Concrete Pavement Field Reference
Preservation and Repair

This publication includes, at the outset, a series of checklists aimed at guiding and assisting with proper procedures. These checklists precede the main content of the field reference to provide a preview of what appears in each section and also to provide some quick references to the entire publication.

You can also find these checklists in a printer-friendly layout at:

www.pavement.com/fieldreference

These are available free of charge for distribution to your paving crews or others who may benefit from these quick and easy-to-use checklists. Again, the checklists are intended to help you with proper procedures.

This field reference also includes several cross-references intended to help you find information quickly. General topics are organized by chapters and may be found either by chapter number or in the table of contents. Also, key words are included in an index at the end of this field reference.

Of course, if you are looking for information, but still can not find it, please call on any ACPA technical staff member.
Table of Contents

Introduction ................................................................. 1

Proper Procedure Checklists ............................................... 3
  Joint and Crack Sealing ............................................... 3
  Dowel Bar Retrofit ................................................... 5
  Cross-Stitching ......................................................... 6
  Full-Depth Repair ..................................................... 7
  Partial-Depth Repair ................................................ 12
  Diamond Grinding .................................................... 14

Chapter 1 – Joint and Crack Sealing .................................... 17
  1.1 Sealant Material Selection ....................................... 18
  1.2 Shape Factor and Recess ........................................ 18
  1.3 Sandblasting & Cleaning ........................................ 21
  1.4 Backer Rod ......................................................... 23
  1.5 Sealing ............................................................. 25
  1.6 Troubleshooting .................................................. 27

Chapter 2 – Dowel Bar Retrofit .......................................... 29
  2.1 Slot Cutting and Preparation .................................... 31
  2.2 Patch Placement Procedures .................................... 34
  2.3 Troubleshooting .................................................. 36
### Chapter 3 – Cross-Stitching

- 3.1 Drilling Holes ......................................................... 40
- 3.2 Installing Tiebars ..................................................... 42
- 3.3 Stitching FAQs ......................................................... 43
- 3.4 Troubleshooting ....................................................... 45

### Chapter 4 – Full-Depth Repair

- 4.1 Determining Repair Boundaries. ............................... 48
- 4.2 Removal of Existing Concrete ................................. 52
- 4.3 Subgrade and Subbase Preparation ........................... 55
- 4.4 Dowel and Tiebar Placement (Jointed Pavements) ........ 56
- 4.5 Load Transfer for CRC Patches ............................... 58
- 4.6 Concrete Placement .................................................. 59
- 4.7 Finishing, Texturing, and Curing ............................. 59
- 4.8 Joint Sealing ............................................................ 60
- 4.9 Opening to Traffic ................................................... 61
- 4.10 Precast Panels. ......................................................... 61
- 4.11 Utility Cuts ............................................................. 63
- 4.12 Troubleshooting ..................................................... 64

### Chapter 5 – Partial-Depth Repair

- 5.1 Determining Repair Boundaries. ............................... 69
- 5.2 Removal of Existing Concrete ................................. 70
- 5.3 Surface Preparation .................................................. 73
- 5.4 Patch Materials and Placement ............................... 75
- 5.5 Finishing ................................................................. 76
- 5.6 Curing ................................................................. 77
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.7 Joint Resealing</td>
<td>77</td>
</tr>
<tr>
<td>5.8 Troubleshooting</td>
<td>77</td>
</tr>
<tr>
<td><strong>Chapter 6 – Diamond Grinding</strong></td>
<td></td>
</tr>
<tr>
<td>6.1 Equipment Setup</td>
<td>80</td>
</tr>
<tr>
<td>6.2 Grinding Procedure</td>
<td>82</td>
</tr>
<tr>
<td>6.3 Acceptance Testing</td>
<td>83</td>
</tr>
<tr>
<td>6.4 Troubleshooting</td>
<td>83</td>
</tr>
<tr>
<td><strong>Index</strong></td>
<td>85</td>
</tr>
</tbody>
</table>
Concrete is one of the most durable construction materials in the world. Even so, after a concrete pavement is traveled on by large numbers of vehicles, it will likely eventually require some resurfacing or repair to return it to an acceptable level of service.

Although many people think of durability only in terms of the original slabs, it also applies to the longevity of repairs and restoration. In fact, when performed correctly, concrete repair and resurfacing can add years of life to a highway, roadway, or airfield pavement.

As is the case with pre-construction and construction processes, the human factor is key to successful and long-lasting concrete pavement repairs. One reason is that the human factor—eyeballing, evaluating, and doing the work—is far less automated in field repairs than in placing new pavements. Because repair projects are often small in size and scope (again, evidence of the durability of concrete), workers typically will hand-finish surfaces or must modify materials to fit unique situations.

Compared to new construction, field repairs sometimes require more engineering judgment and on-the-fly decisions to be made. The primary reason is as old as paving itself: Placing a relatively stable pavement system on a dynamic surface (the ground below) is bound to create a few surprises. In addition to this, there are usage factors (traffic volume, loadings, etc.); climatic conditions; and a host of other things that can affect a pavement. There can be many “unknowns” beneath the surface of the pavement, and of course, there are no two repair scenarios that are exactly alike.

This reference is not intended to be the final word in repair and restoration. Rather, it is a common-sense guide for quality concrete pavement repair and resurfacing. It represents some current best-practices, as well as a good-faith representation of methods, materials, machines, and instruments currently available for field repairs of concrete pavements.

This is a document which serves is to educate, guide, and inform all parties involved in a concrete pavement repair project, from contractors to consultants to agencies/owners…and just about everyone involved in repairing or resurfacing a pavement. Although nothing can replace experience, skill, and sound judgment, it is our hope that this guide will augment those “human factors.”
Last, but not least, it is likely that as this guide is printed and distributed, some new or even currently existing repair or restoration products or processes may be brought to market (or simply brought to our attention). In advance, we humbly offer that, although we have attempted to capture the breadth and depth of best practices, such disclosures are a normal and healthy part of process improvement and advancement of technology.

## Repair Sequencing

If several concrete pavement repair procedures are to be conducted during a single project, a logical sequence of repairs is critical to protecting any previously performed repairs. For example, full- and partial-depth repairs, dowel bar retrofit, and cross-stitching must always precede diamond grinding. If any of these repairs were performed after the diamond grinding, some of the diamond ground surface would be removed.

Figure 1 displays the logical steps towards proper concrete pavement restoration. At any point along the project, the next step (repair) can not be reached (performed) until all steps under it are completed. Not every project will require every step, but the sequence of these steps should be maintained.

Application of this logical sequence of repairs in a project involving more than one repair procedure will help prevent costly damage to previous repairs. This sequencing should be followed not only during the planning phase, but also during completion of the project, because the required repairs for an area might have changed since planning.
Proper Procedure Checklists

NOTE: All proper procedure checklists contained herein can be downloaded for free at: www.pavement.com/fieldreference.

■ Joint and Crack Sealing

Sealant Material (Section 1.1)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ensure the sealant conforms to specifications and is acceptable for use under the current ambient conditions.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>If existing adjacent joints or cracks are sealed, use a sealant that most closely matches adjacent sealants.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Check that no neoprene seals were used in repairs.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>For two-component sealants, ensure mixing proportions are correct.</td>
<td></td>
</tr>
</tbody>
</table>

Shape Factor and Recess (Section 1.2)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check that recess and any backer material (rod) dimensions are considered in the reservoir depth calculation.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Saw joints and cracks at the appropriate depth and width to comply with specified shape factors.</td>
<td></td>
</tr>
</tbody>
</table>

Sandblasting and Cleaning (Section 1.3)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Clean all joint and crack surfaces first by sandblasting each face of the sealant reservoir, followed by high-pressure water, and finally compressed air.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>If necessary, clean the area around the crack with a broom or vacuum sweeper to prevent contamination of cleaned joints and cracks.</td>
<td></td>
</tr>
</tbody>
</table>
3. Ensure that no loose material remains at the bottoms of any joint or crack after cleaning.

4. Check the cleanliness of both crack faces by wiping a finger along them immediately prior to sealing. If the finger-wipe test reveals dirt or dust, repeat tasks 1, 2, and 3, listed above.

5. If it has been over 24 hours since initial sandblasting, repeat tasks 1, 2, 3, and 4, listed above.

**Backer Rod (Section 1.4)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Use a backer rod material that is chemically inert, flexible, non-absorptive, non-shrinkable, and compressible.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Check that the diameter of backer rod is at least 25% larger than the width of the joint reservoir.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Ensure that your procedure is to place the backer rod immediately prior to sealing and not an extended time before.</td>
<td></td>
</tr>
</tbody>
</table>

**Sealing (Section 1.5)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ensure all dowel bar retrofit, partial-depth repairs, full-depth repairs and diamond grinding are completed prior to starting sealing operations.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Ensure that the air temperature is above 50 °F (10 °C) when installing sealants.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>For hot-applied sealants, monitor the temperature of the sealant constantly to ensure it is in compliance with the specifications.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Ensure that crack and joint faces are dry before sealing.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Fill the crack or joint from the bottom up and from beginning to end in one smooth operation.</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>For hot-applied sealants, remove any unused sealant material from the pot and discard it at the end of each day if recommended by the manufacturer.</td>
<td></td>
</tr>
</tbody>
</table>
# Dowel Bar Retrofit

## Slot Cutting and Preparation (Section 2.1)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cut slots using a diamond-bladed slot cutting machine unless the pavement is to have a bonded concrete overlay, in which case a carbide milled slot is acceptable.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Remove the concrete fins within the slots with lightweight chipping hammers (maximum size of 30 lb [14 kg]).</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Clean the slot walls and bottom by sandblasting.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Ensure your process creates slots that can properly hold dowels parallel to the pavement surface and centerline, and at the mid-depth of the slab.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Check that every dowel is lubricated or has a manufacturer-applied bond breaker.</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Ensure every dowel has support chairs and an expansion cap on each end.</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Use a filler board or expanded polystyrene foam material, placed at the mid-length of each dowel.</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Caulk the rim of the joint or crack inside of each dowel bar slot.</td>
<td></td>
</tr>
</tbody>
</table>

## Patch Placement Procedures (Section 2.2)

NOTE: Patch material/placement is the most critical factor for successful dowel bar retrofits.

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ensure all patch materials have been pre-evaluated in a laboratory to meet specifications for work time, rapid-early strength gain, shrinkage, and durability.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Follow the manufacturer’s placement procedures for proprietary patching materials.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Ensure the patch material is placed and consolidated properly, eliminating all air voids.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Follow an appropriate (i.e. similar to previous laboratory testing) curing procedure.</td>
<td></td>
</tr>
</tbody>
</table>
Cross-Stitching

**Drilling Holes (Section 3.1)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check that the drill rig/jig is setup to enter pavement between a 35° and 45° angle from horizontal.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Check that the drill rig/jig is setup to enter pavement at an appropriate distance from the joint/crack so that it will intersect the joint/crack at mid-depth.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Ensure drill stop is setup so that the drill bit will not penetrate the bottom of the pavement.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Select a hole diameter that is adequate to easily insert tiebars, allowing space for epoxy.</td>
<td></td>
</tr>
</tbody>
</table>

**Installing Tiebars (Section 3.2)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cut the tiebars to an appropriate length so that they do not protrude above the pavement surface when inserted.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Pour or inject epoxy into the holes prior to inserting tiebars.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Finish the epoxy so that it is flush with the pavement surface</td>
<td></td>
</tr>
</tbody>
</table>
**Full-Depth Repair**

### Determining Repair Boundaries (Section 4.1)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Conduct a detailed survey to identify repair areas.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Consider all possible distresses for each repair area.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Ensure that all repair areas are rectangular and in-line with the existing joints.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Ensure repair areas are:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a.  At least 2 ft (0.6 m) from any joint.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b.  Straight lines on each boundary, forming rectangles in-line with jointing.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c.  Not within 6 ft (1.8 m) of an existing joint.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d.  Not within 8 to 12 ft (2.4 to 3.6 m) of another patch.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>e.  6 to 12 in. (150 to 300 mm) beyond the excavation limits for a utility cut.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>f.  At least 4 ft (1.2 m) long and have 1 ft (0.3 m) of reinforcement exposed for a CRC pavement.</td>
<td></td>
</tr>
</tbody>
</table>

### Removal of Existing Concrete (Section 4.2)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check saws to ensure all full-depth cuts penetrate the entire pavement, without spalling or cracking adjacent slabs or significantly disturbing the subbase.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>If using the breakup and cleanout method:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a.  Isolate repair by making straight, rectangular cuts.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b.  After the repair is isolated, or during isolation if saw blades bind during cutting, make additional cuts using a wheel saw with at least a 1.5 in. (38 mm) kerf in the middle of the slab.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c.  When using a backhoe or jackhammer, break up the slab starting in the middle, moving outward.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d.  As material is loosened, remove.</td>
<td></td>
</tr>
</tbody>
</table>
3. If using the lift-out method:
   a. Isolate repair by making straight, rectangular cuts. If saw binds, use a carbide-tipped saw to provide a pressure relief cut within the patch area.
   b. Drill holes into the slab at lift-pin locations and install lift-pins.
   c. Lift slab in one or more pieces.
4. If making cuts for a utility repair:
   a. Extend the size of the repair area on each side by 6 to 12 in. (150 to 300 mm) from the planned excavation to provide additional room for proper compaction.

Subgrade and Subbase Preparation (Section 4.3)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check subbase and adjacent slabs for any disturbances.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Remove and replace disturbed subgrade and subbase materials.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Adequately compact granular material.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>If preferred, replace all or some of the disturbed material with concrete or flowable fill.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>If wet, allow material time to dry prior to placing repair patch.</td>
<td></td>
</tr>
</tbody>
</table>

Dowel and Tiebar Placement (Jointed Pavements) (Section 4.4)

NOTE: Re-establishing load transfer across the transverse repair joints is the most critical factor for successful full-depth repairs.

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Follow all specified dowel size and spacing requirements on plans and/or specifications.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Ensure that the drill rigs/jigs are set at the mid-depth of the slab and horizontal to the surface.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Check that the hole size is large enough, accounting for epoxy/grout material.</td>
<td></td>
</tr>
</tbody>
</table>
4. Inject epoxy or grout into the holes prior to inserting the dowel bars.

5. Insert dowels with a turning motion, turning at least 1 full turn.

6. Place a grout retention disk on the dowel after insertion to contain grout or epoxy (this is necessary whenever drilling causes conical spalling of the hole on the joint face).

7. Apply form oil or other thin bondbreaker on the protruding end of each dowel, if a manufacturer applied coating is not included.

Load Transfer for Continuously Reinforced Concrete Pavement (CRC) (Section 4.5)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>During slab removal, expose an extra 1 ft (0.3 m) of reinforcing steel by chipping carefully around the embedded bars.</td>
</tr>
<tr>
<td>2.</td>
<td>Tie, couple, or weld new steel bars to the exposed bars, with an overlap of 4 to 8 in. (100 – 200 mm) on each side.</td>
</tr>
</tbody>
</table>

Concrete Placement (Section 4.6)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ensure that the concrete mixture meets requirements such as opening strength; shrinkage; etc., in the specifications.</td>
</tr>
<tr>
<td>2.</td>
<td>When a bond is required, ensure that all faces of the patch are cleaned prior to placing the concrete.</td>
</tr>
<tr>
<td>3.</td>
<td>Ensure that the concrete is vibrated well around edges of the patch and any reinforcement.</td>
</tr>
<tr>
<td>4.</td>
<td>Check that the ambient temperatures are between 40° and 90°F (4° and 32°C) when placing the concrete.</td>
</tr>
<tr>
<td>5.</td>
<td>If using a proprietary mixture, ensure all manufacturer recommendations are carefully followed.</td>
</tr>
</tbody>
</table>
### Finishing, Texturing, and Curing (Section 4.7)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>For repairs less than 10 ft (3.0 m) in length, strike off the patch surface perpendicular to the centerline.</td>
<td>☐</td>
</tr>
<tr>
<td>2.</td>
<td>For repairs more than 10 ft (3.0 m) in length, strike off the patch surface parallel to the pavement centerline.</td>
<td>☐</td>
</tr>
<tr>
<td>3.</td>
<td>Ensure that the concrete is not over-finished by following good finishing techniques.</td>
<td>☐</td>
</tr>
<tr>
<td>4.</td>
<td>Use a burlap drag, broom or tine texture to match the adjacent pavement, unless grinding operations are to follow.</td>
<td>☐</td>
</tr>
<tr>
<td>5.</td>
<td>Follow proper curing procedures.</td>
<td>☐</td>
</tr>
</tbody>
</table>

### Joint Sealing (Section 4.8)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check the specifications for the sealant material required.</td>
<td>☐</td>
</tr>
<tr>
<td>2.</td>
<td>Seal all joints, particularly if the original joints were sealed.</td>
<td>☐</td>
</tr>
</tbody>
</table>

NOTE: See the Joints and Crack Sealing Checklists for more information.

### Opening to Traffic (Section 4.9)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check specifications for opening to traffic requirements.</td>
<td>☐</td>
</tr>
<tr>
<td>2.</td>
<td>Use the maturity method or other non-destructive testing method, if allowed, to monitor the strength of patches.</td>
<td>☐</td>
</tr>
<tr>
<td>3.</td>
<td>Before removing traffic control and opening the pavement to traffic, ensure that the concrete meets or exceeds the specified opening strength (typically 300 psi of 3rd point flexural strength).</td>
<td>☐</td>
</tr>
<tr>
<td>4.</td>
<td>Do not allow construction traffic onto the patches until it is deemed no risk to the concrete.</td>
<td>☐</td>
</tr>
</tbody>
</table>
# Utility Cuts (Section 4.11)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cut the concrete and carefully unearth the utility line.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Ensure that the excavation does not go directly up against the patch perimeter; instead, leave 6 to 12 in. (150 to 300 mm) or more of the existing grade intact within the patch area.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>After repairs are complete, ensure backfill is fully compacted or use a flowable-fill material.</td>
<td></td>
</tr>
</tbody>
</table>
Partial-Depth Repair

Determining Repair Boundaries (Section 5.1)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Conduct a detailed survey using steel rods, chains, or a hammer to identify weak or delaminated areas.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Ensure that all possible distresses are considered for each repair area.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Extend the boundaries of the repair areas by 3 in. (75 mm) beyond any detected delamination.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Mark all repair areas as rectangles and in-line with the existing joints. (Do not use odd shapes.)</td>
<td></td>
</tr>
</tbody>
</table>

Removal of Existing Concrete (Section 5.2)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Saw along the perimeter of the repair area to a depth of 2 in. (50 mm).</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Remove the concrete by chipping or milling within the repair area to the depth of sound material [minimum depth of 2 in. (50 mm) but at least 0.5 in. (13 mm) into sound concrete].</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Check that the chipping hammers used to remove concrete are no more than 30 lb (14 kg) hammers.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>If, during chipping, over one-half the slab thickness is removed, then stop and instead place a full-depth repair.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>To protect the concrete outside of the patch area during chipping, make a saw cut 2 in. (50 mm) inside the perimeter cuts to provide a buffer.</td>
<td></td>
</tr>
</tbody>
</table>

Surface Preparation (Section 5.3)
### Patch Materials and Placement (Section 5.4)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mix all patch material on-site in a small, mobile drum or paddle mixer.</td>
</tr>
<tr>
<td>2.</td>
<td>When placing concrete, slightly overfill the repair area to account for consolidation.</td>
</tr>
<tr>
<td>3.</td>
<td>Consolidate the concrete using a small spud vibrator with special attention at the repair edges. Do not over vibrate!</td>
</tr>
</tbody>
</table>

### Finishing (Section 5.5)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Finish the repair area level with the existing slabs.</td>
</tr>
<tr>
<td>2.</td>
<td>Remove excess patch material from the surface of adjacent slabs.</td>
</tr>
<tr>
<td>3.</td>
<td>While finishing, move the screed from the center of the patch to the patch boundaries to push the material toward the perimeter joints.</td>
</tr>
<tr>
<td>4.</td>
<td>Apply a surface texture similar to the existing pavement unless a grinding operation is to follow.</td>
</tr>
<tr>
<td>5.</td>
<td>Seal the patch/slab interface with a one-to-one cement grout mixture.</td>
</tr>
<tr>
<td>6.</td>
<td>Fill saw-cut runouts with the same grout mixture.</td>
</tr>
</tbody>
</table>

### Curing (Section 5.6)

### Joint Resealing (Section 5.7)

NOTE: See the Joints and Crack Sealing Checklists for more information.
Diamond Grinding

Equipment Setup (Section 6.1)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Determine the blade width and spacing for this particular pavement, with special consideration for the hardness of the aggregate in the concrete.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Test the grinding equipment on a small test section of pavement prior to full-scale operations.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>During testing, check and compare the resulting surface to ensure the width, depth, and land area are within specification.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>If not within specifications, adjust the blade width and spacing appropriately.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Check the grinding machine vacuum and water cooling functions to ensure they are functioning.</td>
<td></td>
</tr>
</tbody>
</table>

Grinding Procedure (Section 6.2)

NOTE: Grinding operations produce a smooth surface, free of faulting and spalling at the joints and cracks.
Acceptance Testing (Section 6.3)
CHAPTER 1
Joint and Crack Sealing

Key Points:

- Saw sealant reservoirs to the specified dimensions.
- Immediately follow sawing with a power washer to clean the slurry from both sides of the sealant reservoir.
- Sandblast both sides of the sealant reservoir if dried slurry remains after power washing.
- Place backer rod, if used, at the proper depth.
- Place sealants in accordance with the specifications set by the manufacturer.

Joints and cracks are sealed to minimize the infiltration of surface water into a pavement’s subbase and subgrade layers. A saturated subbase or subgrade may be pumped out of joints or cracks by the deflection of slabs under passing loads. Joints and cracks also are sealed to keep out incompressible materials that cause spalling, the breaking or chipping of the slab at joints, cracks, or edges. Sealants may also reduce the entrance of de-icing chemicals, which accelerate corrosion of dowel bars and reinforcing steel.

Although there is much debate on the necessity of sealing joints for water control, especially in light of recent research and development in permeable subbases, the use of joint sealing is often indicated, even if only to prevent incompressibles from entering the opening. The decision to or to not seal a joint in new construction or during repairs is, however, ultimately up to the designer.

For a crack in an existing pavement, is it recommended that if the crack be:

- Less than \(\frac{3}{16}\) in. (5 mm) wide with no spalling, then do nothing.
- Between \(\frac{3}{16}\) in. (5 mm) and 2 in. (50 mm) wide, then seal.
- Larger than 2 in. (50 mm), then perform a full-depth repair.
If spalling is present adjacent to a crack, you should repair the damaged area and then seal the crack. Doing so will protect the repaired area from possible damage caused by slab movement along the crack faces. It is also advisable to use backer rod for all joint and crack sealing.

1.1 Sealant Material Selection

There are many acceptable liquid and preformed materials available for sealing joints and cracks in concrete pavements (Table 1.1). Liquid sealants depend on long-term adhesion to the joint face for successful sealing, whereas preformed compression seals depend on lateral rebound for long-term performance. Regardless of the sealant type, ensure that the sealant conforms to appropriate specifications and is acceptable for use under the current conditions. For repairs, the sealant should typically match adjacent sealants. However, preformed neoprene compression seals are recommended only for use in new pavements. If using two-component sealants, verify the correct mixing proportions to within the tolerances specified by the manufacturer. If using hot-applied sealants, use calibrated thermometers to verify acceptable application temperatures.

1.2 Shape Factor and Recess

Joints and cracks should be sawed (Figure 1.1) to the depth and width required to reach the desired shape factor, typically set by the sealant manufacturer. Thus, selection of a sealant material should precede saw-cut design. Short cracks may be sawed with hand-held saws.

Figure 1.1. Crack-sawing equipment.
<table>
<thead>
<tr>
<th>Sealant Type</th>
<th>Specification(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liquid, Hot-Applied</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubberized Asphalt</td>
<td>ASTM D 6690, Type II</td>
<td>Thermoplastic</td>
</tr>
<tr>
<td>Polymeric</td>
<td>ASTM D 6690, Type I</td>
<td>Self-leveling</td>
</tr>
<tr>
<td>Elastomeric</td>
<td>ASTM D 3406</td>
<td>Self-leveling</td>
</tr>
<tr>
<td>Elastic</td>
<td>ASTM D 1854</td>
<td>Jet fuel resistant</td>
</tr>
<tr>
<td>Elastomeric PVC Coal Tar</td>
<td>ASTM D 3569, 3582</td>
<td>Jet fuel resistant (though PVC is rarely used)</td>
</tr>
<tr>
<td><strong>Liquid, Cold/Ambient-Applied</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Component</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicone</td>
<td>ASTM D 5893</td>
<td>Thermosetting</td>
</tr>
<tr>
<td>Polysulfide</td>
<td>Fed Spec SS-S-200E</td>
<td>Non-sag, toolable, low modulus</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>Fed Spec SS-S-200E</td>
<td>Self-leveling, no tooling, low modulus</td>
</tr>
<tr>
<td>Polychloroprene Elastomeric Lubricant</td>
<td>Fed Spec SS-S-200E</td>
<td>Self-leveling, no tooling, ultra low modulus</td>
</tr>
<tr>
<td>Two Component</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preformed Compression Seals</td>
<td>ASTM D 2628</td>
<td>Jet fuel resistant</td>
</tr>
<tr>
<td>Preformed Filler Material</td>
<td>ASTMD 2835</td>
<td>Jet fuel resistant (Used in installation)</td>
</tr>
<tr>
<td><strong>Expansion Joint Filler</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preformed Filler Material</td>
<td>ASTM D 1751 (AASHTO M 213)</td>
<td>Bituminous, non-extruding, resilient</td>
</tr>
<tr>
<td>Preformed Filler Material</td>
<td>ASTM D 1752 (AASHTO M 153)</td>
<td>Sponge rubber, cork, and recycled PVC</td>
</tr>
<tr>
<td>Preformed Filler Material</td>
<td>ASTM D 994 (AASHTO M 33)</td>
<td>Bituminous</td>
</tr>
<tr>
<td><strong>Backer Rod</strong></td>
<td>ASTM D 5249</td>
<td>For hot- or cold-applied sealants</td>
</tr>
</tbody>
</table>
The dimensions of the crack reservoir (Figure 1.2) are set by a shape factor, defined as the ratio of the depth of the sealant (D) to its width (W). Shape factors generally range from 0.5 to 2.0; recommended values will be supplied by the sealant manufacturer. The depth of the saw cut, however, can be greater than the required sealant depth. For example, if a sawed crack for a silicone sealant is 1/2 in. (13 mm) wide and the shape factor is 0.5, then the required sealant depth is 1/4 in. (6 mm). However, the design of the seal must also allow approximately 1/8 to 1/4 in. (3 to 6 mm) to account for a recess below the pavement surface, as well as 5/8 in. (16 mm) to accommodate the backer rod. The net result will be a sawed crack almost 1.25 in. (30mm) deep.

**FIELD Poured SEALANT**

- Hot-poured sealant – D/W = 1 (typical)
- Silicone sealant – D/W = 0.5 (typical)
- Two-component material cold poured – D/W = 0.5 (typical)

**ISOLATION JOINT**

- 1/4" (6 mm) chamfer or radius
- 1/4" (6 mm) recess typ.
- 1" (25 mm) max.
- 1" (25 mm) max.

---

*Figure 1.2. (Continued on next page)*
1.3 Sandblasting & Cleaning

Crack faces are typically cleaned by using the multiple pass sandblasting technique (Figure 1.3). While standing to one side of the crack, pass the wand along the crack face at an angle, allowing a strong blast on one crack face. Repeat the procedure in the reverse direction while facing the opposite crack face.

Figure 1.2. Typical sealant reservoir details and shape factors for joints or cracks.

Figure 1.3. Sandblasting to remove dried slurry, dust, and debris from the sidewalls of a joint/crack.
Once sandblasting is completed, blow debris out of the crack using compressed air, and then clean the crack with high-pressure water (Figure 1.4). Make sure there is no loose material in the bottom of the joint or crack.

After cleaning the crack, clean the area around the crack with a broom or vacuum sweeper to prevent debris from re-entering the crack before sealing procedures are completed. Another pass of compressed air (Figure 1.5) may be required after cleaning the area to assure the crack is still clean.

Figure 1.4. Water blasting to clean joint faces.

Figure 1.5. Cleaning with compressed air immediately prior to sealing to prevent contamination of the joint or crack.
Cleanliness of both crack faces is extremely important. Improperly prepared crack faces are a major cause of adhesion loss between the sealant and crack faces, resulting in failure of the seal. If wiping a finger along the crack face picks up dirt or dust (Figure 1.6), or if the sealant is not placed within 24 hours of sandblasting, the preparation routine (cleaning with high-pressure water and air, sweeping and vacuuming, and then one final pass of high-pressure air) must be reapplied prior to sealing.

**Figure 1.6. Checking joint faces to ensure cleanliness immediately prior to sealing.**

### 1.4 Backer Rod

Backer material is placed in sawed crack or joint reservoirs to minimize excess stress on sealant material from improper shape factors and to prevent three-sided adhesion, which inhibits the ability of the sealant to expand and compress under thermal stress. Typically, backer materials are rod-shaped, so they are often referred to as “backer rod” (Figure 1.7). Be sure the backer material is chemically inert to prevent reaction with the sealant; flexible to conform to the shape of the crack path; non-absorptive to prevent water retention; non-shrinkable; and compressible to allow for easy installation.
Typical backer materials are polychloroprene, polystyrene, polyurethane, and polyethylene closed-cell forms. Do not use paper, rope, or cord. Be sure the melting temperature of the backer material is at least 25°F (14°C) higher than the sealant application temperature to prevent damage during sealant placement. Also, be sure the uncompressed backer rod has a diameter at least 25% larger than the sealant reservoir so that it remains in position during the sealing operation.

The use of backer rod is especially recommended when there is a history of tears developing within the sealant material. For silicone sealants, the use of a backer rod instead of separating tape is recommended. Immediately prior to sealing the joint/crack, be sure the backer rod is placed at the proper depth (Figure 1.8) for the shape factor of the sealant being used.
1.5 Sealing

Conduct the crack sealing operation only when pavement temperatures are above 50°F (10°C). Monitor application temperatures constantly for hot-applied crack sealants to ensure compliance with manufacturer specified ranges.

Be sure crack faces are clean and moisture-free. The crack faces must be dry before sealing to develop proper bonding. Insert the backer rod into the crack immediately prior to sealing.

Fill the crack from the bottom up to prevent air from becoming trapped under the sealant, which may cause bubbling. Whenever practical, fill the crack from beginning to end in one smooth operation (Figures 1.9 and 1.10). For hot applied sealants, remove and discard any sealant remaining in the pot at the end of each work day if recommended by the manufacturer.

Figure 1.8. Installing backer rod at the correct depth in a new construction joint.
Figure 1.9. Applying asphaltic hot-pour sealant after diamond grinding.

Figure 1.10. Applying silicone sealant.
1.6 Troubleshooting

*Sealant not adhering to joint/crack:*

1. Re-clean joint.
2. Allow sidewalls to dry before sealing.
3. Heat to correct temperature or verify temperature gauges.
4. Wait for higher ambient temperature before sealing.
5. Use correct recess for joint width (especially important for cold applied sealants and if traffic has been pulling sealants out).
6. Allow concrete to cure and dry out completely.
7. Apply sealant when temperature warms to above the dew point.
8. Apply a primer to the joint walls before applying sealant (for silicone materials).

*Sealant picks up or pulls out when opened to traffic:*

1. Close to traffic and delay opening.
2. Seal during cooler temperatures.
3. Apply sealant flush with surface or with specified recess.
4. Use stiffer sealant if too soft for climate.
5. Use a detackifier or blotter to reduce initial tack.
6. Install at correct temperature and continuously verify the temperature gauges on the melter.
7. Repeat preparation routine and then reseal joints that were contaminated with solvent or heat transfer oil.
8. Re-clean joint sidewalls to remove offending material and then reseal.

*Sealant gelling in melting chamber (melter):*

1. Check melter temperature gauges.
2. Use fresh sealant.
3. Use sealant with longer pot life, or conform to manufacturer’s recommended pot life.

*Sealant cracking or debonding:*

1. Use sealant that is more extensible at low temperatures.
2. Improve cleaning procedures or re-clean as recommended.
3. Avoid sealing during extremely hot temperatures if sealant is cracking or debonding due to direct sunlight.

4. Use wider joints.

5. Use closer joint spacing.

6. Use correct shape factor (depth-to-width ratio).

**Voids or bubbles in cured sealant:**

1. Seal during cooler periods and then allow concrete to further dry or cure, or use non-sag type sealant to resist void formation.

2. Backer may be melting with hot-applied sealants; use heat-resistant backer material and check for proper sealant temperature.

3. Install backer rod carefully to avoid damage (i.e. puncturing).

4. Apply sealant from the bottom up.

5. Tighten all connections and bleed off entrapped air.

6. Replace backer material if moisture is present.

7. Cure primer according to manufacturer’s recommendations.

**Sink holes in sealant:**

1. Use larger backer material, reapply (top off) sealant to correct level, or use non-sag sealant.

2. Use heat-resistant backer material.

**Cold-applied sealants not setting up:**

1. Use fresh sealant.

2. Use correct mix ratios and mixing systems.
Dowel bar retrofit, or load transfer restoration, is primarily used on roadways that receive heavily channeled loadings (i.e. highways). Transverse joints or cracks that would benefit from improved load transfer can be identified by measuring the existing load-transfer efficiency with heavy-weight, nondestructive, deflection testing devices such as a Falling Weight Deflectometer (FWD). These tests must be conducted during periods of cooler temperatures (less than about 80°F [27°C]), when the slab joints and cracks are not tightly closed due to thermal expansion. Joints or cracks with a load-transfer efficiency (ratio of the deflection on the unloaded side of a joint or crack to the deflection of the loaded side) less than 60% should be considered for dowel bar retrofit. Dowel bar retrofits should also be performed on joints or cracks that have greater than 1/10 in. (2.5 mm) of faulting or differential deflection of 10 mils (250 µm) or more.

Different sizes of dowels should be specified for different pavement thicknesses (Table 2.1). A minimum length of 14 in. (350 mm) is recommended to allow for at
least 6 in. (150 mm) of embedment on each side of the joint or crack, adequate room for an expansion cap on each end of the dowel bar, and reasonable placement tolerances. Three to four dowels, spaced 12 in. (300 mm) apart, should be used in each wheelpath, with the outermost dowel being 12 in. (300 mm) from the lane edge, except where tiebars from adjacent lanes or shoulders are encountered. A recommended layout for retrofitted dowels is depicted in Figure 2.1. The dowel bars, including the ends, should be epoxy coated or otherwise corrosion resistant.

Table 2.1. Dowel Size Requirements for Dowel Bar Retrofit.

<table>
<thead>
<tr>
<th>Pavement Thickness in. (mm)</th>
<th>Diameter in. (mm)</th>
<th>Min. Length in. (mm)</th>
<th>Spacing in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 8 (&lt; 200)</td>
<td>1.0 (25)</td>
<td>14 (350)</td>
<td>12 (300)</td>
</tr>
<tr>
<td>8 to 9.5 (200 to 240)</td>
<td>1.25 (32)</td>
<td>14 (350)</td>
<td>12 (300)</td>
</tr>
<tr>
<td>10 + (250 +)</td>
<td>1.5 (38)</td>
<td>14 (350)</td>
<td>12 (300)</td>
</tr>
</tbody>
</table>

Figure 2.1. Layout of retrofit dowel slots in relation to longitudinal joints.
2.1 Slot Cutting and Preparation

Using a diamond-bladed slot cutting machine (Figure 2.2), slots are cut across each joint (Figure 2.3) that is to receive a dowel bar retrofit (slots can alternatively be milled out if a bonded concrete overlay is to be applied to the pavement). Multiple-blade saws may be used to expedite slot production. The slots should be cut so the dowels are allowed to rest parallel to the pavement surface and centerline, and at mid-depth of the slab (Figure 2.4).

Lightweight chipping hammers (maximum size of 30 lb [14 kg]) are used to remove the concrete fins within the slots (Figure 2.5). The slot is then cleaned by sandblasting to ensure removal of all sawing residue, dirt, or oil that may prevent complete bonding of the patch material to the slot faces. The rim of the joint or crack inside the slot is then caulked to prevent the patch material from locking up the joint or crack.
Figure 2.3. Dowel bar slots cut using a diamond-bladed slow cutting machine across a skewed joint (note that the slots are parallel to the center-line and not perpendicular to the joint).

Figure 2.4. Retrofit dowel installation details.
Lubricate the dowels, or alternatively, use a manufacturer-applied bond breaker to allow the joint or crack to open and close with temperature changes. Each dowel is placed on a support chair to allow the patch material to surround and consolidate under it. Expansion caps are placed on both ends to provide space for lateral movement (Figure 2.4). A filler board or expanded polystyrene foam material must be placed at the mid-length of each dowel to prevent intrusion of the patch material into the joint or crack (causing point bearing), as well as to help form the joint in the slot (Figure 2.6).
2.2 Patch Placement Procedures

The patch material is the most critical factor in the performance of retrofitted load-transfer devices. To date, high early-strength concrete mixtures have been used in most dowel retrofit installations. The patch material must be durable and should allow a sufficient bond to be established between the existing concrete and the patching material. For this reason, a thorough laboratory evaluation must be performed on any patch material used for load-transfer device retrofitting. The primary variables that must be evaluated are working time, rapid early-strength gain, shrinkage, and durability.

The manufacturer’s recommendations should be followed with all proprietary patching materials. If used, bonding agents should be those recommended by the manufacturer for the placement conditions. The patch material should be placed and properly consolidated (Figure 2.7) to eliminate all voids at the patch/existing concrete pavement interface and at the patch/load-transfer device interface. In general, the same requirements and procedures used for partial-depth repair materials may be used as patch material in dowel-bar retrofit slots. It is also important to follow adequate curing procedures for proper hydration and strength gain of the repair material; doing so will prevent drying shrinkage and subsequent debonding (Figure 2.8). A properly performed dowel bar retrofit, with a mix comparable to the existing pavement, will result in repair areas that are hardly noticeable to drivers (Figure 2.9).
Chapter Two – Dowel Bar Retrofit

Figure 2.7. Vibrating backfill in dowel bar retrofit slots.

Figure 2.8. Dowel bar retrofit slots finished and covered with curing compound.
2.3 Troubleshooting

*Sawcuts (sides of slots) are not parallel to each other or the pavement centerline:*

1. Use a saw slot cutting machine.
2. Check blade alignment.

*Slots are cut too shallow:*

1. Re-saw the slots and remove concrete to the proper depth.

*Slots are too deep:*

1. Use a lighter weight jackhammer, 30 lb (14 kg) max.
2. Do not lean on the jackhammer.
3. Do not orient the jackhammer vertically; use a 45-degree angle and push the tip of the hammer along the bottom of the slot.
4. Stop chipping when within 2 in. (50 mm) of the bottom of the pavement.
5. If jackhammers punch through the bottom of the pavement, make a full-depth repair across the entire lane width at the joint/crack.

*Concrete fin is not easily removed:*

1. Check for mesh reinforcement and sever the steel at each end of the slot before attempting to remove the fin of concrete.
2. Use a concrete saw to cut an additional kerf within the slot perimeter before chipping for removal.

**Dowel cannot be centered over joint/crack because slot does not extend far enough:**

1. Chip out additional slot length with jackhammer so that at least 6 in. (150 mm) of dowel extends on each side.

**Dowels are misaligned after vibration:**

1. Ensure that the slots are sized the exact width of the plastic dowel bar chairs.
2. Do not allow the vibrator to touch the dowel assembly.
3. Check for over-vibration; each slot should only require two to four short, vertical penetrations of a small-diameter spud vibrator.
CHAPTER 3
Cross-Stitching

Key Points:

- Use only for longitudinal cracks and/or longitudinal joints.
- Set up the drill at the proper angle and distance away from crack/joint to ensure proper embedment of tiebars on each side of the crack/joint.
- Do not drill through the bottom of the slab.
- First place grouting material into the hole, and then insert the tiebar.

Cross-stitching is a repair technique intended to provide nearly 100% load transfer across a longitudinal crack or joint that is in reasonably good condition. It employs deformed tiebars, which are epoxied or grouted into holes drilled at an angle through a crack or joint. Stitching is applicable for a number of situations where strengthening cracks or joints is required. Among these are:

- Strengthening longitudinal cracks in slabs to prevent slab migration and to maintain aggregate interlock.
- Mitigating the issue of tiebars being omitted from longitudinal contraction joints (due to construction error).
- Tying roadway lanes or shoulders that are separating and causing a maintenance problem.
- Tying centerline longitudinal joints that are starting to fault.

Stitching is an excellent, non-intrusive procedure to repair uncontrolled longitudinal cracking. However, in some cases it may not be advisable or necessary. Some cracks can perform well simply by sealing and maintaining the crack properly. If the cracks are in moderate or fair condition, stitching is effective. Experience demonstrates that stitching is not a substitute for slab replacement if the degree of cracking is too severe, such as when slabs have multiple cracks or are shattered into more than 4-5 pieces.
3.1 Drilling Holes

Holes are drilled at a 35° to 45° angle from horizontal so that they intersect the longitudinal crack or joint at approximately mid-depth. It is important to drill the first hole at the proper distance and angle so it crosses mid-depth of your particular pavement section. It is also important to maintain this relative distance and angle consistently along the length of the crack or joint. Different equipment can be used, depending on the contractor’s preference and equipment availability (Figure 3.1 and Figure 3.2). For recommendations on angles, distances, and depths of holes, see Table 3.1 and Figure 3.3.

Figure 3.1. Drill rig used to drill holes across longitudinal joints or cracks for cross-stitching.
Table 3.1. Cross-Stitching Bar Dimensions and Angles/Location of Holes.

<table>
<thead>
<tr>
<th>Angle</th>
<th>Slab Thickness, in. (mm)</th>
<th>Distance from Crack to Hole, in. (mm)</th>
<th>Length of Bar, in. (mm)</th>
<th>Diameter of Bar, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 (175)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35°</td>
<td>5.00 (125)</td>
<td>6.50 (165)</td>
<td>12.00 (300)</td>
<td>0.50 (13)</td>
</tr>
<tr>
<td>40°</td>
<td>6.50 (165)</td>
<td>8.00 (200)</td>
<td>12.50 (315)</td>
<td>0.75 (19)</td>
</tr>
<tr>
<td>45°</td>
<td>—</td>
<td>9.50 (240)</td>
<td>14.00 (350)</td>
<td>0.75 (19)</td>
</tr>
<tr>
<td></td>
<td>8 (200)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35°</td>
<td>7.25 (180)</td>
<td>11.00 (275)</td>
<td>14.50 (365)</td>
<td>0.75 (19)</td>
</tr>
<tr>
<td>40°</td>
<td>7.75 (195)</td>
<td>12.50 (315)</td>
<td>16.00 (400)</td>
<td>0.75 (19)</td>
</tr>
<tr>
<td>45°</td>
<td>—</td>
<td>14.50 (365)</td>
<td></td>
<td>1.0 (25)</td>
</tr>
<tr>
<td></td>
<td>9 (225)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35°</td>
<td>8.50 (210)</td>
<td>14.00 (350)</td>
<td>16.00 (400)</td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td>—</td>
<td>16.00 (400)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45°</td>
<td>—</td>
<td>18.50 (465)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 (250)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35°</td>
<td>—</td>
<td>12.00 (300)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td>—</td>
<td>14.00 (350)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45°</td>
<td>—</td>
<td>16.50 (415)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 (275)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35°</td>
<td>—</td>
<td>12.00 (300)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td>—</td>
<td>14.00 (350)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45°</td>
<td>—</td>
<td>16.50 (415)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 (300)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35°</td>
<td>—</td>
<td>12.00 (300)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td>—</td>
<td>14.00 (350)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45°</td>
<td>—</td>
<td>16.50 (415)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13 (325)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35°</td>
<td>—</td>
<td>12.00 (300)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td>—</td>
<td>14.00 (350)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45°</td>
<td>—</td>
<td>16.50 (415)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14 (350)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35°</td>
<td>—</td>
<td>12.00 (300)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td>—</td>
<td>14.00 (350)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45°</td>
<td>—</td>
<td>16.50 (415)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Select a drill that minimizes damage to the concrete surface, such as a hydraulic powered drill and a drill bit diameter no more than 0.375 in. (10 mm) larger than the tiebar diameter, and choose a gang-mounted drill if higher productivity is needed for larger jobs. All dust and debris should be air-blown from holes after drilling operations are completed.

### 3.2 Installing Tiebars

Inject (pouring is acceptable for small quantities) epoxy into the hole, leaving adequate space for the tiebar (Figure 3.4). Insert the tiebar into the hole with a twisting motion and remove the excess material, finishing the surface of the epoxy so that it is flush with the pavement surface (Figure 3.5).
3.3 Stitching FAQs

*Can Transverse Cracks be Stitched?*

Do not stitch transverse cracks. Transverse cracks often form active boundaries to slabs or segments of concrete and undergo thermal expansive and contraction movements (opening and closing). Cross-stitching prevents opening or closing of joints and cracks. If joint movement is restrained, stresses can build within the slab and result in spalling and cracking near the ends of the bars. These effects have been observed on highway applications where stitching was tried on working transverse cracks.
**Should Drifted Slabs be Moved Together Before Stitching?**

Do not attempt to move drifted slabs back into position against adjacent slabs. First, there is usually no real concern or maintenance expense if slabs drift apart. Therefore moving the slabs may be a waste of resources. Second, the mechanical energy required to push the slabs would make this impractical in most cases.

**How Should Drifted Slabs be Connected?**

Of primary concern in connecting slabs that have drifted apart is preventing the backfill (either epoxy or grout) from flowing into the space between slabs. To prevent this, clean and fill the space between the slabs before stitching. A sand-cement grout is a suitable backfill for this purpose. However, this is not recommended for airfield facilities because of concerns about foreign object damage, or FOD.

**Can Cross-Stitching be Used to Tie New Lanes?**

Do not use cross-stitching to tie a new lane to an existing one. When possible, drill laterally into the side of an existing lane, epoxy-fill the tiebars into the holes, and then place the new lane. This is a better alternative than using a diagonal configuration, as occurs in cross-stitching.

**How Should the Joint Adjacent to a Stitched Crack be Treated?**

After stitching a longitudinal crack, it may be necessary to treat a nearby longitudinal joint. The primary concern is whether a crack has formed below the sawcut for the longitudinal joint. If a crack has occurred and the joint functions properly, then no treatment other than joint sealing is warranted. However, if there is no crack extending below the joint cut, then it is advantageous to fill the saw cut with epoxy to strengthen the slab at this location (Figure 4.6). If the joint is not functioning, but a joint sealant has already been installed satisfactorily, then no further action is recommended.
A careful review of the joint is necessary to render a decision on whether epoxy treatment is necessary. Several cores should be taken along the joint to determine the prevailing condition (cracked or un-cracked). If the joint warrants epoxy filling, then the following process obtains best results:

- Clean the sawcut with water. Allow reservoir to dry.
- Drill plug holes to a depth below the sawcut at any location where the crack crosses the non-functioning joint.
- Place compression plugs or cement grout plugs into plug holes.
- Install or pour epoxy into sawcut using properly sized nozzle. (Do not overfill.)

Figure 3.6. Details for epoxy filling a joint reservoir near stitched crack.
3.4 Troubleshooting

*Dowel bars do not fit or do not have sufficient room for grout:*
1. Drill holes slightly larger.
2. Change drill bit.

**Concrete surface is being extremely damaged during drilling:**
1. Check alignment of drill bit.
2. Change/sharpen drill bit.
3. Select a different drill type.

*Epoxy around dowel bars flows back out of the holes after dowels inserted:*
1. Inject/pour epoxy into the hole before inserting dowel.
2. Use a twisting motion when inserting the dowel.
CHAPTER 4
Full-Depth Repair

Key Points:
- Lay out patches and estimate material quantities as accurately as possible to avoid discrepancies in the field, as well as cost overruns.
- Provide load transfer between all full-depth patches and the surrounding pavement.
- Strike-off the patch level with the surrounding pavement and provide the patch a similar surface treatment.
- Use durable materials, a well-graded mix design, and a proper curing regiment for a long-lasting repair.
- Prior to paving, test the concrete mixture for strength, strength gain and durability properties at the range of air temperature it will be placed in on the project.

There are several types of distress in a concrete pavement that may require full-depth repair:
- Joint or crack spalling, if spalling is one-half the slab thickness or deeper.
- Corner breaking.
- Durability (“D”) cracking.
- Patch deterioration.
- Slab shattering, which is defined as a slab broken into four or more pieces with some or all cracks of medium to high severity.
- Punchouts.

In addition to being used for distressed pavements, full-depth slab replacement is also used at utility cuts to reestablish the pavement structure across the utility access and installation trench.

Regardless of the function, once the boundary of a full-depth repair/replacement is defined, the area is isolated by full-depth saw cuts and then removed. Adequate
load transfer is of utmost concern, as are proper finishing, texturing, curing, and joint sealing procedures. If proper procedures are followed, full-depth repair is very reliable and long-lasting.

A number of solutions are available to make short work of full-depth repairs. For example, the concrete mixture and proportions can be modified to allow early opening to traffic, if indicated. Special proprietary materials are also available that reach specified strengths in just a few hours. There are also a variety of precast concrete pavement options available for slab replacement.

### 4.1 Determining Repair Boundaries

First, a detailed survey should be conducted to accurately identify the required repair areas. The survey should identify surface cracking, but also categorize all significant underlying distresses so they may be addressed appropriately. For example, the deterioration near joints and cracks in freeze-thaw climates is often greater at the bottom of the slab than is apparent at the surface (Figure 4.1). This causes a possible misidentification of the distress, which can result in an incorrect repair procedure.

![Figure 4.1. There may be more severe deterioration below the surface than what is evident from the surface.](image)

For continuously reinforced pavements, the most common distress requiring full-depth repair is referred to as a punchout. This typically occurs in the wheelpath when two transverse cracks in close proximity are bridged by a short longitudinal crack, after millions of load repetitions. These small area(s) in the wheelpath can begin to further deteriorate, often leading to damage of the underlying subbase material (see Figure 4.2).
For jointed plain concrete pavements, partial-length slab replacement is often acceptable when the pavement distresses are not through the entire length of the slab in the direction of traffic. A minimum slab length is required to avoid rocking and pumping of the repair section or remaining intact slab. General experience indicates that 4 to 6 ft (1.2 to 1.8 m) is an acceptable minimum slab length when load transfer is provided. Although partial-width slab replacements are acceptable, full-width slab replacement is often preferred, because boundaries are well defined.

The recommended minimum guidelines for patching are:

- Sawing full-depth a minimum of 2 ft (0.6 m) from any joints.
- Using straight-line sawcuts, forming rectangles in-line with the jointing pattern.
- Extending the patch boundary to the joint if the patch boundary is within 6 ft (1.8 m) of an existing transverse joint.
- Connecting patches to make one large patch if the patches are 8 to 12 ft (2.4 to 3.6 m) from each other in a single lane. This alternative requires two sawcuts instead of four, as well as one removal instead of two (Table 4.1).
- Making two additional cuts if the patch is a utility cut. The cuts should be 6 to 12 in. (150 to 300 mm) beyond the limits of the excavation and any sloughing of the trench and made after the trench has been backfilled.

![Figure 4.2. Progression of a punchout in continuously reinforced concrete pavement.](image)
Table 4.1. Maximum Distance Between Full-Depth Repairs to Maintain Cost-Effectiveness.*

<table>
<thead>
<tr>
<th>Pavement Thickness in. (mm)</th>
<th>Patch or Lane Width ft (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11 (3.3)</td>
</tr>
<tr>
<td>6 (150)</td>
<td>16 (4.9)</td>
</tr>
<tr>
<td>7 (175)</td>
<td>14 (4.3)</td>
</tr>
<tr>
<td>8 (200)</td>
<td>12 (3.6)</td>
</tr>
<tr>
<td>9 (225)</td>
<td>11 (3.3)</td>
</tr>
<tr>
<td>10 (250)</td>
<td>10 (3.0)</td>
</tr>
<tr>
<td>11 (275)</td>
<td>9 (3.7)</td>
</tr>
<tr>
<td>12 (300)</td>
<td>8 (2.4)</td>
</tr>
</tbody>
</table>

*If patches are closer than the distances listed, they should be combined into one repair.

Not all distresses in a concrete pavement require full-depth repair. In fact, other repair techniques are proving to be equally cost-effective and as reliable as full-depth repairs. Figure 4.3 shows an example of a roadway with several distresses and the possible full-depth repair area corresponding to each appropriate distress.

Figure 4.3. Example layout of patches according to distresses and proximity to joints.
A full-depth saw cut (Figure 4.4) will completely separate the concrete that is to be removed, leaving smooth vertical faces, and eliminating unwanted damage at the bottom of the slab. Since the resulting surfaces are smooth, they will not provide aggregate interlock with the repair patch. Thus, load transfer must be reestablished by using dowel bars in jointed pavements. For continuously reinforced concrete pavements, load transfer methods are discussed later in this chapter.

Figure 4.4. Diamond-bladed full-depth sawing around the perimeter of a distressed area.

The repair boundary for a continuously reinforced pavement should extend beyond the punchout(s); be at least 4 ft (1.2 m) long; and have 1 ft (0.3 m) of reinforcement exposed by way of a partial depth cut (Figure 4.5).
4.2 Removal of Existing Concrete

Removal procedures must not, in turn, spall or crack adjacent concrete or significantly disturb the subbase or subgrade. There are two basic methods to remove concrete pavement:

1. **Breakup and cleanout method.** This is normally accomplished by using a pavement breaker or jackhammer to break the slab, followed by a backhoe to remove the pieces. This method typically disturbs the subbase and requires re-shaping, replacement, or filling with concrete patch material. It also has the potential to damage the adjacent slab if proper sawing procedures are not followed.

After the repair is isolated by full-depth saw cuts (or before, if saw blades bind while cutting), make additional cuts using a wheel saw (Figure 4.6) with at least 1.5 in. (38 mm) kerf. These cuts should be within the repair area, positioned to relieve pressure on the perimeter sawing, and at least 1.5 ft (450 mm) from each perimeter cut (Figure 4.7 and Figure 4.8).
Breakup should begin in the center of the removal area, within the inner saw cuts (Figure 4.8). After breaking up the inner area, use a backhoe to gently pull the outer region free of the adjacent slab. Alternatively, the strip can be broken up with relatively lightweight, hand-held jackhammers.
2. Lift-out method. This is normally accomplished using a crane or front-end loader to lift the deteriorated concrete from its position (Figure 4.9). This method generally does not disturb the subbase and lift-out operations should be controlled closely to prevent damage to adjacent slabs. After the repair area is isolated by full-depth saw cuts, holes are drilled through the slab and fitted with lift pins. The slab is then lifted in one or more pieces. If it is necessary to decrease the lifting load, the slab may be cut into smaller pieces.

Figure 4.8. Breakup of a full-depth repair area after sawing the perimeter and making a kerf cut several inches from the perimeter cut (note the remaining slab with kerf cuts in the background).

Figure 4.9. Concrete slab removal using the lift-out method.
During hot weather, the sawing equipment may bind during initial saw cuts, so it may be necessary to perform sawing at night when the temperatures are lower and the slabs are contracted. Another solution is to use a carbide-tipped wheel saw to provide a pressure relief cut within the patch area prior to boundary sawing (see Figure 4.7).

### 4.3 Subgrade and Subbase Preparation

After the deteriorated and loose concrete has been removed, the subbase course should be examined. All disturbed material should be removed, replaced and properly compacted (Figure 4.10). It can be difficult to adequately compact granular material, but failure to do so may result in later settlement of the patch. Replacing some or all disturbed subbase material with concrete or flowable fill may be the best alternative. If excessive moisture exists in the repair area, it should be allowed to dry or the subbase material replaced before casting the repair patch.

![Figure 4.10. Patch area compaction.](image_url)
4.4 Dowel and Tiebar Placement (Jointed Pavements)

Re-establishing load transfer across the transverse repair joints is the most critical factor affecting full-depth repair performance. For jointed pavements, load transfer is best achieved by a sufficient size and number of properly installed dowel bars. Dowels improve pavement performance by:

- Helping maintain the alignment of adjoining slabs.
- Limiting or reducing stresses that result from loads on the pavement. Different sizes of dowels should be specified for different thicknesses of pavements (Table 4.2).

Table 4.2. Dowel Size Requirements for Full-Depth Repairs in Jointed Concrete Pavements.

<table>
<thead>
<tr>
<th>Pavement Thickness in. (mm)</th>
<th>Dowel Diameter in. (mm)</th>
<th>Drilled Hole Diameter in. (mm)</th>
<th>Min. Length in. (mm)</th>
<th>Spacing in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 6 (≤ 150)</td>
<td>0.75 (19)</td>
<td>0.95 (24)</td>
<td>1.0 (25)</td>
<td>14 (350)</td>
</tr>
<tr>
<td>6.5 to 8 (&lt; 200)</td>
<td>1.0 (25)</td>
<td>1.2 (30)</td>
<td>1.08 (27)</td>
<td>12 (300)</td>
</tr>
<tr>
<td>8 to 9.5 (200 to 240)</td>
<td>1.25 (32)</td>
<td>1.45 (37)</td>
<td>1.33 (34)</td>
<td></td>
</tr>
<tr>
<td>10 + (250 +)</td>
<td>1.5 (38)</td>
<td>1.7 (43)</td>
<td>1.58 (40)</td>
<td></td>
</tr>
</tbody>
</table>

Dowels provide load transfer across joints, while at the same time allowing the joint to open and close as the surrounding pavement expands and contracts in response to temperature and moisture changes. They are installed in holes drilled at specified locations into the exposed face of the existing slab. Some specifications require three, four, or five dowels per wheelpath, whereas others require dowels across the entire lane width.

Gang drills can drill multiple holes simultaneously (Figure 4.11). The frame holds the drills in a horizontal position at the correct height (one-half the slab thickness) and prevents the drill bit from wandering. The depth of the holes should be approximately one-half the length of the dowel bar. Hole diameters exceeding the bar diameter by about 1/16 in. (1.6 mm) are recommended when using epoxy anchoring materials. Cement-based grout requires a hole diameter 0.20 to 0.25 in. (5 to 6 mm) larger than the nominal outside dowel diameter.
Before installing dowels, place grout (cementitious or epoxy) in the back of each hole (Figure 4.12). This ensures that the material flows out around each bar, fully encasing it. Do not coat one end of the bar with grout or epoxy and then insert the bar into the hole – the air pressure inside the hole will force the grouting material back out of the hole, leaving a void around the bar. The end of the bar that extends into the repair area should have a bond breaker applied to it to prevent bonding with the patch material. This bond breaker may be applied at the manufacturer or field-applied.

**Installing Dowels**

1. Inject grout to back of hole
2. Twist one turn while pushing in dowel
3. Place grout retention desk to hold in grout (optional)

*Figure 4.12. Steps for placing dowels in drilled holes.*
Deformed tie bars have surface ridges that provide a locking anchorage with surrounding concrete. In contrast to dowels, tiebars assist with load transfer but prevent movement at the repair interface. They are placed in joints that are not intended to have movement, such as longitudinal joints. Be sure that all dowels, tiebars, or other reinforcements are clean, free of flaking rust, and are epoxy-coated or otherwise non-corrosive.

4.5 Load Transfer for CRC Patches

Re-establishing load transfer for full-depth repairs in continuously reinforced concrete pavements requires leaving some (approximately 1 ft [0.3 m] on either side of the repair) of the longitudinal reinforcing bars exposed. New bars are tied, coupled, or welded to the exposed ends of the bars, reinstating the continuous longitudinal reinforcement (Figure 4.13).

![Diagram of load transfer for CRC patches](image-url)

Figure 4.13. Restoring load transfer for full-depth CRC patches.
4.6 Concrete Placement

The concrete mixture selection for a full-depth repair is heavily dependent on the required strength before opening. If it is acceptable for the concrete to cure for several days (similar to new construction), regular concrete mixtures can be used. If an earlier accelerated opening (4 to 24 hours) is required, a high early-strength concrete mixture can be used, or the cement content (not the same as the cementitious content) can be increased. All concrete placement techniques should follow standard procedures. Prior to paving, concrete mixtures should be tested for strength, strength gain and durability properties at the approximate temperature in which the pavement will be placed during the project.

Be careful to ensure the concrete is vibrated well around the edges of the patch and beneath any reinforcement. When a bond is required between the existing pavement and repair material, all exposed concrete faces should be cleaned by sandblasting. Ambient temperatures should be between 40° and 90°F (4° and 32°C) for any concrete placement.

Proprietary, rapid-set cementitious materials are available; some can reach sufficient strength for traffic in as little as four hours. These materials should be used in compliance with manufacturer’s recommendations for bonding, placing, curing, time required before opening to traffic, and temperature ranges.

4.7 Finishing, Texturing, and Curing

Finishing techniques should follow standard procedures. For repairs less than 10 ft (3.0 m) in length, the surface of the concrete should be struck off with a screed perpendicular (against the direction of traffic) to the centerline of the pavement. For repairs more than 10 ft (3.0 m) in length, the surface should be struck off with the screed parallel (in the direction of traffic) to the centerline of the pavement (Figure 4.14). Be careful the concrete is not overfinished. Before the concrete becomes nonplastic, and unless a grinding operation is to follow, the surface should be given a burlap drag or broom finish to match approximately the surface finish of the existing adjacent concrete pavement.
There are many ways to cure concrete in a repair area – wet burlap (with or without sand), impervious paper, pigmented curing membranes, and ponding or constant spraying. However, the most common curing procedure is a prompt application of a membrane-forming curing compound.

A curing procedure should be started as soon as the bleed water has disappeared from the surface of the concrete. For most paving mixtures, under typical placement conditions, this occurs within ½ hour of concrete placement. Proper curing is essential to achieving a good, long-lasting repair. A useful rule of thumb is that proper application of a white-pigmented curing compound has occurred when the concrete surface is completely white, as if painted. Any gray areas, streaks or blotches are an indication of under-application.

### 4.8 Joint Sealing

Longitudinal and transverse joints are typically sealed, particularly if the original pavement had sealed joints. If necessary, transverse and longitudinal joints within the repair area must be sawed while the concrete is green to control cracking. If the concrete cracks before initial sawing, the resulting crack should be prepared and sealed. For more information on joint and crack sealing, see Chapter 1 – Joint and Crack Sealing.
4.9 Opening to Traffic

For most concrete repair situations, it is preferable to require a minimum concrete strength prior to opening the repair area to traffic. Thanks to modern concrete mixture technologies, a mixture can be designed and proportioned to obtain a desired strength in the time required. In most cases, the opening strengths listed in Table 4.3 are sufficient for opening to public traffic. Occasionally, early loads by construction vehicles may be allowed if they will not damage the repair. The use of maturity methods to estimate opening strength is recommended.

Table 4.3. Minimum Opening Strength for Full-Depth Repairs.

<table>
<thead>
<tr>
<th>Slab Thickness in. (mm)</th>
<th>Strength for Opening to Traffic, psi (MPa)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Repair Length &lt; 10 ft (3 m)</td>
<td>Slab Replacements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compressive</td>
<td>3rd-Point Flexural</td>
<td>Compressive</td>
</tr>
<tr>
<td>6.0 (150)</td>
<td>3000 (20.7)</td>
<td>490 (3.4)</td>
<td>3600 (24.8)</td>
</tr>
<tr>
<td>7.0 (175)</td>
<td>2400 (16.5)</td>
<td>370 (2.6)</td>
<td>2700 (18.6)</td>
</tr>
<tr>
<td>8.0 (200)</td>
<td>2150 (14.8)</td>
<td>340 (2.3)</td>
<td>2150 (14.8)</td>
</tr>
<tr>
<td>9.0 (225)</td>
<td>2000 (13.8)</td>
<td>275 (1.9)</td>
<td>2000 (13.8)</td>
</tr>
<tr>
<td>10.0+ (250+)</td>
<td>2000 (13.8)</td>
<td>250 (1.7)</td>
<td>2000 (13.8)</td>
</tr>
</tbody>
</table>

Maturity testing is the most flexible testing method to determine opening strength, particularly when early opening is required. Maturity testing employs small thermocouples or maturity probes that can be monitored continuously or periodically. Flexural or compressive strength testing requires testing specimens at a laboratory.

4.10 Precast Panels

In areas where very short work windows are available, such as for a highly trafficked roadway in an urban area, precast panels (Figure 4.14) have been used successfully in many locations. In some cases, cracked and damaged pavement panels have been removed and replaced with precast panels in as little as four hours.

There are a variety of precast panel approaches available to the contractor today. The differences between the available approaches relate to a variety of aspects, including:

- Load transfer mechanism
- Bedding material/subgrade preparation
Slab reinforcement (mild, prestress, post-tension)
Slab geometry (flat panel, warped panel)

All approaches offer benefits which can include:
- Faster construction
- Reduced user cost
- Reduced section thickness
- Controlled concrete fabrication conditions
- Improved performance

Successful use of precast pavement panel technology is very much contingent upon a thorough pavement survey. The dimensions (thickness, width and length) of the pavement slabs in the repair areas must be clearly defined. In addition, subgrade conditions must be considered. If the material below the exiting pavement slab is damaged during slab removal, steps should be taken to address this (see Section 4.3 – Subgrade and Subbase Preparation). In some cases, where ride and smoothness are very important, the pavement can be diamond-ground after precast slab installation.

Use of precast pavement slabs as a full depth repair strategy is relatively new. Existing techniques are being refined and new approaches are being developed.
4.11 Utility Cuts

Access to sewers, drainage structures, water mains, gas mains and service lines, telecommunication lines, and power conduits requires cutting and removing the pavement and subsequent full-depth replacement. Careless compaction of fill materials in these trenches during replacement often causes soft spots in the subgrade. Controlled low-strength material (flowable fill) is an economical, more reliable alternative for backfill in these areas.

Flowable-fill materials are self-leveling and do not require compaction. The mixtures generally contain cement; sand; supplementary cementitious materials (SCMs), including fly ash, blast furnace slag, silica fume, activated metakaolin, rice husk ash, etc.; and water. Also, they will typically develop 28-day compressive strengths of 50-100 psi (0.35-0.70 MPa). Correctly proportioned flowable-fill materials provide enough strength to prevent settlement, but are easy to remove using a backhoe or front-end loader if excavation is necessary for future utility repair.

When performing utility cuts, the pavement should be cut back 6 to 12 in. (150 to 300 mm) after trench compaction is complete (Figure 4.15). This ensures the new patch will have a rim of compacted subbase material around the trench to help bridge the utility trench in case of poor compaction and subsequent settlement of the repair area.

Saw cut full-depth and remove the concrete 6 – 12 in. (150 – 300 mm) away from any sloughed edges of utility trench. Drill and install dowel bars as required. Place, finish and cure new concrete. Re-establish joint pattern and seal all transverse and longitudinal joints if required.

Figure 4.16. Detail for utility cut restoration patches.
### 4.12 Troubleshooting

**Undercut spalling (deterioration on bottom of slab) is evident after removal of concrete from patch area:**

1. Saw back into adjacent slab until sound concrete is encountered.
2. Use double saw cuts, 6 in. (150 mm) apart, around patch area to reduce damage to adjacent slabs during concrete removal.
3. Use a carbide-tipped wheel saw to make pressure relief cuts 4 in. (100 mm) wide inside future repair areas if some still remain on the same project.

**Saws bind when cutting full-depth exterior cuts:**

1. Shut down saw and remove saw from blade.
2. Wait for slab to cool and release blade if possible, or make another full-depth angled cut inside the area to be removed to provide a small pie-shaped piece adjacent to the stuck saw blade.
3. Make transverse saw cuts when the pavement is cool.
4. Use a carbide-tipped wheel saw to make pressure relief cuts 4 in. (100 mm) wide inside the area to be removed.

**Lifting out a patch for full-depth repair damages adjacent slab:**

1. Adjust lift cables and reposition lifting device to assure a vertical pull.
2. Re-saw and remove broken section of adjacent slab.
3. Use a forklift or crane instead of a front-end loader.

**Slab disintegrates when attempting to lift out:**

1. Complete removal of patch area with backhoe or shovels.
2. Angle lift pins and position cables so fragmented pieces are bound together during liftout.
3. Keep lift height to absolute minimum on fragmented slabs.

**Patches become filled with rainwater, saturating the subbase:**

1. Pump the rainwater from the patch area, or drain it through a trench cut through the shoulder.
2. Re-compact subbase, adding material as necessary.
3. Allow small depressions in subbase to be filled with concrete during placement of patch material.
Grout around dowel bars flows back out of the holes after dowels inserted:

1. Pump grout to back of hole first.
2. Use a twisting motion when inserting the dowel.
3. Add a grout retention disk around the bar to prevent grout from leaking out.

Dowels appear misaligned once inserted into holes:

1. Use a gang-mounted drill rig referenced off the slab surface to drill dowel holes.
2. Check dowel drill bit diameter to ensure it is not too large for the dowels used on the project.
3. Check to see if grout is flowing out of the dowel holes, thus allowing the bars to tip. If settling is noticeable, use grout retention disks.
Partial-depth repair is typically used to repair spalling at pavement joints (Figure 5.1), cracks, or midslab locations. Spalling can occur when unsealed joints or cracks are filled with incompressibles, preventing closing of the joint or crack in hot weather and resulting in breakage of the concrete. Other causes of spalling at joints include poor consolidation, inadequate curing, or poor repairs. Spalling at midslab is generally caused by reinforcement that is too close to the surface, foreign matter in the concrete, or a poor surface finish.

Spalls create a rough ride and can accelerate further deterioration. Because spalling is typically a localized distress, it warrants a localized repair. However, if several severe spalls are present on one joint, it may be more economical to perform a full-depth repair along the entire joint than to repair individual spalls (Figure 5.2).

**Key Points:**

- Clean repair area thoroughly (typically by sandblasting followed by clean, compressed air) before placing material.
- To prevent point bearing, re-form the joint (or crack) by placing compressible material across the patch before placing repair material.
- Use a durable repair material, particularly for freeze-thaw resistance.
- Mix repair material in small quantities; follow manufacturer’s instructions, if applicable.
Figure 5.1. Minor joint spalling.

Figure 5.2. Severe spalling.
Spalls should not be filled with temporary patch material such as asphalt or cold patch. These can introduce additional incompressibles into the joint area, further accelerating the deterioration and causing more spalling. Instead, spalls should be left open and the joints should be kept free of incompressibles until proper repair procedures can be used to repair the area and re-form the joint.

The performance of partial-depth repairs is highly dependent on the quality of the construction operations and the durability of the material. The rate of deterioration of the existing concrete pavement should also be considered when decided if partial-depth repair is the appropriate pavement restoration method to use. In general, if sound construction practices and a durable material are used, partial-depth repairs can last five to 15 years, or longer. In the case of poor materials or workmanship, partial depth repairs rarely last more than three years.

### 5.1 Determining Repair Boundaries

Before beginning work, a survey should be completed to establish the repair boundaries and determine areas of unsound or delaminated concrete. During the survey, all areas of unsound concrete or delamination should be determined by using a sounding technique. Sounding is accomplished by striking the existing concrete surface with a steel rod, chain, or hammer.

Delaminated or unsound concrete will produce a dull or hollow thud, while sound concrete will produce a sharp metallic ring. The repair boundaries should be extended 3 in. (75 mm) beyond the detected delaminated or spalled area to assure removal of all unsound concrete (Figure 5.3). This area should be kept square or rectangular in-line with the existing jointing pattern to avoid irregular shapes. Irregular shapes may cause cracks to develop in the repair material. If repair areas are closer than 24 in. (600 mm) apart, they should be combined to help reduce costs and eliminate numerous small patches.
5.2 Removal of Existing Concrete

Removing existing concrete can be done by sawing and chipping, or by a milling process. To remove concrete by sawing and chipping, a minimum 2 in. (50 mm) deep saw cut should be made in a rectangular pattern at least 3 in. (75 mm) outside of all detectable deterioration. This 2 in. (50 mm) deep cut will provide a vertical face that is deep enough to assure the integrity of the patch (Figure 5.4).

**Figure 5.3. Spall repair procedures.**
Additional sawcuts may be made within the repair area to speed chipping. A saw cut 2 in. (50 mm) away from joints might reduce the possibility of damaging the opposite joint face. A saw cut along an existing joint—made by skimming the blade along the joint face—will remove sealant residue and leave a clean vertical joint face (Figure 5.5).

Concrete within the repair area should be removed to the bottom of the saw cuts or 0.5 in. (13 mm) into visually sound and clean concrete, whichever is deeper, with light pneumatic tools. It is important that the proper tools be used. The recommended maximum size of the chipping hammer for partial-depth repairs is 30 lb (14 kg).
Concrete within the repair area also can be removed using carbide-tipped, cold milling equipment (Figure 5.6). Cold milling is especially effective where the repair area extends over a large portion of a joint or crack. Milling machines must be equipped with a device for stopping at a preset depth to prevent excessive removal or damage to existing dowel bars or reinforcement. After removing the concrete in the repair area, sound the pavement again to be sure all the delaminated or unsound concrete has been removed.

Figure 5.5. Layout of sawcuts for partial-depth patch.
Occasionally, what appears to be spalling at the surface of the pavement will actually extend through more than one-half the slab thickness. Do not attempt partial-depth repair at these locations. The area should be marked and a full-depth repair should be performed. Full-depth repair also should be performed if the concrete below mid-slab depth is damaged during chipping, or if dowel bars or reinforcing steel are encountered during removal. Steel encountered in spall areas must be completely exposed for 0.5 in. (13 mm), cleaned, and re-embedded in the patch material.

5.3 Surface Preparation

Prior to patching, all exposed concrete surfaces and any exposed steel must be sandblasted to remove all loose particles, oil, dirt, dust, asphalt, rust, or other contaminants. After sandblasting, air-blow or water-blast the area to remove sandblasting media (Figure 5.7). Check the prepared surface for cleanliness immediately prior to placing the new patch material, because any contamination of the surface will reduce the bond between the repair material and the existing concrete.
When placing a partial-depth patch adjacent to any joint or crack, there must be no bond between the repair patch and the face of the adjacent concrete. Prevention of such bonding can be accomplished by placing a compressible insert (expanded polystyrene foam, asphalt-impregnated fiberboard (Figure 5.8), plastic joint inserts, etc.) along the joint prior to placing the repair material. This will separate the repair area from the adjacent slab while also allowing space for the joint or crack to be properly sealed. The new joint or crack should be no less than the width of the existing joint or crack.

Figure 5.7. Clean, compressed air removes dust, debris, and sandblasting media.

Figure 5.8. Compressible inserts are used to re-form the joints or cracks.
Failure to re-form a joint or crack may result in point bearing and failure by blowup, delamination, or new shear planes in the adjacent slab (Figure 5.9). When placing a partial-depth patch along a shoulder joint, place a piece of joint material along the slab edge, even with the surface, to prevent the patch material from penetrating the shoulder interface. Otherwise, the material may restrict longitudinal movement of the slab in response to thermal changes, resulting in damage to the repair and/or the shoulder.

**Need for Compressible Insert**

![Diagram of Point bearing](image)

**Figure 5.9. Point bearing causes premature failure of the repair.**

### 5.4 Patch Materials and Placement

High early-strength concrete should be used when early opening to traffic is required. Normal set Type I (GU) portland cement concrete can be used when the patch material can be protected from traffic for at least 24 hours. For faster setting materials such as Type III (HE) cements, patches can be opened as soon as the material can withstand loads without plastic deformation. If proprietary, rapid-set patching materials are used, be sure to follow manufacturer's recommendations. These include bonding, placing, time required before opening to traffic, and temperature ranges.

Remove all sandblasting residue using oil-free air-blowing equipment just prior to placing the patch material. The volume of patch material required for a partial-depth repair is usually less than 2.0 ft³ (0.056 m³). Therefore, patching material should be mixed on-site in a small, mobile drum or paddle mixer. Transit mix trucks and other large equipment cannot produce such small quantities efficiently since maximum mixing times for a given temperature may be exceeded, thereby decreasing the quality and resulting in wasted material.
The repair area should be slightly overfilled to compensate for consolidation. Perform the primary consolidation using small spud vibrators to eliminate voids at the interface of the patch and the existing concrete. Vibrators greater than 1 in. (25 mm) in diameter are not recommended for this work. On very small repairs, hand tools are sufficient to work the repair and attain adequate consolidation.

### 5.5 Finishing

Finish the repair area level with the existing pavement and then remove all excess material on adjacent pavement surfaces. The recommended finishing procedure is to screed from the center of the patch area to the patch boundaries. By moving the screed toward the patch boundaries, the material is worked into the interface, increasing the potential for high bond strength. After finishing, and unless a grinding operation is to follow, a surface texture should be applied to the patch to match the surface finish approximately with the existing adjacent concrete pavement.

The patch/slab interface should be sealed with a one-to-one cement grout (Figure 5.10). This grout will form a moisture barrier over the interface and impede delamination of the patch. (Delamination of the patch also can start to occur if water at the interface freezes in cold weather.)

Saw-cut runouts extending beyond the patch perimeter at patch corners also can be filled with grout to help prevent moisture penetration that may undermine the bond. In lieu of grout, the patch/slab interface can be sealed with a material similar to that used to seal the adjacent joint or crack.

*Figure 5.10. Sealing of the patch/slab interface.*
5.6 Curing

Proper curing of partial-depth repairs is very important for two reasons: First, the large surface-to-volume ratio is susceptible to quick moisture loss; secondly, because concrete gains bond strength much slower than it develops compressive strength. Proper curing procedures typically require curing compound to be applied at the time bleed water has evaporated from the surface. Because curing is critical for partial-depth patches, apply either a double application of liquid-membrane-forming curing compound or, equivalently, one application at twice the coverage rate (Figure 5.11). In general, the procedures used for curing full-depth repairs also can be considered for partial-depth repairs.

Figure 5.11. Good curing is essential for long-lasting partial-depth repairs.

5.7 Joint Resealing

It is important to reseal the repaired joint or crack, because doing so will help prevent moisture and incompressibles from causing further damage. Any transverse and longitudinal joints constructed within the patch area must be resawed to assure that the proper joint seal reservoir is cut. It is also important that the joint faces are clean and dry for good sealant performance. Joints should be resealed based on the recommendations outlined in Chapter 1 – Joint and Crack Sealing.
5.8 Troubleshooting

More deterioration found below surface than is evident above:
1. Extend limits of repair area into sound concrete.
2. If deterioration extends below one-half the depth, perform a full-depth repair.

Dowel bar or reinforcing steel exposed during concrete removal:
1. If the steel is in the upper third of the slab, remove steel to edges of the patch and continue.
2. If removal extends to the mid-depth of the slab, perform a full-depth repair.

Patch material flows into joint or crack:
1. Ensure joint insert extends far enough into adjacent joint/crack and below patch.
2. Ensure insert is correct size for joint/crack width.

Patch Cracking or Debonding:
1. Check that joint insert was used, and used properly.
2. Ensure insert is correct size for joint/crack width and inserted correctly.
3. Check that patch area was cleaned immediately prior to grout and/or concrete placement.
4. Check that grout material did not dry out before concrete placement.
5. Ensure curing compound was applied adequately.
6. Check that patch material is not susceptible to shrinkage or durability problems.
CHAPTER 6
Diamond Grinding

Key Points:
- Understand the pavement conditions (roughness, aggregate type, concrete strength, etc.) to ensure proper equipment set-up.
- Blade type and spacing on the grinding head are related to aggregate hardness, pavement roughness, etc.
- Correct blade spacing improves the longevity of the diamond-ground surface and reduces hydroplaning.

Diamond grinding removes faults, re-profiles pavements, removes surface defects, improves friction, lowers noise levels, and restores pavement to a smooth, longitudinally textured surface. Diamond grinding should be considered when a pavement survey reveals surface defects such as:

- Faulted joints in excess of 0.125 in. (3 mm).
- Roughness in excess of 0.125 in. (3 mm) in a 10-ft (3-m) length.
- Wheelpath wear up to 0.375 in. (10 mm).

If a large area requires grinding to improve skid resistance, economics may favor grinding the entire pavement surface. Pavements also can be ground to reduce tire-pavement noise.

The diamond grinding process is not a high-impact process and, as such, typically does not damage joints. The pavement grinder is similar to a wood plane: the front wheels pass over a fault or bump, the cutting head shaves the bump off, and the rear wheels ride in the smooth path left by the cutting head.

Diamond grinding requires heavy, specially designed equipment (Figure 6.1) that uses diamond saw blades gang-mounted on a cutting head (Figure 6.2). Spacers are placed between the saw blades to reduce the amount of cutting that is to be done. This combination of saw blades and spacers gives a diamond ground pavement its characteristic “corduroy” texture, which can significantly reduce hydroplaning, improve traction, and reduce stopping distances.
6.1 Equipment Setup

Before work begins, test the equipment in a small test section to ensure that the proper blade spacing is being used for the specific aggregate on the project. The width of the spacers between the saw blades varies depending on the hardness of the aggregates. The harder the aggregate, the thinner the spacing between the blades. As the diamond grinding head cuts the surface of the pavement, thin fins of concrete formed in the unground areas are left between the cutting blades. If it is discovered during the grinding operations that enough fins remain to affect ride quality (Figure 6.3), immediately adjust spacers on the grinding head to a smaller width to prevent the problem. If this is not discovered until after grinding is completed, a roller or blade can be run across the surface to knock the fins down.
It should be noted, however, that a certain level of fins remaining after grinding is not only acceptable but also valuable, because it shows that the grinding operation was performed at the optimum spacing for the aggregate hardness. See Figure 6.4 for more information on grinding head setup.

**Figure 6.3. Excessive fins remaining after diamond grinding.**

**Figure 6.4.** Typical groove widths (blade kerf), land area (spacer width), and depth of diamond ground surfaces for pavement planning.
When grinding pavements that are susceptible to polishing (i.e., those with soft aggregates), the spacing must be wider to provide a larger land area between the blades. The land area thickness, measured at the thickest point, should be a minimum of 0.080-in. (2-mm), with an average thickness of 0.100 in. (2.5 mm). For harder aggregates, not subject to polishing, the minimum land area should be 0.065 in. (1.7 mm), with an average of 0.080 in. (2 mm).

### 6.2 Grinding Procedure

The pavement should be ground in the longitudinal direction, beginning and ending at lines normal to the pavement centerline. The grinding operation should produce a uniform finished surface, free of faulting and spalling at joints and cracks.

When rough areas are identified, a target post-grinding smoothness level should be set. Following the grinding, smoothness testing should be performed.

Prior to diamond grinding, dowel bar retrofit should be considered to prevent faulted joints and cracks from reoccurring. After grinding, joints that were previously sealed must be cleaned, re-sawed to the proper dimensions, and then resealed.

Grinding can be performed on only lanes that require the treatment, if desired. The edges of the ground areas can be feathered into the adjoining areas to eliminate any potential sharp drop offs or ledges (Figure 6.5).

![Figure 6.5. A diamond ground ledge, which requires feathering for a smooth ride.](image-url)
The removal of slurry residue from the grinding operation should be continuous, using a vacuum system integrated into the rear of the grinding machine. Grinding slurry should not be permitted to flow across adjacent lanes into gutters or other drainage facilities. Slurry sometimes can be discharged onto grassy slopes nearby the shoulders of the pavement. Be sure to check state and local regulations. If other disposal methods are indicated, make arrangements to place slurry in tankers and then dispose it in compliance with those regulations.

### 6.3 Acceptance Testing

After grinding and texturing, the pavement should be tested for smoothness. Testing is typically accomplished using either non-contact profilers or California Profilo-graphs. The testing equipment and procedures used in acceptance testing should be the same as those used in the initial evaluation. The pavement should show a 65-70% improvement in smoothness when compared to prior-to-grinding values.

Note that grinding up to 0.5 in. (13 mm) off the surface of a pavement will not reduce the load-carrying capability of that pavement.

### 6.4 Troubleshooting

**Concrete fins fail to break off:**
- Reduce the spacing between the blades.

**Light vehicles and motorcycles experience vehicle tracking:**
- Reduce the spacing between the blades.

**Some areas are left without diamond ground texture:**
- If un-textured area exceeds project specifications, regrind area.

**Large amounts of concrete slurry are left on pavement surface:**
- Stop grinding operations and check the vacuum unit, the skirt surrounding the cutting head, and the discharge pipe.
Index

A
Activated metokaolin, 63
Adhesion, 18, 23
Adhering, 27
Aggregate
  Hardness, 14, 79, 80, 81
  Interlock, 39, 51
  Type, 79
Air temperature, 4
Air voids, 5
Ambient temperature, 9, 27, 59
Asphalt-impregnated fiberboard, 74

B
Backer rod, 3, 4, 17, 18, 19, 20, 23, 24, 25, 28
Backhoe, 7, 52, 53, 63, 64
Blast furnace slag, 63
Bleed water, 60, 77
Blowup, 75
Bond, 5, 9, 25, 31, 33, 34, 57, 59, 73, 74, 75, 76, 77
Bond breaker, 5, 33, 57
Bonded concrete overlay, 5, 29, 31
Breakup and cleanout method, 7, 52
Broom finish, 10, 59
Burlap drag, 10, 59
Carbide milled slot, 5
Carbide-tipped saw, 8, 55, 64
Cement, 13, 44, 45, 56, 59, 63, 75, 76
Cement content, 59
Chipping hammer, 5, 12, 29, 31, 33, 71
Cleaning, 3, 4, 21, 22, 23, 27
Compressed air, 3, 22, 29, 67, 74
Compressible insert, (see Joint)
Concrete fin, 5, 31, 33, 36, 83
Consolidation, 5, 13, 33, 34, 67, 76
Construction traffic, 10
Contamination 3, 22, 73
Continuously reinforced concrete pavement (CRC), 7, 9, 48-49, 51, 52, 58
Corner breaking, 47
Corrosion, 17, 30
Crack, (see Joint)
Crane, 54, 64
Cross-Stitching, 6, 39, 40, 41, 43, 44, 45
Curing, 5, 10, 13, 27, 28, 34, 35, 47, 59, 60, 67, 77, 78
  Compound, 13, 35, 60, 77, 78
  Procedure, 5, 10, 13, 34, 60, 77

D
De-icing chemicals, 17
Deflection, 17, 29
Delamination, 12, 69, 75, 76
Detackifier, 27
Deterioration, 47, 48, 64, 67, 69, 70, 77

C
California Profilograph, 15, 83
Diamond grinding, 4, 14, 26, 79, 80, 81, 82, 83
Diamond saw blades, (see Saw blade)
Diamond-bladed slot cutting machine, (see Slot cutting machine)
Dowel bar retrofit, 4, 5, 14, 29, 30, 31, 33, 34, 35, 37, 82
Dowel bars, 4, 5, 8, 9, 14, 17, 29, 30, 31, 32, 33, 34, 35, 37, 39, 46, 51, 56, 57, 58, 65, 72, 73, 78, 82
Drifted slabs, 44
Drill
   Bit, 6, 42, 45, 56
   Rig, 6, 8, 40, 65
   Stop, 6
Durability, 1, 5, 34, 47, 69, 78
Durability (“D”) cracking, 47

E
Early opening to traffic, (see Opening to traffic)
Epoxy, 6, 8, 9, 30, 39, 42, 43, 44, 45, 46, 56, 57, 58
Expanded polystyrene foam, 5, 33, 74
Expansion cap, 5 29, 32, 33, 34

F
Falling Weight Deflectometer (FWD), 29
Faulting, 14, 39, 79, 82
Feather, 14, 82
Filler board, 5, 33
Finger-wipe test, 4, 23
Finishing, 1, 6, 10, 13, 42, 47, 59, 60, 67, 76
Fins, 5, 29, 31, 80, 81, 83
Flowable fill, 8, 11, 55, 63
Fly ash, 63
Foreign object damage (FOD), 44
Forklift, 64
Form oil, 9
Freeze-thaw, 29, 48, 67
Friction, 79
Front-end loader, 54, 63, 64
Full-depth repair, 4, 7, 8, 12, 14, 17, 36, 47, 48, 49, 50, 51, 53, 54, 55, 56, 57, 58, 59, 61, 63, 64, 65, 67, 73, 77, 78
Gang drill, 42, 56, 65
Grinding, 4, 10, 13, 14, 15, 26, 59, 76, 79, 80, 81, 82, 83
Grout, 8, 9, 13, 39, 44, 45, 56, 57, 65, 76, 78
Grout retention disk, 9, 65

H
Hammer, 12, 33, 36, 69, 71
Hardness of the aggregate, (see Aggregate)
High early-strength concrete, 34, 59, 75
High-pressure water, 3, 22, 23
Hot-poured sealant, (see Sealant)
Hydraulic powered drill, 42
Hydroplaning, 79

I
Incompressibles, 17, 67, 69, 77
Infiltration, 17
Isolation joint, 20

J
Jackhammer, 7, 36, 37, 52
Joint, 3, 4, 5, 6, 7, 8, 10, 12, 13, 17, 18, 19, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 33, 34, 36, 37, 39, 40, 41, 43, 44, 45, 47, 48, 49, 50, 56, 58, 60, 67, 68, 69, 71, 72, 74, 75, 76, 77, 78, 79, 82
Compressible insert, 12, 74
Face, 3, 4, 18, 21, 22, 23, 56, 70, 71, 74, 77
Recess, 3, 18, 20, 27
Resealing, 13, 77
Reservoir (see Sealant reservoir), 3, 4, 17, 20, 21, 24, 45, 77
Sealing, 10, 17, 44, 47, 60
Joint seal reservoir, 77
Jointed plain concrete pavements, 49

L
Lateral rebound, 18
Lift-out method, 8, 54
Lift-pin, 8, 54, 64
Lighter weight jackhammer, (see Jackhammer)
Lightweight chipping hammers, (see Chipping hammer)
Liquid-membrane-forming curing compound, 13, 77
Load transfer, 8, 9, 29, 39, 47, 49, 51, 56, 58, 61
Long-term performance, 18
Longitudinal crack, 39, 40, 43, 44, 48

M
Maturity method, 10, 61
Mesh reinforcement, 36
Mill, 5, 12, 31, 70, 72, 73
Mobile drum, 13, 75

N
Noise levels, 79

O
Opening strength, 9, 10, 61
Opening to traffic, 10, 48, 59, 61, 75
Over-finished, 10, 59

P
Paddle mixer, 13, 75
Partial-depth repairs, 4, 14, 69, 71, 77
Patch, 5, 7, 8, 9, 10, 11, 12, 13, 29, 31, 33, 34, 47, 49, 50, 51, 52, 55, 57, 59, 63, 64, 65, 67, 69, 70, 72, 73, 74, 75, 76, 77, 78
Boundaries, 13, 65, 76
Materials, 5, 13, 75
Placement, 5, 34
Permeable subbase, 17
Plastic joint inserts, 74
Point bearing, 29, 33, 67, 75
Polystyrene foam, 5, 33, 34, 74
Ponding, 60
Pot life, 27
Power washer, 17
Precast panels, 48, 61
Preformed compression seal, (see Sealant)
Pressure relief cut, 8, 53, 55, 64
Pumping, 17, 49
Punchout, 47, 48, 49, 51

R
Rapid-early strength gain, 5
Rapid-set materials, 59, 75
Recess, (see Joint)
Reinforcement, 7, 9, 36, 51, 58, 59, 61, 67, 72
Reinforcing steel, 9, 17, 73, 78
Repair
Area, 7, 8, 12, 13, 29, 34, 48, 50, 54, 55, 57, 60, 61, 62, 63, 64, 67, 69, 71, 72, 74, 76, 77
Boundaries, 7, 12, 48, 69
Repairs, 1, 3, 4, 8, 10, 11, 14, 17, 18, 48, 50, 56, 58, 59, 61, 67, 69, 71, 76, 77
Reservoir, (see Joint)
Rice husk ash, 63
Ride quality, 80
Roughness, 79
Concrete Pavement Field Reference *Preservation and Repair*

**S**

Sand, 44, 60, 63

Sandblasting, 3, 4, 5, 12, 21, 22, 23, 29, 31, 59, 67, 73, 74, 75

Saw blade, 7, 14, 31, 36, 64, 71, 79, 80, 81
  - Alignment, 36
  - Binding, 7, 55, 64
  - Diamond, 79
  - Runouts, 13, 76
  - Sawing, 17, 18, 29, 31, 49, 51, 52, 54, 55, 60, 70
  - Spacing, 8, 14, 28, 30, 56, 79, 80, 81, 82, 83
  - Wheel, 7, 53, 55, 64
  - Width 3, 4, 14, 18, 20, 27, 28, 36, 37, 49, 50, 56, 62, 74, 78, 80, 81

Screed, 13, 59, 76

Sealant, 3, 4, 10, 13, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 44, 71, 77

Cracking, 27

Debonding, 27

Gelling, 27

Material, 3, 4, 10, 13, 18, 23, 24
  - Cold-applied, 19, 28
  - Hot-applied, 4, 18, 28
  - Neoprene seals, 3, 18, 21
  - Two-component, 3, 18, 20

Reservoir, 3, 17, 21, 24, 77

Sealing, 3, 4, 10, 13, 17, 18, 19, 21, 22, 23, 24, 25, 27, 39, 44, 47, 60, 76, 77

Silicone, 20, 26

Shape factor, 3, 18, 20, 21, 24, 28, 33

Shrinkage, 5, 9, 34, 78

Silica fume, 63

Silicone sealants, 24

Skid resistance, 79

Slab migration, 39

Slab shattering, 47

Slot cutting machine, 5, 31, 32, 36
  - Diamond-bladed, 5, 31

Slurry, 14, 17, 21, 83

Smooth, 4, 14, 25, 51, 62, 79
  - Smoothness, 14, 15, 62, 82, 83
  - Smoothness testing, 15, 82

Sounding, 69

Spall, 52, 70, 73

Spalling, 7, 14, 17, 18, 43, 47, 64, 67, 68, 69, 73, 82
  - Spud vibrator, 13, 37, 76

Spud vibrators, (see Vibrator)

Stitching, 6, 39, 40, 41, 43, 44, 45

Stopping distances, 79

Subbase, 7, 8, 17, 48, 52, 54, 55, 62, 63, 64

Subgrade, 8, 17, 52, 55, 61, 62, 63

Supplementary cementitious materials (SCMs), 63

Support chair, 5, 33, 37

Surface
  - Defects, 79
  - Preparation, 12, 73
  - Texture, (see Texture)

Surface-to-volume ratio, 77

**T**

Temperature changes, 33, 56

Texture, 10, 13, 15, 47, 48, 59, 76, 79, 83

Tiebar, 8, 39, 42, 56

Tiebars, 6, 30, 39, 42, 44, 58
  - Placement, 8, 56

Tine, 10

Traction, 79

Traffic control, 10

Transverse cracks, 43, 48

Trenches, 63

Troubleshooting, 27, 36, 45, 64, 77, 83
Index

U
Utility cut, 7, 11, 47, 49, 63

V
Vacuum, 3, 14, 22, 83
Vibrator, 9, 13, 37, 59, 76
Voids, 5, 28, 34, 76

W
Water, 3, 12, 14, 17, 22, 23, 45, 60, 63, 73, 76, 77
Water-blasting, 12, 73
Wheel saw, (see Saw)
Wheelpath, 30, 48, , 56, 79