Evaluation and Selection Guide of Method of Repair for Routine Maintenance

For TxDOT Maintenance Engineers

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Project 0-5821

Project Title: Develop Guidelines for Routine Maintenance of Concrete Pavement
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The Texas A&M University System, College Station, Texas 77843-3135
Training Session for Engineers

- **Purpose:**
  - Provide training to identify the distresses
  - Provide guidelines to select the appropriate methods of repairs
Outline of Presentation

- Pavement Condition Evaluation Techniques
- Routine Maintenance Strategy Guidelines
- Repair Decision Flowcharts
- Routine Maintenance Repair Details
Pavement Condition Evaluation Techniques

- Visual Survey
- Ground Penetration Radar (GPR)
- Falling Weight Deflectometer (FWD)
- Dynamic Cone Penetrometer (DCP)
- Coring
Visual Survey

- General Information about Pavement
  - Age
  - Aggregate type
- Condition Record Information
  - Recent visual and deflection information
- Condition of Joint or Crack Sealing
- Surface and Subsurface Drainage Condition
  - Possible locations for GPR and DCP testing
Visual Survey (cont.)

- **Functional Conditions**
  - Factors affecting ride quality (roughness)
  - Possible locations for FWD, GPR, and DCP testing

- **Structural Conditions**
  - Factors affecting premature failure
  - Possible locations for FWD, GPR, and DCP testing

- **Identification of Distressed Areas for FDR**
## Visual Survey Check list

<table>
<thead>
<tr>
<th>No.</th>
<th>Check list</th>
<th>Notes</th>
<th>Further inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pavement age (yr.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Aggregate type (hard or soft)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Year of recent pavement distress survey (yr.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Year of recent pavement deflection survey (yr.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Joint sealant age (yr.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sealant damage of transverse joint or crack (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sealant damage of longitudinal joint or crack (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Sealant damage of sealed crack (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Trapped surface water in depressed area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Standing water or slab staining</td>
<td></td>
<td>GPR, DCP</td>
</tr>
<tr>
<td>11</td>
<td>Pumping with or without staining</td>
<td></td>
<td>GPR, DCP</td>
</tr>
<tr>
<td>12</td>
<td>Bump (stable or unstable, depth, in.)</td>
<td></td>
<td>GPR, DCP</td>
</tr>
<tr>
<td>13</td>
<td>Settlement (stable or unstable, depth, in.)</td>
<td></td>
<td>GPR, DCP</td>
</tr>
</tbody>
</table>
Visual Survey Check list (cont.)

<table>
<thead>
<tr>
<th>No.</th>
<th>Check list</th>
<th>Notes</th>
<th>Further inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Joint Spall (width, depth, % of joint spall &gt; 2 in.)</td>
<td></td>
<td>FWD</td>
</tr>
<tr>
<td>15</td>
<td>Crack Spall (width, depth, % of crack spall &gt; 2 in.)</td>
<td></td>
<td>FWD</td>
</tr>
<tr>
<td>16</td>
<td>Deep spall (depth, in.)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
<tr>
<td>17</td>
<td>Patching (number/mile)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
<tr>
<td>18</td>
<td>Faulting (depth, in.)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
<tr>
<td>19</td>
<td>Transverse crack (width, number/slab)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
<tr>
<td>20</td>
<td>Longitudinal crack (width, number/slab)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
<tr>
<td>21</td>
<td>Shoulder separation (width, in.)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
<tr>
<td>22</td>
<td>Corner break (spall width, fault depth, % of slab)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
<tr>
<td>23</td>
<td>Faulted crack or deep delamination (depth, in.)</td>
<td></td>
<td>Steel corrosion</td>
</tr>
<tr>
<td>24</td>
<td>Punchout (spall width, fault depth, % of slab)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
<tr>
<td>25</td>
<td>Reflection crack in ACOL (spall width, fault depth, number/mile)</td>
<td></td>
<td>FWD, GPR, DCP</td>
</tr>
</tbody>
</table>
Ground Penetration Radar

- Image Analysis
  - Void, ground water, dowel bar detection
- Dielectric Constant (DC) Analysis
  - DC value > 9 → Check drainage/wet condition
Ground Penetration Radar (cont.)

**Image Analysis**

- **Bad**
- **Poor**
- **Patch**

- **Void**
- **Erosion or Moisture**
- **Moisture**

**DC Analysis**
Falling Weight Deflectometer

- Load Transfer Efficiency (LTE)
- Deflection (Basin Area)
- Overall Structural Capacity (Effective Thickness)

Example of FWD Testing Locations
LTE Testing

Measure of independent action

\[
LTE = \frac{d_U}{d_L} \times 100
\]

Where, LTE = Load transfer effectiveness, percent
- \(d_U\) = Deflection on the unloaded side of the joint or crack, mils
- \(d_L\) = Deflection at the loaded side of the joint or crack, mils

LTE < 70%  →  Retrofit load transfer
Falling Weight Deflectometer (cont.)

- **Deflection Testing**

\[ \text{AREA} = \frac{6(D_0 + 2D_1 + 2D_2 + D_3)}{D_0} \]

Where, \( \text{AREA} = \) FWD deflection parameter, in.

- \( D_0 = \) Deflection at the loading position, mils
- \( D_1 = \) Deflection at 12 in. from the loading position, mils
- \( D_2 = \) Deflection at 24 in. from the loading position, mils
- \( D_3 = \) Deflection at 36 in. from the loading position, mils

**Basin area < 25**  ➡️  **Check base/subgrade support**

Radius of Relative Stiffness vs. Basin Area

\[ BA = 6 \frac{d_1 + 2(d_2 + d_3 + d_4 + d_5 + d_6) + d_7}{d_1} \]

\[ \ell = 0.0284 \cdot BA^2 - 0.2891 \cdot BA + 0.992 \]

\( BA = \) Basin area of seven sensors (in.)

\( d_i = \) Deflection of \( i^{th} \) sensor (mils)

\( \ell = \) Radius of relative stiffness (in.)
Falling Weight Deflectometer (cont.)

- Effective Thickness
  - Measure of structural capacity

\[
h_e = \left( \ell^4 \cdot \frac{12(1-\nu^2)k_{dyn}}{E_c} \right)^{\frac{1}{3}}
\]

Where, 
- \( h_e \) = effective slab thickness (in.)
- \( \ell \) = radius of relative stiffness (in.)
- \( \nu \) = Poisson’s ratio of the concrete
- \( k_{dyn} \) = dynamic modulus of subgrade reaction (psi/in.)
- \( E_c \) = elastic modulus of the PCC layer (psi)

\( h_e < h_c \) → Check base/subgrade support
Dynamic Cone Penetrometer

- Base/Subgrade Strength
- Soil Modulus
- Penetration Ratio (PR, mm/blow)
  - Typical flexible base
    - $E_{\text{base}} = 60 \sim 80$ ksi or
    - $PR_{\text{base}} = 1 \sim 2$ mm/blow
  - Soft subgrade or low strength
    - $E_{\text{subgrade}} < 6$ ksi or
    - $PR_{\text{subgrade}} > 50$ mm/blow (= 2 in./blow)
Dynamic Cone Penetrometer (cont.)

- **Modulus of Soils**

  \[ E = 2550 \times CBR^{0.64} \]

  \[ CBR = 292 / PR^{1.12} \]

  Where, \( E \) = Elastic modulus, psi
  
  \( CBR \) = California bearing ratio
  
  \( PR \) = Penetration ratio, mm/blow

  - **Base:** \( y = 0.9x + 356.4 \)
  
  - **Subgrade:** \( y = 19.4x - 3272.5 \)
Coring

- Void, Erosion Detection
- Concrete Strength
Routine Maintenance Strategy Guidelines

- Performance Monitoring
- Preservative
- Functional CPR
- Structural CPR
- Remove and Replace
Maintenance Strategy

- As pavement condition degrades,
  - Repair costs and time of repair go up
  - Future renewal options become limited

- Preservative maintenance extend pavement life cost effectively
## Performance Monitoring

<table>
<thead>
<tr>
<th>Type of Activity</th>
<th>Type of Condition</th>
<th>Quantifiable Condition Factors</th>
<th>Repair Type and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct Distress Survey</td>
<td>Pavement age; PCC &gt; 10 years ACOL &gt; 2 years</td>
<td>Pavement age</td>
<td>Monitor age for more than 10 year old PCC pavements or 2 year old ACOL pavements.</td>
</tr>
<tr>
<td>Conduct Distress and FWD Survey</td>
<td>Pavement deflection data &gt; 3 years</td>
<td>Recent FWD data</td>
<td>Conduct FWD testing based on visual survey results.</td>
</tr>
</tbody>
</table>
| Conduct FWD and GPR Survey; DCP Testing | • Pumping with or without staining  
• Missing joint seal material  
• Edge drop off | • Pumping  
• Joint seals condition  
• Surface DC of GPR  
• PR of DCP | • Conduct selected FWD and DCP testing based on visual and GPR survey results, PR > 2 in./drop indicates soft subgrade materials, soil modulus < 6000 psi.  
• GPR is useful to detect subsurface moisture and voided areas, DC > 9 indicates presence of subsurface water. |
## Preservative

<table>
<thead>
<tr>
<th>Type of Activity</th>
<th>Type of Condition</th>
<th>Quantifiable Condition Factors</th>
<th>Repair Type and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack sealing (CS)</td>
<td>Working cracks</td>
<td>Crack width &gt; 0.03 in.</td>
<td>Crack sealing for working crack in CRC pavement</td>
</tr>
</tbody>
</table>
| Reseal joints and cracks (JS) | Visible sealant damage on transverse and longitudinal joints and sealed cracks | • Sealant age  
• Visible sealant damage; cracking and debonding                   | • Keep joint well width < 1 in.; widened joint wells may be noisy.  
• Trapped subsurface water should be removed before re-sealing operations. |
| Transverse grade re-profiling (TGP) | Trapped surface water in depressed areas | Trapped surface water in depressed areas                           | • Depressed area degrade riding quality and cause impact loading  
• Trapped surface water can cause safety problem.                                  |
| Retrofit edge drains (RED) | • Standing water  
• Trapped surface water  
• Saturated base layer and subgrade | • Presence of standing water  
• Slab staining  
• Surface DC  
• Subgrade strength |
|                           |                                          |                                                                     | Edge drain is not recommended if the base is unstabilized, the base contains > 15% fines, or the pavement structure is undrainable. |
## Functional CPR

<table>
<thead>
<tr>
<th>Type of Activity</th>
<th>Type of Condition</th>
<th>Quantifiable Condition Factors</th>
<th>Repair Type and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial depth repair (PDR)</td>
<td>Spalled joint/crack</td>
<td>Density and width of spalling</td>
<td>• Spalling depth less than 1/3 thickness of the slab and no reinforcing steel exposure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Spalling 1/2 thickness of the slab and if remaining slab is strong with no other</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>distress and steel is not corroded</td>
</tr>
<tr>
<td>Diamond grinding (DG)</td>
<td>• Rough and noisy patches</td>
<td>• Density of patching</td>
<td>Restore load transfer before grinding if structurally defected</td>
</tr>
<tr>
<td></td>
<td>• Faulting</td>
<td>• Depth of faulting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Bump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thin ACOL</td>
<td>• Rough and noisy patches</td>
<td>• Density of patching</td>
<td>• Employ for hard aggregate pavements</td>
</tr>
<tr>
<td></td>
<td>• Faulting</td>
<td>• Depth of faulting</td>
<td>• Restore load transfer before the overlay if structurally defected</td>
</tr>
<tr>
<td></td>
<td>• Hard aggregate</td>
<td></td>
<td>• Use crack attenuating mix and good aggregate</td>
</tr>
<tr>
<td></td>
<td>• Settlement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Structural CPR

<table>
<thead>
<tr>
<th>Type of Activity</th>
<th>Type of Condition</th>
<th>Quantifiable Condition Factors</th>
<th>Repair Type and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restore load transfer (RLT)</td>
<td>• High deflection</td>
<td>• Faulting</td>
<td>• Dowel bar retrofit</td>
</tr>
<tr>
<td></td>
<td>• Low LTE</td>
<td>• Deflection</td>
<td>• Check the deflection basin area and LTE of joint/crack</td>
</tr>
<tr>
<td></td>
<td>• Reflection crack in ACOL</td>
<td>• LTE</td>
<td>• Employ RLT when 2 in. wide spalled joint in ACOL &gt; 20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Crack width and density of spalling in ACOL</td>
<td></td>
</tr>
<tr>
<td>Cross Stitching (CST)</td>
<td>• Longitudinal crack</td>
<td>• Width of the crack</td>
<td>• Cross stitching and joint seal when shoulder joint separation is between 1/2 in. and 1 in.</td>
</tr>
<tr>
<td></td>
<td>• Separated shoulder joint</td>
<td>• or shoulder joint separation</td>
<td>• Slab undersealing where pumping and void detected</td>
</tr>
<tr>
<td></td>
<td>• Low LTE</td>
<td>• Lane to shoulder LTE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pumping</td>
<td></td>
</tr>
<tr>
<td>Slab undersealing (SU)</td>
<td>• Water-filled voids at or under joints</td>
<td>• Presence of voids</td>
<td><strong>GPR is recommended</strong> to locate holes in a way that will ensure good grout distribution and void filling</td>
</tr>
<tr>
<td></td>
<td>• Settlement</td>
<td>• Slab staining</td>
<td></td>
</tr>
</tbody>
</table>
## Remove and Replace

<table>
<thead>
<tr>
<th>Type of Activity</th>
<th>Type of Condition</th>
<th>Quantifiable Condition Factors</th>
<th>Repair Type and Notes</th>
</tr>
</thead>
</table>
| Full depth repair (FDR)   | • Corner break • Shattered slabs • Punchouts • Broken cluster area | • Severity and number of cracks • Spalling • Faulting | • Soft subgrade materials may require removal  
• Full depth repair for broken cluster should be extended to 1/2 of crack spacing between next cracks |
Repair Decision Flowcharts

- AC/Non AC Overlayed Jointed Concrete Pavement
- AC/Non AC Overlayed Continuously Reinforced Concrete Pavement

- Based on the pavement condition evaluation
- Decision flowchart is self explanatory
- Provides guidance for effective routine maintenance
Decision Flowchart for AC/Non AC Overlayed JCP Routine Maintenance

Performance Monitoring

- Assemble pavement condition data
  - Pavement age: JCP > 10 years or ACOL > 2 years
    - Yes: Monitor pavement age
    - No: Continue
  - Pavement deflection data > 3 years old
    - Yes: Conduct distress survey
    - No: Conduct distress and FWD survey

- Pavement with or without signage, or Missing joint sealant material, or Edge drop cut
  - Yes: Conduct FWD and GPR survey; DCP testing
  - No: Continue

Preservation

- Sealant damage on more than 20% of transverse joints or longitudinal joints or sealed cracks
  - Yes: Reseal joints and cracks for weathered or debonded sealants
  - No: Continue

- Trapped surface water in depressed areas
  - Yes: Transverse grade re-profiling to allow drainage of depressed areas
  - No: Continue

- GPR located water under slab (DC > 0) and a subgrade PR > 0.2 flow
  - Yes: Edge drain for trapped subsurface water
  - No: Continue

1) Conduct selected FWD and DCP testing based on visual and GPR survey results. GPR is useful to detect subsurface moisture and voided areas; penetration rate (PR) > 2" drop indicates soft subgrade materials.

2) Keep joint well width > 1"; widened joint wells may be noisy. Trapped subsurface water should be removed before re-sealing operations.

3) Edge drain is not recommended if the base is unstabilized, the base contains > 15% fines, or the pavement structure is unreliable.
Decision Flowchart for AC/Non AC Overlayed JCP Routine Maintenance (cont.)

1. **2" wide spall > 10% of crack/joint**
   - **Yes**
     - Partial depth repair for JCP or Patch for AC/LT.\(^4\)
   - **No**

2. **patches/paint > 10 or Topping > 1/4", or Stable bump, or Stable settlement**
   - **Yes**
     - Deflection basin area > 25 in.
   - **No**

3. **Longitudinal crack, or Shoulder joint separation > 1/2", or Fraying on shoulder joint, or shoulder LTE < 70%**
   - **Yes**
     - Cross stitching and joint crack sealing.\(^3\)
   - **No**

4. **GPR indicated voided crack/joints > 70%, or Unstable bump, or Unstable settlement**
   - **Yes**
     - Slab undersanding
   - **No**

5. **Comer breaks > 10%, or shattered slab**
   - **Yes**
     - Full depth repair.\(^6\)
   - **No**

**Notes:**
- \(^3\) Joint seal only when shoulder joint separation width < 1/2": Cross stitching and joint seal when shoulder joint separation width is between 1/2" and 1": Remove and replace shoulder when joint separation width > 1": Slab undersanding where pumping and void detected.
- \(^4\) The depth of spall should be less than 1/3 the thickness of the slab and no reinforcing steel exposure. Patch spall for AC overlayed AC pavement.
- \(^6\) Soft subgrade materials may require removal.
Decision Flowchart for AC/Non AC Overlayed CRCP Routine Maintenance

Performance Monitoring

- Assemble pavement condition data
- Pavement age: CRCP > 10 years or ACOL > 2 years
  - Yes: Conduct distress and FWD survey
  - No: Monitor pavement age
- Pumping with or without staining, or Missing joint seal material, or Edge drop off
  - Yes: Contact FWD and GPR survey; DCP testing
  - No:
- Working cracks > 0.62"
  - Yes: Crack sealing
  - No:
- Sealant damage on more than 20% of longitudinal joints or sealed cracks
  - Yes: Rescued joints and cracks for weathered or debonded sections
  - No:
- Trapped surface water in depressed areas
  - Yes: Transverse grade or profiling to allow drainage of depressed areas
  - No:
- GPR located water under slab (DC > 9) and a subgrade PH < 2.5 show
  - Yes: Edge drain for trapped subsurface water
  - No:

Maintenance

- Conduct distress survey

1) Conduct selected FWD and DCP testing based on visual and GPR survey results. GPR is useful to detect subsurface moisture and voided areas; penetration ratio (PR) > 2". Drop indicates soil subgrade materials.

2) Trapped subsurface water should be removed before re-sealing operations.

3) Edge drain is not recommended if the base is stabilized, the base contains > 15% fines, or the pavement structure is unworkable.
Decision Flowchart for AC/Non AC Overlaid CRCP Routine Maintenance (cont.)

- **Functional CPR**
  - 2" wide spall > 10% of crack, or Deep spall
    - Yes: Partial depth repair for CRCP or Patch for AC overlay
    - No: Patches/mills > 10%, or Stable bump, or Stable settlement
      - Yes: Retrofit load transfer
      - No: Faulted crack < 1/4"
        - Yes: Cross stitching and joint/crack sealing
        - No: Longitudinal crack, or Shoulder joint separation > 1/2", or Foundation on shoulder joint, or shoulder 1.7% < 50%,
          - Yes: Curb underseal
          - No: GPR indicated voided crack/joints > 20%, or Unstable bump, or Unstable pavement
            - Yes: Slab undersealing
            - No: Structural CPR
              - 1.7% > 50% or Deflection basin area > 25 ft
                - Yes: Hand aggregate
                - No: Diamond grinding
      - No: Faulted crack > 1/4"

- **Structural CPR**
  - Longitudinal crack, or Shoulder joint separation > 1/2", or Foundation on shoulder joint, or shoulder 1.7% < 50%
    - Yes: Cross stitching and joint/crack sealing
    - No: GPR indicated voided crack/joints > 20%, or Unstable bump, or Unstable pavement
      - Yes: Slab undersealing
      - No: Functional CPR
        - 2" wide spall > 10% of crack, or Deep spall
          - Yes: Partial depth repair for CRCP or Patch for AC overlay
          - No: Patches/mills > 10%, or Stable bump, or Stable settlement
            - Yes: Retrofit load transfer
            - No: Faulted crack < 1/4"
              - Yes: Cross stitching and joint/crack sealing
              - No: Longitudinal crack, or Shoulder joint separation > 1/2", or Foundation on shoulder joint, or shoulder 1.7% < 50%,
                - Yes: Curb underseal
                - No: GPR indicated voided crack/joints > 20%, or Unstable bump, or Unstable pavement
                  - Yes: Slab undersealing
                  - No: Structural CPR
                    - 1.7% > 50% or Deflection basin area > 25 ft
                      - Yes: Hand aggregate
                      - No: Diamond grinding
          - No: Faulted crack > 1/4"

- **Remove and Replace**
  - 2" wide spall > 10% of crack, or Deep spall
    - Yes: Partial depth repair for CRCP or Patch for AC overlay
    - No: Patches/mills > 10%, or Stable bump, or Stable settlement
      - Yes: Retrofit load transfer
      - No: Faulted crack < 1/4"
        - Yes: Cross stitching and joint/crack sealing
        - No: Longitudinal crack, or Shoulder joint separation > 1/2", or Foundation on shoulder joint, or shoulder 1.7% < 50%,
          - Yes: Curb underseal
          - No: GPR indicated voided crack/joints > 20%, or Unstable bump, or Unstable pavement
            - Yes: Slab undersealing
            - No: Functional CPR
              - 2" wide spall > 10% of crack, or Deep spall
                - Yes: Partial depth repair for CRCP or Patch for AC overlay
                - No: Patches/mills > 10%, or Stable bump, or Stable settlement
                  - Yes: Retrofit load transfer
                  - No: Faulted crack < 1/4"
                    - Yes: Cross stitching and joint/crack sealing
                    - No: Longitudinal crack, or Shoulder joint separation > 1/2", or Foundation on shoulder joint, or shoulder 1.7% < 50%,
                      - Yes: Curb underseal
                      - No: GPR indicated voided crack/joints > 20%, or Unstable bump, or Unstable pavement
                        - Yes: Slab undersealing
                        - No: Structural CPR
                          - 1.7% > 50% or Deflection basin area > 25 ft
                            - Yes: Hand aggregate
                            - No: Diamond grinding
          - No: Faulted crack > 1/4"

4. The depth of spall should be less than 5/8 the thickness of the slab and no reinforcing steel exposure. Spalling 1/2 thickness of the slab and removing slab is strong with no other distress and steel is not corroded. Patch spall for AC overlayed 3C pavement.

5. Joint Seal only when shoulder joint separation width < 1/2". Cross stitching and joint seal when shoulder joint separation width is between 1/2" and 1": Remove and replace shoulder when joint separation width > 1": Slab undersealing where pumping and void detected.

6. Soft subgrade materials may require removal. Full depth repair for broken cluster should be extended to 1/3 of crack spacing between each cracks.
Decision Flowchart Example - Performance Monitoring Stage

1. Assemble pavement condition data
2. Pavement age: PCC > 10 years or ACOL > 2 years
   - Yes: Conduct distress survey
   - No: Monitor pavement age
3. Pavement evaluation data > 3 years old
   - Yes: Conduct distress and GPR survey
   - No: Conduct FWD and GPR survey; DCP testing for selected area
4. Pumping with or without staining, missing joint seal material, or edge drop off
   - Yes: Conduct distress and GPR survey
   - No: Conduct FWD and GPR survey; DCP testing for selected area
Decision Flowchart Example (cont.)

- Preservative Maintenance

1. CRCP working cracks > 0.03" or ACOL reflection crack?
   - Yes → Crack sealing
   - No

2. Sealant damage on more than 20% of transverse joints or longitudinal joints or sealed cracks?
   - Yes → Reseal joints and cracks for weathered or debonded sealants
   - No

3. Trapped surface water in depressed areas?
   - Yes → Transverse grade re-profiling to allow drainage of depressed areas
   - No

4. GPR located water under slab (DC > 9) and a subgrade PR < 2"/blow?
   - Yes → Edge drain for trapped subsurface water
   - No
**Decision Flowchart Example (cont.)**

- **Functional CPR**

  - 2" wide spall > 10% of crack/joint, or deep spall
    - No
    - Yes: Partial depth repair for PCC or patch for ACOL
  - Patches/mile > 10, faulting > 1/4", stable bump, stable settlement, or badly spalled ACOL, reflection crack
    - Yes
    - No
  - L1E > 70% or deflection basin area > 2.3 in.
    - Yes
    - No
    - Yes: Hard aggregate or ACOL
    - No: Diamond grinding
Routine Maintenance Repair Details

- **Preservative**
  - Seal joint and cracks
  - Retrofit edge drains

- **Functional CPR**
  - Partial depth repair
  - Diamond grinding

- **Structural CPR**
  - Retrofit load transfer
  - Cross stitching
  - Slab undersealing

- **Remove and Replace**
  - Full depth repair
Seal Joint and Cracks

- **Object of repair**
  - Reduce infiltration of moisture and incompressive material, Reduce pumping and faulting

- **Limitations**
  - Questionable for long-term effectiveness

- **Unit repair cost** *
  - $0.75 - 1.25/ft (hot pour), $1.00 - $2.00/ft (silicon)

- **Expected life extension**
  - 3 - 8 years

- **Typical repair work time**
  - 5,000 ft / day (hot pour)

- **Recommendations**
  - Select proper sealing material based on temperature and moisture conditions

Seal Joint and Cracks – GA, CA DOT

**Detail A**
(Re-seal transverse joints in PCC pavement.)
(Re-seal free joint in slab replacement.)

- Low Modulus Silicone Sealant
- Backer rod compatible with silicone sealant and slightly oversized to resist movement during sealing operation.
- Initial saw cut in original pavement or initial opening of joint.

**Detail B**
(Seal locked joints* in slab replacement.)
(Seal cracks in PCC pavement.)
(Re-seal longitudinal joints in PCC pavement.)

- Low Modulus Silicone Sealant
- Existing crack, initial saw cut in original pavement, or initial opening of joint.
- Use ½ inch width for cracks.

**Detail C**
(Re-seal joints in bridge decks & approach slabs)

- Low Modulus Silicone Sealant
- Backer rod compatible with silicone sealant and slightly oversized to resist movement during sealing operation.

**Liquid Sealant Type R**
Retrofit Transverse and Longitudinal Joints

**Table A (Type R Joint)**

<table>
<thead>
<tr>
<th>Sawn Joint Width</th>
<th>Backer Rod Diameter</th>
<th>Dimension &quot;d&quot;</th>
<th>Dimension &quot;g&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>1(\frac{1}{4})&quot;</td>
<td>3/4&quot;</td>
<td>2(\frac{1}{4})&quot;</td>
</tr>
<tr>
<td>1(\frac{1}{4})&quot;</td>
<td>1(\frac{3}{8})&quot;</td>
<td>3/4&quot;</td>
<td>2&quot;</td>
</tr>
<tr>
<td>1(\frac{1}{2})&quot;</td>
<td>1/&quot;&quot;</td>
<td>3/4&quot;</td>
<td>1(\frac{3}{4})&quot;</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>3/8&quot;</td>
<td>3/4&quot;</td>
<td>1(\frac{1}{2})&quot;</td>
</tr>
<tr>
<td>1/&quot;</td>
<td>1/&quot;&quot;</td>
<td>3/4&quot;</td>
<td>1(\frac{1}{4})&quot;</td>
</tr>
</tbody>
</table>
Retrofit Edge Drains

- **Object of repair**
  - Provide drainage of surface water, reduce pumping, faulting, and other moisture damage

- **Limitations**
  - May accelerate deterioration if not maintained well, Not recommended if no base or base contains excessive amount of fines (>15% passing No. 200 sieve)

- **Unit repair cost** *
  - $2.00 - $4.00/ft

- **Expected life extension**
  - Life of existing pavement

- **Typical repair work time**
  - 1 mile / day

- **Recommendations**
  - Proper design, construction, and maintenance is essential

Retrofit Edge Drains – CT, IA DOT

Construct edge drain out side of shoulder if PCC shoulder

6. If longitudinal subdrain (shoulder) is not to be placed or if not present on side of roadway to be patched, then place proposed 3 inch slotted corrugated pipe at low end of patch.

7. 6 inches granular subbase if required by plan. When placed, granular subbase should extend over longitudinal subdrain, if present.
Partial Depth Repair

- **Object of repair**
  - Repair spall and distress without removing entire slab

- **Limitations**
  - Full-depth repair is needed if the damage extends below 1/3 the slab thickness

- **Unit repair cost** *
  - $325 - $500/yd³

- **Expected life extension**
  - 3 - 10 years

- **Typical repair work time**
  - 4 to 12 repairs / hr, curing time not included

- **Recommendations**
  - Partial depth repairs should restore the joint face, and joint should be sealed properly

Partial Depth Repair – GA DOT

TRAFFIC

1/4 x 5' CLOSED CELL POLYETHYLENE FOAM

GREATER THAN 2'-0'

SPALL (TYPICAL)

2'-0' OR LESS

POTHOLE (TYPICAL)

12' OR LESS

SAWED JOINTS (TYPICAL)

LONGITUDINAL JOINTS

2''

1''

2''

1''

2''

12'' OR LESS

SAW CUTOFF 2' TO 3'

DEEP

AREA OF SPALL REPAIR

LONGITUDINAL SECTION THROUGH SPALL

12 FEET MIN.

2''

VARIES

1''

5'' MAX.

AREA OF SPALL REPAIR

SECTION THROUGH TRANSVERSE JOINT
Partial Depth Repair – TxDOT Lufkin

Inside lane
Unit repair cost: $7.26/ft

Outside lane
Unit repair cost: $2.17/lb

NOTE:
TRANSVERSE JOINT REPAIR SHALL BE CLEANED OF ALL LOOSE MATERIAL

HMA 4 in.
PCC 8 in.
Crack by faulting

Underseal or Fiber screed
Milled HMA

PCC 8 in.

PFC 1 ¼ – 1 ½ in.
Coat Surface Treat ½ in.
Level up 1 ½ in.

Repair and overlay
Deep Partial Depth Repair

Proposed by Dr. Moonchul Won and Detailed by TTI

**STEP 1**

**STEP 2**

**DRILL & EPOXY**

12~18 in.

**OPTIONAL STEEL BAR**

2~3 in.

1~11/2 in. DIA.

4 in.

12~18 in.

4 in. 12~18 in. 12~18 in.

ROUNDED END
Diamond Grinding

- **Object of repair**
  - Provide smooth riding surface with good texture, reduce noise

- **Limitations**
  - Roughness will return if underlying causes not addressed

- **Unit repair cost** *
  - $1.80 - $7.80/yd²

- **Expected life extension**
  - 8 - 12 years

- **Typical repair work time**
  - 2,500 yd²/day

- **Recommendations**
  - Grinding should not be employed on pavements with material problems

Diamond Grinding – ACPA

![Image of diamond grinding](image.png)

<table>
<thead>
<tr>
<th></th>
<th>Hard Aggregate</th>
<th>Soft Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grooves</td>
<td>2.25-3.75 mm</td>
<td>2.50-3.75 mm</td>
</tr>
<tr>
<td>Land Area</td>
<td>1.50-3.25 mm</td>
<td>2.00 mm</td>
</tr>
<tr>
<td>Height</td>
<td>1.50 mm</td>
<td>1.50 mm</td>
</tr>
<tr>
<td>Grooves/m</td>
<td>164-197</td>
<td>174-197</td>
</tr>
</tbody>
</table>

Note: Ranges provided for reference.
Retrofit Load Transfer

- **Object of repair**
  - Restore load transfer to reduce faulting, pumping, and crack/joint deterioration

- **Limitations**
  - Pavements exhibiting material related distresses such as D-cracking or reactive aggregate are not good for dowel bar retrofitting

- **Unit repair cost** *
  - $25 - $35/dowel

- **Expected life extension**
  - 10 - 15 years

- **Typical repair work time**
  - 150 joint / day

- **Recommendations**
  - Diamond grinding is needed to remove existing faulting, and Slab stabilization is needed to address loss of support

Retrofit Load Transfer – CA DOT
Retrofit Load Transfer – CA DOT

PLAN

SECTION A-A

ELEVATION

Dowel Bar Placement Detail

Foam Core Insert Detail

Expansion Cap Detail

[Diagrams of retrofit load transfer details]
Retrofit Load Transfer – WA DOT
Cross Stitching

- **Object of repair**
  - Hold longitudinal crack or joint together and prevent opening of crack or joint

- **Limitations**
  - Applicable for fair condition and may not prevent secondary cracking or crack propagation

- **Unit repair cost** *
  - $9 - $10/bar

- **Expected life extension**
  - 3 - 6 years

- **Typical repair work time**
  - 1,500 ft / day

- **Recommendations**
  - Cross stitching and joint seal when shoulder joint separation is between ½ in. and 1 in.
  - Rehabilitation is required when secondary cracks develop

Cross Stitching – ACPA

TOP VIEW

Cross Stitching
Transverse joint

20-30 in. 24 in. min.

Tiebars Inserted and Grouted Into Drilled Holes
Deformed Bar

PC SLAB
BASE

Longitudinal Crack

*Note: Holes are alternated to each side of the crack spaced 20-30 in. on center. Must start hole proper distance from crack to get intersection at mid-depth.
Slab Undersealing

- **Object of repair**
  - Restore uniform support by filling void and reduce corner deflection, pumping, and faulting

- **Limitations**
  - Difficult to identify poorly supported area, restrictions on climatic condition, Can increase damage if slab is lifted

- **Unit repair cost** *
  - $1.30 - $1.40/yd²

- **Expected life extension**
  - 3 - 6 years

- **Typical repair work time**
  - 100 slab / day

- **Recommendations**
  - Experienced contractor and proper inspection are essential

Slab Undersealing – ACPA

Grout will fill void under pavement without lifting it

Entire Slab Settled

Outside Edge Settled

Location of Holes Varies for Defect to be Corrected
Full Depth Repair

- **Object of repair**
  - Remove all deterioration in the distressed area, restore load transfer at joints and cracks

- **Limitations**
  - Additional joints introduced by full-depth repairs may add to the pavement roughness

- **Unit repair cost** *
  - $90 - $100/yd²

- **Expected life extension**
  - 5 - 15 years

- **Typical repair work time**
  - 4 to 6 repairs / hr, curing time not included

- **Recommendations**
  - If the deterioration is widespread over the entire project length, an overlay or reconstruction may be more cost effective

Full Depth Repair – ACPA
Full Depth Repair – ACPA

1. 610 mm overlap length for splice.
2. 50 to 100 mm overlap length for typical coupler.
3. 200 mm for single weld; 100 mm for double weld.

<table>
<thead>
<tr>
<th>PATCH TYPE</th>
<th>MINIMUM OFFSET</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRCP with tied steel splice</td>
<td>600 mm (24 in)</td>
</tr>
<tr>
<td>CRCP with welded steel splice</td>
<td>100–200 mm (4–8 in)</td>
</tr>
<tr>
<td>CRCP with mechanical steel splice</td>
<td>50–100 mm (2–4 in)</td>
</tr>
<tr>
<td>Low-volume aggregate interlock or utility</td>
<td>50 mm (2 in)</td>
</tr>
</tbody>
</table>
Full Depth Repair – TxDOT

### Table No. 1: Steel Bars Size and Spacing

<table>
<thead>
<tr>
<th>Type of Reinforcements</th>
<th>Type Pavement</th>
<th>Paverment Thickness (Inches)</th>
<th>Tiebars</th>
<th>Regular Rebars</th>
<th>All Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse Bars</td>
<td>Crop</td>
<td>#6 24</td>
<td>#6 24</td>
<td>#6 24</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Crop (CRCP)</td>
<td>#6 24</td>
<td>#6 24</td>
<td>#6 24</td>
<td>12</td>
</tr>
<tr>
<td>Longitudinal Bars</td>
<td>Crop</td>
<td>#6 6.5</td>
<td>#6 6.5</td>
<td>#6 6.5</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Crop (CRCP)</td>
<td>#6 6.5</td>
<td>#6 6.5</td>
<td>#6 6.5</td>
<td>12</td>
</tr>
</tbody>
</table>

### Table No. 2: Domes (Smooth Bars)

<table>
<thead>
<tr>
<th>Paverment Thickness (Inches)</th>
<th>Size and Dia.</th>
<th>Length (Inches)</th>
<th>Spacing (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>#6 11 in.</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>#5 11/2 in.</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>2/10</td>
<td>#10 11/2 in.</td>
<td>18</td>
<td>12</td>
</tr>
</tbody>
</table>
Full Depth Repair – MI DOT
Full Depth Repair – MI DOT

*NOTE: IF EXISTING REINFORCEMENT LAPS ARE ENCOUNTERED IN THIS AREA, FINAL SAW CUT MUST BE MOVED BACK TO PROVIDE MINIMUM 2'-6" LAP OF PAVEMENT REINFORCEMENT.*
Precast Concrete Full Depth Repair

1. Precast PCC panel
2. Slab removal
3. Dowel slots
4. Flowable fill
5. PCC panel Installation
6. Finishing
Summary

- Pavement condition evaluation
  - Visual survey - identify concrete pavement surface conditions and select further NDT testing areas
  - GPR - analyze images of the base conditions and DC values for voids and underlying water
  - FWD - evaluate structural conditions of system, LTE of joint/crack, and loss of support below the slab
  - DCP - evaluate the in situ strength of base and subgrade soils

- Step by step repair method decision process
  - Simple decision tree by criteria based on visual survey and NDT information
Summary (cont.)

- Routine maintenance stages
  - Preservative maintenance - minor treatment to keep away from possible moisture damage
  - Reseal joint and cracks, Retrofit edge drains
  - Functional CPR - fix localized distresses or overall riding quality
  - Partial depth repair, Diamond grinding, Thin AC overlay
  - Structural CPR - eliminate the cause of structural distresses and restore structural capacity
  - Retrofit load transfer, Cross stitching, Slab undersealing
  - Remove and replace - early strength concrete or precast concrete panel are highly recommended
  - Full depth repair
Questions ?