"Moving Advancements into Practice"

MAP Brief Spring 2026

Best practices and promising technologies that can be used now to enhance concrete paving

Partial-Depth Repairs

SPRING 2026

PROJECT TITLE
Parial-Depth Repairs

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Introduction

The Federal Highway Administration (FHWA) describes pavement preservation as work that is planned and performed to improve a pavement or sustain it in a state of good repair. A common principle in pavement preservation is to keep good roads in good condition. Applying high-quality preservation treatments while pavements are still performing adequately can slow the rate of deterioration, lengthen pavements' usable life, and maintain performance in a cost-efficient way while also improving safety and user satisfaction. Pavement preservation guidance is available at https://www.fhwa.dot.gov/preservation/.

One type of concrete pavement preservation treatment includes partial-depth repairs (PDRs), which consist of the removal and replacement of shallow areas of deteriorated concrete. When distress is confined to the upper half of the slab and the existing load transfer devices (when present) remain functional, PDRs can serve as an alternative to full-depth repairs (FDRs). PDRs can be particularly useful for repairing spalling and deterioration that occurs at joints and at the surface. These repairs restore the overall integrity of the pavement, extending its service life. Weiss et al. (2016) provide guidance on the applicability of PDRs for concrete pavements exhibiting premature joint deterioration.

The success of PDRs can be highly dependent on the quality of the installation, since they involve removal of only a portion of the slab and bonding of the patch material to the remaining concrete rather than a straightforward slab removal and replacement. Attention to detail is key in all specified removal, preparation, placement, and curing procedures. When PDRs are used to address appropriate distresses and are installed using good materials and construction practices, service lives of 10 to 20 years or more can be achieved (Darter 2017).

Distresses located in the upper half of the slab are treatable with PDRs, particularly distresses that occur at or along joints. Figure 1 shows some examples of joint distresses that can be addressed using PDRs.

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Figure 1. Examples of spalling at PDR candidate locations

Common causes of these types of distresses include the following:

- Freeze-thaw damage due to an inadequate air void system or excessive permeability
- Damage from deicing chemicals
- Spalling from incompressible materials in joints or cracks

PDRs can also be useful for addressing other forms of surface deterioration. Factors that may cause these other forms of deterioration include the following:

- Poor consolidation, curing, or finishing practices
- Delamination or shallow reinforcement
- Other localized surface issues

It is also important to recognize when PDRs are not an appropriate repair method. PDRs are not recommended as a long-term solution for pavements with the following issues:

- Joint deterioration caused by materials-related distress (MRD) issues involving aggregate durability, such as D-cracking or alkali-silica reaction (ASR)
- Transverse joint spalling resulting from lockup of the joint due to dowel bar misalignment
- Any deterioration that extends beyond the mid-depth of the slab

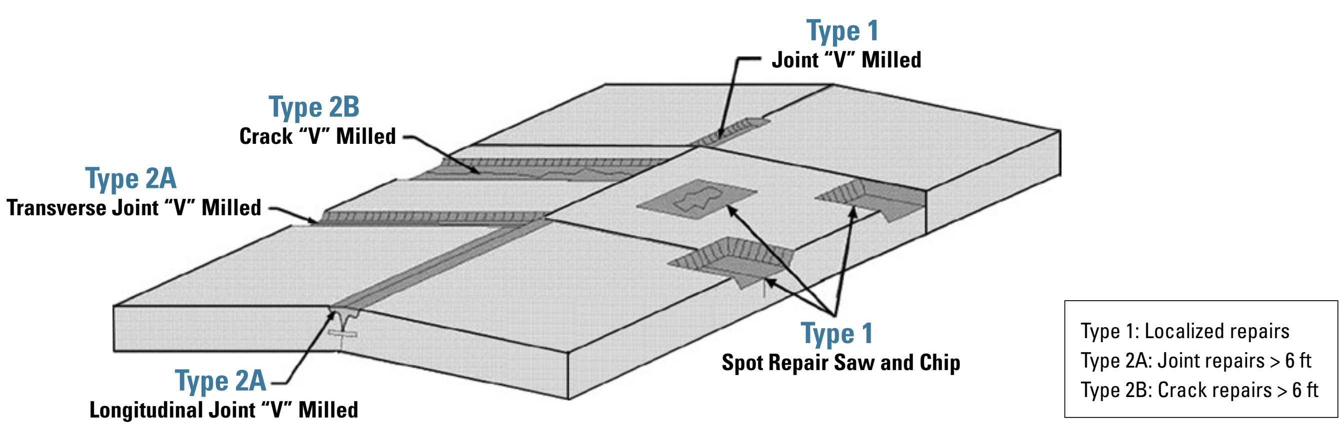
When scoping a concrete pavement preservation project that includes PDRs, it is recommended that a bid item for FDRs is included. This approach allows areas with distress extending below the slab's mid-depth that may not be obvious from the surface to be changed to full-depth repair. Areas of distress can also be cored just outside the distress area to confirm that the deterioration is not occurring at the bottom of the slab.

Types of Partial-Depth Repairs

Different types of PDRs can be categorized based on factors such as the location of the repair, the size of the repair, and the removal method. For the purposes of this MAP brief, the general types of PDRs for cracks, joints, and spalls are defined by Frentress and Harrington (2012), as shown in Figure 2. These include Type 1 repairs for spalling areas less than 6 ft in length and Type 2 repairs for spalling areas longer than 6 ft in length. Note that many agencies use their own terminology to determine types of PDRs.

The deteriorated concrete can be removed by either sawing around the perimeter of the repair and breaking out the area with light jackhammers or by using small milling machines for longer spalls along a joint. For repairs performed using conventional concrete mixtures, the repair area should be angled out slightly (approximately 30° to 60°) at the edges to help facilitate bonding, but repairs using proprietary materials should be performed according to the manufacturer's recommendations for repair areas, dimensions, and geometries. Typical details for sawing and chip removal are shown in Figure 3.

When constructing a PDR along an existing joint or crack, it is critical that the working joint or crack interface be restored at the same location as in the existing and surrounding concrete slab. This joint or crack may be restored either by providing compression relief through the installation of a preformed insert at the existing joint or crack or by sawing the PDR over the existing joint or crack upon completion of the patch. When sawing to provide compression relief at an existing joint, the sawcut must be for the full thickness of the repair plus an additional 0.25 to 1 in.



Adapted from Frentress and Harrington 2012, CP Tech Center

Figure 2. Types of PDRs

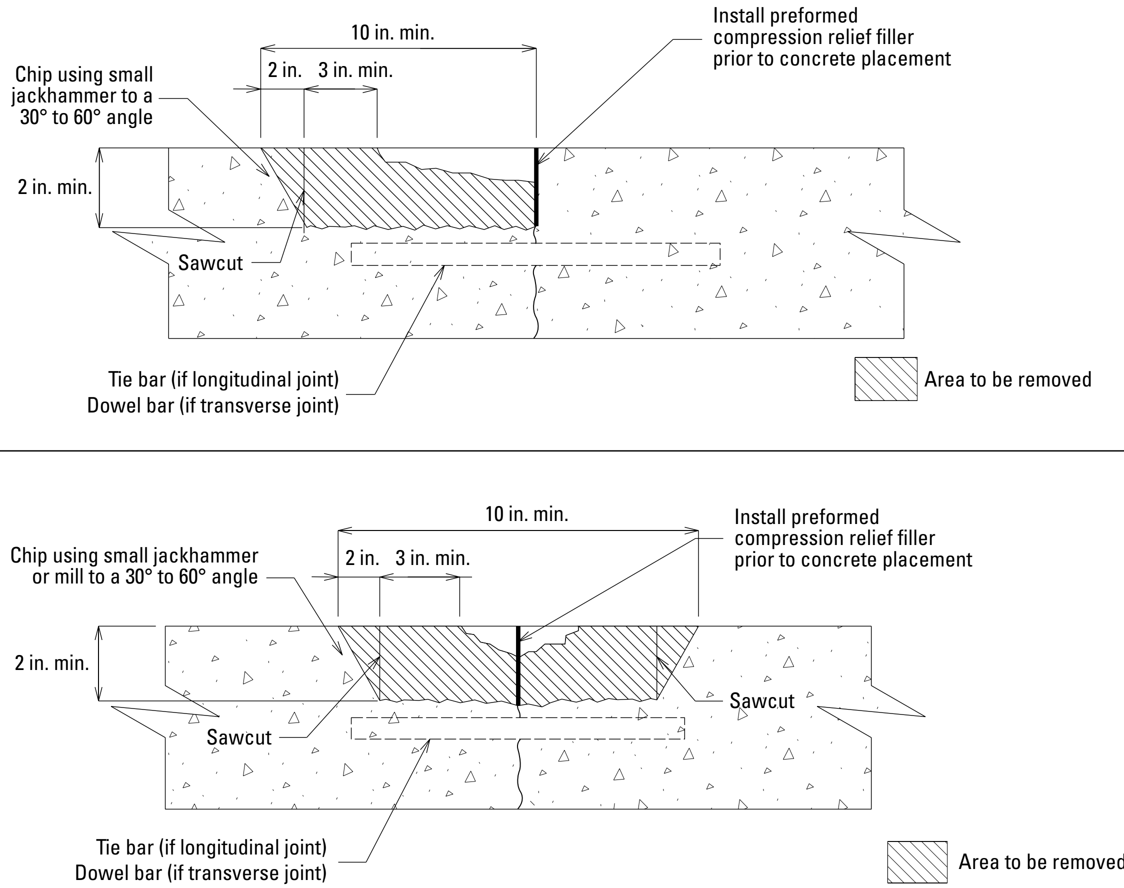


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Figure 3. Typical PDR details for sawing and chip removal

On joints or cracks, some agencies allow longer longitudinal runs that combine a series of smaller repairs into a single, continuous repair. This can help improve the overall efficiency of construction operations and can be quickly and effectively performed using milling procedures. Removal of distressed concrete is often completed with small milling machines. A typical detail for removal by milling is shown in Figure 4.

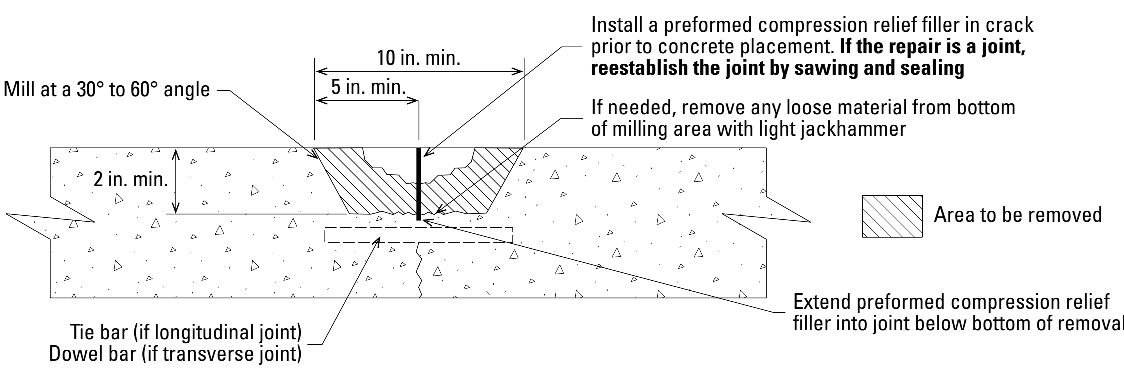

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Figure 4. Typical detail for a PDR with removal by milling

Repair Materials

A variety of patching materials may be used in PDRs. These materials include conventional concrete mixtures and mixtures containing modified hydraulic cements, as well as a variety of polymer-based and bituminous materials.

Portland Cement Concrete Mixtures

Conventional portland cement concrete mixtures are an appropriate and widely used material for PDRs. Typical mixtures combine concrete with coarse aggregate not larger than half the minimum repair thickness, with a 0.375 in. maximum size often used. The material should be a low-slump, low-shrinkage mixture with a water-cementitious materials (w/cm) ratio not exceeding 0.45. Adequate air entrainment is important for repairs performed in cold-weather states.

For repairs that must be opened to traffic quickly, a mixture featuring either a Type I/II or Type IL cement with a set-accelerating admixture or a Type III cement have been used successfully. Conventional concrete mixtures, with or without admixtures, are more widely used than most other materials thanks to their relatively low cost, availability, and ease of use. In cool weather conditions, insulating layers can be used during installation to help retain the heat of hydration and reduce curing time. Concrete mixtures produced using Type III cement should be used with caution because they can be more difficult to work with and may develop shrinkage cracks.

Many state and local highway agencies have developed standard mixtures for use in their PDRs. As an example, the Minnesota Department of Transportation (MnDOT) has had good success with a cementitious mixture (3U18) that provides an 18-hour opening strength of 3,000 psi. Refer to MnDOT specification section 3105 for more information.

Concrete Mixtures with Alternative Cementitious Materials

A number of modified hydraulic cements are available for use in PDRs, including gypsum-based cements, calcium aluminate cements, and other hydraulic cement–based mixtures. Calcium sulfoaluminate (CSA) cements have been successfully used by a number of state and local agencies for PDRs. CSA cements offer rapid strength gain, good durability, and high sulfate resistance while also exhibiting very low shrinkage. Refer to Chapter 5 of the *Concrete Pavement Preservation Guide* (Smith et al. 2022) for more information on the use of modified hydraulic cements for PDRs.

Polymer-Based Materials

The primary advantage of polymers is their ability to cure much faster than most cementitious materials; however, they tend to be costlier, and some are sensitive to temperature and moisture conditions. Polymers used for pavement repairs include urethane resins and epoxies, among others. Polymer-based concretes are formed by combining polymer resin, aggregate, and an initiator. Aggregate is added to the resin to make the polymer concrete more thermally compatible with the in-place concrete, to provide a wearing surface, and to make the mixture more economical. It should be noted that large differences in the coefficient of thermal expansion can lead to debonding.

Bituminous Materials

Conventional bituminous materials are often considered temporary repair materials that are used on concrete pavements until more rigorous patching can be performed. They have the advantage of being relatively low in cost, widely available, and easy to handle and place, and they generally need little, if any, cure time. In some cases, they have even demonstrated a service life of 3 to 5 years. The use of conventional bituminous materials should largely be considered a stopgap, temporary repair measure.

Refer to Chapter 5 of the *Concrete Pavement Preservation Guide* (Smith et al. 2022) for more information on polymer-based and bituminous-based materials.

Bonding Agents

The purpose of a bonding agent is to enhance the bond between the repair material and the existing pavement. Not all repair materials require a bonding agent, and in some cases simply having a clean, textured, and saturated surface-dry condition for the existing concrete is sufficient to ensure a good bond. However, bonding agents are specified by some agencies and may be required for some proprietary products.

When a bonding agent is used, it is critical that it does not dry before the placement of the repair material. If the bonding agent dries, it may inhibit the bonding of the patch material, causing the PDR to fail. Bonding agents that dry should be removed by media blasting. Sand-cement grouts are commonly used as bonding agents with concrete repair materials, but epoxy bonding agents have also been used with both concrete and proprietary repair materials as a means of reducing repair closure times. One common sand-cement grout formulation is as follows (Frentress and Harrington 2012):

- Two parts cement
- One part water
- One part sand

This sand-cement-water grout mixture produces a mortar with a thick, creamy consistency, which helps to fill any small spalls or gouges that may be left by the removal process.

Construction of Partial-Depth Repairs

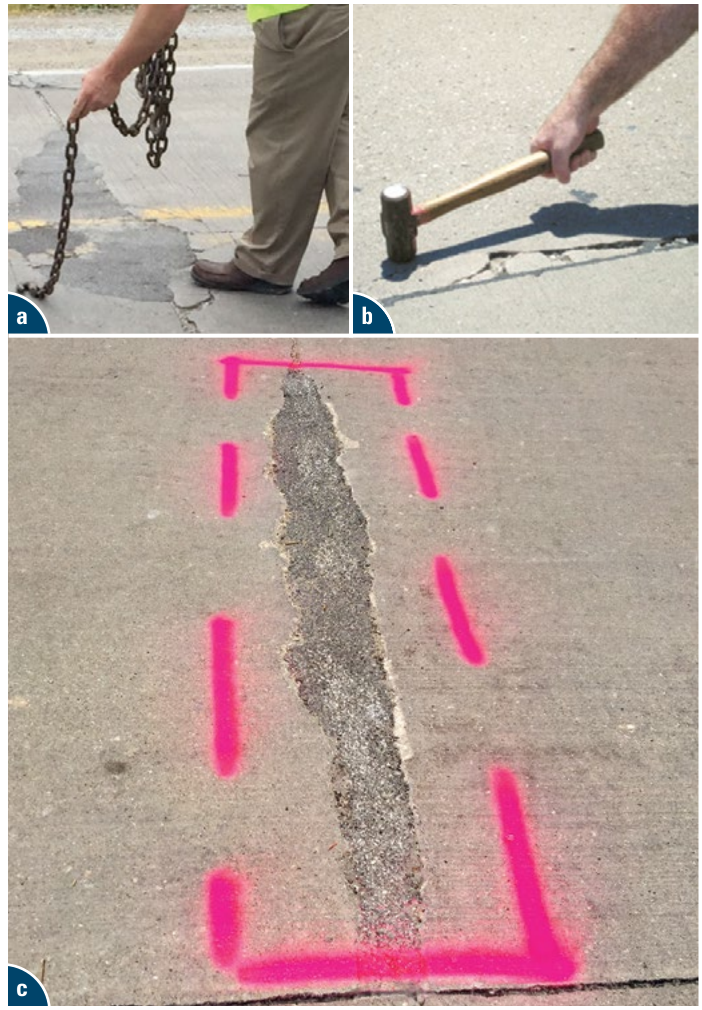
There are eight essential steps and one optional step for the successful construction of PDRs.

Step 1: Determine Repair Boundaries

It is important that all weak and deteriorated concrete is located and removed if the repair operation is to be effective. It is recommended that the repair boundaries extend 3 in. beyond the detected delaminated or spalled area to ensure the removal of all unsound concrete. Sounding the pavement by dragging a heavy chain across it or tapping it with a small sledgehammer is a way to detect the unsound concrete. Areas yielding a sharp metallic ringing sound are judged to be acceptable, while those emitting a dull or hollow thud are delaminated or unsound. Figure 5 illustrates the process of sounding concrete with a hammer. Figure 6 shows various methods of sounding and the use of paint to mark the boundary of a PDR.

If there is a significant amount of time between the field marking and the construction process, the repair boundaries should be verified.

When cement-based repair materials are used, a minimum repair length (along the joint or crack) of 10 in. and a minimum repair width (away from the joint or crack) of 5 in. are recommended. When proprietary materials are used, the manufacturer's recommendations for repair dimensions should be followed. For cement-based materials, the repair should be at least 2 in. deep to provide sufficient mass to bond to the underlying substrate; other products (e.g., some polymers and epoxies) allow for a thinner application (Darter 2017).



Snyder and Associates, Inc., used with permission (a and c); Frentress and Harrington 2012, CP Tech Center (b)

Figure 6. Sounding concrete (a) by chain drag and (b) by hammer and (c) the use of paint to mark PDR removal area

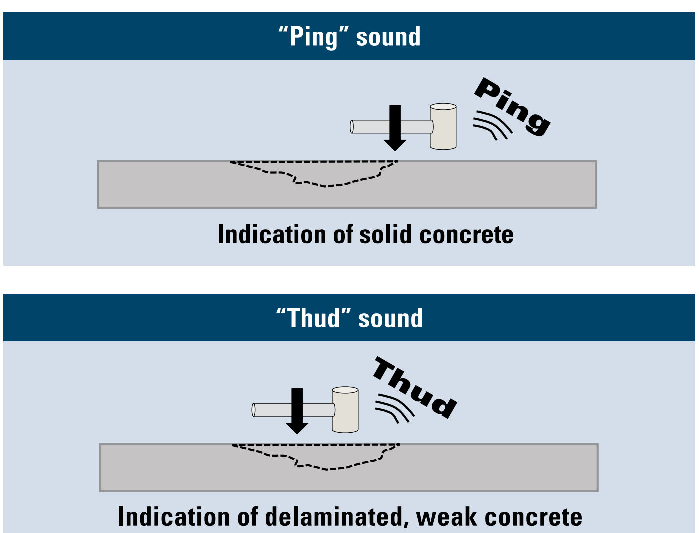


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Figure 5. Sounding a concrete pavement

Step 2: Concrete Removal

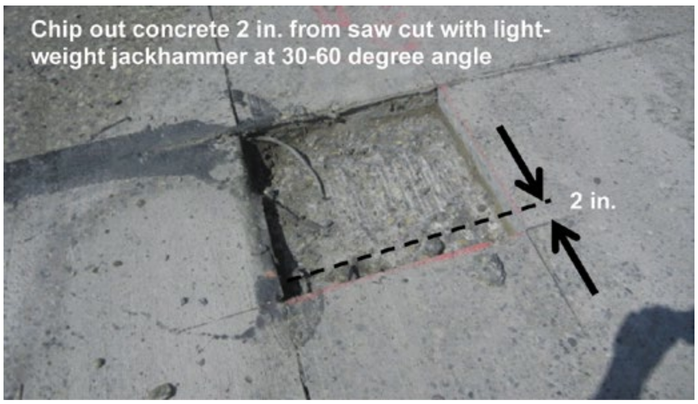
The second step of the construction process is the removal of the unsound material. It is important to remember that PDRs should be limited to no more than half of the slab thickness. The removal procedure should not expose any embedded dowel bars or tie bars, since these bars are placed at the mid-depth of the slab. If bars are encountered, the repair should be converted to a full-depth repair. If it becomes clear after removal that the deteriorated concrete extends deeper than half the depth of the slab, the repair should also be converted to a full-depth repair.

Deteriorated concrete should be completely removed from the existing pavement by sawing and chipping, chipping only, or milling.

When removing concrete by sawing and chipping, a 2 in. deep cut is made, followed by the removal of the unsound concrete using a light jackhammer (15 to 30 lb) to produce an angle between 30° and 60°. This creates a roughened surface that promotes bonding of the repair material to the existing sound concrete. Figure 7 shows an area of concrete removed by sawing.

When deteriorated concrete is removed by chipping only, the area is not sawed prior to removal by jackhammers. Removal by chipping is shown in Figure 8.

Another removal method includes the use of a milling machine with cutting heads of 12 to 18 in. in width. A milled repair area is shown in Figure 9.



Kevin McMullen, Wisconsin Concrete Pavement Association, from Frentress and Harrington 2012, CP Tech Center

Figure 7. Removal by sawing

John Donahue, MoDOT, used with permission

Figure 8. Removal by chipping only

Kevin McMullen, Wisconsin Concrete Pavement Association, from Frentress and Harrington 2012, CP Tech Center

Figure 9. Milling along a longitudinal joint

Common milling heads used in the industry include the V head, the rounded head, the tapered edge, and the vertical edge. Removal by milling can be completed with nine-ton milling machines as well as milling head attachments to skid steer equipment. Figure 10 shows the resulting removal areas from various milling head types and typical milling equipment.

V head and tapered/vertical edge milling heads: Daniel P. Frentress, Frentress Enterprises LLC, from Frentress and Harrington 2012, CP Tech Center; Rounded head: Kevin McMullen, Wisconsin Concrete Pavement Association, from Frentress and Harrington 2012, CP Tech Center; Illustrations and machines: Snyder & Associates, Inc., used with permission

Figure 10. Milling head types

The final step before preparing the repair area includes sounding the removal area to ensure that all deficient concrete has been removed, regardless of the removal method used. This process is shown in Figure 11.

Step 3: Repair Area Preparation

Following the removal of the concrete, the surface of the repair area must be prepared to provide a clean, roughened surface for the development of a good bond between the repair material and the existing slab. Dry sweeping, media blasting, and compressed air blasting are normally sufficient for obtaining an adequately clean surface. Figure 12 shows examples of media and air blasting.

Snyder and Associates, Inc., used with permission

Figure 11. Sounding the removal area

John Donahue, MoDOT, used with permission

Figure 12. Media blasting (top) and air blasting (bottom) of PDR area

High-pressure water blasting can also be used, followed by air blasting for final cleaning. It is important that all slurry be removed prior to the placement of the repair material. If any loose material (e.g., dust, asphalt, or slurry) is present, the surface should be cleaned again. If there is a delay between the preparation/cleaning operation and the placement of the repair material, the surface of the repair should be cleaned again.

Step 4: Restoring the Joint or Crack

A common cause of failure for PDRs at joints is excessive compressive stresses on the repair material. If a PDR is placed without restoring the working interface (joint or crack), the PDR will mostly likely fail due to the point-bearing compressive forces created when the slabs expand. Two methods can be used to restore the working joint or crack interface: (1) use of a compressible relief material or (2) sawing.

When the compressible relief method is used, a preformed compressible insert is placed between the new concrete and the adjoining slab (if deterioration is on one side of a joint) or directly in the joint or crack (if restoring a joint or crack). The latter case is shown in Figure 13. The compressible relief material is typically a strip of polystyrene, polyethylene, asphalt-impregnated fiberboard, waxed cardboard, or other compressible material.

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Figure 13. Placement of compression relief material

The compression relief material must be placed so that it prevents intrusion of the repair material into the joint or crack opening. Failure to do so can result in the development of compressive stresses at lower depths that will damage the repair. It is recommended that the compression relief material extend 0.25 to 1 in. below the deepest removal depth for stability and extend beyond the repair boundaries.

In lieu of using a compression relief material, some agencies allow for the use of sawing to reestablish a joint. If sawing is used, the sawcut must go through the entire thickness of the repair and be made as soon as the repair material has gained sufficient strength to permit sawing without significantly raveling the concrete. Timing is critical in the sawing operation. If sawing occurs too late, cracks may form within or around the edges of the patch, compromising its longevity.

Step 5: Bonding Agent Application

If a bonding agent is used, it must be applied just prior to placement of the repair material. Cement grouts are commonly used, but epoxy grouts may be used when early opening times are required.

The existing surface should be in a saturated surface-dry condition prior to the application of cement grouts. When epoxies or other manufactured grouts are used, the manufacturer's directions should be followed. Thorough coating of the bottom and sides of the repair area is essential. Successful applications have been completed with a soft brush for epoxy grouts and with a stiff bristle broom for cement-based grouts. Excess grout or epoxy should not be permitted to collect in pockets. The grout should be placed immediately before the repair material is placed so that the grout does not dry. If the bonding agent dries, it will need to be removed by media blasting, and fresh material must be reapplied before continuing. Figure 14 shows the application of a cement grout material to the existing concrete of a PDR area.

Snyder and Associates, Inc., used with permission

Figure 14. Cement-based grout application

Step 6: Repair Material Placement

Repair Material Mixing

Small drum mixers, paddle-type mixers, or mobile mixers are typically used to produce the repair material mixture. Based on trial batches, repair materials may be weighed and bagged in advance to facilitate the batching process. For long joint/crack repairs, ready mix or mobile mixers can also be used to produce the required amount of material in an efficient manner (Frentress and Harrington 2012), as shown in Figure 15.

Careful observation of mixing times and water content for prepackaged rapid-setting materials is important because of their quick-setting nature. Mixing longer than needed for good blending reduces the already short time available for placing and finishing the material (Frentress and Harrington 2012). For polymer-based repair materials (especially hot-applied materials), specialized mixing equipment is required to produce consistent mixtures (Ram et al. 2019).

Placement and Consolidation of Material

Concrete and most rapid-setting proprietary repair materials should not be placed when the air temperature or pavement temperature is below 40°F. Additional precautions, such as the use of warm water, insulating covers, and longer cure times, may be required at temperatures below 55°F.

Effective consolidation of the repair materials is critical and will help to avoid premature failures. Consolidation is typically provided by using an internal vibrator with a head diameter of 1 in. or less.

Kevin McMullen, Wisconsin Concrete Pavement Association, from Frentress and Harrington 2012, CP Tech Center

Figure 15. Placement of PDR material on a long joint using a mobile concrete truck

The placement and consolidation procedure begins by slightly overfilling the area with repair material to allow for a reduction in volume during consolidation. The vibrator is held at a slight angle (15° to 30°) from vertical and is moved through the repair to consolidate the entire repair area. As with conventional concrete placement, the vibrator should not be used to move material from one place to another within the repair because this may result in segregation. Adequate consolidation is achieved when the mixture stops settling, air bubbles no longer emerge, and a smooth layer of mortar appears at the surface. On very small repairs, the mixture can be consolidated using hand tools. Figure 16 shows the consolidation of PDR material.

Screeding and Finishing

PDRs are usually small enough that a stiff board can be used to screed the repair surface and make it flush with the existing pavement. The surface of the concrete should be floated from the center toward the perimeter of the repair to establish contact and enhance bonding to the existing slab, as illustrated in Figure 17. When finishing a patch area, the repair material should be floated just enough to ensure a flat surface, and then the finisher should move on to the next area to minimize the potential of the bonding agent drying. PDRs cover a small area and have little effect on surface friction but are often textured to match the surrounding slab as much as possible.

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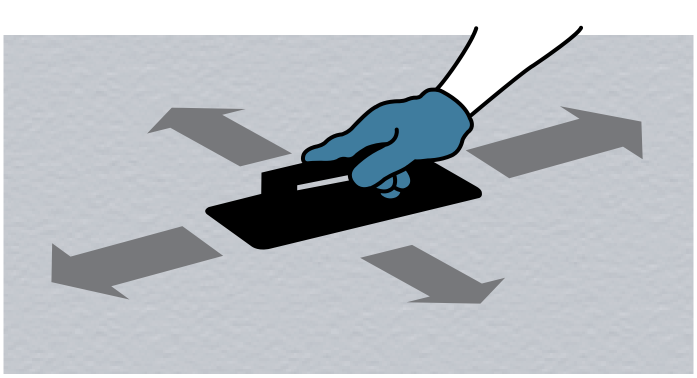
Figure 16. Consolidation of PDR material using a vibrator



CP Tech Center

Figure 17. Finishing a PDR from the center to the outside perimeter

As previously discussed, if the sawing method is used to restore the working joint or crack interface, a relief cut should be made in the patching material in a timely fashion to reestablish the joint before cracking occurs. This cut should be made through the full thickness of the PDR plus 0.25 to 1 in. (Frentress and Harrington 2012).

As soon as feasible after the PDR has been placed, it is recommended to apply cement grout to the perimeter edges of the repair area to form a moisture barrier, as shown in Figure 18. Typically, the bonding agent grout is used for this step. Alternatively, in lieu of grout, the runouts can be sealed with the material used to seal the adjacent joint or crack.

Step 7: Curing

Because PDRs have a large surface area in relation to their volume, they can lose moisture quickly. For this reason, curing is an important component of the construction process and must be conducted effectively in order to prevent the development of shrinkage cracks, which may lead to premature failure of the repair.

Curing Methods

For concrete materials, the most common curing method is to apply a white-pigmented curing compound as soon as the bleed water has evaporated from the repair surface. Some agencies require that curing compound be applied to repairs at 1.5 to 2 times the normal application rate. Moist burlap and polyethylene may also be used for curing, and in cold weather the use of insulating blankets or tarps may be required to help retain heat and thereby ensure strength development. The curing of proprietary repair materials should follow the manufacturer's recommendations. Figure 19 shows different types of curing.

Snyder and Associates, Inc., used with permission

Figure 18. Application of grout to the outer perimeter of the patch area

Snyder and Associates, Inc., used with permission

Figure 19. Use of (a) curing agent and (b) insulating blankets for PDRs

Snyder and Associates, Inc., used with permission

Figure 20. Sawing compression relief material and sealing a PDR

Step 8: Diamond Grinding (Optional)

PDRs may result in increased roughness if not finished properly. Some agencies may perform diamond grinding after PDRs are completed to obtain an appropriate level of smoothness. If diamond grinding is performed, it is recommended that the repairs be sounded to ensure that the repaired areas are solid and that no debonding has occurred.

Step 9: Joint Sealing

The final step in the construction of PDRs is joint sealing. Note that if a compressible insert was used to reestablish the joint or crack, the joint should be resawed at this point so that it accepts the joint sealer. After that, both joint faces should receive media blasting and air blasting followed by filling with a joint sealer. More information on joint resealing is provided in Chapter 10 of the *Concrete Pavement Preservation Guide* (Smith et al. 2022). Figure 20 shows the sawing and sealing of a PDR, and Figure 21 shows a PDR in Minnesota that has been in service for years.

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Figure 21. Completed PDR

Opening to Traffic

It is important that PDRs attain sufficient strength before being opened to traffic. Opening compressive strength values of 2,000 psi is appropriate given the confinement of this type of repair. Cylinders or beams cast in the field using the repair material can be tested for strength to determine the appropriate opening time. A recent review of state specifications and rehabilitation policies has recommended a compressive strength of 2,000 psi for both FDRs and PDRs (Collier et al. 2018).

Additional Resources on Partial-Depth Repairs

Concrete Pavement Rehabilitation Guide. Minnesota Department of Transportation. https://www.dot.state.mn.us/materials/concretedocs/concretepavementrepairguide/ConcreteGuide/story.html.

Concrete Pavement Preservation Guide, Third Edition. National Concrete Pavement Technology Center. https://www.intrans.iastate.edu/wp-content/uploads/2022/08/concrete_pvmt_preservation_guide_3rd_edition_web.pdf.

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Pavement Preservation Checklist Series #20: Partial-Depth Repair of Portland Cement Concrete Pavements. Federal Highway Administration. https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19048.pdf.

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