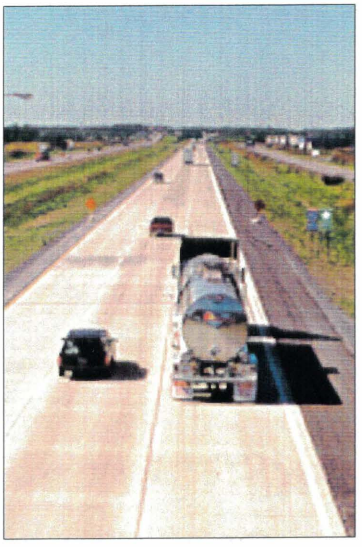
**Draft Interim Guidelines**

# Concrete Pavement Repair Manual

## ODOT Project No. 2133

Submitted to

**Oklahoma Department of Transportation
Oklahoma City, Oklahoma**



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# Table of Contents

# 1. Design of Full-Depth Repairs

The design of full-depth repairs in concrete pavement consists of four basic steps. Each step entails the consideration of various factors and adherence to certain accepted practices. The sections below present the important aspects of each design step.

## Step 1. Identification of Candidate Pavement Distresses

Table 1 lists the distresses and corresponding minimum severity levels for which full-depth repairs are warranted. Figure 1 illustrates a highly deteriorated transverse crack that is well suited for a full-depth repair.

Not clear on how to use

Table 1. General distress criteria for full-depth repair.

| Distress Type | Minimum Severity Level Required for Full-Depth Repair |
|---|---|
| **Jointed Plain & Jointed Reinforced Concrete (JPC & JRC) Pavement** | |
| Blowup | Low |
| Corner Break | Low |
| D-Cracking | Moderate |
| Deterioration Adjacent to Existing Repair | Moderate |
| Joint Deterioration | Moderate |
| Spalling | Moderate |
| Reactive Aggregate | Moderate |
| Transverse Cracking | Moderate |
| Longitudinal Cracking | High |
| **Continuously Reinforced Concrete (CRC) Pavement** | |
| Blowup | Low |
| Punchout | Moderate |
| Transverse Cracking (Steel Rupture) | Moderate |
| Localized Distress | Moderate |
| Construction Joint Distress | Moderate |
| D-cracking | High |
| Longitudinal Cracking | High |
| Repair Deterioration | High |

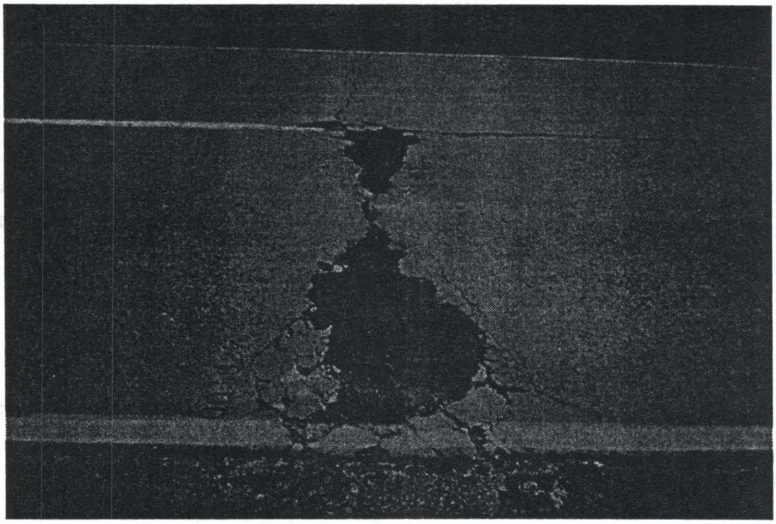

Figure 1. High-severity transverse crack.

## Step 2. Selection of the Appropriate Repair Boundary

➢ <u>General</u>

- Structural testing (i.e., deflection testing and coring) should be performed to provide information on the extent of deterioration in the distressed areas.
- Repair boundaries must be extended to beyond the limits of subbase voids (as detected by structural testing or sounding) or to at least 3 ft (0.9 m) beyond the boundaries of visible deterioration at the surface.

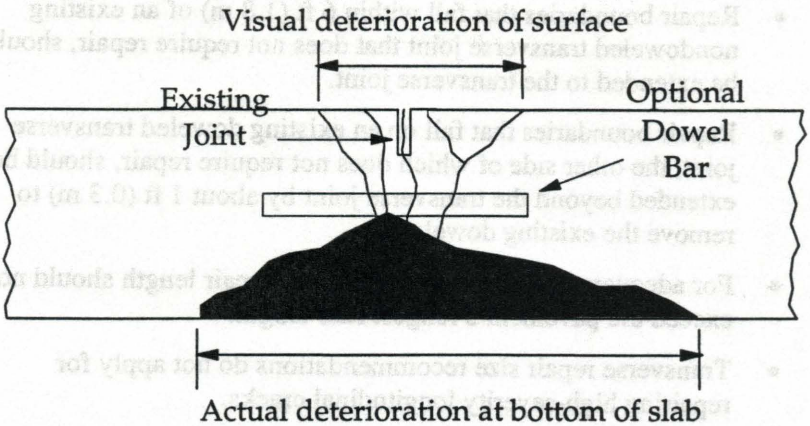


Figure 2. Illustration of potential extent of deterioration beneath a joint.

- Repair boundaries should be wide enough to remove all cracks and any accompanying distresses, such as spalls.
- Repair boundaries should be located off the wheelpath to avoid edge loads.
- Repair boundaries should be parallel, without irregular corners or shapes.
- All repair areas must clearly identified in the field using spray paint or other suitable marking materials.

JPC and JRC Pavements — Nomentlature

- Larger, highly distressed areas should be identified separately, since complete removal and replacement of the slab is generally the most cost-effective.
- Repair boundaries must be extended laterally the complete width of the lane.
- A minimum repair length of 6 ft (1.8 m) is required to satisfy performance criteria in jointed PCC using dowel bars.
- For nondoweled, jointed concrete pavement, a minimum repair length of 8 to 10 ft (2.4 to 3.0 m) is required.

- Repair boundaries that fall within 6 ft (1.8 m) of an existing nondoweled transverse joint that does not require repair, should be extended to the transverse joint.
- Repair boundaries that fall on an existing doweled transverse joint, the other side of which does not require repair, should be extended beyond the transverse joint by about 1 ft (0.3 m) to remove the existing dowels.
- For adequate performance, the longest repair length should not exceed the pavement's longest slab length.
- Transverse repair size recommendations do not apply for repairing high-severity longitudinal cracks.
- Longitudinal full-depth repairs should begin and end at existing transverse joints.

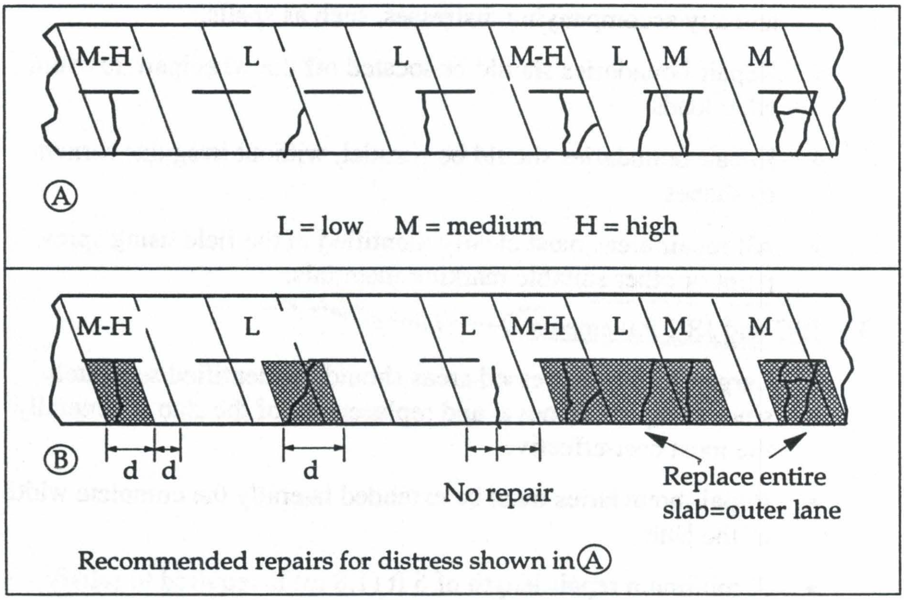


Figure 3. Repair recommendations for JPC pavements.

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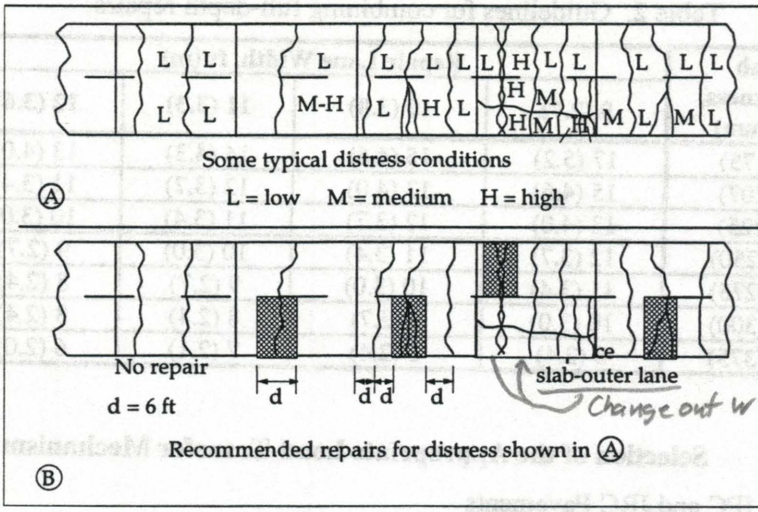


Change out whole slab ?

Figure 4. Repair recommendations for JRC pavements.

➢ <u>CRC Pavements</u>

- CRC pavements should have a minimum repair length of 6 ft (1.8 m) in areas containing tied steel and 4 ft (1.2 m) in areas containing mechanically connected or welded steel.
- A minimum repair width of 6 ft (1.8 m) is required.
- If the repair boundary falls on a crack, extend the repair beyond the crack by 6 in (152 mm).
- If the boundaries of two minimum-width repairs are within the distances noted in table 2, combine the two repairs into one large one.

Table 2. Guidelines for combining full-depth repairs.

| Slab Thickness, in (mm) | Repair Lane Width, ft (m) | | | |
|---|---|---|---|---|
| | 9 (2.7) | 10 (3.0) | 11 (3.3) | 12 (3.6) |
| 7 (175) | 17 (5.2) | 15 (4.6) | 14 (4.3) | 13 (4.0) |
| 8 (207) | 15 (4.6) | 13 (4.0) | 12 (3.7) | 11 (3.4) |
| 9 (225) | 13 (4.0) | 12 (3.7) | 11 (3.4) | 10 (3.0) |
| 10 (250) | 12 (3.7) | 11 (3.4) | 10 (3.0) | 9 (2.7) |
| 11 (275) | 11 (3.4) | 10 (3.0) | 9 (2.7) | 8 (2.4) |
| 12 (300) | 10 (3.0) | 9 (2.7) | 8 (2.4) | 8 (2.4) |
| 15 (375) | 8 (2.4) | 8 (2.4) | 7 (2.1) | 6 (2.0) |

**Step 3. Selection of the Appropriate Load-Transfer Mechanism**

➢ JPC and JRC Pavements

- For proper load transfer at transverse repair joints, where the existing slab is doweled, the repair joint should also be doweled.
    - If the existing slab is nondoweled, then the appropriate load transfer mechanism should be selected based on the criteria summarized in table 3.
    - Load transfer devices should be located in the wheelpath. At least four to five dowels with a minimum diameter of 1.5 in (38 mm) and length of 18 in (450 mm) spaced 12 in (300 mm) apart should be placed under each wheelpath, as shown in figure 5.

➢ CRC Pavements

- CRC pavement should be repaired with rough joint faces and should reestablish continuous reinforcement.
- New steel bars are necessary to maintain the continuity of the reinforcing bars that run longitudinally through the pavement. The new steel is attached to salvaged lengths of the old bars using tied, mechanically fastened, or welded splices (figure 6). As discussed earlier, pavements should have a minimum repair length of 6 ft (1.8 m) in areas containing tied steel and 4 ft (1.2 m) in repair areas containing mechanically connected or welded steel. An alternative to splicing to the old steel is drilling holes and anchoring all new reinforcing bars into the old concrete.

Dowel everything

Table 3. Full-depth repair load transfer recommendations for nondoweled JPC pavement.

| Climate | Subbase | Average Annual Daily Truck Traffic | | |
|---|---|---|---|---|
| | | Light (<100) | Medium (100 to 500) | Heavy (>500) |
| Wet | Granular | Aggregate Interlock | Dowels** | Dowels |
| | High Quality Stabilized | Aggregate Interlock | Dowels** | Dowels |
| Dry | Granular | Aggregate Interlock | Dowels** | Dowels |
| | High Quality Stabilized | Aggregate Interlock | Aggregate Interlock | Dowels** |

*The boundary between wet and dry climates is the zero Thornthwaite Moisture Index contour.

** Required if the required future pavement life is greater than 5 years.

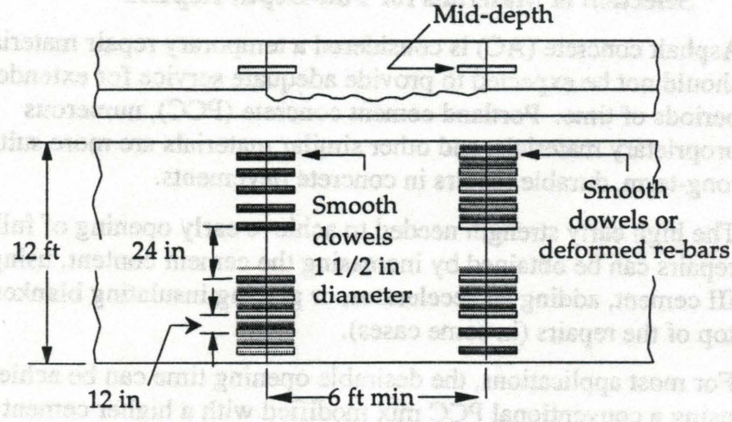


Figure 5. Dowel bar spacing and diameter for heavy truck traffic loading.

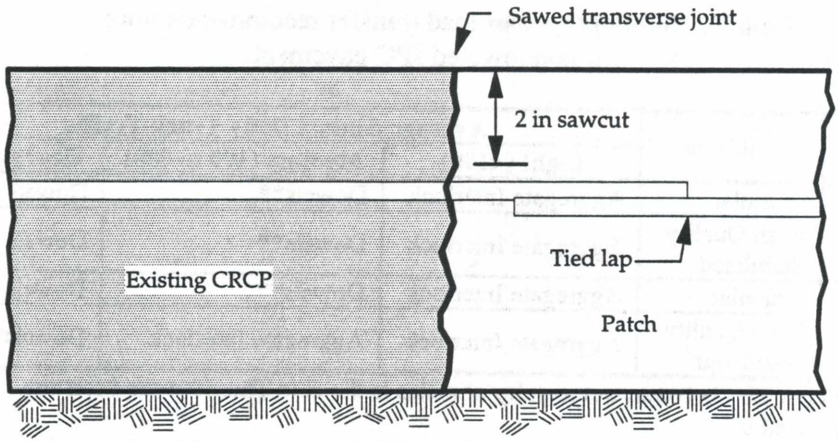

Figure 6. Load transfer in CRC pavements.

**Step 4. Selection of Materials for Full-Depth Repairs**

- Asphalt concrete (AC) is considered a temporary repair material and should not be expected to provide adequate service for extended periods of time. Portland cement concrete (PCC), numerous proprietary materials, and other similar materials are more suited for long-term, durable repairs in concrete pavements.
- The high early strength needed to achieve early opening of full-depth repairs can be obtained by increasing the cement content, using Type III cement, adding an accelerator, or placing insulating blankets on top of the repairs (in some cases).
- For most applications, the desirable opening time can be achieved using a conventional PCC mix modified with a higher cement content (and an accelerator, if a very fast opening time is required) to provide high early strength.
- Proprietary rapid-setting materials are available that can be used to achieve opening times as short as 1 hour, but at a premium price.
- The required minimum compressive strength and minimum PCC modulus of rupture at the time of opening are shown in table 4. Table 5 shows the approximate time necessary for different mixes to reach a compressive strength of 2,000 psi (13.8 MPa).

Table 4. Minimum opening strength necessary for full-depth repairs.

| Slab Thickness, in (mm) | Strength for Opening to Traffic, psi (MPa) | | | |
|---|---|---|---|---|
| | Repair Length (< 10 ft [< 3 m]) | | Slab Replacements | |
| | Compressive | 3rd-Point Flexural | Compressive | 3rd-Point Flexural |
| 6.0 (150) | 3000 (20.7) | 490 (3.4) | 3600 (24.8) | 540 (3.7) |
| 7.0 (175) | 2400 (16.5) | 370 (2.6) | 2700 (18.6) | 410 (2.8) |
| 8.0 (200) | 2150 (14.8) | 340 (2.3) | 2150 (14.8) | 340 (2.3) |
| 9.0 (225) | 2000 (13.8) | 275 (1.9) | 2000 (13.8) | 300 (2.1) |
| > 10.0 (> 250) | 2000 (13.8) | 250 (1.7) | 2000 (13.8) | 300 (2.1) |

Table 5. Approximate time necessary for different mixes to reach a compressive strength of 2000 psi (13.8 MPa).

| For Mixes Using: | Typical Time to Opening Strength |
|---|---|
| Certain blended cements | 2 to 4 hours |
| Sulfo-aluminate cements | 2 to 4 hours |
| Type III cement with non-chloride accelerating admixture | 4 to 6 hours |
| Type III cement with calcium chloride ($CaCl_2$) accelerator | 4 to 6 hours |
| Type I cement with calcium chloride ($CaCl_2$) accelerator | 6 to 8 hours |
| Type III cement with Type A water-reducing admixture | 12 to 24 hours |
| Type I (air-entrained paving mix without fly ash) | 24 to 72 hours |

## Step 5. Selection of Equipment for Full-Depth Repairs

➢ Sawing Equipment

- Diamond blade saws are better than carbide-tooth wheel saws for full-depth transverse cuts through existing concrete.
- Wheel saws are acceptable for cuts in asphalt shoulder along the repair area, or if the CPR is being performed to prepare the pavement for an AC overlay (more than 4 in [100 mm] thick) or an unbonded PCC overlay.

- Diamond saw blades that can extend to the full depth and sever existing tie bars should be used for isolation cuts along a tied shoulder and for interior or centerline joints.
- Wheel saws can be used for pressure-relief cuts.

➤ <u>Concrete Removal Equipment</u>

- The liftout method of concrete removal is the preferred method because it is less damaging to the subbase and requires less labor than breaking the concrete and removing the pieces. The liftout method entails the use of steel chains connected to lift pins that are inserted in holes drilled through the old concrete surface. A backhoe is then used to lift the concrete out of its place.
- Highly deteriorated concrete should be removed using the breakup method. In this method, the concrete is broken into small pieces using drop hammers, hydraulic rams, or jackhammers. The fragments can then be removed using a backhoe.

➤ <u>Repair Area Preparation Equipment</u>

- Lightweight jackhammers (15 lb [7 kg] maximum) should be used for chipping within 4 to 6 in (100 to 150 mm) of a boundary saw cut. In CRC pavement, they should also be used for breaking the concrete between the partial-depth saw cut and the full-depth saw cut to protect the reinforcing bars.
- For doweled repairs, the preferred equipment for creating dowel sockets is tractor-mounted gang drills. These drills can drill several holes simultaneously while maintaining proper alignment. Drilling holes with hand-held drills is cumbersome and should be avoided due to the likelihood of misalignment.
- Single hand-held drills are acceptable for drilling holes in adjacent concrete to insert deformed reinforcing tie bars.

EZ Drill

Single gang is easy to rent manaurverable
Not going to see many gang drills on small operation

# 2. Construction of Full-Depth Repairs

The construction of full-depth repairs consists of five distinct steps. The first four steps, beginning with isolation of the repair area and ending with the installation of the concrete patch, are required steps. Execution of the fifth step, which involves post-construction finishes to the patch, is highly recommended but not always necessary. The following sections discuss the key points of each construction step.

## Step 1. Isolation of the Repair Area

➢ <u>General</u>

- The deteriorated area of the pavement must be isolated from the adjacent concrete and shoulder materials using full-depth saw cuts, as illustrated in figure 7.
- The longitudinal cuts along the shoulder or adjacent longitudinal joints should be cut full depth.
- To prevent damage to the subbase, the saw cut must not be allowed to penetrate more than 0.5 in (13 mm) into the subbase.
- A 4-in (100-mm) wide cut should be made in the asphalt shoulder along the repair area at the slab/shoulder interface to provide room for placement of a form for the repair/shoulder interface.
- In case of a tied concrete shoulder, the shoulder face can be used as a form for patch material placement.
- In hot weather, when the concrete has expanded and compressed the joints, a slanted pressure-relief cut may be needed within the repair boundaries to prevent spalling of the adjacent concrete during removal.

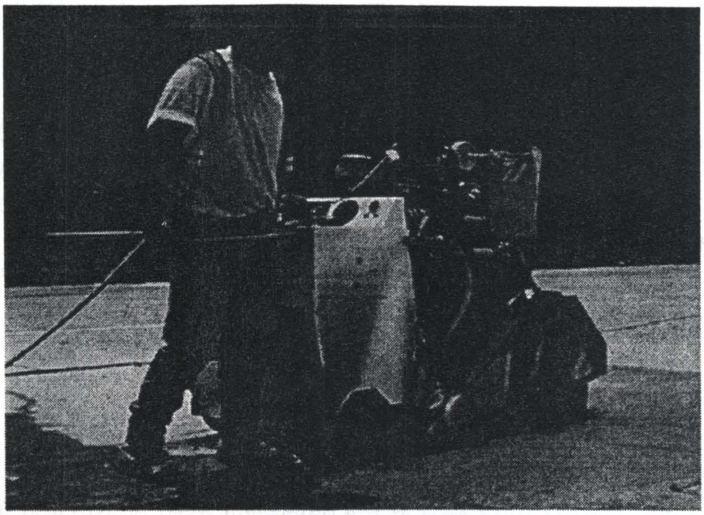

Figure 7. Full depth sawing operation.

- Wheel saw cuts should be no closer than 6 to 8 in (150 to 200 mm) from the repair boundary. The wheel saw cut should not enter an adjacent slab and should not penetrate more than 0.5 in (12 mm) into the subbase.
- Sawing at night, during cooler temperatures, is an alternative to pressure-relief cuts.
- If the pavement is left in service, full-depth repairs should be completed within 2 days of sawing operations to avoid pumping and erosion beneath the slab.

➢ <u>JPC and JRC Pavements</u>

- For doweled repairs, isolate the deteriorated area of the pavement from the adjacent pavement materials using full-depth saw cuts at the repair boundary.
- For nondoweled repairs with aggregate interlock load transfer, an outer partial-depth saw cut at the repair boundary and a second full-depth saw cut at the repair boundary are required. The concrete between the full-depth cut and the partial-depth cut is then chipped off to provide aggregate interlock.

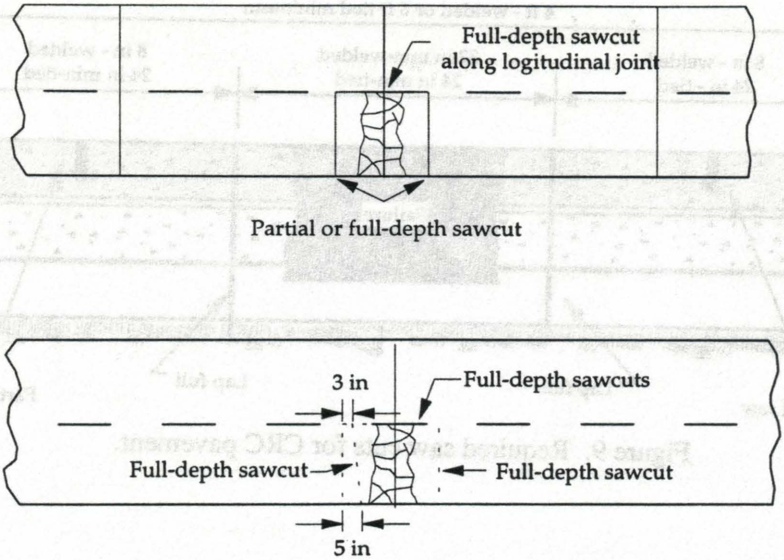


Figure 8. Saw cut locations for full-depth repairs of jointed concrete pavements.

➤ <u>CRC Pavements</u>

- Partial-depth saw cuts are made in CRC pavement at the outer boundaries of the repair area. These saw cuts should extend down about one-fourth to one-third of the slab thickness and should be located at least 18 in (457 mm) from the nearest tight transverse crack.
- Generally, two full-depth saw cuts within the boundary of the full-depth repair are made at a specified distance from the partial-depth cuts. The required distance is 24 in (610 mm) for tied laps and 8 in (203 mm) for mechanical connections or welded laps. The full-depth cuts are made for liftout removal, and the concrete between the full-depth cut and the partial-depth cut is then chipped off to provide aggregate interlock and to expose the steel reinforcement.
- If, upon inspection, more than 10 percent of the reinforcement bars (rebars) are seriously damaged or corroded, or if three or more of the adjacent bars are broken, then the repair boundaries must be extended another lap distance.

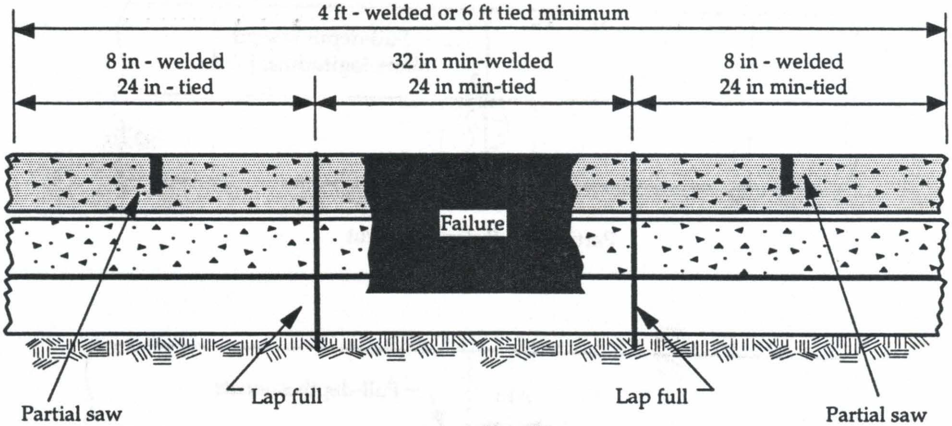


Figure 9. Required saw cuts for CRC pavement.

## Step 2. Removal of Existing Deteriorated Concrete

➢ <u>Liftout Method</u>

- Saw cuts can be made within the repair area to provide additional space for lateral movement of the slab during vertical liftout.
- If devices like torque claws or forklifts are used for concrete removal, the wheel saw cut necessary to get leverage on the deteriorated concrete segment, should be within the repair area.
- If the concrete being lifted significantly cracks, damages, or spalls the top of adjacent slabs, then the repair area should be extended.
- If adjacent slabs are damaged frequently, a second saw cut (a full-depth saw cut within the repair boundary and an outer partial-depth saw cut at the repair boundary) may be required. After the deteriorated slab is lifted out, a lightweight jackhammer (15 lb [7 kg] maximum) should then be used to chip the joint face to the outer saw cut.

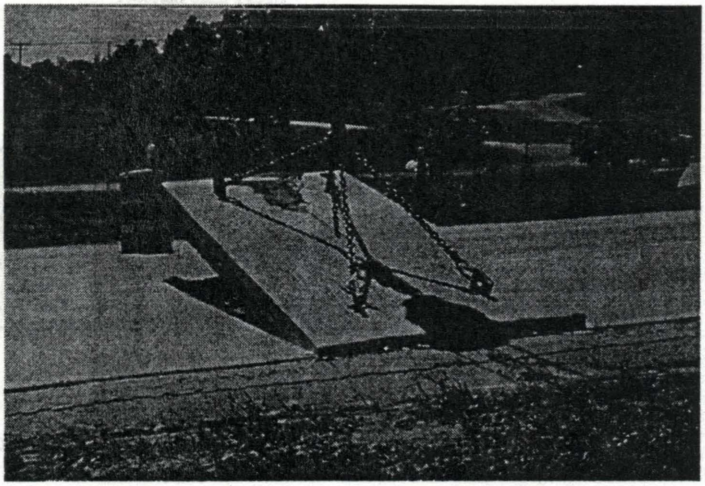

Figure 10. PCC slab liftout in progress.

- As described earlier, the dual saw cut procedure can also be used if a roughened joint face is required to provide aggregate interlock load transfer. Again, a lightweight jackhammer should be used to chip the joint face to the outer saw cut.
- The chipping should not undercut the outer kerf, as this will result in loss of aggregate load transfer.

➢ <u>Breakup Method</u>

- To minimize damage to the subbase and subgrade, the mechanized breaking equipment's break energy must be controlled. Excessive break energy may push concrete pieces into the granular layers.
- To minimize potential damage to surrounding concrete during breakup, a full-depth buffer saw cut should be provided within the repair area and a partial-depth (one-fourth to one-third the slab thickness) saw cut should be provided at the boundary of the repair area.
- Buffer cuts should be located about 12 in (0.3 m) away from the partial-depth transverse boundary saw cut and 12 in (0.3 m) away from the full-depth longitudinal boundary saw cut.

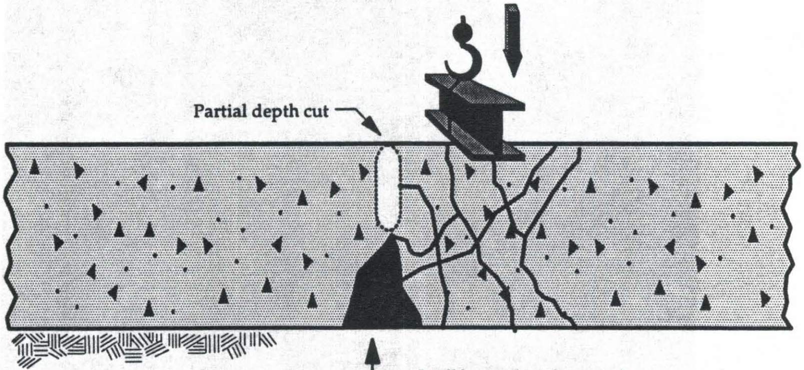

Figure 11. Illustration of spalling as a result of heavy hammer use.

- Concrete should first be broken at the center of the removal area. The break energy should be reduced for the area between the buffer cuts and the boundary saw cuts. The reduction in energy depends on the concrete strength and on the presence of reinforcement.
- Buffer cuts are not required if jackhammers are used to breakup the entire repair area. The center of the removal area should first be broken with the larger pneumatic hammers.
- Chipped edges along the repair boundaries should extend down vertically and never undercut the joint.
- The repair area needs to be extended if the concrete face under the partial-depth cut gets spalled.
- If more than 10 percent of the rebars are damaged or three or more adjacent rebars are broken, the repair area must be extended to expose more reinforcing steel.

**Step 3. Preparation of the Repair Area**

➢ Restoring the Foundation

- All subbase and subgrade materials disturbed during concrete removal should be removed and replaced with similar material or a suitable equivalent.
- Replacing deteriorated subbase material with concrete is the best performance alternative and is generally cost-effective for repairs less than 10 ft (3 m) long. This eliminates the need to add and compact additional subbase materials.
- The repair area may need to be dried and a lateral drain placed in cases where excess moisture exists.

➢ Installing Dowels in JPC and JRC Pavements

- Dowel sockets should be placed on 12-in (300-mm) centers at mid-depth of the exposed face of the existing slab.
- Drilled holes should be 0.25 in (6 mm) larger than the dowels if grout is used as the dowel anchoring material.
- Holes should be drilled 0.063 in (1.6 mm) larger than the dowels to allow room for epoxy mortar anchoring material.
- Dowel sockets must be thoroughly blown out with compressed air following drilling.
- Quick-setting, non-shrinking cement grout or epoxy resin is injected into the back of the dowel hole.
    - Grout can be inserted using a long flexible tube that places the material in the back of the socket.
    - Epoxy-type materials can be inserted using a cartridge with a long nozzle that dispenses the material to the rear of the hole (figure 12).

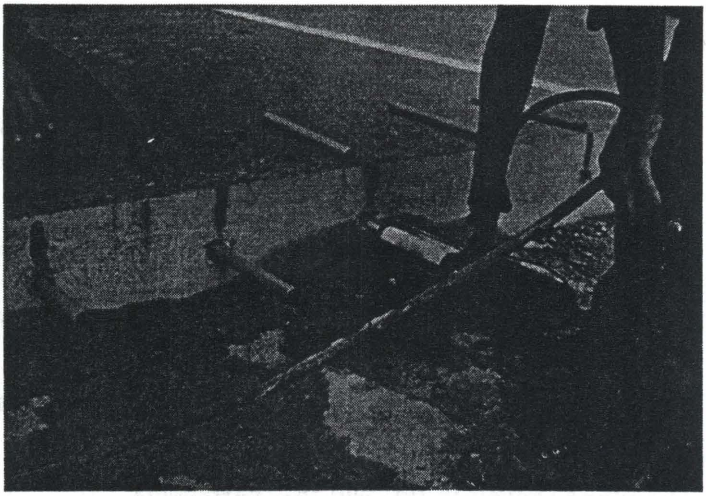

Figure 12. Epoxy resin injection into dowel holes.

- A thin grout retention disk is placed over the dowel prior to placement to prevent the anchoring material from flowing out of the hole.
- Dowels should be inserted with a twisting motion to ensure they are completely coated with grout or epoxy.
- The exposed part of the dowel should be greased lightly to facilitate horizontal movement and prevent the new PCC from adhering to the "free end." A dowel sleeve or cap may also be used and is generally preferable.
- If cracks, heavy mesh reinforcement, or other obstructions exist at the planned location for a hole, the hole should be adjusted away from the obstacle or should be eliminated.

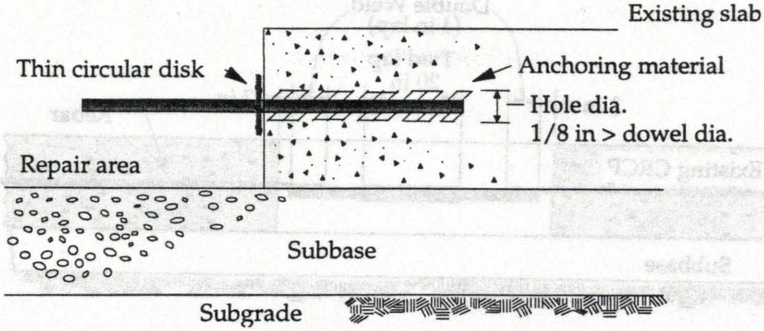


Figure 13. Illustration of dowel bar anchoring in slab interface.

➢ <u>Restoring Continuous Reinforcement in CRC Pavements</u>

- New reinforcing steel for CRC pavement repair areas should match the original grade, quality, and number.
- New rebar should be about 4 in (100 mm) shorter than the full-depth repair length and either tied, mechanically connected, or welded to the existing reinforcement. The bars should rest on supporting chairs if the full-depth repair is longer than 4 ft (1.25 m).
- Depending on the type of splice used, different overlap lengths are required to develop the full bar strength. The necessary lap length for a tied splice is 18 in (457 mm) for #5 bars (16 mm) and 21 in (533 mm) for #6 bars (19 mm).
- The necessary lap length using a welded splice of 0.25 in (6 mm) is a continuous weld made 4 in (100 mm) long on both sides of the bars or 8 in (200 mm) long on one side of the bar.
- For welded splices, it is required that a separate new bar be welded to each exposed old bar and the two new bars be tied together near the center of the full-depth repair.
- Mechanical couplers require less old steel exposed and only require about 1 to 2 in (25 to 50 mm) overlap between the old steel and the new steel.

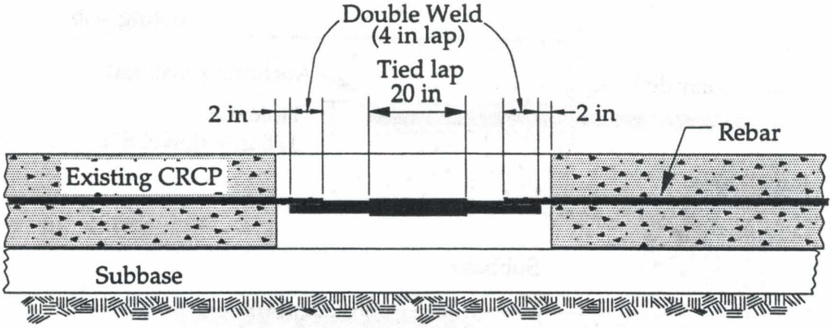


Figure 14. Details of welded or mechanical connection for CRC pavement repair.

- If rebars are anchored to the old concrete, holes should be drilled into the old concrete to the depth specified for a wire-tied overlap. The holes should be cleaned and the reinforcement anchored using the same grout material used to anchor dowels.

➤ <u>Forming for Repairs</u>

- A sturdy wooden form made from straight boards should be placed along the outside edge of the full-depth repairs next to asphalt shoulders.
- For short-jointed pavements with repairs less than 15 ft (4.5 m) long, a thin (0.25-in [5-mm]) fiberboard bondbreaker should be placed along any longitudinal face with an existing concrete lane or concrete shoulder. The bondbreaker should be placed flush with the longitudinal face of the repair and should match the repair area depth and length.
- For long-jointed pavements, bond breakers can be used for greater lengths.
- Bond-breaking boards are not required at a tied interface between an existing slab and a repair slab.

➤ Tying Repairs to Adjacent Pavement

- Full slab replacements and repairs greater than 15 ft (4.5 m) long require the full-depth repair to be tied to the existing pavement.

- Single hand-held drills are acceptable for drilling holes to insert the deformed reinforcing tie bars. The tie bars should be spaced along the longitudinal joint at 30-in (750-mm) intervals and should have an embedment length that is adequate to provide good pullout resistance.

- Tie bars can be anchored using the same grout material used to anchor dowels.

**Step 4. Installation of the Full-Depth Concrete Patch**

The Standard State specifications govern the placement, finishing, and curing of the concrete repair and should be consulted in conjunction with the information provided below.

➤ Placing the Concrete

- Concrete should be placed soon after the repair area has been prepared.

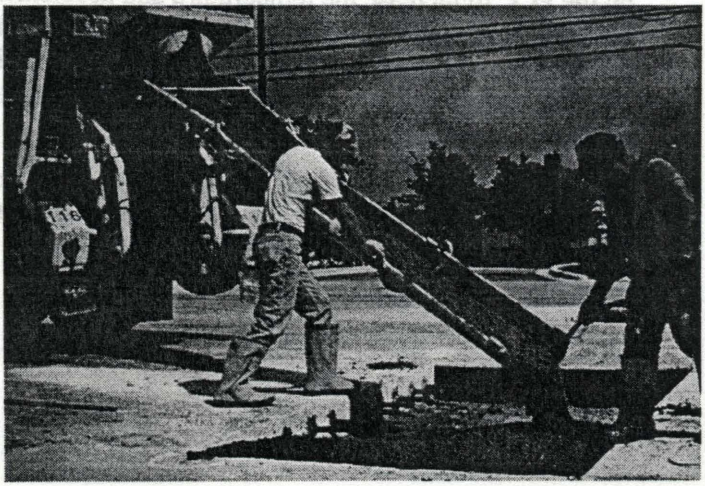

Figure 15. Concrete being placed into full depth repair cut.

- Attaining good consolidation around dowel bars is very important for adequate load transfer and long-term performance.
- The spud vibrator should be vertically penetrated to adequately mobilize the repair concrete. However, the vibrator should not be dragged through the mix because this may result in segregate and loss of entrained air.
- The addition of water to increase workability of the PCC should be avoided because of the loss in strength and increased shrinkage.
- Slump of the full-depth repair concrete should be between 2 and 4 in (50 and 100 mm).

➢ <u>Finishing the Repair</u>

- For repairs shorter than 10 ft (3 m), a straight edge finishing tool with the blade parallel to the longitudinal joint can be pulled across the pavement. For longer repairs, a vibratory screed is necessary to finish the surface.

➢ <u>Curing the Concrete</u>

- Immediately following placement and finishing, the concrete should be covered with a curing compound (figure 16), wet burlap, polyethylene sheeting, or State-approved equivalent.
- Under certain circumstances, insulation blankets may be placed on the PCC to increase the temperature and accelerate strength gain. Insulation blankets for high early strength concrete are needed for early opening repair areas. However, the insulation blankets should be placed over polyethylene sheeting to prevent excessive moisture loss.
- Insulation blankets should not be used in warm temperatures. If the boards create excessive heat, shrinkage cracks may be induced on the repair surface due to thermal shock.

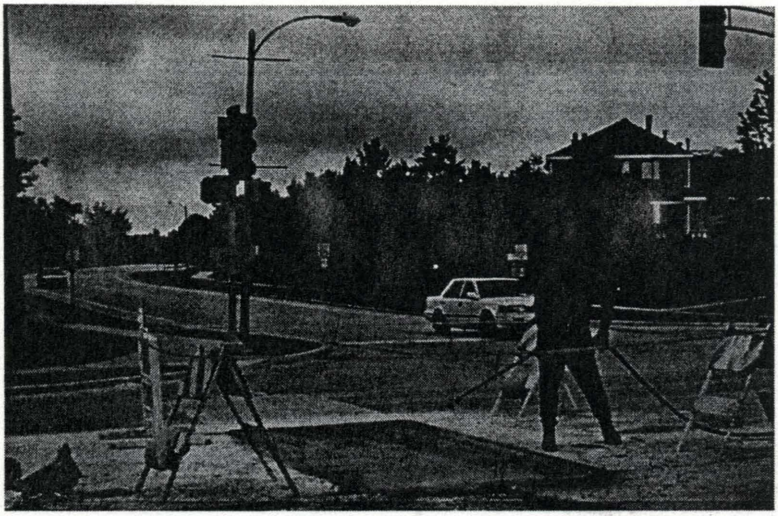

Figure 16. Application of curing compound to full-depth patch.

### Step 5. Post-Construction Patch Finishing

➢ Restoring Ride Quality

- To provide adequate smoothness, if the pavement contains many closely spaced full-depth repairs, either the entire repair lane or the full-depth repair areas need to be diamond ground before sawing and sealing the joints.

➢ Sealing the Patch Perimeter

- For transverse joints, the reservoir depth should be a minimum of 2 in (50 mm).
- The reservoir width and depth should be consistent with the joint spacing and sealant type. A backer rod may be needed for adequate sealant shape factor.
- Longitudinal joints should be a minimum of 0.5 in (13 mm) deep and 0.25 in (6 mm) wide.

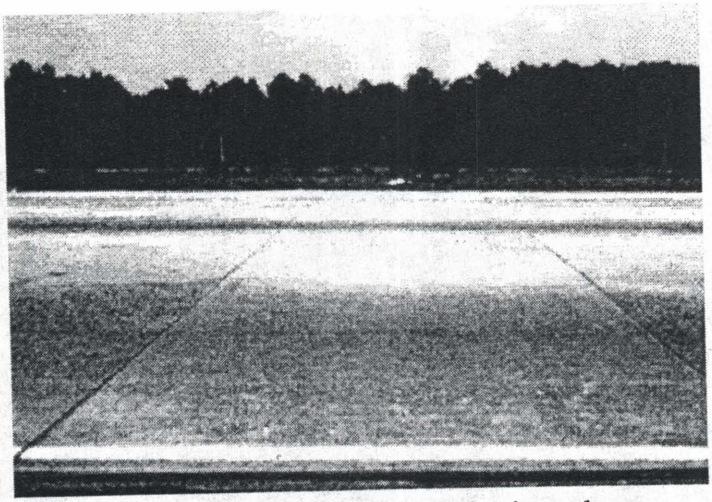

Figure 17. A completed full depth patch.

# 3. Design of Partial-Depth Repairs

As with full-depth repairs, the design of partial-depth repairs in concrete pavement consists of four basic steps. Each step entails the consideration of various factors and adherence to certain accepted practices. The sections below present the important aspects of each design step.

### Step 1. Identification of Candidate Pavement Distresses

- Partial-depth repairs are an alternative to full-depth repairs where the distresses are limited to the upper one-third of the slab. Cores can be taken at joints to find out how deep the spalls extend.
- If unsound concrete extends full-depth or more than one-third of the slab thickness, the area should be marked for full-depth repairs.
- The load transfer devices (if any) must be functional and no structural damage must be present.
- Partial-depth repairs are well suited for spalls created by compressive stresses from incompressible materials in joints or by the use of joint inserts. Localized surface defects, such as scaling, weak concrete due to improper finishing, and so on, can also be repaired effectively with partial-depth repairs.
- Partial-depth repairs should not be constructed in areas where the reinforcing or temperature steel is placed too near the slab surface, the joint spalls are due to misaligned dowels, or where D-cracking or reactive aggregates are a problem.
- Generally, partial-depth repairs are placed along transverse joints, but they can be located along longitudinal joints or elsewhere in the slab.
- Partial-depth repair is not required for spalls less than 6 in (152 mm) long and 1.5 in (38 mm) wide at the widest point.

### Step 2. Selection of the Appropriate Repair Boundary

- Repair boundaries must include all weak concrete. "Sounding" techniques, such as those using a ballpeen hammer (figure 18) or chain drag, should be used to identify the extent of spall deterioration not detectable at the surface.
- Boundaries of all removal should be kept rectangular.
- The partial-depth repair area marked for removal should extend 2 to 6 in (50 to 150 mm) beyond the spalled area.
- The partial-depth repair should be at least 4 in (100 mm) wide.
- If a spall is less than 6 in (150 mm) long or less than 1.5 in (38 mm) wide, it should not be repaired using partial-depth repairs. Instead, it should be filled with a joint sealant or a grout.
- Partial-depth repairs should be at least 2 in (50 mm) deep but no deeper than one-third of the pavement slab thickness.
- If repair areas are less than 12 in (300 mm) apart, they should be combined to reduce costs and provide a more pleasing appearance.
- Before any work begins, the repair area must be identified clearly. Removal locations should be painted on the pavement surface, as shown in figure 19.

Figure 18. Sounding with ballpeen hammer.

Figure 19. Marking of repair area.

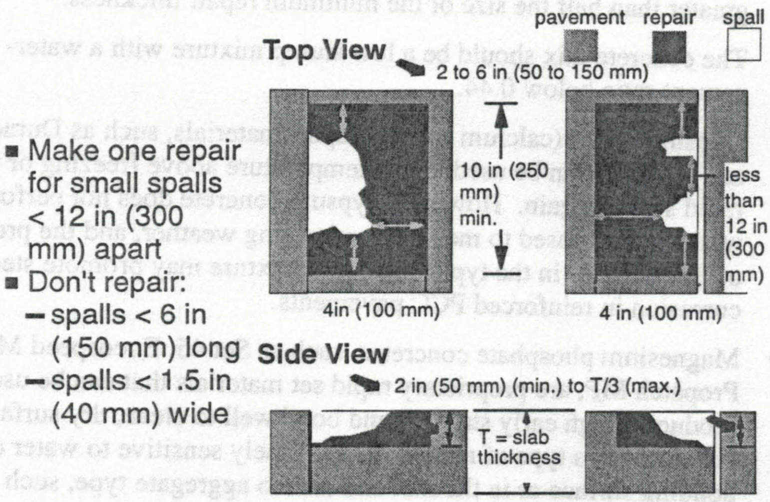


Figure 20. Typical partial-depth repair dimensions.

## Step 3. Selection of Materials for Partial-Depth Repairs

- Material selection for partial-depth repairs should consider the following factors: mixing time and required equipment, working time, temperature range for placement, curing time, aggregate requirements, repair area moisture conditions, cost, repair size, and bonding requirements.
- Increased user costs and the safety hazards to motorists and maintenance crews often necessitate the use of fast-track materials, particularly in high traffic areas.
- Normal set concrete can be used when the repair material can be protected from traffic for more than 24 hours.
- Normal set concrete should not be used when the air temperature is below 40 °F (4 °C). At temperature below 55 °F (13 °C), a longer curing period or insulation mats may be required.
- Type III cement or an accelerating admixture is used for repairs that need to be opened to traffic quickly. An insulating layer can be placed on the hydrating PCC to retain the heat of hydration to the rate of strength development.
- If Type I or III PCC is used, the coarse aggregate should not be greater than half the size of the minimum repair thickness.
- The concrete mix should be a low slump mixture with a water-cement ratio below 0.44.
- Gypsum-based (calcium sulfate) repair materials, such as Duracal and Rockite, can be used in any temperature above freezing or for rapid strength gain. However, gypsum concrete does not perform well when exposed to moisture or freezing weather, and the presence of free sulfates in the typical gypsum mixture may promote steel corrosion in reinforced PCC pavements.
- Magnesium phosphate concretes, such as Set 45, Eucospeed MP, and Propatch MP, are proprietary rapid set materials that can be used to produce a high early strength and bond well to clean, dry surfaces. However, this type of material is extremely sensitive to water on the bonding surface or in the mix and also to aggregate type, such as limestones. These materials can be somewhat difficult to place and finish due to the rapid set time, and they have a narrow range of placement temperatures.

- Calcium aluminate concretes (CAC), such as Five Star HP, can also be used for rapid strength gain, good bonding properties on dry surfaces, and very low shrinkage. However, loss of strength can occur from a chemical conversion that typically occurs at elevated curing temperatures. The disadvantage of using CAC is that the placement and finishing can be more difficult than conventional PCC because of the rapid set characteristics and the limited placement temperature range.
- For the rapid set proprietary materials, it is important that the manufacturer's recommendations be followed.
- When polymer concretes such as Burke 88/LPL, Mark 103 Carbo-Poxy are used, the epoxy concrete mix design must be compatible with the concrete in the pavement. The epoxy components should be mixed in strict compliance with the manufacturer's recommendations before aggregate is added. Deep epoxy repairs need to be placed in lifts to control heat evolution. Epoxy concrete should not be used to patch spalls caused by reinforcing steel corrosion, as it may accelerate the rate of deterioration of the adjacent concrete.
- Methyl methacrylate concrete and molecular weight methacrylate concretes, such as SikaPronto 11 and Degaur 510, are polymer-modified concretes with long working times, high compressive strengths, and good adhesion. The disadvantage with methacrylates is that many of them are volatile and may pose a health hazard to those exposed to the fumes for prolonged periods of time.
- Polyurethane concretes, such as Percol FL and Penatron R/M-3003, are generally very quick setting (90 seconds), and some manufacturers state that the materials are moisture-tolerant.
- Joints cannot be re-established with bituminous repair materials; therefore, bituminous repair materials should not be used for a permanent partial-depth repair.

## Step 4. Selection of Equipment for Partial-Depth Repairs

- <u>Sawing and Chipping Equipment</u>
  - Single-bladed concrete saws should be used to saw the repair boundaries.
  - The maximum jackhammer size for chipping is 30 lb (13.5 kg).

- Jackhammers should always be fitted with spade bits; gouge bits can damage sound concrete.
- Lightweight jackhammers (15 lb (7 kg) maximum) and chisels should be used to remove material from the edges of the repair area.
- Double-bladed concrete saws should be used to resaw joints adjacent to the repair area.

➢ <u>Milling Equipment</u>

- Carbide-tipped cold milling machines, such as the one in figure 21, should have a maximum drum diameter of 3 ft (0.9 m). Machines with 12- to 18-in (305- to 457-mm) wide cutting heads are more conducive to the typical sizes of spalled areas.

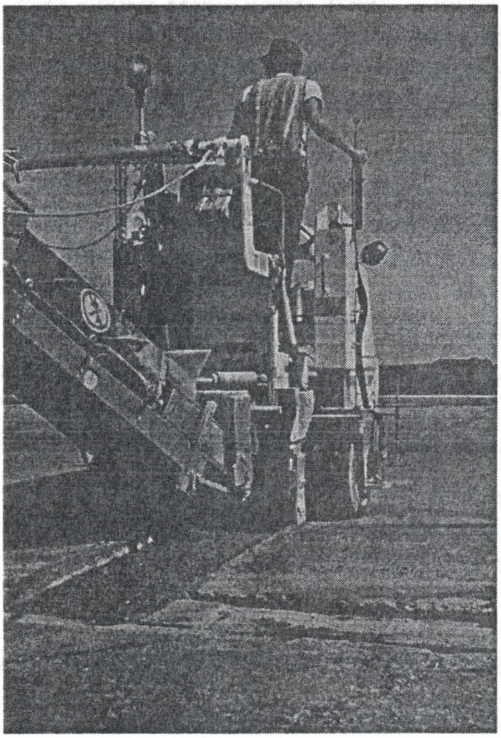

Figure 21. Carbide-tipped milling machine.

- Waterblasting Equipment
  - Waterblasting machines should be capable of producing a stream of water at 15,000 to 30,000 psi (100,000 to 200,000 kPa) and should be controlled by a mobile robot.
- Cleaning Equipment
  - Sandblasting and airblasting equipment shouls be capable of supplying a minimum nozzle pressure of 90 psi (620 kPa) at 120 $ft^3/min$ (3.4 $m^3/min$). Moreover, the air compressors used for cleaning joints should be equipped with functional oil- and moisture-removal filters.
- Mixing Equipment
  - Small drum or paddle-type mixers with capacities adequate for partial-depth patching are used for batching bagged raw or premixed materials.

# 4. Construction of Partial-Depth Repairs

The construction of partial-depth repairs consists of four distinct steps. The first three steps, beginning with the removal of existing deteriorated concrete and ending with the installation of the partial-depth patch, are required steps. Execution of the fourth step, which involves post-construction finishes to the patch, is highly recommended but not always necessary. The following sections discuss the key points of each construction step.

## Step 1. Removal of Existing Deteriorated Concrete

➢ <u>General</u>

- Partial-depth repairs should not be used if the concrete below one-third the slab depth is damaged during chipping, or if dowel bars or heavy reinforcement are encountered during concrete removal. The area should be marked for full-depth repairs.

➢ <u>Sawing and Chipping</u>

- Saw cuts should have a minimum depth of 1.5 in (38 mm).
- To avoid delays in repair material placement caused by saturation of the repair area, sawing can be done 1 or 2 days ahead of the removal and repair operations.
- Additional saw cuts can be made within the repair area to speed chipping removal.
- Saw overcuts must be cleaned and sealed after the partial-depth repair is made.
- The deteriorated concrete in the center of the repair is removed toward the marked edge of the repair boundaries and to a minimum depth of 1.5 in (38 mm).
- Jackhammers used to remove the unsound concrete should not be operated at more than a 45-degree angle from the pavement to minimize damage to the sound concrete.
- When removing material from the edges of the repair area, care should be taken not to damage or crack the sound concrete beneath and adjacent to the repair area.

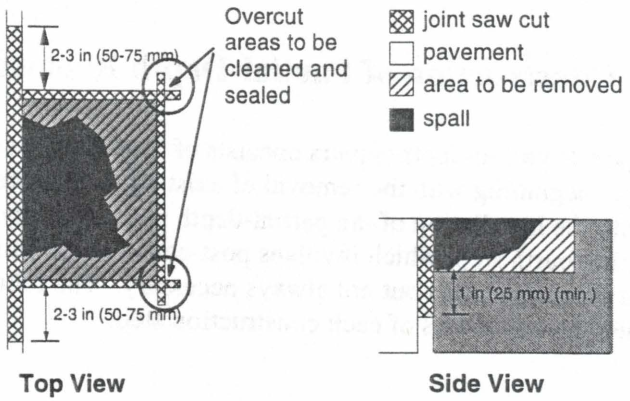


Figure 22. Saw cut dimensions.

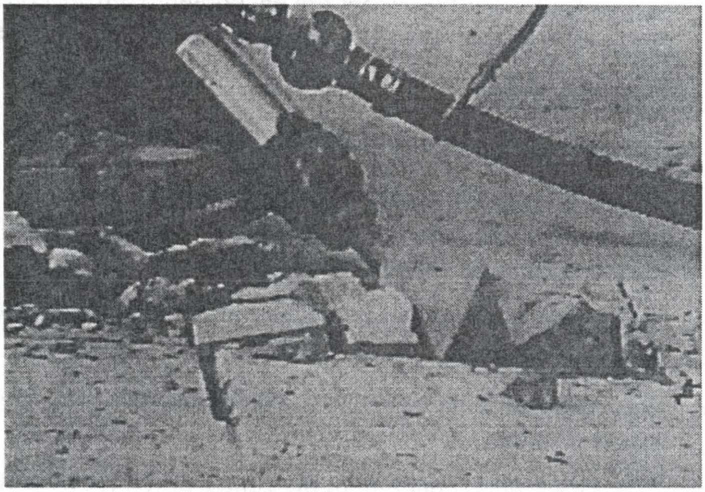

Figure 23. Using jackhammers.

- Milling
  - Milling is effective when repairing large areas such as an entire lane width or a majority of the lane width.
  - Whenever possible, the milling machine should be oriented such that the rounded edges of the holes it produces are parallel to the direction of traffic. If this orientation is not possible, the rounded edges should be made vertical using a lightweight jackhammer.
  - Milling depth must be controlled to avert damage to dowel bars or longitudinal reinforcement and to ensure that the milling depth does not extend to more than one-third the slab width.
  - Sounding should be used to check the bottom of the milling area to ensure that all unsound material has been removed. Unsound material must be chipped free.
- Waterblasting
  - Waterblasting slurry must be washed away before it dries. A shield must be built around the repair to protect traffic if the repair is next to a lane carrying traffic.

**Step 2. Preparation of the Repair Area**

- Cleaning
  - Following the removal of deteriorated concrete and, if necessary, old joint sealant, the repair area must be sandblasted and airblasted to remove loose concrete, dust, laitance, and other debris.
- Preparation for Nonflexible Repair Materials
  - Old sealant in the adjacent joint and 3 to 4 in (75 to 100 mm) beyond the repair must be removed, and the joint must be resawed.
  - The joints next to the repair should be resawed using a double-bladed concrete saw. The cut should be at least 1 in (25 mm) deeper than the repair and should extend 2 to 3 in (50 to 75 mm) beyond the repair in each direction.

- All sawing slurry should be washed from the repair area before it dries.
- A bond breaker must be installed in all joints that are next to the repair (figure 24). The concrete repair material should never be placed directly against the adjacent slab.
- Joint bond breakers with a scored top strip should be used because the strip can later be torn away to make a reservoir for the joint sealant.
- The bond breaker should extend 1 in (25 mm) below and 3 in (75 mm) beyond the repair boundaries to keep the repair material out of the joint.
- The bond breaker should be slightly wider than the joint so that it is slightly compressed.
- For longitudinal joints, an alternative to the compressible joint insert described above is a thin polyethylene strip or asphalt-impregnated roofing felt.

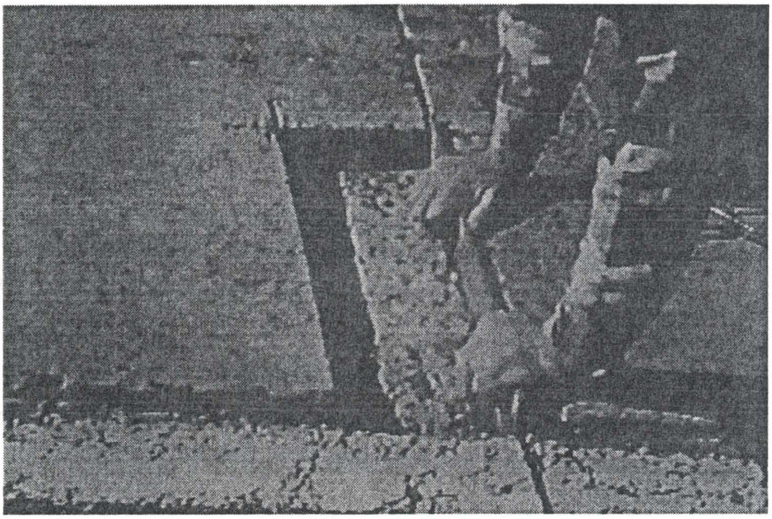

Figure 24. Insertion of bond breaker at transverse joint.

- A rigid fiberboard should be used at the lane-shoulder joint where more support is needed. The fiberboard should be even with the surface and slightly below the repair depth to prevent penetration of repair material into the shoulder.

➢ Preparation for Flexible Repair Materials

- If flexible material is used, the old sealant must be removed; however, sawing may not be needed.
- If there are metal or plastic inserts in the joint, they must be sawed out. Joints need not be sawed when weather conditions are adverse.

**Step 3. Installation of the Partial-Depth Patch**

➢ Application of Bonding Agents

- Some partial-depth repair materials require epoxy or proprietary bonding agents. Manufacturers' specifications should be followed in regards to bonding agents and the repair materials being used for the repair.
- The bonding agent is applied after cleaning and just prior to placing the repair material. Thorough coating of the bottom and sides of the repair area is essential. This may be accomplished by brushing the grout, epoxy, or other material onto the concrete with a stiff bristle brush, as shown in figure 25.
- To ensure adequate bond, the bond material should cover the entire area including the repair walls and should overlap the pavement surface.

➢ Mixing and Placing the Repair Material

- Rapid-setting materials should not be mixed for long because this reduces the already short time available for placing and finishing.
- The repair area should be overfilled slightly to allow for reduction in volume during consolidation.

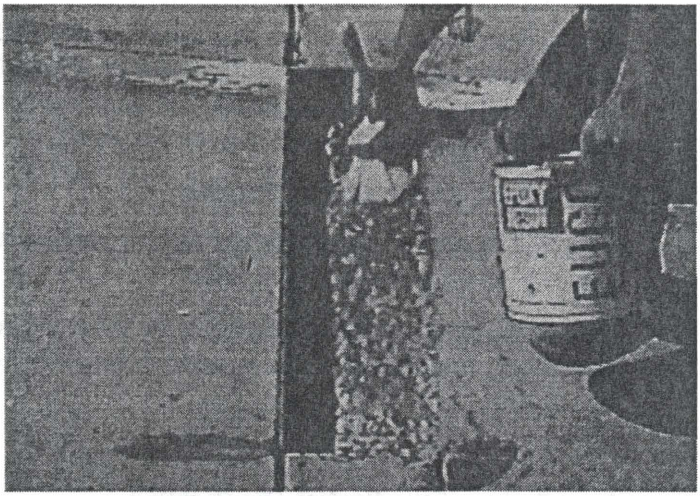

Figure 25. Application of bonding agent.

- The repair material should be sufficiently consolidated during placement to remove all voids located at the interface between the repair material and the existing PCC.
- Cementitious and some polymeric materials may be vibrated using a small internal vibrator, a vibrating screed (if the repair is very large), or by rodding or tamping with hand tools (if the repair is very small).
- Small pencil vibrators should be used for most repairs.
- The vibrator is held at a slight angle (15 to 30 degrees) from vertical and is moved at random through the repair material until the entire area has been covered.
- The vibrator should be lifted up and down, but not moved horizontally in the repair material. The mix has been vibrated enough when it stops settling, air bubbles no longer appear, and a smooth layer of mortar appears at the surface of the repair.
- Avoid overvibrating the material, as it may lead to segregation or a reduction in entrained air (if applicable).

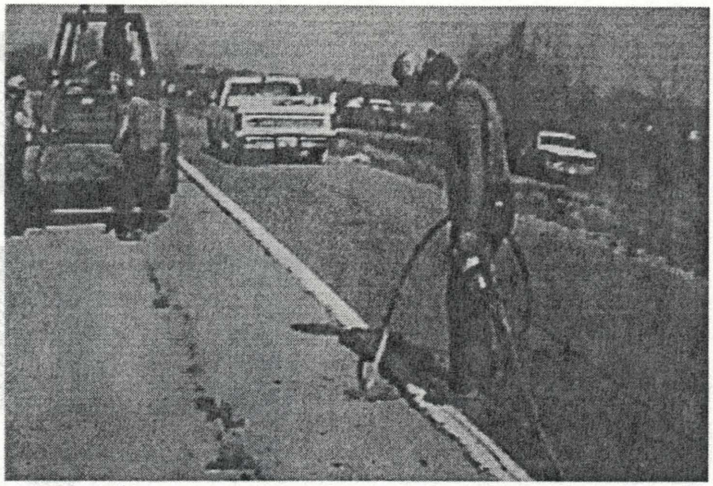

Figure 26. Vibratory compaction of repair material.

- Bituminous materials may be compacted using a vibratory roller or a plate. These should be compacted with three to eight passes until they are level with the pavement.

➢ Finishing the Repair

- A stiff board can be used to screed the repair surface and make it flush with the existing pavement.
- The material should be worked towards the repair edges using at least two passes.
- Hand floating and troweling should originate at the center of the repair and move radially out toward the patch boundaries. This finishing pattern aids in the consolidation and bonding at the repair boundary.
- Extra mortar from troweling can be used to fill saw overcuts.

➢ Curing the Repair Material

- The manufacturer's recommendations should be followed for materials that require curing.
- Repairs may be water-cured by continuously spraying them with water or by covering them with moist burlap.

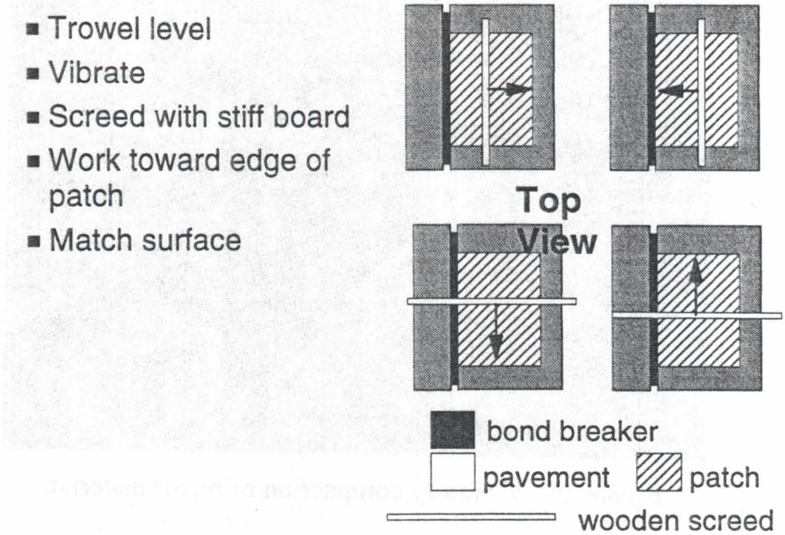


Figure 27. Screeding and finishing techniques.

- Sealed curing prevents moisture loss but does not add moisture to the repair. Repairs may be covered with polyethylene sheeting or a curing compound can be applied to their surfaces. Pigmented curing compounds can also be used with PCC-based repair materials.

**Step 4. Post-Construction Patch Finishing**

➢ Restoring Ride Quality

- Patches that are significantly uneven with the existing pavement surface should be diamond ground to restore smoothness.

➢ Sealing Joints

- A minimum 1-week cure time should be allowed before joints adjacent to partial-depth patches are sealed. Sealing should take place after any diamond grinding operations performed.

- Joint faces should be clean and dry for good sealant performance. The proper joint shape factor should be provided. Sawing followed by sandblasting to remove dirt and saw laitance may be necessary to obtain the proper shape factor.
- If a scored bond breaker has been used, the tear-off strip should be removed and the selected joint sealant applied.

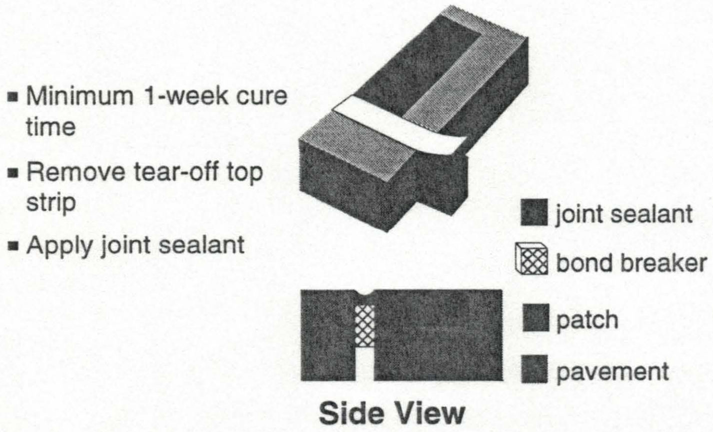


Figure 28. Joint sealing.

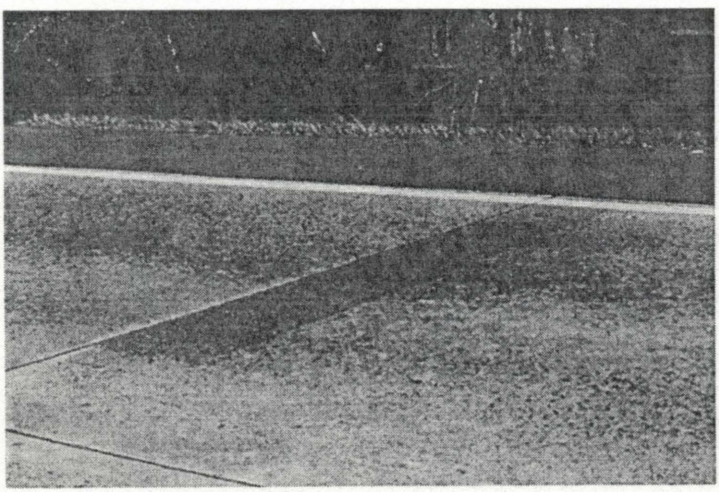

Figure 29. A completed partial depth repair patch.

Determining

# 5. ~~Design~~ of Joint and Crack Seal Treatments

The design of joint reseal treatments and crack seal treatments consists of three basic steps. Each step entails the consideration of various factors and adherence to certain accepted practices. The sections below present the important aspects of each design step.

**Step 1. Determining When to Reseal Joints**

- If extensive deterioration is present, particularly moisture-related damage, joint resealing may not be warranted without additional CPR procedures.
- Joint resealing should be performed when the existing sealant material is no longer performing its intended function of preventing the entry of water and incompressibles into the joint. If the existing joints are in good condition but the sealant is deteriorating, joint resealing should be considered.
- After a sealant inspection, pavement, and traffic survey, the criteria shown in table 6 can be used to make decisions on the need for resealing PCC joints.
- Sealing operations should be performed on all joints and cracks.
- The optimum time to perform joint resealing is in the spring or the fall.
- All CPR, including full-depth repairs, partial-depth repairs, retrofit edgedrains, retrofit load transfer, undersealing, and diamond grinding, should be completed before resealing begins.
- Crack sealing is most effective when conducted on pavements exhibiting little structural deterioration.

Table 6. Decision table for resealing PCC joints.

| Sealant Rating* | Pavement Rating | Traffic Rating | Climatic Region | | | |
|---|---|---|---|---|---|---|
| | | | Freeze | | Nonfreeze | |
| | | | Wet | Dry | Wet | Dry |
| Fair | Good | Low | Possibly | Possibly | Possibly | Possibly |
| Fair | Good | Medium | Yes | Possibly | Possibly | Possibly |
| Fair | Good | High | Yes | Yes | Yes | Possibly |
| Fair | Fair | Low | Yes | Possibly | Possibly | Possibly |
| Fair | Fair | Medium | Yes | Yes | Yes | Possibly |
| Fair | Fair | High | Yes | Yes | Yes | Possibly |
| Fair | Poor | Low | Possibly | Possibly | Possibly | Possibly |
| Fair | Poor | Medium | Yes | Yes | Yes | Possibly |
| Fair | Poor | High | Yes | Yes | Yes | Yes |
| Poor | Good | Low | Yes | Possibly | Possibly | Possibly |
| Poor | Good | Medium | Yes | Yes | Yes | Possibly |
| Poor | Good | High | Yes | Yes | Yes | Yes |
| Poor | Fair | Low | Yes | Yes | Yes | Possibly |
| Poor | Fair | Medium | Yes | Yes | Yes | Yes |
| Poor | Fair | High | Yes | Yes | Yes | Yes |
| Poor | Poor | Low | Yes | Yes | Yes | Possibly |
| Poor | Poor | Medium | Yes | Yes | Yes | Yes |
| Poor | Poor | High | Yes | Yes | Yes | Yes |

* Sealants rated in "Good" condition do not require replacement.

➢ It is important to determine the objective of the resealing project. Possible objectives include:

- Temporarily sealing pavement joints for 1 to 2 years until the pavement is overlaid or replaced.
- Sealing and maintaining watertight joints for 3 to 5 years.
- Sealing and maintaining watertight joints for a period extending more than 5 years.

**Step 2. Selection of Materials for Sealing Operations**

➢ Sealant Materials

- Sealant materials are subject to very harsh conditions. Selected sealants must be able to:
  - ▫ Withstand horizontal movement and vertical shear at all temperatures to which they are exposed.
  - ▫ Withstand environmental effects such as weathering, extreme temperatures, and excess moisture.
  - ▫ Resist stone and sand penetration at all temperatures.
  - ▫ Maintain complete bond to concrete joint sidewalls at all temperatures.
- Typically, higher quality sealants are specified for joint resealing operations than for crack sealing operations.
- It may be more cost-effective to use lower quality sealants in joints or cracks that experience little movement or that will be overlaid or otherwise rehabilitated in the near future.
- No one sealant can meet the demands of every sealant project. The proper sealant type must be selected based on the conditions present and the overall objective of the sealing.
- Although inexpensive, asphalt cement has poor elastic properties and is generally not used for sealing medium- and high-volume roadways.
- Asphalt rubber has improved elasticity, greater cohesiveness, and an increased softening point. The quality of asphalt rubber varies with the quality of rubber incorporated.

- Rubberized asphalt sealants have become the industry standard in the past 15 years. These possess a greater working range with respect to low temperature extensibility and resistance to high-temperature softening and tracking.

- Low-modulus rubberized asphalt sealants incorporate softer grades of asphalt cement that further improve the performance of the sealant at low temperatures.

- PVC coal tar sealants have a high softening point and bond well to concrete, which makes them extremely useful in cases where the sealant may be subject to fuel spills or jet blasts.

- Emulsion sealants perform reasonably well but are temperature-sensitive and are prone to cracking.

- The retention of elasticity of polysulfide and polyurethane sealants is good, but they lack adhesion to the concrete joint surface. These sealants require an additional mixing operation, thereby increasing overall costs.

- Silicone sealants have performed well in terms of retained elasticity, improved temperature resistance, and bond strength. Their properties include good extensibility, resistance to weathering, and low-temperature susceptibility. These sealants have excellent bond strength in combination with a low modulus, which allows them to be placed thinner than other types of sealants. Because of silicone's thin layer application and lower associated equipment costs, the ratio of in-place cost compared to rubberized asphalt is not nearly as high as the ratio of material costs (for a given volume). Performance of silicone sealants is typically tied to joint cleanliness and tooling effectiveness.

- Nonself-leveling silicone sealant requires a separate tooling operation to press the sealant against the sidewall and to form a uniform recessed surface. Recently developed self-leveling silicone sealants can be placed in one step because they freely flow to fill the joint reservoir without tooling.

- Preformed compression seals have a good history of performance when used with new PCC pavements; however, because of their expense and the need for vertical sidewalls, they are not commonly used on PCC pavement restoration projects.

➢ Backer Rod Materials

- Backer rod is an important component of joint sealing for the following reasons:
  - It keepts liquid sealant from flowing out of the joint bottom.
  - It keeps liquid sealant from adhering to the reservoir bottom.
  - It helps define the shape of the seal, which, in turn, helps optimize sealant performance.
- Backer rod, which is usually made of a polyethylene material, should be compatible with the sealant.
- Backer rod size is dependent on joint width, but they are to be compressed approximately 25 percent during installation to prevent excessive movement and to ensure that the correct depth of sealant is achieved. Sizing requirements for backer rods are shown in table 7.

**Step 3. Designing the Transverse Joint Reservoir**

➢ The dimensions of the sealant and the sealant reservoir can greatly affect the performance of a sealant material.

➢ As illustrated in figure 30, critical dimensions include the joint width (W) and depth (D) and the sealant width (W) and depth (T).

➢ The shape factor, which is defined as the ratio of the sealant width (W) to sealant depth (T), affects the buildup of stresses in the sealant (figure 31) and, subsequently, sealant performance. Recommended shape factors for various sealant types are shown in table 8.

➢ Joint spacing, the thermal coefficient of expansion of the concrete, extreme or average temperature range, and the coefficient of friction between the slab and underlying layers are factors that influence the joint width.

➢ The sealant width and depth are designed based on the maximum joint opening, the shape factor, and the maximum allowable strain in the sealant.

Table 7. Sizing requirements for backer rods.

| Reservoir Width, in (mm) | Backer Rod Diameter, in (mm) |
|---|---|
| 1/8 (3) | 1/4 (6) |
| 3/16 (5) | 1/4 (6) |
| 1/4 (6) | 3/8 (10) |
| 5/16 (8) | 3/8 (10) |
| 3/8 (10) | 1/2 (13) |
| 1/2 (13) | 5/8 (16) |
| 5/8 (16) | 3/4 (19) |
| 3/4 (19) | 7/8 (22) |
| 7/8 (22) | 1 (25) |
| 1 (25) | 1-1/4 (32) |
| 1-1/4 (32) | 1-1/2 (38) |
| 1-1/2 (38) | 2 (50) |

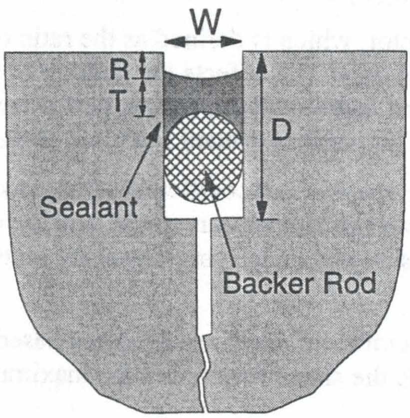


Figure 30. Illustration of sealant shape factor.

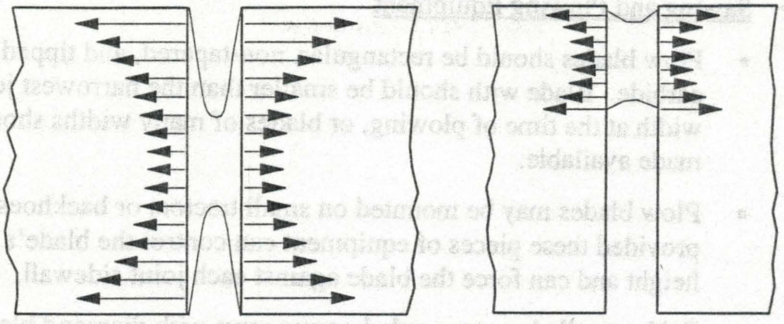

Figure 31. Relative effect of shape factor on sealant stress.

Table 8. Recommended joint seal shape factors.

| Sealant Material Type | Recommended Shape Factor (W:T) |
|---|---|
| Rubberized asphalt | 1:1 |
| Silicone | 2:1 |
| PVC coal tar | 1:2 |
| Polysulfide and polyurethane | 1:1 |

- The sealant is recessed approximately 0.25 to 0.375 in (6 to 10 mm) to avoid extrusion problems.
- The joint reservoir depth is the sum of the selected sealant depth (T), the compressed backer rod thickness, and the depth that the sealant surface is to be recessed (R).

## Step 4. Selection of Equipment for Sealing Operations

➤ Sawing and Plowing Equipment

- Plow blades should be rectangular, non-tapered, and tipped with carbide. Blade with should be smaller than the narrowest joint width at the time of plowing, or blades of many widths should be made available.

- Plow blades may be mounted on small tractors or backhoes, provided these pieces of equipment can control the blade's height and can force the blade against each joint sidewall.

- Self-propelled, water-cooled power saws with diamond blades are most appropriate for joint sawing operations.

- Double blades separated by a spacer to the desired width of the joint are preferred over single blade, full-width saws.

➤ Cleaning Equipment

- Sandblasting and airblasting equipment should be capable of supplying a minimum nozzle pressure of 90 psi (620 kPa) at 120 $ft^3$/min (3.4 $m^3$/min). Moreover, the air compressors used for cleaning joints should be equipped with functional oil- and moisture-removal filters.

➤ Backer Rod Installation Tools

- Backer rods are easily inserted with a double-wheeled steel roller or any smooth, blunt tool that will force the rod uniformly to the desired depth. Automated, self-guiding insertion tools, such as the one in figure 32, are commonly and successfully used.

➤ Sealant Installation Equipment

- Hot-applied sealant melter–applicators should have the following capabilities:
    - ▫ Can effectively raise the temperature of the sealant without overheating it.
    - ▫ Allows the operator to maintain exact sealant temperatures in the range of 325 to 480 °F (163 to 249 °C).
    - ▫ Heats a sufficient amount of sealant so that installation is not delayed.

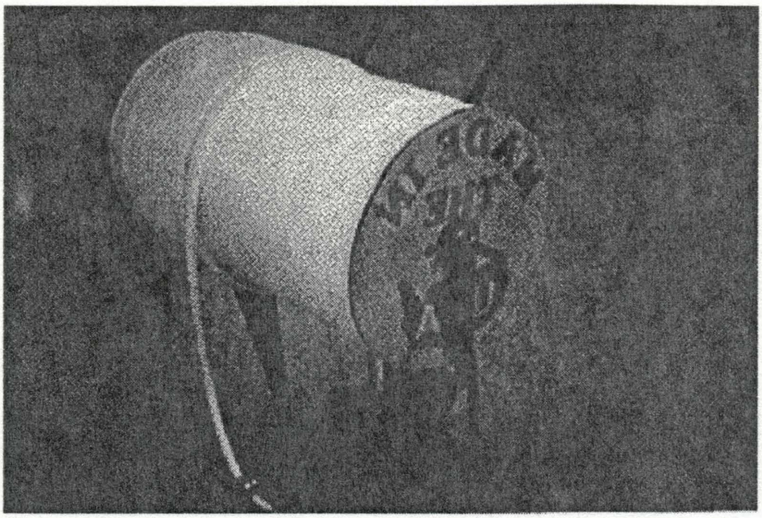

Figure 32. Automated, self-guided backer rod insertion tool.

- ▫ Equipped with double-walled heating chamber, heating oil heat transfer medium, mechanical agitator, accurate thermostats, reversible pump, and properly sized application nozzle (i.e., small enough to fit into joint reservoir).

- Silicone sealant pump–applicators should have the following capabilities:

  - ▫ Maintains a feed rate of at least 0.4 gal/min (1.5 L/min).
  - ▫ Equipped with properly sized application nozzle.
  - ▫ Does not allow air into the system, resulting in air bubbles in the sealant or premature curing of the sealant.

Installation of

# 6. ~~Construction~~ of Joint and Crack Seal ~~Treatments~~

The construction of joint reseal treatments in concrete pavement consists of five steps. With the exception of the second step, refacing joint sidewalls, each step is required for successful installation of the new joint seal. The following sections discuss the key points of each construction step. The last section in this chapter discusses the special considerations associated with sealing cracks in concrete.

## Step 1. Removal of Existing Sealant

- The sealant removal process must not result in the damage of joint sidewalls or in the development of additional pavement distresses.
- Using due care, the following procedures provide adequate removal results:
  - Manual removal is typically used only for preformed compression seals. This method is not feasible for most field-molded sealants.
  - Sawing is the most efficient and common removal method. It is efficient because the sawing also shapes the reservoir for the new material. Sawing becomes ineffective with extremely sticky materials, such as PVC coal tar, because the material clogs the saw blade.
  - Plowing can be very effective at removing existing sealant (figure 33). It is particularly useful in conjunction with a saw, as it decreases the likelihood of the saw blades "gumming up" during sawing.
  - Manual cutting using a knife is labor-intensive and time-consuming, and should be avoided.

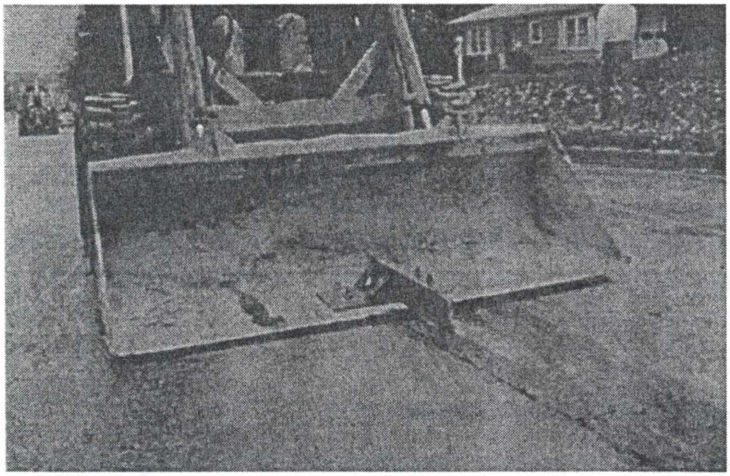

Figure 33. Joint plowing operation.

**Step 2. Refacing the Joint Reservoir Sidewalls**

- Joint refacing involves the removal of a minimum amount of concrete (0.04 in [1 mm] to 0.08 in [2 mm]) along each joint sidewall to create fresh surfaces to which the new sealant can bond. Unless the joint width is too narrow, it is highly recommended that joint refacing be performed.
- If sawing is used to remove the old sealant, sawing and joint refacing can be accomplished in one step. Other methods to remove the sealant need to be followed by joint refacing with a water-cooled diamond saw blade.
- After joint refacing, uniform width and depth of a joint in compliance with the design dimensions should be achieved. No spalls should result from resawing. The sealant should be removed completely and fresh concrete exposed on both sides of each joint.

**Step 3. Cleaning the Joint Reservoir**

- The slurry left by a wet sawing operation should not be allowed to dry in the joint and should be removed immediately after sawing by flushing the joints with low-pressure water, followed by waterblasting with high-pressure water.

- Following the initial joint cleaning, no loose sealant or slurry should remain in the joint reservoir (figure 34).
- To keep from recontaminating the joints, sawing and cleaning debris should be removed from the surrounding pavement surface by a vacuum or by air blowing.
- After the joint has sufficiently dried, sandblasting is done to remove all slurry dust, old sealant, and other contaminants, and to leave a roughened surface of freshly exposed concrete to which sealant can bond.
- To achieve adequate results, the sandblasting nozzle must be held no more than 2 in (50 mm) from the pavement surface. At least one pass must be made over each joint wall holding the nozzle at a 60-degree angle with the pavement surface to clean the top 1 in (25 mm) of the joint face.
- The entire length of the joint must be cleaned uniformly, and any remaining contaminants or sealant must be removed with repeated passes.

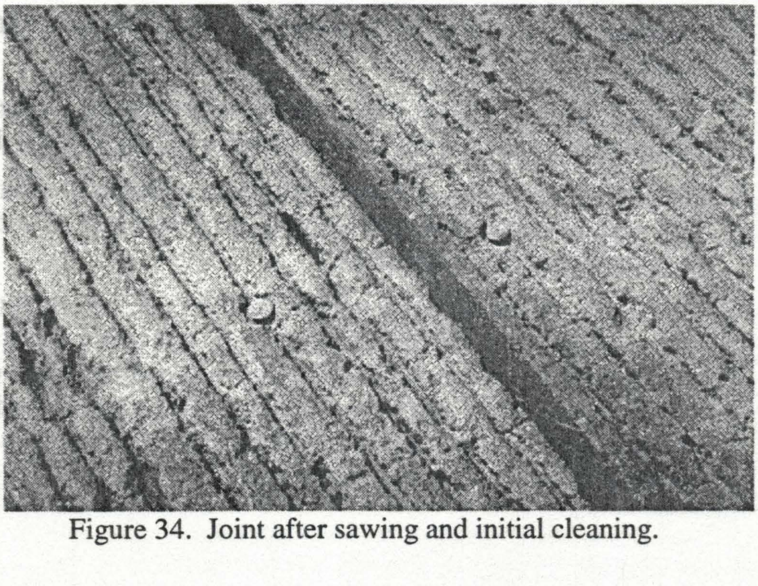

Figure 34. Joint after sawing and initial cleaning.

- To reduce operator fatigue, a piece of wood or angle iron can be attached to the blasting hose, allowing the operator to stand erect while blasting the joints. Even with this attachment, it is difficult to keep the nozzle at the proper angle and height and directed at the joint wall. Extending a piece of sharpened angle iron past the nozzle tip can help keep the nozzle directed at the joint wall and elevated 2 in (50 mm) above the pavement surface.
- Traffic in nearby lanes should be protected from sand and dust using a portable shield and low-dust abrasive.
- Sandblasting is followed by airblasting to remove sand, dirt, and dust from the joint and pavement surface. This should be done just prior to sealing to ensure that the sealant material will enter a clean reservoir.
- It is critical that the air supply be completely free from oil and moisture and that the volume and velocity of the air stream be at least 90 psi (620 kPa) at 120 $ft^3$/min (3.4 $m^3$/min).
- The airblasting nozzle must be held no more than 2 in (50 mm) from the pavement surface.
- Debris must be blown in front of the nozzle to prevent recontaminating the joints.
- Additional passes may be necessary to remove all dust, dirt, and sand.
- As each joint is cleaned, debris on the surrounding pavement must be vacuumed or blown away, taking care not to contaminate the joints.
- Following airblasting, the joint must be completely clean and dry. All dust, dirt, and sand must be removed from the joint and the surrounding pavement surface.
- The joints should be inspected for dust, dirt, oil, old sealant, and other debris. One method of detecting dust is to run one's finger along the joint wall and observe if any dust particles are stuck to it. Another procedure is to wrap a piece of black cloth around a piece of backer rod or a finger and run it through the joint. Any dust that remains is easily observed with this method.

**Step 4. Installation of Backer Rod**

- Backer rod is installed after a thorough inspection to ensure that the joint is free of debris.
- The backer rod should be compressed 25 percent during installation.
- The depth of the installation tool must be slightly greater than the required depth of backer rod because the rod compresses slightly when installed.
- Care should be taken to ensure that the backer rod is not stretched, which may result in shrinkage.
- Since joint widths vary, depending on sawing accuracy and the presence of spalls, a variety of diameters of backer rod should be available to meet the needs of the project.
- The top of the backer rod should be at the design depth, with less than 0.063 in (1.6 mm) variation. If the correct depth is not achieved in the first pass, a second pass with the insertion tool will be required. It is very important that the backer rod is at the proper depth.
- If necessary, the rod is trimmed at each end to produce a tight seal.
- Backer rod must be of large enough diameter that gaps are not formed between it and the joint sidewalls. The rod must be tight enough in the joint that it cannot slip down into the joint when sealant is placed on it; however, it cannot be so tight that it is torn during insertion.
- No gaps should be allowed between rod segments or at joint intersections. If the rod is stretched during insertion, it may shrink before sealant insertion, causing sealant to leak through the gaps and resulting in seal failure.
- When transverse and longitudinal joints are being sealed in one operation, better results are obtained if rod is installed in the entire length of the transverse joints. That rod is then cut at the intersection with longitudinal joints and rod is installed in the longitudinal joints.

## Step 5. Installation of Sealant

➤ General

- Sealant should be installed shortly after the backer rod is in the proper position to prevent the collection of debris on top of the backer rod.
- Sealant should not be installed when the pavement is wet, as moisture will inhibit sealant bonding. Hot-applied thermoplastic sealants should not be installed when the air temperature is less than 50 °F (8 °C) and silicone sealants should not be placed at temperatures below 40 °F (4 °C).
- Sealant must be slightly recessed at 0.125 to 0.25 in (3.2 to 6.4 mm) below the pavement surface.
- The sealant application nozzle should fit into the joint reservoir so that the joint can be filled from the bottom up.
- Sealant should be applied in one pass, progressing in a backward motion. The reservoir should be filled to the required level and if additional sealant is required in low sections, it should be added as soon as possible.
- Bubbles, sunken sealant, and sealant that remains tacky after the normal setting time must be corrected as soon as they are detected.
- Any sealant spilled onto the pavement surface should be removed before it cures.
- When transverse joints are sealed with silicone and longitudinal joints are sealed with hot-pour material, it is good practice to seal transverse joints first. This prevents hot-applied sealant from flowing into and contaminating the transverse reservoirs. Although some contamination of longitudinal reservoirs will occur while placing transverse silicone, silicone is more viscous than hot-applied sealant, and the extent of longitudinal joint contamination is tolerable.
- All sealant must be inspected after installation by looking at the material and seal characteristics. This early inspection provides assurance that the installation meets requirements.

- Traffic should not be allowed onto the pavement until the sealant has set and there is no danger of tracking or stone intrusion.

➢ Hot-Applied Sealant

- Hot-applied sealant should not be installed before reaching proper installation temperature. About the first 1 gal (4 L) is unusable and should be discarded, and pumping should be started only after fresh sealant is ejected from the nozzle at an acceptable temperature.
- The use of supplementary temperature monitoring devices is necessary so that the sealant temperature can be observed closely. Special equipment is used to install sealant that must be hot when applied. The equipment for installation must be able to raise the sealant temperature quickly, without overheating the sealant. It must give exact control of the sealant temperature, and it must allow the operator to insert sealant from the bottom of the sealant reservoir.
- Hot-applied sealant should be recirculated through the wand into the melting chamber when not applying the sealant.

➢ Silicone Sealant

- Nonself-leveling silicone sealants must be forced against the backer rod and joint sidewalls by use of the proper application equipment, such as small trowels, pieces of backer rod, or sections of tubing.
- A concave sealant surface about 0.25 in (6.4 mm) below the pavement surface is desirable.

**Step 6. Special Considerations for Crack Sealing**

➢ Guidelines for sealing cracks in concrete pavement are shown in table 9.

➢ Plastic shrinkage cracks that remain tight and are less than 0.125 in (3.2 mm) wide need not be sealed.

➢ Cracks less than 0.75 in (19 mm) but greater than 0.125 in (3.2 mm) are required to be sealed.

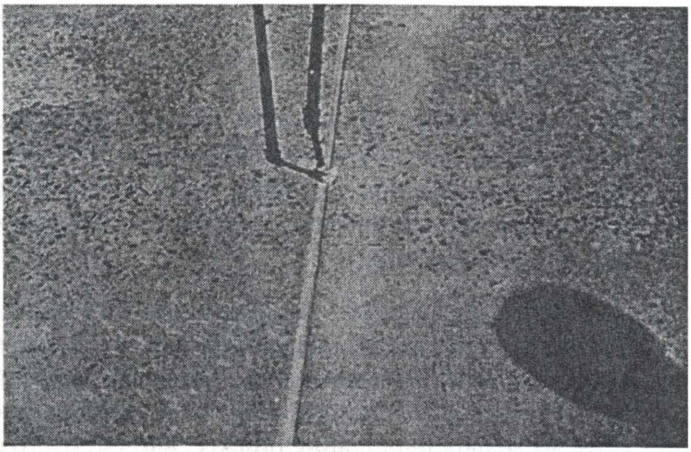

Figure 35. Appliation of sealant into joint reservoir.

Table 9. Guidelines for crack sealing on PCC pavements.

| Crack Condition | | Repair Procedures | | | |
|---|---|---|---|---|---|
| **Crack Width (in)** | **Spall Condition** | **Repair Spalls** | **Saw Crack** | **Install Backer Rod** | **Install Sealant** |
| <= 0.125 | None | | | | No |
| 0.125 - 0.75 | Minor | | Yes | Yes | Yes |
| 0.375 - 0.75 | Major | Yes | Yes | Yes | Yes |
| >0.75 | None | | Yes | Yes | Yes |
| >0.75 | Major | Yes | | Yes | Yes |

- Cracks greater than 0.75 (19 mm) should be evaluated for other PCC restoration methods.
- Working cracks, especially wider cracks, need to have backer rods placed to maintain the proper shape factor of the sealant. Wider cracks may also require some type of load transfer retrofit.
- Cracks are more difficult to shape and seal because they are not straight. Special crack-sawing blades should be used to follow crack wander.
- It is desirable to obtain the same shape factor at working cracks that is developed at joints on a project. Routers should not be used for concrete pavements. Diamond saws produce better reservoir results and increased productivity than routers.
- All the cleaning steps used in joint sealing are also followed in crack sealing, including use of backer rod and uniform sealant installation.

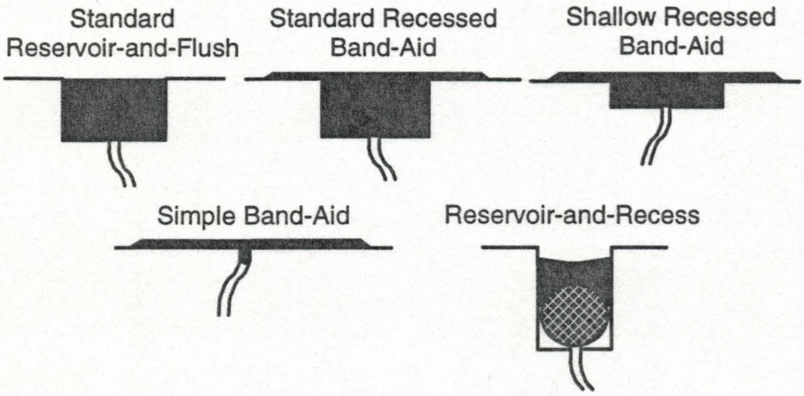


Figure 36. Material placement configuration for crack sealing.

# 7. Design of Slab Stabilization Repairs

The design of slab stabilization repairs in concrete pavement consists of four basic steps. Each step involves the consideration of various factors and adherence to certain established practices. The sections below present the important aspects of each design step.

**Step 1. Identification of Candidate Slabs**

- Slab stabilization does not correct depressions, increase the design structural capacity, stop erosion, or eliminate faulting. It restores the slab support, resulting in smaller deflections under traffic load.
- Slab stabilization should be performed only at joints and working cracks where loss of support is known to exist.
- All joints and working cracks along a project should not be stabilized because it often leads to pumping grout into areas that do not have voids.
- For maximum effectiveness, slab stabilization should be performed prior to the onset of pavement damage due to loss of support.
- To maximize the benefit of stabilization, other rehabilitation work may need to be performed. The cause of the voids and distresses need to be addressed prior to slab stabilization.

**Step 2. Detection of Voids**

- General
  - Deflection testing, in conjunction with visual surveys, is the most effective approach for locating and estimating the size of underslab voids.
  - Ground penetrating radar (GPR) should not be used because of misinterpretation of reading of shallow voids and because false readings due to excessive moisture further reduce overall accuracy of void detection.

➢ <u>Visual Surveys</u>

- The accuracy in identifying the amount and location of the voids using only visual inspection is low. Inaccurate estimates can subsequently result in continued deterioration and problems such as slab lift, broken slabs, insufficient material used for stabilization, and generally poor performance.
- Faulting of transverse cracks and joints, pumping, and corner breaks are good indicators of loss of support and probable void locations.
- The presence of ejected fines (figure 37) at or near joints and cracks in the traffic lane or shoulder is a good indicator of pumping and the migration of water and fines within the pavement structure.
- When conducting a visual survey, it is important to determine the percentage of joints and cracks suffering loss of support. Visual evidence of pumping is directly related to the percentage of joints and cracks affected.

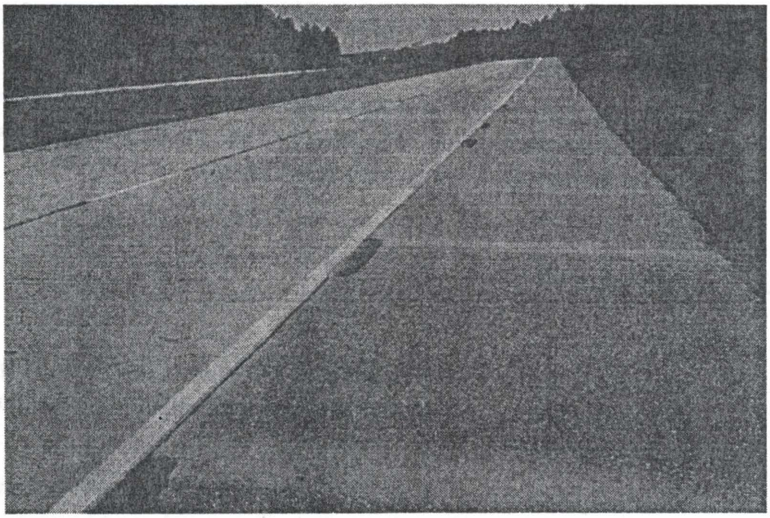

Figure 37. Pumping of fines indicating probably loss of support.

➢ Deflection Testing

- Deflection testing can determine whether a loss of support has occurred and provide a rough estimate of the quantity of material needed to adequately fill the voids.
- Deflection testing must be conducted at cool temperatures to avoid problems with slab expansion and increased load transfer at the transverse joints and cracks due to aggregate interlock.
- Specifications based on a single corner deflection are not desirable or recommended because variation in load transfer from joint to joint can cause considerable variation in corner deflections.
- Deflection testing must be carried out using the Falling Weight Deflectometer (FWD). This device measures surface deflections under various loading magnitudes, from which load-versus-deflection plots can be developed.
- A load-versus-deflection plot that does not pass through the origin indicates that a void likely exists at that location. It is generally believed that the further the plot deviates from the origin, the larger the void.
- Void detection via deflection testing can be conducted concurrently with the stabilization operation, providing close coordination between the void detection and slab stabilization operations.
- When applying the deflection approach, it is important that similar equipment and loads are applied both during the evaluation phase and after the slab stabilization process.

## Step 3. Selection of Slab Stabilization Materials

➢ General

- The material selected for slab stabilization must be able to penetrate into very thin voids and have sufficient strength and durability to withstand the imposed loads, moisture fluctuations, and temperature extremes.

- Slab stabilization materials are required to have sufficient strength to support the slab and yet have the initial fluidity to flow into and fill small voids beneath the pavement.
- At the proper consistency, the stabilization material should have sufficient consistency to displace free water from under the slab.
- The material should remain insoluble, incompressible, and nonerodible after installation and hardening.

➢ Pozzolan-Cement Grout

- Pozzolan-cement grouts are used by most agencies, partly because the materials are readily available and cost-effective.
- The grout mix must be fluid enough to pass through the flow cone in 9 to 16 seconds.
- The 7-day compressive strength of the pozzolan-cement grout mix, as measured by AASHTO T 106, should be greater than or equal to 600 psi (4,137 kPa).

➢ Polyurethane

- The benefits of polyurethane include its high tensile strength and rapid cure time that allow the pavement to be opened to traffic within 15 to 30 minutes of the repair.
- Good tensile strength allows polyurethane to withstand traffic vibration once it is placed beneath the pavement.

**Step 4. Selection of Stabilization Equipment**

➢ Mixing Equipment

- Batching and mixing of the grout or polyurethane is generally accomplished using a self-contained, mobile apparatus.
- Colloidal mixing equipment provides the best results for pozzolan-cement grouts. Paddle- or conveyor belt-type mixers provide inadequate mixing for pozzolan-cement grout.

- Drilling Equipment
    - Hand drills or pneumatic drills capable of drilling 1.5- to 2.5-in (38- to 64-mm) holes through concrete and steel reinforcement should be used.
    - Hand-held electric-pneumatic rock drills are typical for drilling injection holes for polyurethane stabilization.
- Injection Equipment
    - A positive-displacement injection pump, or a non-pulsing progressive-cavity pump, capable of maintaining pressures between 25 and 200 psi (0.15 and 1.4 MPa) should be used. A desirable pumping rate is approximately 1.5 gallons per minute (5.7 liters per minute).
    - Expanding-rubber packers are preferable because they hold the injection pipe and nozzle tightly in place. Drive packers do not provide as tight a fit as expanding-rubber packers, thus allowing some grout to extrude during injection.
    - To induce adequate grout velocity and fewer tendencies for the grout to separate, the diameter of the hoses that transport grout from the pump to the packer should be 0.75 to 1.5 in (20 to 40 mm). A grout return hose should be used to recirculate the grout and prevent it from hardening in the hose.
    - Grout packers are not used for urethane grouting operations. Instead, plastic nozzles are inserted into the holes. These nozzles screw onto the injection hose.
- Slab Deflection Monitoring Equipment
    - Uplift beams or laser levels can be used to monitor slab deflection.

# 8. Construction of Slab Stabilization Repairs

The construction of slab stabilization repairs consists of two required steps—locating and drilling the injection holes and injecting the stabilization material—and a third highly recommended step—post-construction testing. The key points of each of these steps are discussed in the sections below.

**Step 1. Locating and Drilling Injection Holes**

- The injection holes are generally located near the void boundary farthest from the nearby joint or crack.
- Hole patterns vary depending on the pavement type, joint spacing, existing slab distresses, and so on.
- The injection holes may be relocated during the slab stabilization process, depending on the performance of the operation. Each project is different, and flexibility in the hole pattern is necessary to improve stabilization performance.
- If grout flows easily between the holes before sufficient back pressure occurs during the injection, the hole-to-hole spacing may be increased. If the grout does not flow easily, the spacing may be reduced.
- Typically, four injection holes are used to ensure uniform distribution of the grout.
- Holes are placed in each wheelpath on both the approach slab and the leave slab at the transverse crack or joint.
- The holes in the approach slab are approximately 8 to 12 in (203 to 305 mm) from the joint and the holes on the leave side are approximately 18 to 24 in (457 to 610 mm) from the joint.
- Concrete pavements built on stabilized bases need to have the hole extend through the base and into the subgrade, because voids generally develop beneath stabilized bases in PCC pavements.
- Holes should not be drilled beyond the void boundary, as this may result in slab lift during grout injection.

- For grout applications, drilled holes should be between 1.5 and 2.5 in (38 and 64 mm) in diameter. Larger holes may break the bottom of the slab and smaller holes are not efficient for grout injection.
- For polyurethane stabilization, the maximum hole diameter should not exceed 0.63 in (15 mm).
- The downward pressure of any drill should be less than 200 lb (90 kg) to avoid conical spalling and breakthrough of the slab. The resulting broken pieces of the slab can seal off the entrance to the void and possibly weaken the slab.

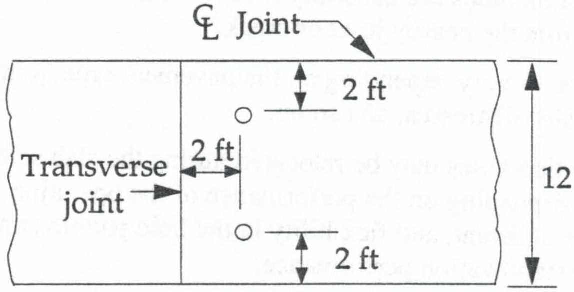


Figure 38. Typical hole pattern for JPC and JRC pavements.

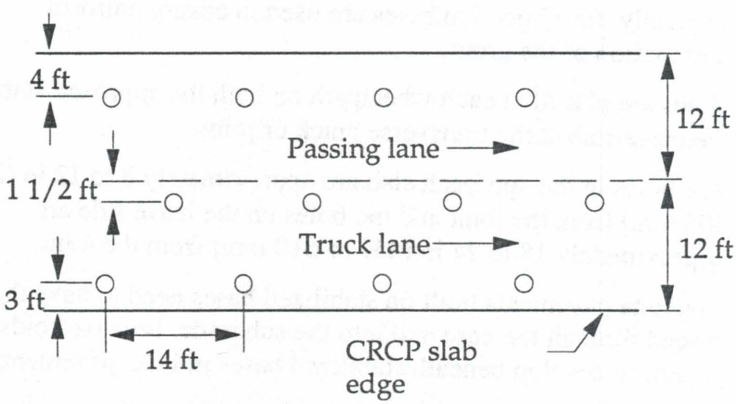


Figure 39. Typical hole pattern for CRC pavements.

## Step 2. Injection of Stabilization Material

- Following hole placement and drilling, the grout packer or expanding-rubber packer is connected to the discharge hose on the pressure grout pump and placed into the drilled holes (figure 40).
- The discharge end of the packer is not extended past the bottom of the concrete slab when placed into the drilled hole.
- Grout injection should start at the centerline holes in each slab and work toward holes near the shoulders to let collected water flow towards the outer edge.
- If a transverse joint opens wider than a longitudinal joint, it may be desirable to begin injection through holes near the shoulder joint and drive the excess water out through the transverse joint.
- When stabilizing shoulders, care should be taken to avoid raising the shoulders; they are thinner than the mainline slabs and easier to lift.
- Most specifications for slab stabilization limit the lift to less than 0.05 to 0.10 in (1 to 2 mm). Voids can be created under the pavement due to excessive lifts, resulting in uneven support.
- Slab uplift should not be allowed to exceed 0.25 in (6.4 mm) for a given slab corner. Pumping should be ceased when any of the following conditions occur:
  - The slab begins to rise.
  - The grout no longer pumps at the maximum allowable pressure.
  - The grout begins to flow up through an adjacent hole.
- Relief holes can be used to determine when to cease pumping. If the grout is displacing water from beneath the slab, pumping should be continued until an undiluted mixture of grout is observed flowing from the same area.
- Grout injection should not continue if after 1 minute there is no evidence of grout in any adjacent hole, joint, or crack, and the uplift gauge has not measured any slab movement. This is an indication that the grout is flowing into a large cavity, which will require correction by another repair procedure.

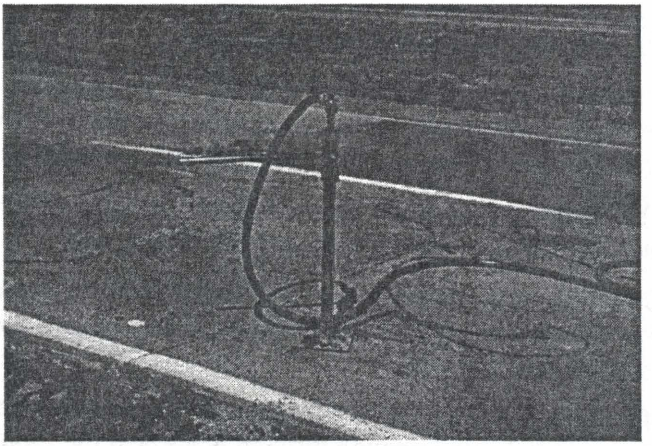

Figure 40. Grout packer connected to a discharge hose.

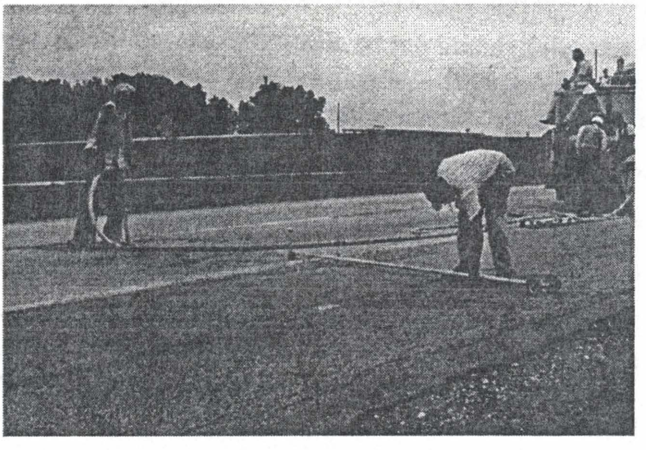

Figure 41. Equipment to monitor slab uplift.

- Close monitoring of the slab during stabilization is necessary to ensure that the slab does not rise.
- Although excessive slab lift is undesirable, some slab lift may be necessary to ensure proper spread of the grouting material.
- For polyurethane, the amount of rise is controlled using the pumping unit by regulating the rate of injection of the material.
- When the nozzle is removed from the hole, any excessive polyurethane material should be removed from the area and the hole sealed with a nonexpansive cementitious grout.
- If all slabs are scheduled to be stabilized, proper injection techniques should be followed to ensure that those slabs that do not have voids will not accept grout.

**Step 3. Post-Construction Testing of the Stabilized Slabs**

- The effectiveness of slab stabilization can be determined only by monitoring the subsequent performance of the pavement.
- The best early indication of the effectiveness is obtained by remeasuring the slab deflections after grouting and determining if the deflection has reduced to the point of full support.
- If the deflections are still high, the slab may need to be stabilized again.

# 9. Design of Load Transfer Restoration Repairs

There are three sequential steps in the design of load transfer restoration repairs and each is required to be performed. Discussed below are the important aspects of each design step.

**Step 1. Identification of Candidate Projects**

- ➢ The following identifiers should be used as indicators for candidate projects for load transfer restoration:
  - Deflection load transfer of 60 percent or less.
  - Faulting greater than 0.10 in (2.5 mm).
  - Differential deflection of 10 mils (0.25 mm) or more.
  - Total faulting level of 32 in/mi (500 mm/km) or more.
- ➢ Load transfer restoration repairs may be done concurrently with full-depth repairs, but must occur after slab stabilization and slab jacking operations, if performed. Diamond grinding, diamond grooving, and joint/crack sealing should be completed after load transfer restoration.

**Step 2. Selection of Dowel Bars**

- ➢ The most effective and the recommended means of load transfer restoration is through the use of smooth round dowel bars placed in slots cut across the joint or crack.
- ➢ Dowel bars with diameters of at least 1.25 in (32 mm) have been successfully used. However, larger diameter (1.5-in [38-mm] or greater) bars are recommended since they are more effective at reducing faulting, especially on higher trafficked pavements (i.e., 0.5 million or more ESALs/year in the outer lane).
- ➢ Dowels should be at least 18 in (450 mm) long.
- ➢ Use three to five dowels in each wheelpath, spaced 12 in (305 mm) apart.

- The outermost dowel should be no more than 12 in (300 mm) from the outer lane edge. However, when tied concrete shoulders exist, this distance can be increased to 18 in (450 mm).
- It is required that the dowel bars be epoxy-coated for corrosion resistance.

## Step 3. Selection of Backfill Materials

- General
  - Backfill material properties that should be considered include compressive strength, flexural strength, bond strength, modulus of elasticity, scaling resistance, abrasion resistance, thermal compatibility, shrinkage, and freeze-thaw resistance.
  - Repair materials that work well for partial-depth repair methods typically work just as well for load transfer restoration.
- Proprietary Materials
  - Proprietary materials, such as Set 45 and Road Patch, are quick setting and allow early opening of the repair site.
- Polymer Concretes
  - Polymer concretes usually reach 80 percent of their ultimate compressive strength in 45 minutes to 2 hours after placement in temperatures ranging from 40° to 100° F (4 to 38° C). A short pot life of about 15 minutes requires that polymer concrete be mixed, placed, and finished quickly by qualified personnel.
- PCC
  - PCC is the most commonly used repair material, since it costs less than other materials, practitioners are familiar with the material, and there are no thermal compatibility problems with PCC pavements. Sand and an aggregate with a maximum size of 0.38 in (9.5 mm) are commonly used in the PCC mix. Proper mix design procedures must be used to ensure adequate strength and durability. High-alumina cement should not be used because it is susceptible to conversion of some of its calcium aluminate hydrate components, which may result in significant strength loss.

## Step 4. Selection of Equipment

➢ Slot Cutting Equipment

- A single, diamond blade slot cutter is most commonly used for cutting slots. A small hand-held hammer or a lightweight jackhammer (30 lb [14 kg]) is often used to remove the concrete fins left by the series of saw cuts. Use of large jackhammers may break through the concrete.
- A modified milling machine can also be used for slot cutting.

➢ Cleaning Equipment

- A vacuum system must be used to remove saw slurry or milled concrete.
- Sandblasting and airblasting equipment, capable of supplying a minimum nozzle pressure of 90 psi (620 kPa) at 120 $ft^3$/min (3.4 $m^3$/min), should be used to thoroughly clean the slots.

# 10. Construction of Load Transfer Restoration Repairs

The construction of load transfer restoration repairs consists of four required steps. The following sections discuss the key points of each construction step.

**Step 1. Cutting the Slots**

- The slots should be aligned parallel to the centerline within the maximum allowable variations to keep the dowels in proper alignment and prevent them from locking up and tying the slabs together.
- Spalling should be held to a minimum and care must be taken during sawing and material removal, so as not to damage the surrounding sound concrete.
- A 1- to 2-in (25- to 51-mm) wide slot is required for each dowel bar.
- The slot should be deep enough to position the dowel at mid-depth of the slab, allowing a clearance of approximately 0.5 in (13 mm) beneath the dowel bar for placement on chairs.
- More than one pass may be required to get the slot to the required depth.
- The slot must also be long enough that the dowel will lie across the bottom of the slot without the ends hitting the curve of the saw cut. This typically requires that the surface length of the saw cut to be approximately 3 to 4 ft (0.9 to 1.2 m) for an 18-in (450-mm) dowel bar.
- Traffic can be permitted on the pavement after the slots are cut, but should be limited to only a few days.
- When traffic is on the lane with the saw cut slots, no work on the adjacent lane should be allowed as this could result in cracking of the sawed slots.
- A small hammer should be used to remove concrete fins. The hammer is placed at the end of the fin and jackhammered down and along the bottom of the saw cut. The hammer can also be placed along the side of the slot to break away the fin.

- The bottom of the saw cut is flattened with a small hammerhead on a small jackhammer to remove rocks and burrs along the bottom of the saw cut.
- The joint or crack will require full-depth repair if the joint or crack is broken.

**Step 2. Cleaning and Preparing the Slots**

- Once the removal of the concrete is completed, the slots should be thoroughly sandblasted to remove dust and sawing slurry and to provide a macro rough surface to which the repair material can bond.
- The sides and bottom of the slots are then airblasted to remove all loose debris.
- The slots must be thoroughly cleaned and inspected. If touching the slot sides or bottom reveals dust or laitance, the slot must be recleaned.
- The sidewalls and bottom of the slot are typically coated with epoxy resin prior to the placement of the dowels and backfill material to keep the backfill material from flowing down into the joint or crack.

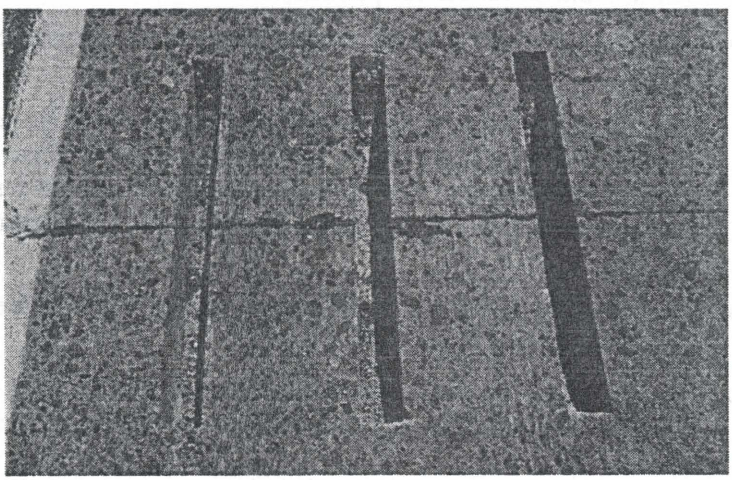

Figure 42. Dowel slots across a crack.

### Step 3. Placing the Load Transfer Devices

- ➢ Epoxy-coated dowel bars are lightly greased or oiled their full length to facilitate joint movement.
- ➢ The coating of grease on the dowel should not be excessively thick because this may build in additional dowel looseness, which diminishes load transfer.
- ➢ Care must be taken to prevent the bondbreaker or grease from falling onto the slot sides or bottom, which could prevent the backfill material from bonding to the concrete.
- ➢ Plastic sleeves over the dowels should not be used because they may also build in additional dowel looseness.
- ➢ A 0.25-in (6-mm) non-metallic or epoxy-coated expansion cap is placed on both ends of the dowel to allow for joint closure after installation of the dowel. (0.5-in [13-mm] expansion caps are required if only one cap is used).
- ➢ Support chairs in the slot allow the dowel to be positioned in the slot so that it lies horizontally and parallel to the centerline of the pavement at the mid-depth of the slab. The support chairs also ensure that the backfill material can flow around and fully support the dowel.
- ➢ The legs and sides of the chair should be snug against the slot wall to keep the dowel from moving and becoming misaligned during placement of the backfill material.
- ➢ A filler board or a joint-forming insert is positioned at the mid-point of the dowel to prevent the backfill material from flowing down into the crack below the joint saw cut or into the sides of the joint or crack. The filler board also allows for some future expansion room if the joint or crack is not tightly closed.
- ➢ The filler board should be over the joint or crack with half of the dowel length on each side.

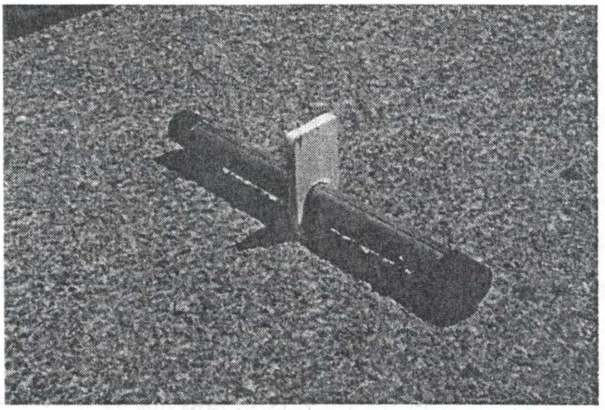

Figure 43. Dowel bar with expansion caps and joint-forming insert.

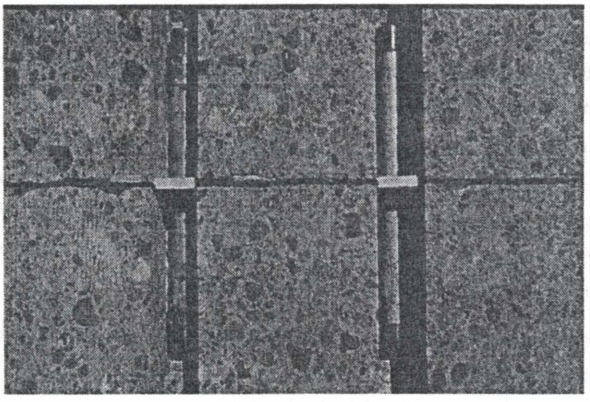

Figure 44. Dowel placement across a joint.

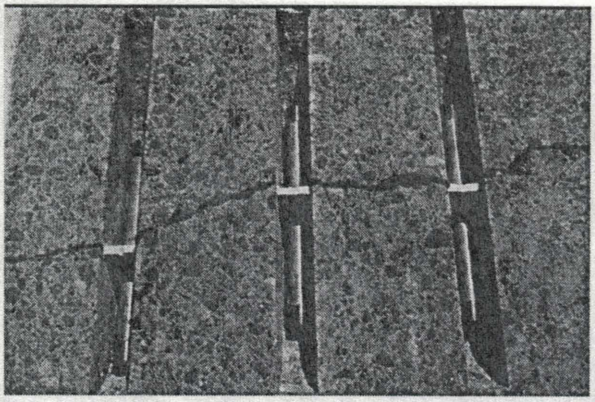

Figure 45. Dowel placement across a crack.

**Step 4. Backfilling the Slots**

- Due to the relatively small quantities involved, mobile batch trucks for mixing the backfill material should not be used. The concrete will be poorly mixed and of inconsistent quality when using mobile batch trucks.
- After placing the backfill material into the slot, it should be consolidated with a small spud vibrator.
- To ensure that the dowel bars are not misaligned, care must be taken not to hit the dowel bar with the vibrator.
- A curing compound is typically placed on the backfill material to reduce shrinkage.
- The finish of the load-transfer restoration repair area is not important.
- The last step in the installation process is recutting the joint with a diamond saw blade. The lane is opened to traffic when the backfill material has gained adequate strength.
- Load transfer restoration projects are typically followed by diamond grinding to improve rideability, which can be maintained for a long time due to lower faulting resulting from improved load transfer across the joints and cracks.

Figure 46. A completed load restoration project.

# 11. Shoulder Restoration

The following sections discuss the various alternatives for restoring asphalt and concrete shoulders built adjacent to concrete mainline pavement. For each shoulder type, guidelines are provided for both reconstruction and rehabilitation options

**Step 1. General**

- Shoulder rehabilitation methods are influenced by restoration methods of the mainline pavement. Alternatives for shoulder restoration should be formulated at the same time as the mainline. If shoulder restoration procedures are different from those of the mainline, scheduling accommodations should be made to ensure that the two operations do not interfere with one another.
- Distresses to be noted while surveying the shoulder are the same as those that would be noted for a mainline pavement of the same type. In addition to those distresses, the condition of the joint between the shoulder and the pavement edge should be noted. Excessive dropoffs and poor lane-shoulder sealant condition need to be remedied.

To tie or not to tie?

**Step 2. Asphalt Shoulders**

- <u>Reconstruction</u>

  - If severe shoulder deterioration exists or if drainage improvements are necessary, the bituminous shoulder may have to be reconstructed.
  - When circumstances warrant the reconstruction of a bituminous shoulder, the design thickness should be related to the anticipated load capacity, which is indirectly a function of the mainline pavement design.
  - A percentage of the mainline traffic should be used to estimate the loading that may be applied to the bituminous shoulder.

- Cross slope and drainage should be considered carefully when designing and constructing a bituminous shoulder.

➢ Rehabilitation

- Rehabilitation of the bituminous shoulder can encompass all of the accepted restoration methods used for mainline AC pavements.

- Some general guidelines on the type of rehabilitation for different types of bituminous shoulder distresses are shown in table 10.

**Step 3. Concrete Shoulders**

➢ A visual distress survey is typically conducted, the structural history reviewed, and deflection data collected, if applicable. This is generally performed in conjunction with the evaluation of the mainline pavement.

➢ The load transfer efficiency should be determined at the pavement/shoulder joint similar to the evaluation of the transverse joints in the mainline pavement.

To tie or not to tie?

Table 10. Summary of shoulder rehabilitation options for key bituminous shoulder distress types.

| Shoulder Distress | Rehabilitation Alternatives |
|---|---|
| Pumping (at lane-shoulder joint) | 1. Underseal PCC pavement and seal lane-shoulder joint.<br>2. Add PCC shoulder. |
| Alligator and block cracking | 1. Perform localized sealing or patching, including lane-shoulder joint.<br>2. Recycle or reconstruct with AC.<br>3. Add PCC shoulder. |
| Weathering and raveling | 1. Rejuvenator or seal coat.<br>2. Chip seal or surface treatment.<br>3. Surface recycling. |
| Shoving | 1. Localized patching and sealing of lane-shoulder joint.<br>2. Localized removal and replacement. |
| Settlements/heaves (including dropoff) and shoulder separation | 1. Localized patching and sealing of lane-shoulder joint.<br>2. Localized removal and replacement.<br>3. Recycle or reconstruct with AC.<br>4. Add PCC shoulder. |

No

➢ Reconstruction

- If reconstruction of the shoulder is warranted, the shoulder thickness should be equal to that of the mainline pavement.

- If the shoulder is tapered, the shoulder should be the same thickness as the mainline, then tapered to no less than 6 in (152 mm) at the outside edge.

- The PCC shoulders should be tied to the mainline with 30-in (762-mm) long Grade 40 deformed steel bars, with a diameter of 0.63 in (15.8 mm) and spaced on 30-in (762-mm) centers.

- The tie bars must be placed in holes drilled into the mainline slab and anchored with epoxy resin or grout.

- If D-cracking or significant edge distresses exist on the mainline pavement, PCC shoulders should not be constructed.

➢ Rehabilitation

- Deteriorated cracks and joints in the PCC shoulder are rehabilitated using partial-depth or full-depth repairs.

- If extensive spalling exists along the lane-shoulder joint, tiebar effectiveness should be examined.
- Slab stabilization of the PCC shoulder can be performed, especially at the slab and shoulder corners, where pumping and erosion are most likely to occur.
- Some general guidelines on the type of rehabilitation for different types of bituminous shoulder distresses are shown in table 11.
- The restoration techniques used for PCC shoulders are identical to those used on the mainline PCC pavements.

Table 11. Summary of shoulder rehabilitation options for key PCC shoulder distress types.

| **Shoulder Distress** | **Rehabilitation Alternatives** |
|---|---|
| Cracking | 1. Seal cracks.<br>2. Localized repairs.<br>3. Recycle, reconstruction, or overlay. |
| Pumping/Faulting | 1. Underseal slab corners and seal lane-shoulder joint.<br>2. Underseal and overlay. |
| Spalling | 1. Partial- or full-depth repairs.<br>2. Localized reconstruction. |

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