



PDHonline Course C509 (2 PDH)

Full-Depth Concrete Pavement Repair

Instructor: John Huang, Ph.D., PE and John Poullain, PE

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PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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1.0 Introduction

Full-depth repair (FDR) is a concrete pavement restoration technique that restores isolated slab structural integrity and rideability and deters further deterioration, thus extending the pavement's service life. FDR is suitable for a wide variety of distresses that are beyond partial-depth repair, such as transverse & longitudinal cracks, corner breaks, deteriorated joints, D-Cracking, blowups, and punch-outs. FDR involves making lane-width, full-depth saw cuts to remove the deteriorated concrete down to the base; repairing the disturbed base; installing load-transfer devices; and refilling the excavated area with new concrete. The cost of FDR is largely dependent upon the size, number, and location of repair areas, as well as the type of concrete mix used.

2.0 Project Selection

2.1 FDR Limitations

- Use partial-depth repair instead of FDR for spalls limited to the top one-third of the slab.
- Full depth repairs should be used for rigid pavements with deterioration limited to isolated slabs, not widespread over the entire project length.
- Structurally deficient pavements may require a structural enhancement, such as an overlay or tied rigid shoulders, instead of one or more isolated, full depth repairs.
- If the pavement has a severe material problem, such as reactive aggregate or alkali-silica reaction (ASR), FDR will only provide temporary relief from roughness and further deterioration caused by spalling. Continued deterioration of the original pavement is likely to result in the redevelopment of spalling and roughness.
- Pavements with base course or subgrade problems, as indicated by differential settlements or load-deflection tests, are not good candidates for isolated full depth concrete repairs.

2.2 Distress Types

Transverse cracking of medium and high severity are recommended for FDR. Some cracks that extend through the depth of a slab can begin moving and functioning as joints. Transverse cracks that function as joints are often called "working cracks" and are subject to about the same range of movement as transverse joints. Working cracks develop and deteriorate from one or more of these causes:

- Lock-up of the dowel bars in a nearby joint
- Rupture or corrosion of steel in jointed-reinforced slab
- Poor joint spacing
- Loss of aggregate interlock along the crack face
- Inadequate joint sawing
- Excessive curling and warping of slabs
- Lack of subgrade support

Transverse cracks that remain tight (hairline cracks) and do not extend to the bottom of a slab do not require any special treatment, (e.g., plastic shrinkage cracks). Most plastic shrinkage

cracks remain very tight and extend into the slab about 25-50 mm (1-2 inch). These hairline cracks do not allow much water to penetrate the pavement substructure and rarely deteriorate or influence the serviceability of a concrete pavement. Low severity working cracks with poor load transfer may be repaired by restoring the load transfer using dowel bars (See Publication FHWA-SA-97-103 for details). Medium to high severity distress working cracks are good candidates for FDR.



Figure 1. Transverse crack

Longitudinal cracking of high severity warrants FDR. A high severity condition indicates that a crack is greater than 12 mm (0.5 inch) wide, spalling extends more than 150 mm (6 inch) from the crack, and faulting is greater than 12 mm (0.5 inch). If the condition is less severe, other CPR procedures, such as partial depth repairs, cross-stitching, retrofit dowel bars, or sawing and sealing are sufficient.



Figure 2. Longitudinal crack

"D" cracking is a pattern of cracks caused by the freeze-thaw expansive pressures of certain coarse aggregates. The disintegration and spalling associated with these stresses normally begins near the joints as a result of the higher moisture levels necessary for the course

aggregates to expand in volume during freezing. Medium and high severity "D" cracking could warrant full depth repair. However, like for any other materials related distress, FDR only provides a temporary treatment.



Figure 3. "D" cracking

Shattered Slabs & corner breaks develop in slabs receiving marginal support from the subbase or subgrade. Any heavy loads that pass over these slabs cause large vertical deflections and high tensile stresses in the concrete. Over time the unsupported slab will pump subbase or subgrade fines out from beneath the slab, leading to voids and eventual cracking over the uneven support. Shattered slabs also may result from frost heave or swelling soil problems. Shattered slabs and corner breaks are good candidates for using FDR.

Punchouts in continuously reinforced concrete pavements (CRCP) are candidates for FDR as they represent a structural failure of the pavement. They form after many load cycles when the longitudinal steel ruptures along the faces of two closely spaced cracks, usually less than 0.6 m (2 ft) apart.



Figure 4. Punchout

Blowups occur in hot weather at transverse joints or cracks which do not allow sufficient expansion of the concrete slabs. The insufficient expansion width of joints is usually caused by

infiltration of incompressible material into the joint. Blowups of any severity warrant FDR due to the localized disruption to pavement integrity and the potential safety hazard.



Figure 5. Blowup

Distress	Severity
Jointed Concrete Pavement (JCP)	
Blowup	Low
Corner Break	Low
D-Cracking	Medium
Deterioration	Adjacent to Existing Repair Medium
Joint Deterioration	Medium (with faulting 6mm (0.25 in))
Spalling	Medium
Reactive Aggregate	Medium
Transverse Cracking	Medium (with faulting 6mm (0.25 in))
Longitudinal Cracking	High (with faulting 12mm (0.5 inch))
Continuously Reinforced Concrete Pavement (CRCP)	
Blowup	Low
Punchout	Medium (with faulting 6mm (0.25 in))
Transverse Cracking (Steel Rupture)	Medium (with faulting 6mm (0.25 in))
Localized Distress	Medium
Construction Joint Distress	Medium
D-cracking	High
Longitudinal Cracking	High (with faulting 12 mm (0.5 in))
Repair Deterioration	High

Table 1. General distress criteria for full .depth repair

2.3 Pavement Type

2.3.1 Jointed Concrete Pavement (JCP)

JCP has transverse joints spaced at regular intervals to control temperature-induced contraction and expansion in the concrete. Smooth dowel bars are used at the transverse joints for load transfer between slabs. JCP also has longitudinal joints to control random longitudinal cracking; these joints are connected with tie bars.

JCP typically requires far more repairs at the joints themselves than between them. Some pavements develop mid-panel cracks that deteriorate under repeated heavy traffic loading. Locking of the doweled joints will accelerated this crack deterioration by forcing open the mid-panel cracks. These cracks soon lose their aggregate interlock under repeated heavy traffic loadings. Some pavements may have joints with very little deterioration but one or more mid-panel cracks in each slab opened wide and essentially acting as joints. The types of JCP distresses that can be successfully addressed through FDR are described in Table 1.

For most FDR of jointed pavements, doweled transverse joints are essential for load transfer. The design of the retrofit dowel layouts includes the number of devices, diameter, and spacing of the dowel bars. Factors such as large diameter dowel bars and dowel bars spaced closely together will serve to reduce the bearing stresses of the dowels on the concrete. Lower dowel bearing stress reduces the development of dowel looseness, which reduces the potential for faulting. For interstate-type pavements, at least four to five dowels should be located in the wheel path to provide effective load transfer (Figure 5). The use of 38 mm (1.5 inches) diameter dowels is recommended because they provide the most cost effective load transfer capacity. It is expected that concentrating retrofitted dowels in the wheel path should provide adequate performance for the shorter service life expected from a rehabilitated pavement.

2.3.2 Continuously Reinforced Concrete Pavements (CRCP)

CRCP is a Portland cement concrete (PCC) pavement that has continuous longitudinal steel reinforcement and no intermediate transverse expansion or contraction joints. The pavement is allowed to crack in a random transverse cracking pattern and the cracks are held tightly together by the continuous steel reinforcement.

Most full-depth repairs on CRCP will be placed at the areas exhibiting punchouts and other localized distresses. FDR may also be required at medium and high severity transverse cracks in which the steel has ruptured. The type of CRCP distresses that can be addressed through FDR are listed in Table 1.

For full-depth patching in continuously reinforced pavements, new steel bars are necessary to maintain the continuity of the reinforcing bars that run longitudinally through the pavement. The reinforcing bars provide load transfer at the closely spaced cracks by keeping the cracks from opening. Reliable methods to attach the new bars to the salvaged lengths of the old bars

include tied splices, mechanical fastened splices and welded splices. The bars should rest on supporting chairs if the patch is longer than 1.25 m (4 ft) to avoid bending, sagging or stressing the splices. Compared with tied splices, mechanical couples do not require as much old steel exposure. Most mechanical couples require about 25-50 mm (1-2 inch) overlap. A single 6 mm (0.25 inch) weld requires 200 mm (8 inch) lap length, and a double weld requires 100 mm (4 inch) lap length. To avoid buckling, it is better to weld a separate new bar to each exposed old bar, then use a tied splice to connect the new bars near the center of the patch.

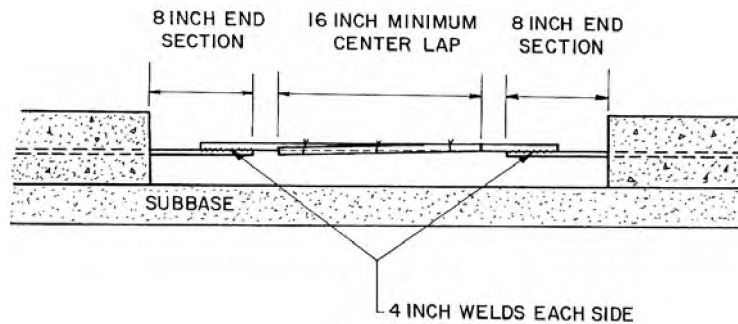


Figure 6. CRCP full depth repair welded splice details

To save construction time, some agencies avoid splicing to the old steel by drilling holes and anchoring all new reinforcing bars into the old concrete. This procedure makes the repair faster because it does not require any hand chipping to expose the lap length of existing reinforcing bars. Holes for reinforcing bars are drilled into the transverse faces to the depth specified for a wire-tied over.

2.4 Repair Area Boundaries

Experienced personnel should conduct field survey to identify and mark the distressed areas. Personnel should perform this survey as near as possible to the time of construction and should include additional distressed areas that have occurred since the previous pavement inspection. Engineering judgment, coring, load-deflection studies, and sounding techniques such as striking the concrete surface with a hammer, steel rod, or by dragging a chain, should be used to define the extent of the deterioration beneath the surface and determine repair boundaries. Pay special attention to distress caused by "D" cracking because of the difficulty in determining its extent beneath the slab surface.

Guidelines for locating repair boundaries are provided below:

- Patches must be of sufficient size to eliminate rocking and longitudinal cracking of the patch. Minimum repair length is 1.8m (6 ft) for repairs provided with mechanical load-transfer devices, and 2.4 - 3m (8 - 10 ft) for repairs with aggregate interlock joints.
- All repairs should be full-lane width. Avoid partial-lane-width repairs due to their relative instability.
- Minimum distance from the FDR joints to the nearest transverse crack or joint is 1.8m (6 ft).

- A boundary that would fall at an existing doweled transverse joint should be extended 0.3 m (1 ft) to include the existing joint.
- If distress is present on only one side of an existing nondoweled joint, that joint may be used as a boundary.
- Reinforcement is needed in JRCP where the patch length is longer than 4.6m (15 ft). It may be more economical to place additional doweled transverse joints at 4.6m interval than to place reinforcement.

On multiple-lane highways, it is generally not necessary to match joints in adjacent lanes, as long as:

- The minimum length requirements are met.
- All of the deteriorated area has been included within the repair boundaries.
- A separation fiberboard has been placed along the longitudinal joint.
- The patch is not tied to the adjacent lane

However, if the distressed areas in both lanes are similar and both lanes are to be repaired, aligning repair boundaries to avoid small offsets and to maintain continuity may be desirable.

Combining two smaller patches into one large patch often can reduce repair cost. When two patches will be closer than the distances as shown in Table 2, it is probably more cost-effective to combine them into on large patch. However, the longest patch length should not exceed the pavement's longest slab.

Slab Thickness mm (in)	PATCH (LANE) WIDTH m (ft)			
	2.7 (9)	3.0 (10)	3.3 (11)	3.6(12)
175 (7)	5.2 (17)	4.6 (15)	4.3 (14)	4.0 (13)
200 (8)	4.6 (16)	4.0 (13)	3.7 (12)	3.4 (11)
225 (9)	4.0 (13)	3.7 (12)	3.4 (11)	3.0 (10)
250 (10)	3.7 (12)	3.4 (11)	3.0 (10)	2.7 (9)
275 (11)	3.4 (11)	3.0 (10)	2.7 (9)	2.4 (8)
300 (12)	3.0 (10)	2.7 (9)	2.4 (8)	2.4 (8)
375 (15)	2.4 (8)	2.4 (8)	2.1 (7)	2.0 (6)

Table 2. Maximum cost effective distance between two repairs

2.5 Material Selection

Repair materials are selected based on available curing time, climatic conditions, cost, equipment requirements, mixing and placing time, desired service life, and the size and depth of repairs. Material properties, such as strength gain, modulus of elasticity, bond strength, scaling resistance, sulfate resistance, abrasion resistance, shrinkage characteristics, coefficient of thermal expansion, and freeze-thaw durability, should also be included in the selection process. Repair materials must be compatible in strength and volume stability with the existing pavement.

The concrete mixture design should be based on the available lane closure time. Nowadays, State highway agencies often want to open FDR as soon as possible to alleviate traffic

congestion. The shorter the time available before opening to traffic, the more rapid the strength gaining and curing of the concrete must be, and also the more expensive the concrete becomes.

Typical FDR operations utilize concrete mixes containing 390-502 kg/m³ (658-846 lbs/yd³) of either cement Type I or Type III cement. A set-accelerator is frequently used to permit opening in 4 to 6 hours. Without the accelerator, these mixes allow opening in 12 to 72 hours. The use of proprietary concrete mixes is necessary to achieve opening times in as little as 2 hours. Using insulating blankets (or boards) during the first few hours after placement also can improve the strength development of any mix. Regardless of the mix design used, the concrete mixture for FDR should have the following properties:

- 6.5 ± 1.5 percent of entrained air in the concrete (less air may be permissible in nonfreeze areas).
- 50 to 100 mm (2 to 4 inch) slump

Mixes using Type III cement may require slightly more mix water than a similar mix with Type I portland cement. However, too much extra water may cause the concrete to suffer from high shrinkage during curing. A water-reducing admixture will disperse cement particles and reduce the water necessary for workability.

Calcium chloride (CaCl₂) or another accelerating chemical admixture is recommended for use as accelerator in the patching concrete, provided that it is added as specified. It should be noted that initial set may occur within 30 minutes on warm days, therefore, use only 1 % of calcium chloride by weight of cement when air temperature exceeds 27° (80°). Up to 2% is acceptable in lower temperatures. For on-site mixing, add calcium chloride in liquid form to the mixer before other admixtures are added (except the air-entraining admixture). When using calcium chloride, considerations should be given to the remaining service life of the adjacent pavement and weather dowel bars and reinforcing steel are coated.

If calcium chloride or other accelerating admixture are being added at the plant and the concrete consistently arrives at the site too stiff, then the calcium chloride should be added at the site. If, after the addition of calcium chloride at the site, the concrete is still too stiff, the ready-mix plant operator should be notified to increase the slump an appropriate amount, up to 150 mm (6 inch).

Chemical admixture may be added to the concrete at the batch plant if the air temperatures are moderate (less than 20°[68°F]) and the batch plant is less than 15 minutes from the project site. Non chloride accelerators are recommended for CRCP and JRCF full-depth repairs.

3.0 Construction

3.1 Define Repair Boundaries

Mark the repair boundaries as determined by the previous survey. Additional areas of distress that have occurred since the initial survey should be included. If the project plans contain partial-depth repairs, the project specifications should include a special provision that provides the engineer freedom to change some partial-depth repair to full-depth repairs.

3.2 Saw Old Concrete

The purpose of sawing is to separate the repair section from adjacent concrete & shoulder materials using full-depth cuts. After sawing, an immediate concern is that the isolated section has no load-transfer capacity. As such, traffic running over the section can pump or punch into the subbase, causing unnecessary damage. Therefore, after sawing is done, concrete removal should start within 2 days.

It is preferable to use diamond-bladed saws for full-depth transverse cuts. Diamond-bladed saws produce straight, smooth, vertical faces that improve the accuracy of dowel bar placement. Any interior or centerline longitudinal joint also requires a full-depth cut through the existing joint reservoir. To avoid spall damage during removal, the sawing operation should be continued through the joint. This is to ensure that the base of the blade reaches the intersection with the transverse boundary cuts. If diamond-bladed saws bind during hot weather, then the concrete slabs are in compression from thermal expansion. One way to cure this problem is to saw at night during cooler temperatures, or provide pressure-relief cuts with carbide-toothed wheel saws. The contractor may elect to use one or more wheel saw cuts within each patch area to give removal equipment space to grasp the old concrete.

3.2.1 CRCP: Sawing of Patching Boundaries

The outer boundaries of repair should be cut, partial-depth above the steel reinforcement, with a diamond blade saw. If any of the steel reinforcement is sawed through, the length of the patch must be increased by the lap length required (Figure 8 and 9). The partial depth cut should be located at least 460 mm (18 inches) from the nearest tight transverse crack. They should not cross an existing crack, and adequate room should be left for the required lap distance and center area.

After the partial-depth cuts, two full-depth sawcuts are then made at a specified distance in from partial-depth cuts. The distance depends on the method of lapping used to connect reinforcement. The recommended distance is 610 mm (24 inches) for tied laps, and 200 mm (8 inches) for mechanical connections or welded laps. This distance may be reduced depending on the required lap length.

3.3 Remove Repair Section

As mentioned before, concrete removal should start no later than 2 days after sawing. There are two basic methods of removing deteriorated concrete from the repair area:

3.3.1 Lift-out

It is preferable to lift the deteriorated concrete whenever possible. Lifting the old concrete imparts no damage to the subbase and is usually faster and requires less labor than any method that breaks the concrete before removal.

The most common lift-out method uses a steel chain connected to lift pins. Operators drill at least two vertical holes through the repair section, then insert one lift pin into each hole. The operators fasten the chain to a crane or front-end loader that is capable of lifting the repair section vertically, then swinging it onto a flatbed or dump truck for removal from the site. Other lift equipment includes forklifts, vertical bridges, lateral-pressure lifts and a torque claws.

Damage during lift-out is not entirely avoidable, and it will probably be necessary to extend the repair if the lifting operation chips the remaining concrete. Damage most often occurs if the repair section swings during the lift and chips the faces of the remaining concrete. Making a wheel cut within the patch area can provide some additional space for lateral movement.



Figure 7. Lift out

3.3.2 Breakup

Sometimes concrete joints or cracks are so deteriorated that it is unsafe to remove them by lift-out. In these cases it is necessary to break the deteriorated concrete into small fragments for removal by backhoe and hand tools. The drawback to this method is that it often damages the subbase and requires more repair preparation than a lift-out operation. The damage occurs

because the break hammer pushes pieces into the subbase, which requires the backhoe operation to dig into the subbase surface to scoop out broken concrete.

When using mechanized breaking equipment like drop hammers or hydraulic rams, operators must exercise control on the equipment's break energy. Operators should begin breaking the concrete in the center of the removal area and move outward toward buffer cuts. Buffer cuts are made about 0.3m (1 ft) away from the perimeter saw cuts within the patch. The operator should reduce the break energy (drop height) before starting on the area outside the buffer cuts. Then there will be less chance of damaging concrete beyond the patch perimeter.



Figure 8. Breakup via drop hammer

3.4 Prepare the Patch Area

After removing the old concrete and loose material, the area is ready for subbase preparation. If removing operations damage the subbase, it may be necessary to add and compact new subbase material. Ideal backfill materials can reach optimum compaction with small plate compactors that can maneuver in the confined patch area. Use vibratory plate compactors that have a centrifugal force rating from 17 to 27 kN (4000 to 6000 lb). If the repair area fills with rainwater after concrete removal, the water should be pumped out or drained through a trench cut at the shoulder before repairing the subbase.

3.5 Transverse Joints - Dowels

Dowel bars are smooth steel bars used at transverse joints that provide a mechanical connection between slabs without restricting horizontal joint movement. They provide load transfer capacity between adjacent slabs as surface vehicles move from one slab to the next. This reduces joint deflection and stress in the approach and leave slabs. For FDR, at least one doweled joint should be installed to allow free horizontal movement of the repair area.

3.5.1 Drilling Dowel Holes

Automatic dowel drilling rigs are preferable to single, hand-held drills. It is difficult to drill consistent holes using hand-held drills because they are heavy and do not have an alignment guide or jig. Dowel drill rigs contain one or more drills attached parallel in the rig's frame. The frame acts as the alignment jig to control drill alignment and wandering. However, single, frame-mounted or hand-held drills are necessary where there is not enough room for the multiple-drill rigs.

There are several varieties of drill rigs. The difference depends on their mount and whether they reference the slab or subbase. The three basic types of drill rigs are as following:

- Self propelled, subbase-reference rig
- Self propelled, slab-reference rig
- Boom-mounted, slab reference rig

Standard pneumatic or hydraulic percussion drills provide acceptable drilling results for dowel holes. Both drill a typical 225 mm (9 inch) hole in about 30 seconds. Standard pneumatic drills cause slightly more spalling on the slab edge when starting to drill because they impart more energy than hydraulic drills. However, this should not affect dowel performance when good installation techniques are followed.

Hole diameter depends on the anchoring material. Cement-based grout requires a hole diameter 5-6 mm (0.20-0.25 inch) larger than the nominal outside dowel diameter. Epoxy anchoring materials only require a hole diameter about 2 mm (1/16 inch) larger than the nominal dowel diameter.

3.5.2 Anchorage

Anchoring the dowels is critical to the performance of full depth repairs. The following procedure is recommended:

1. Remove debris & dust from dowel holes with compressed air. Debris & dust prevent the epoxy or non-shrink grout from bonding to the concrete around the hole perimeter. Insert the air nozzle to the back of the hole to force out all dust and debris. Always check the air for oil and moisture contamination from the compressor. Oil & moisture prevents good bonding. The compressor should deliver air at a minimum of 3.4 m³ per minute (120 ft³/min) and develop 0.6 MPa (90 psi) nozzle pressure. If holes are wet, allow them to dry before installing dowels.
2. Place quick-setting, non-shrinking cement grout or epoxy resin in the back of the dowel hole. For grout, use a flexible tube with a long nose that places the material in the back of the hole to ensure that the anchoring material will flow forward along the entire dowel embedment length during insertion. This also decreases the likelihood of leaving voids between the dowel and the concrete. For non-shrink cementitious grouts, a caulk-gun-

type tool is preferable. Epoxy-type materials can be placed using a cartridge with a long nozzle that dispenses the material to the rear of the hole.

3. Optionally, place a grout retention disk (a thin donut-shaped plastic disk) over the dowel and against the slab face, as illustrated in figure 8-3. This prevents the anchoring material from flowing out of the hole and helps create an effective face at the entrance of the dowel hole (the location of the critical bearing stress). When metered properly, some anchoring material should be visible from the sides of the disk after installation. If no grout is visible, there may not be enough in the hole.
4. Insert the dowel into the hole while twisting it one full revolution to evenly distribute the material around the dowel's circumference. This ensures a uniform coating of the anchoring material over the dowel bar and prevents voids.
5. Lightly grease the protruding end of the dowel to facilitate horizontal movement.

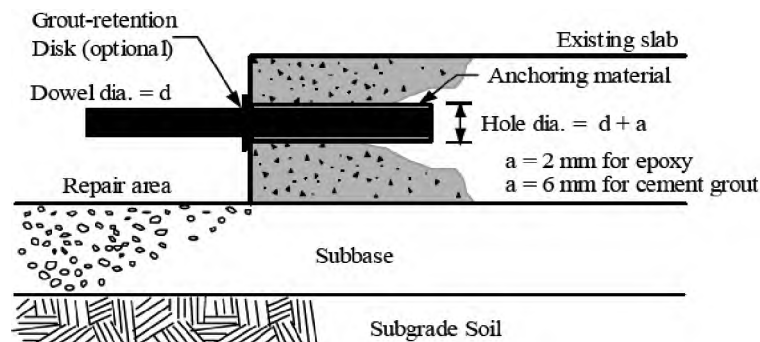


Figure 9. Dowel bar anchoring in slab face



Figure 10. Grout retention disk

3.6 Longitudinal Joints - Tie Bars

Tie bars are deformed rebars used along the longitudinal joint, usually 25 mm (1 inch) in diameter. Tie bars are anchored into the existing slab. These bars allow no horizontal movement of the joint and should be epoxy-coated to improve corrosion resistance. Although they may provide some minimal amount of load transfer, they are not designed to act as load transfer devices and should not be used as such.

Full slab replacements and repairs longer than 4.5 m (15 ft) require a tie system along the longitudinal joint. Drill and anchor tie bars or wiggle bolts using the same anchoring grout used for dowels. Either #10M (#3) to #20M (#6) deformed reinforcing bars or two-part threaded couples are acceptable in most specifications. Typically these are spaced along the longitudinal joint at 750 mm (30 inch).



Figure 11. Tie bars along a longitudinal joint

3.6 Prepare Longitudinal Joints

For repairs less than 4.5 m (15 ft) long, place a bond breaking board along any longitudinal face with an existing concrete lane or concrete shoulder. A thin, 5 mm (0.20 inch) fiberboard or similar material should match the repair area depth and length and sit flush with the longitudinal face of the repair. The bond breaker allows the patch and the old concrete to move independently.

3.7 Place New Concrete

Place concrete into the repair area from ready-mix truck or other mobile batch vehicles. Distribute the concrete evenly to avoid the need of excessive shoveling. Use care to attain good concrete consolidation around dowel bars and along the patch perimeter. Honeycombing reduces concrete strength and durability. Use vertical penetrations of a standard spud vibrator

to adequately consolidate the patching concrete. Do not drag the vibrator through the mix this may cause segregation and loss of entrained air.

Careful control of mixing times and water content is very important because of the quick setting nature of the materials used in FDR. Do not add extra water to the wet concrete in order to achieve “greater workability,” because this may reduce strength and increase shrinkage.

3.8 Finishing & Texturing

A critical aspect of full depth repairs is obtaining a level finish of the repair area with the surrounding pavement. Both vibratory screeds and 3m (10 ft) straightedges are good tools to strike off and finish a repair surface. It is better to pull the finishing tool across the pavement with the blade parallel to the longitudinal joint for short repairs (<3m (10 ft)). The tool rests on the old concrete on both sides of the repair and follows the surface of the adjoining slabs. The patch surface will then match the surrounding surface profile. For patches longer than 3m (10 ft), finish the surface with longitudinally with a vibratory screed. A good finishing technique can develop an adequate transition between the patch and old concrete. In some cases, a ride specification comparable to the local ride specification may be needed for CPR projects. Patched pavements that do not meet a specified ride requirement will require correction by diamond grinding.

Texture the patch surface so that it is similar to the surface of the adjacent pavement. Burlap drag and transverse tined surfaces are common.

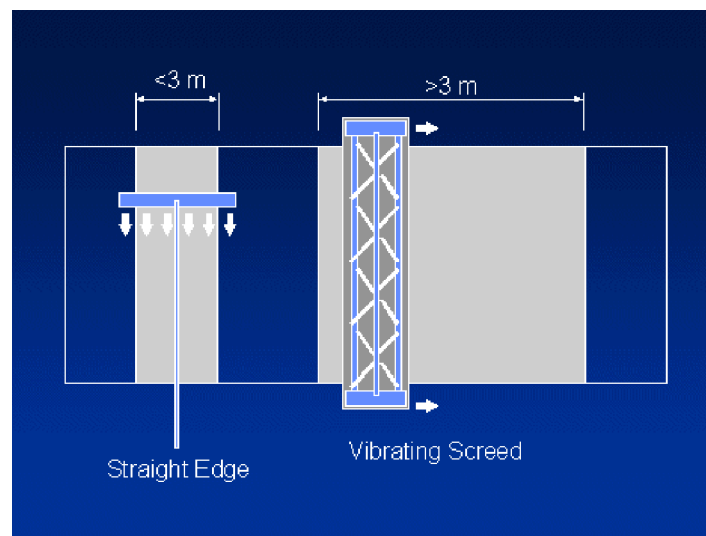


Figure 12. Straightedge and vibrating screed

3.9 Curing

Curing is important to help the concrete achieve good strength and durability. Adequate attention to curing will reduce the development of shrinkage cracking and promote more complete cement hydration by preventing moisture loss from the concrete. Proper curing is even

more important when accelerating admixtures are used. The first few hours after pouring the concrete are the most critical for good curing. Therefore, apply the curing compound and insulation as soon as possible after finishing the surface.

In general, a liquid-membrane-forming curing compound is adequate as long as it is applied evenly and sufficiently. Use well-maintained pressure spraying equipment that will allow an even application. An application rate of about 5.0m²/L (200 ft²/gal) is sufficient.

In cold weather (<50F or 10C), the use of insulating blankets and tarps can accelerate hydration and promote higher early strength, thus allowing for earlier opening to traffic. Special care is required during the removal of insulation blankets, because rapid cooling of the pavement surface can cause pavement cracking.

In hot weather (>100F or 40C), the use of pigmented curing compounds is highly recommended over other curing procedures (e.g. moist burlap or polyethylene). Insulation blankets are not necessary in hot weather, and if used can result in concrete cracking.

3.8 Saw and Seal joint

Joint sealing at the patch boundaries reduces spalling and minimizes water infiltration. Both longitudinal and transverse repair joints must be sealed. Joints should be sawed or formed, sandblasted, and air blasted. A backer rod should be inserted and joint sealant applied. For longitudinal joints, hot-poured asphalt-rubber sealants are most commonly specified. For transverse joints; higher type sealants such as low-modulus silicone are commonly used.

Timing for sawing of intermediate joints is crucial. Sawing too early can lead to spalling along the cut or dislodging of aggregate particles; while sawing too late can result in random cracking in the repaired area.

3.10 Opening to Traffic

There are two methods to determine when to open FDR to traffic:

- Specified minimum strength
- Specified minimum time after completing placement

For most concrete pavement applications, it is preferable to measure the concrete strength to determine when it is acceptable for traffic. This is not always true for concrete repair, particularly where quick opening is critical. Most patch mixes fall into three categories for opening to traffic: 4 to 6 hour, 12 to 24 hour, and 24 to 72 hour (conventional) (Table 3). Small variations in air temperature also influence concrete strength development. Maturity meters, or pulse-velocity devices is preferable to a specified time requirement. An agency may stipulate that the repair attain a minimum strength before it may be open to traffic. Recommended minimum strength for traffic opening are :

- Compressive Strength: 13.8 MPa (2,000 lbf/in²).
- Modulus of Rupture: 2.1 MPa (300 lbf/in²) center-point loading, or 1.7 MPa (250 lbf/in²) third-point loading

For Mixes Using:	Typical Time to Opening Strength
Certain blended cements	2 - 4 hours
Sulfo-aluminate cements	2 - 4 hours
Type III cement with non-chloride accelerating admixture	4 - 6 hours
Type III cement with calcium chloride (CaCl ₂) accelerator	4 - 6 hours
Type I cement with calcium chloride (CaCl ₂) accelerator	6 - 8 hours
Type III cement with Type A water-reducing admixture	12 - 24 hours
Type I (air-entrained paving mix without fly ash)	24 - 72 hours

Table 3. Typical "Opening to Traffic" times for different PCC mixes