Existing Joint or Crack
- Existing PCC Pavement

**SECTION A-A**

- Option 1: Sawed Edges

**SECTION B-B**

- Initial Saw Cut
- Existing Joint or Crack
- Existing PCC Pavement

**HMA PATCH**

- Existing HMA or PCC Pavement

**PCC PATCH ABUTTING JOINT**

- Initial Saw Cut
- Existing Joint or Crack
- Existing PCC Pavement
Partial Depth Repairs
SUDAS & Iowa DOT

• SUDAS (7040) requires compression relief material

• Iowa DOT (2530) allows compression relief boards or sawcutting for patches greater than 6’

• Iowa DOT (2530)
  – Partial Depth Finish Patches < 6’ long
  – Partial Depth PCC Joint and Crack Repair Patches ≥ 6’
Partial-Depth Repair Steps

1. Sounding

2. Marking Removal

3. Removal

4. Sand & Air Blast
Partial-Depth Repair Steps

5. Compression relief
6. Grout/Epoxy
7. Patch (Grout edge)
8. Curing
9. Joint seal
Partial-Depth Repair Removal
Sawing / Jackhammers

- Small to medium walk-behind saw for perimeter cuts
  - Maneuverability
  - Positioning on paint marks

- Select light-weight hammer
  - 15 to 30 pound
  - More control
  - Less fatigue

- Use chisel or narrow spade bit for removal
Partial-Depth Repair Removal
Milling

V Head
Tapered Head
Rounded Head
Vertical Head

High Flow Skid Steer
18K-lb Milling Machine
18K-lb Milling Machine
18K-lb Milling Machine
Partial Depth Repair (Over-depth Repairs)

- SUDAS: pay 2 x cost of partial depth repair for full depth repair

- Iowa DOT: pay for over-depth patches area calculated at mid depth of patch in addition to partial depth quantity
Full-Depth Repair

Key Factors for Success

• Removal (4’ min.)
• Dowel bar holes (grout or epoxy)
• Cleaning holes
• Proper material selection
• Proper placement and curing
Full Depth Repairs - Construction

1. Inject grout to back of hole
2. Twist one turn while pushing in dowel
3. Place grout retention disk to hold in grout
Iowa DOT: Full Depth Finish Patches By Area & By Area 50’+(SY) and By Count (Each)  
SUDAS: By Area (SY)
3.02 FULL DEPTH PATCHING (Continued)

2. Tie Bars and Dowel Bars: Comply with Section 7010 and the figures in Sections 7010 and 7040.
   a. When there is a common line between two adjacent patches, a bent bar may be placed in a keyway and later straightened.
   b. Coat dowel bars extending into the patch area with a bond breaker. Do not coat tie bars.
# Full-Depth Repair - Opening

### Table 6.6. Minimum Opening Strengths for FDRs (ACPA 2006)

<table>
<thead>
<tr>
<th>Slab Thickness, mm (in.)</th>
<th>Strength for Opening to Traffic, MPa (lbf/in.²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Repair Length &lt; 3 m (10 ft)</td>
</tr>
<tr>
<td></td>
<td>Compressive</td>
</tr>
<tr>
<td>150 (6.0)</td>
<td>20.7 (3000)</td>
</tr>
<tr>
<td>175 (7.0)</td>
<td>16.5 (2400)</td>
</tr>
<tr>
<td>200 (8.0)</td>
<td>14.8 (2150)</td>
</tr>
<tr>
<td>225 (9.0)</td>
<td>13.8 (2000)</td>
</tr>
<tr>
<td>250+ (10.0+)</td>
<td>13.8 (2000)</td>
</tr>
</tbody>
</table>

### Table 7010.01: Minimum Age and Tested Strength of Pavement Before Opening

<table>
<thead>
<tr>
<th>Class of Mix</th>
<th>Type of Cement</th>
<th>Minimum Age For Opening ¹</th>
<th>Minimum Compressive Strength (psi)</th>
<th>Minimum Flexural Strength Center Point (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Type I</td>
<td>7 Days ²</td>
<td>3,000</td>
<td>500</td>
</tr>
<tr>
<td>M</td>
<td>Type I</td>
<td>48 Hours</td>
<td>3,000</td>
<td>500</td>
</tr>
</tbody>
</table>

¹ Opening without testing only allowed upon approval of Engineer
² Five calendar days for concrete 9 inches thick or more.

Note: Maturity Testing is not required for FDR
Dowel Bar Retrofit

- Restores load transfer
- Reduces probability of pumping, faulting, and corner breaks
- Improves long-term rideability
- Increases service life
Dowel Bar Retrofit

- Need compressible insert
- 3 bars per wheel path, 6 bars per lane, 12” spacing
- 14” min. length

<table>
<thead>
<tr>
<th>Pavement Thickness (in.)</th>
<th>Dowel Diameter (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>8 to 9.5</td>
<td>1.25</td>
</tr>
<tr>
<td>≥10”</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Dowel Bar Retrofit

1. Extend concrete patch material 1/8" above existing concrete surface for projects to be diamond ground; construct flush if diamond grinding is not required.

2. Sawcut joint width 3/16" min to 5/16" max. Saw after concrete patch material has set.

PLAN VIEW

SECTION A-A

Construct bottom of slot parallel to pavement surface.

SECTION B-B

Place chair parallel to surface.
## Case Study – NW State St, Ankeny

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>SUDAS NO.</th>
<th>ITEM</th>
<th>UNIT</th>
<th>TOTAL QTY</th>
<th>AS-BUILT QTY</th>
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<tbody>
<tr>
<td>DIVISION 7</td>
<td></td>
<td>STREETS AND RELATED WORK</td>
<td></td>
<td></td>
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<tr>
<td>7.01</td>
<td>7040-1.08-C</td>
<td>Partial Depth Patches, PCC</td>
<td>SF</td>
<td>1,356</td>
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<tr>
<td>7.02</td>
<td>7040-1.08-D</td>
<td>Crack and Joint Cleaning and Filling, Hot Pour</td>
<td>LF</td>
<td>1,546</td>
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<tr>
<td>DIVISION 8</td>
<td></td>
<td>TRAFFIC CONTROL</td>
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<td>8.01</td>
<td>8030-108-A-O</td>
<td>Temporary Traffic Control</td>
<td>LS</td>
<td>1</td>
<td></td>
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<tr>
<td>8.02</td>
<td>Special</td>
<td>Portable Dynamic Message Signs (PDMS)</td>
<td>CDAY</td>
<td>5</td>
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<tr>
<td>DIVISION 11</td>
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<td>MISCELLANEOUS</td>
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<td>11.01</td>
<td>11.020-1.08-A</td>
<td>Mobilization</td>
<td>LS</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

### Diagram

- **Legend**
  - **Light Blue**: Saw and Seal Joint
  - **Yellow**: Partial Depth Repair of Joint up to 6" in Length
  - **Pink**: Partial Depth Repair of Joint or Random Crack greater than 6" in Length

**Begin Project at STA. 2+00**

Credit: Adam Lust, City of Ankeny
Case Study – NW State St, Ankeny

Credit: Adam Lust, City of Ankeny
Case Study – NW State St, Ankeny

Credit: Adam Lust, City of Ankeny
Case Study – NW State St, Ankeny

Credit: Adam Lust, City of Ankeny
CONSTRUCTED IN 1991, 0.50 MILE IN LENGTH
ROADWAY WIDTH OF 41’ BOC, 8” PCC NO DOWELS
ADT = 7,300 - 7,700
DOWEL BAR RETROFIT, FULL DEPTH REPAIR, DIAMOND GRINDING AND CLEAN JOINTS / SEAL
FIRST OF ITS KIND FOR THE CITY
MARCH 5, 2015, ESTIMATE: $334,510
3 BIDS: $317,620 - $347,500
45 WORKING DAY CONTRACT
FAVORABLE BID - UNIT PRICES ALLOWED CITY TO ADD ADDITIONAL REHAB TO CENTER TURN LANE, ADDITIONAL FULL DEPTH REPAIRS, AND JOINT SEALING
CASE STUDY – Asbury Rd, Dubuque

Credit: Robert Schiesl, City of Dubuque
CASE STUDY – Asbury Rd, Dubuque

Credit: Robert Schiesl, City of Dubuque
DIAMOND GRINDING

- SUDAS SPECIFICATION FOR RIDEABILITY - 22 INCHES/MILE

- WESTBOUND BEFORE = 42.96 (INCHES/MILE)
  - WESTBOUND AFTER = 12.36 (INCHES/MILE)

- EASTBOUND BEFORE = 53.33 (INCHES/MILE)
  - EASTBOUND AFTER = 10.61 (INCHES/MILE)

- CENTER TURN LANE BEFORE = 37.71 (INCHES/MILE)
  - CENTER TURN LANE AFTER GRINDING = 13.38 (INCHES/MILE)
CASE STUDY – Asbury Rd, Dubuque

COMPLETED PROJECT - DETAILS

- **PROJECT COMPLETION:** 29 WORKING DAYS
  45 DAY CONTRACT

- **FINAL CONSTRUCTION COST:** $354,822 $31 / SY

- **TOTAL PROJECT COST:** $400,791 $35 / SY
  INCLUDES: DESIGN, CONSTRUCTION, INSPECTION

- **DOWEL BARS INSTALLED:** 3,300

- **FULL DEPTH PATCHES, PCC:** 350 SY

- **DIAMOND GRINDING:** 11,600 SY

- **TRAFFIC CONTROL:** $37,000

Credit: Robert Schiesl, City of Dubuque
CASE STUDY – West Des Moines

Investigation

Design

• Plans
• Standard Specification
• Standard detail

Construction

Credit: Jeff Nash, City of West Des Moines
Pavement Condition
• Joint Spalling
• Corner cracks
• Low friction
• Previous patches

Patching & Dowel bar Retrofit
CASE STUDY – US 30, Denison

Dowel bar retrofit and diamond grinding
CASE STUDY – US 30, Denison

- Previous IRI – 277 inches/mile (2017)
- New IRI – 116.7 inches/mile
- Previous PCI – 18 (very poor)
- Estimated new PCI – 87 (good)
<table>
<thead>
<tr>
<th>Distress</th>
<th>Slab Stabilization</th>
<th>Slab Jacking</th>
<th>Partial-Depth Repair</th>
<th>FDR</th>
<th>Retrofitted Edgedrains</th>
<th>DBR</th>
<th>Cross Stitching/Slot Stitching</th>
<th>Diamond Grinding</th>
<th>Diamond Grooving</th>
<th>Joint Resealing</th>
<th>Crack Sealing</th>
<th>Thin Concrete Overlay</th>
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<tbody>
<tr>
<td>Corner breaks</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
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<td></td>
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<td>Linear cracking</td>
<td></td>
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<td>✓</td>
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<td>Punchouts</td>
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<tr>
<td>Alkali-aggregate reaction</td>
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<tr>
<td>Map cracking, crazing, scaling</td>
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<td></td>
<td>✓</td>
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<td>Joint seal damage</td>
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<td>Joint spalling</td>
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<td>Blowup</td>
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<td>Pumping</td>
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<td>Faulting</td>
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<td>Bumps, settlements, heaves</td>
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<td>Polishing/low friction</td>
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Bid Prices

- Patch, Partial Depth Repair, PCC: $25-30/SF
- Patch, Full depth Repair: $100-130/ SY
- Dowel Bar Retrofit: $35-$40 EA
- Partial Depth PCC Joint and Crack Repair Patches- $35/ LF
- Pavement Surface Repair (Grind Limestone): $3-4/SY
- Pavement Surface Repair (Grind Gravel): $5-$6/SY (Slurry Management will add $)
- Crack & Joint Clean & Fill: $1.00 - $1.50 per foot
- Sealer Material: $1 per pound (6500-7000 lbs per mile)
- Mobilization: (5-8%) Varies by project

Iowa DOT Bid Express (average prices)
THANK YOU!

Representing the National Concrete Pavement Technology Center