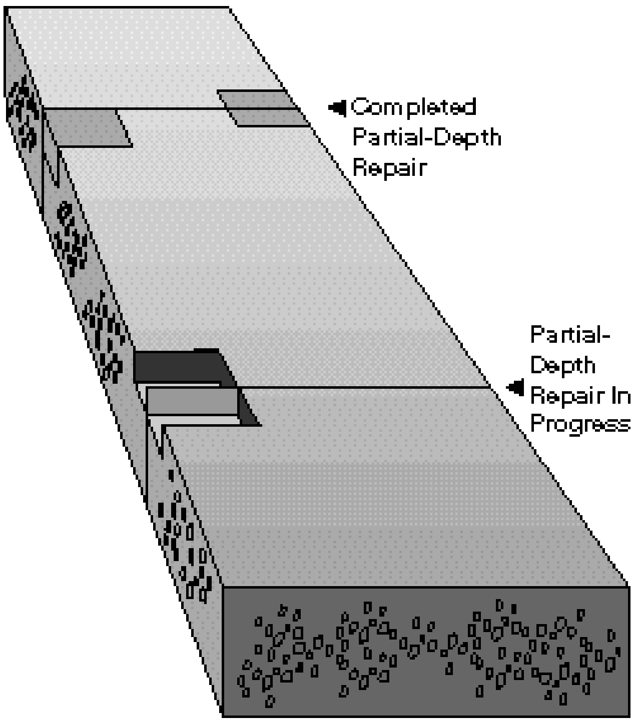
CONCRETE PAVING *Technology*

Guidelines for Partial-Depth Spall Repair



PURPOSE

This publication provides guidance for repairing spalling at joints and cracks in concrete pavement slabs. These recommendations apply to pavements for highways, streets and roads, and airports.

INTRODUCTION

Partial-depth repair is a rehabilitation technique that restores localized surface distress, such as spalling at joints and/or cracks in the upper one-third to one-half of a concrete pavement. Surface spalls create a rough ride and can accelerate development of further problems. Partial-depth patches replace unsound concrete, restore the rideability of the pavement, deter further deterioration, and provide suitable edges for effective joint and crack resealing.

Partial-depth patches are usually very small. Each patch typically covers an area less than about 1 sq. m (1.2 sq. yd) and are often only 50-75 mm (2-3 in.) deep. Installing a partial-depth repair involves determining the extent of the deterioration, removing the deteriorated concrete, cleaning the patch area, placing the patch material, and re-forming the joint system.

The most common problem partial-depth repair is used for is spalling, but it can also be used for small areas with severe scaling. Spalling is the breaking, cracking, chipping, or fraying of the slab edges that occurs within 50 mm (2 in.) of joints and cracks or their corners. (1) Spalling differs from cracking in that a crack is a fracture through most or all the thickness of the slab. A typical transverse joint spall for which partial-depth repair would be appropriate is shown in Figure 1.

Figure 1. Transverse joint spalling.

One of the causes of spalling is the obstruction of joint closure due to incompressibles in the joint system. Incompressibles are sands, small stones, and fragments of concrete that become lodged in joints and cracks when they are open during cool weather. When the slabs expand in hot weather, the incompressibles inhibit the closing of the joints and cracks. This sets up uneven point-bearing pressures at the joint or crack face, which cause the concrete to crush or spall.

Another cause of spalling is the use of plastic or metal joint-forming inserts. Joints constructed with plastic inserts often require extra finishing, which can draw water to the surface. This increases the water-cement ratio of the paste at the surface and makes the surface susceptible to spalling and scaling. Similarly, metal joint-forming inserts, sometimes called unitube, and high reinforcing steel can cause spalling if placed too close to the surface. Corrosion and expansion of the steel or inserts, or entrapment of incompressibles in the inserts, can lead to cracking, breaking, and debonding of the surrounding concrete.

Finally, late sawing and material durability problems such as alkali-silica reactivity (ASR), D-cracking, or freeze-thaw damage can cause spalling. Late sawing may induce micro-fracturing at the joint face, which could break off and cause spalling. Material problems cause the concrete joint face to deteriorate and spall.

Spalls that are smaller than 50 mm (2 in.) by 150 mm (6 in.) do not affect ride quality and do not need partial-depth repair. Individual small spalls adjacent to joints or cracks can simply be filled with sealant. However, when several small spalls exist along a joint or crack, it may be preferable to repair the full length of the spalled area.

Limitations —

Partial-depth repair is usually not appropriate for visible spalls that extend more than 150-250 mm (6-10 in.) from the joint and are moderately severe. Such spalls may indicate that more deterioration is taking place below the slab surface. These spalls are often caused by material problems, such as D-cracking, ASR, or by corrosion or lockup of dowel bars at transverse joints. Full-depth repair is more appropriate for these distresses (Figure 2). If there is no obvious indication of the depth or cause of the spalling, coring is necessary to determine whether deterioration exists below the surface. For more information on full-depth repairs, see ACPA publication *Guidelines for Full-Depth Repair (TB002P).* [2]

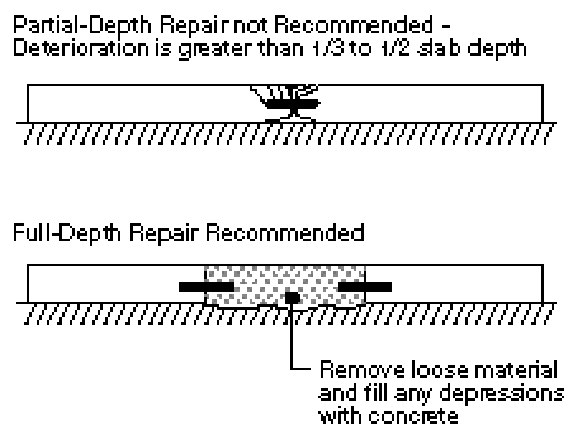


Figure 2. Joint deterioration warranting full-depth repair.

A partial-depth repair cannot correct a crack through the full thickness of the slab. Depending on the cracks condition, either sawing and sealing or full-depth repair is the appropriate repair for cracking. However, surface spalling at a crack can be corrected by partial-depth repair, as long as the crack itself is reestablished through the partial-depth repair and subsequently sealed.

Partial-depth repairs should not be used to repair spalling caused by corrosion of metal joint-forming inserts or reinforcing steel if the metal is to be left in place. All metal must be removed before placing a partial-depth repair. In general, partial-depth repairs should be applied only to spalls that are confined to the upper one-third to one-half of the slab thickness and do not expose reinforcing steel or load transfer devices. If it is possible to cut and fully remove the reinforcing steel exposed in the spalled area, (as in the case of mesh reinforcement placed too high), a partial-depth repair can be successful, as long as the spall is no deeper than one-third to one-half of the slab thickness.

Pavements that have little remaining structural life, as evidenced by a substantial amount of fatigue cracking and/or rapid crack deterioration, are not good candidates for partial-depth repairs or other non-overlay restoration techniques. A concrete overlay or reconstruction is a better rehabilitation alternative in this situation.

DESIGN

Concurrent Work —

Partial-depth repair may be done either alone or as part of a comprehensive concrete pavement restoration (CPR) project. When done as part of a comprehensive project, the sequence of partial-depth repair and other restoration techniques is important. Figure 3 illustrates where partial-depth repair fits into the overall scheme of a restoration program. [3,4]

Partial-depth repair should be done after slab stabilization, so that any accidental spalling that may occur during slab stabilization can be repaired. It should be done before or concurrently with full-depth repair, so that either a partial-depth or a full-depth repair can be done depending on the depth of the deterioration. Partial- and full-depth repair should precede diamond grinding, which restores the rideability of the pavement to a high smoothness level.* These techniques are followed by joint resealing. One of the objectives of partial-depth repair is to provide new joint edges suitable for resealing. For more information on these other restoration techniques, see references 2-8.

* A good finishing technique can create an adequate transition between the patch and the existing concrete. However, if the pavement will have many closely spaced repairs, it may be difficult to achieve a surface smoothness comparable to modern standards. In such cases, it is necessary to restore the ride quality with diamond grinding.

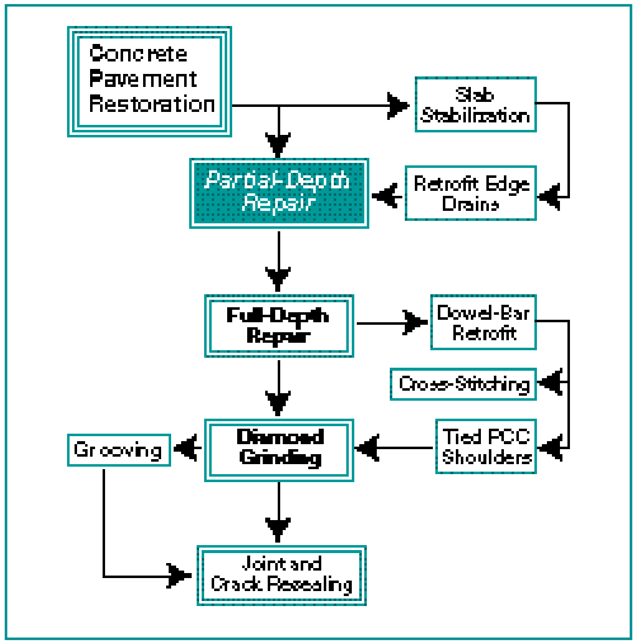


Figure 3. Location of Partial-depth repair in an overall Concrete Pavement Restoration sequence.

CPR - Area Management — Because the distresses that partial-depth repairs repair are progressive (that is, they get worse if neglected), it is important that they be repaired as timely as possible. One way to do this is with the "CPR - Area Management" concept.

CPR - Area Management is a multiyear contract between a highway or airport agency and a contractor to repair and manage pavement deterioration. The agency contracts for very broad CPR quantities, certain traffic-control windows, and distress surveys. The contractor commits to specific unit prices based on broad quantities, without exact areas or items marked on the pavement or plans.

After the contract award, the agency and contractor jointly conduct a detailed distress survey and agree on the specific repairs for that year. After determining the amount of work, the contractor develops a site-specific work plan and traffic control scheme. Finally, the agency issues a work order to begin work. The sequence is repeated in successive years. [4]

Size —

Good judgment is essential in defining the limits for partial-depth repairs, particularly where more deterioration exists than is visible on the slab surface. Some engineers attempt to cut costs by limiting patch size despite the expanse of deterioration, which can reduce the repair's ability to extend pavement service life. Furthermore, for partial-depth patches, the cost is in the labor and not in the materials.

To size a repair, it is necessary to know the extent of typical deterioration on the pavement. Each repair should replace the concrete and all significant distress. It is also advantageous to keep the patch boundaries square or rectangular, and to avoid internal corners in the patch area. Irregular shapes and internal corners are more difficult to saw and usually do not perform well.

It may be necessary to extend the size of patches beyond the minimum length when marking the pavement removal areas just before construction. Use the following guidelines when determining the repair sizes:(9)

- Use a minimum length of 300 mm (12 in.).
- Use a minimum width of 100 mm (4 in.).
- Extend the patch limits beyond the delamination marks or visible spalls by 75-100 mm (3-4 in.).
- Do not place a patch if the spall is less than 150 mm (6 in.) long and less than 35 mm (1.5 in.) wide.
- If two patches will be less than 0.6 m (2 ft) apart, combine them into one large patch.
- Repair the entire joint length if there are more than two spalls along a transverse joint.

It is during removal of the concrete that you determine the depth of the patch. See Figure 4 for a typical layout for a partial-depth repair.

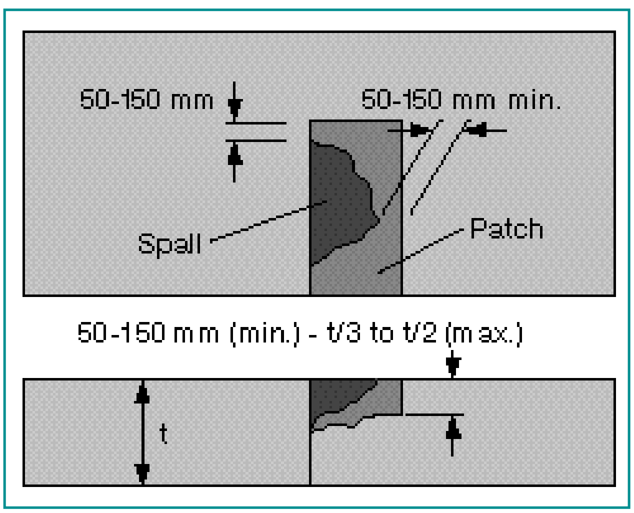


Figure 4. Typical patch layout for a partial-depth repair

Material Selection —

The selection of the patching material depends on many factors. These include time available before opening to traffic, air temperature during construction, funding, desired service life, and the size and the depth of the patches. The ideal partial-depth repair material would have good workability, quick mixing time, fast setting time, rapid strength development, low shrinkage, strong bonding capability, good long-term strength and durability, thermal compatibility with the existing concrete, and a reasonable cost.

Among the material properties that should be considered are strength gain, modulus of elasticity, bond strength, freeze-thaw resistance, scaling resistance, sulfate resistance, abrasion resistance, coefficient of thermal expansion, and shrinkage. References 10, 11, 12, and 13 present laboratory test results from several organizations on a variety of different repair products and include suggested specifications.

Volume change refers to shrinkage of the material due to moisture loss or contraction and expansion due to temperature changes. Excessive volume change can cause the repair material to debond from the surrounding concrete, and may cause cracking within the repair material itself. Some repair materials can be mixed with agents that will decrease the likelihood of debonding and shrinkage cracking. Some of the factors that influence the degree of volume change are the size of the aggregate, the water-cement ratio (for cementitious mixtures), and retention of heat and moisture during curing.

Rapid strength development is important when downtime must be minimized. The rate of strength development is influenced by the properties of the repair material as well as the ambient temperatures during placement and the curing methods used. Both cement and epoxy materials will gain strength more slowly at low temperatures.

The cost of using any repair material depends not only on the material costs itself but also labor time for mixing and placement, equipment requirements, curing requirements, and allowable closure time. These costs may be different for different repair materials.

Repair Materials —

Cementitious Repair Materials —

Normal concrete mixtures containing Type I cement (ASTM C150) [14] may be used when the repairs can be protected from traffic for 24 hours or more.[15] A set accelerator may be added to the mix to reduce the setting time. The aggregate used in the repairs should have a maximum size no greater than one-half the minimum repair depth.

These repairs are usually bonded to the existing concrete with a grout, which consists of sand and cement in a 1:1 ratio by volume and enough water to produce a creamy consistency. The repair material must be placed before the grout dries. If the grout is left exposed long enough to dry, the repair area must be cleaned by sandblasting and the grout reapplied.

Normal-strength concrete repair mixtures should not be placed when the air temperature is below 4°C (40°F). At temperatures below 13°C (55°F), a longer curing period and/or insulation mats may be required.

High-early-strength PCC mixtures usually containing Type III cement (ASTM C150) [14] with or without admixtures, can gain strengths in excess of 21 MPa (3000 psi) within 24 hours. These are usually used when early opening to traffic (e.g., 4 hours) is required.[15] An epoxy bonding agent is usually used with these mixtures. The repair material is placed when the epoxy becomes tacky.

Specialty cement mixtures contain some kind of cement in place of or in addition to normal Type I or Type III cement. This may be some other hydraulic cement, a gypsum-based cement, magnesium phosphate cement, or high-alumina cement, for example.

- **Gypsum-based (calcium sulfate) cement mixtures** can gain strength rapidly and can be used in temperatures above freezing and up to 43°C (110°F). Some evidence suggests that these materials do not perform well when exposed to moisture and freezing temperatures. [16]

- **Magnesium phosphate and magnesium ammonium phosphate cement mixtures** can come in normal (fast) setting, intermediate setting, and retarded setting versions. Magnesium phosphate mixtures are normal setting mixes that set very rapidly, and so should be mixed in small quantities and worked rapidly. At temperatures below 27°C (81°F), the working time is about 10 minutes. At higher temperatures, the working time may be greatly reduced.

  The retarded setting mix is a magnesium ammonium phosphate cement mixture and it was developed to be used in southern states and on hot summer days when the temperature exceeds 29°C (85°F). This material produces similar properties to the regular magnesium phosphate materials when tested at 21°C (70°F). Intermediate magnesium ammonium phosphate mixes have setting times about half way between the regular setting and retarded setting versions.

  All these mixtures have low permeability and bond well to any clean and dry surface. However, the strength of these materials is sensitive to moisture content of the existing concrete materials. They cannot be used in pavements that contain limestone aggregates. The presence of limestone aggregates may be detected by wetting a freshly exposed concrete surface with vinegar. Bubbles will appear if the concrete contains limestone aggregates. [10, 17]

- **High-alumina cement mixtures** should not be used and are not recommended. They are susceptible to a conversion of some of its calcium aluminate hydrate components, which results in significant strength loss.

- **Accelerating admixtures/additives** such as calcium chloride, are sometimes added to cementitious patch materials to reduce the time to opening. Though this does not usually cause problems, the designer should be aware some patches may develop premature wear because the paste in the patch material may not get well cured.

- **Alumina powder** has been used as an admixture with Type I or Type III cement mixtures to counteract shrinkage. However, the reactivity of aluminum powder can be difficult to control in field proportioning, particularly in small batch operations. Furthermore, the use of alumina powder may decrease the bond strength and patch abra-

Table 1 : Properties of Partial-Depth Repair Materials [10]

Category	Working Time	Installation Temperature	Time to Traffic	Moisture Conditions of *	
				Repair Surface	Aggregate
Normal concrete mixtures	15 - 30 min.	4° - 43°C (40° - 110°F).	4 - 72 hours	SSD to dry	1-3% to dry
High-early-strength PCC mixtures	15 - 30 min.	0° - 43°C (32° - 110°F).	4 - 6 hours	SSD to dry	1-3% to dry
Gypsum-based (calcium sulfate) cement mixtures	15 - 30 min.	0° - 43°C (32° - 110°F).	1 - 2 hours	SSD to dry	1-3% to dry
Magnesium phosphate cement mixtures	5 - 45 min.	0° - 32°C (32° - 90°F).	1 - 2 hours	Dry	1-3% to dry
Epoxy-resin mortars or epoxy concretes	5 - 15 min.	4° - 32°C (40° - 90°F).	1 - 3 hours	Dry	Dry
Methyl-methacrylate concretes	30 - 60 min.	4° - 54°C (40° - 130°F).	1 - 2 hours	Dry	Dry
Polyurethane concretes	1 min.	> -18°C (> 0°F).	10 - 20 min.	Dry	Dry

* *SSD = Saturated Surface Dry; Dry = Oven-dried*

sion resistance. This results from the expansive nature of the alumina powder, which causes the density of the paste to decrease. An alternative is a shrinkage-compensating cement (ASTM C 845, Type K). [18]

- **Other rapid setting materials** are also available that can perform adequately. However, some rapid hardening repair materials are accelerated with high alkaline bearing materials. These materials may react with certain siliceous aggregates to form ASR. Therefore, it is important to make sure that no chemical incompatibilities exist between the patch material and the aggregates.

Specialty Repair Materials —
Rapid-strength proprietary materials must be placed according to the manufacturer's recommendations concerning bonding, placing, curing, and opening time. Preparation of the repair area should be done as described in this bulletin, except where the manufacturer's recommendations indicate otherwise. It is also very important to follow the manufacturer's recommendations concerning suitable temperature ranges for placement. Some proprietary materials are very sensitive to temperature and construction procedures.

Polymer concretes are a combination of polymer resin, aggregate, and a set initiator. The aggregate can range in size from sand to 9.5-mm (3/8 in.) stone. Polymer concrete are categorized by the type of resin used, such as epoxies, methacrylates, and polyurethane. [10, 17]

- **Epoxy-resin mortars or epoxy concretes** have been used since the 1950s. In general, they have excellent adhesive properties and low permeability. However, the setting times, placement temperature ranges, strengths, bonding capabilities, and abrasion resistance properties of various epoxy mixtures can vary widely. The particular epoxy mix under consideration should be carefully evaluated in the laboratory at the exposure extremes before use. The main disadvantage of epoxy concretes is that they are not thermally compatible with normal concrete, and this can sometimes result in early repair failure. Larger aggregate increases the volume stability and reduces the risk of debonding.

  Epoxy concretes should not be used to repair spalls caused by reinforcing steel corrosion because the epoxy can accelerate the corrosion in the steel.[10,17] The epoxy resin catalyst should be preconditioned before blending.

The epoxy components should be mixed in strict compliance with the manufacturer's recommendations before aggregate is added.[15] The material should be blended in a suitable mixer until homogeneous. If the blended material begins to develop excessive heat, the material should be discarded. Depending on the manufacturer's recommendations, a priming coat of blended epoxy may be required.

- **Methyl-methacrylate concretes** have working times between 30 and 60 minutes, high compressive strengths, and adhere well to clean dry concrete. They can be placed over a wide range of temperatures from 4 to 54°C (40 to 130°F). A major concern with methyl methacrylates is their volatility and hazardous nature. The fumes pose a health hazard and can ignite if exposed to a spark or flame. High-molecular-weight methacrylate (HMWM) is a newer type of methacrylate that possesses many of the same properties as conventional methacrylate but without the volatility or health hazard.[10, 17]

- **Polyester-styrene concretes** are similar to methyl-methacrylate concretes, possessing many of the same properties, but having a much slower rate of strength gain. This limits their usefulness for partial-depth spall repair.

- **Polyurethane concretes** consist of a two-part polyurethane resin mixed with aggregate. These materials set very rapidly. Two types of polyurethane materials are currently available. The older type is moisture sensitive and foams when it comes into contact with water. The newer ones are claimed to be moisture resistant and suitable for placing on wet surfaces.

- **Other polymeric materials** that have been used in the past or are under development include acrylic concrete and furfuryl-alcohol-polymer concrete. Acrylic concrete has good bond strength, but requires dry aggregate, and can pose environmental and health hazards. Furfuryl-alcohol-polymer concrete was developed for rapid repair of bomb-damaged runways. It develops high early strength, and can be placed in wet conditions and at temperatures between -17°C and 52°C (-1 and 126°F). How this material would perform in highway repairs is not known.[17]

Bituminous Materials —
Bituminous concrete materials are sometimes used for partial-depth spall repairs of concrete pavements. However, they do deteriorate rapidly and are considered only temporary repairs.

CONSTRUCTION

Preliminary Quantity Estimation —

During plan, the design engineer should conduct a field survey. The objective of the survey is to mark approximate boundaries of areas requiring partial-depth repair to aid in the bidding process. Depending on how much time passes between the field survey and the start of construction, the actual extent of the deterioration may be greater than that shown on the plans. This is because spalling is progressive and areas of delamination can exist at the joints that have not yet spalled out. It is imperative that these areas also be repaired during construction. Therefore, it should be anticipated that the quantity of repair required could be greater than that originally estimated in the preliminary survey.

Marking Repair Boundaries —

Just prior to starting work, a preconstruction survey should be conducted to mark the actual repair boundaries. The survey should be conducted by the

Figure 5. Sounding the pavement with a chain.

Figure 6. Marking repair boundaries with spray paint.

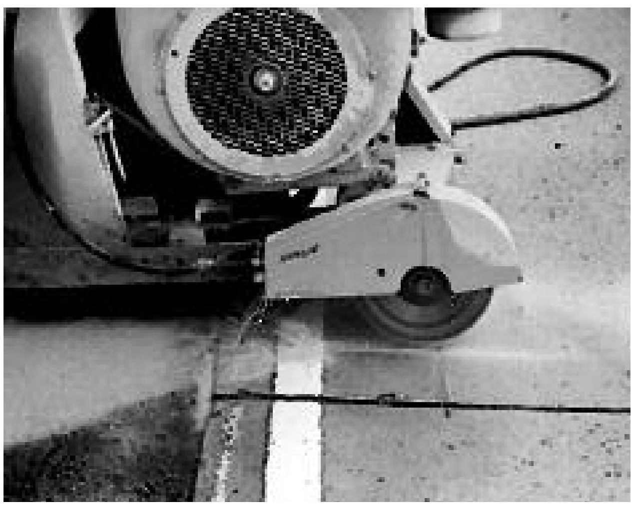


Figure 7. Sawing repair boundaries

Figure 8. Chipping out the concrete within the repair area.

specifying agency and the contractor together. During the preconstruction survey, all areas of delamination should be identified using a sounding technique. Sounding is done by striking the concrete surface with a hammer, steel rod, or by dragging a chain (Figure 5) along the surface, and listening to the sound produced. A sharp metallic ring indicates areas where the concrete is sound, whereas a dull or hollow sound indicates areas where the concrete is delaminated. [10, 15, 19, 20]

Sounding should start along the pavement transverse joints or cracks and any midslab areas that exhibit visible spalling or severe scaling. If available, refer to the partial-depth patch locations shown in the plans for guidance, but do not rely on them completely. The conditions may be worse than when the engineers drafted the plans because of the continued spall deterioration.

To ensure that all unsound concrete is removed, the limits of the partial-depth repair should extend 100 mm (4 in.) beyond the delaminated or spalled area. [9, 15, 20] A square or rectangular boundary of the area to be removed should be marked with paint, as illustrated in Figure 6. Irregular shapes and internal corners may cause cracks to develop in the patch.

Areas less than 0.6 m (2 ft) apart should be combined into one repair area. Although this increases the quantity of repair material used, it expedites the construction process and improves the overall appearance of the partial-depth repair project.

Concrete Removal —

Spalled or delaminated concrete can be removed within the repair boundaries by sawing and chipping or milling.

Sawing and Chipping — To remove spalled or delaminated concrete by sawing and chipping, saw cuts are made around the perimeter of the repair area, as illustrated in Figure 7.

This provides vertical faces at the repair edges and sufficient depth to prevent spalling of the repair material along the repair perimeter. The saw cuts should be at least 25-50 mm (1-2 in.) deep. [9, 15, 19, 20, 21] The sawcut should slightly overrun the patch perimeter so that the bottom of the cut intersects the patch corner. Additional sawcuts are often made within the repair area to speed the removal of concrete by chipping.

The repair area should be chipped out to a depth of at least 35 mm (1.4 in.) with light pneumatic tools, less than 13 kg (30 lb.), as illustrated in Figure 8, until sound and clean concrete is exposed.

It is important that the proper tools be used. Using a pneumatic hammer that is too large will cause damage and fracture the concrete below the depth actually needed to reach sound material. [15, 19, 21] Jackhammers heavier than 13 kg (30 lb.) should not be used, because they may break through the slab completely. They may also cause microcracking which can weaken the bond between the existing concrete and the repair material.

For best results, use lighter, 7-kg (15 lb.) hammers. It is easier to control the depth of chipping with them. Operate the jackhammers and mechanical chipping tools at an angle of about 45°. This helps minimize the damage to the sound concrete. Finally, spade bits are preferable to gouge bits for control of chipping. Even light hammers with gouge bits can damage sound concrete. [9]

Removal near the repair boundaries must be completed with 5 to 7 kg (10 to 15 lb.) hammers and should continue until sound and clean concrete along the entire bottom of the repair area is exposed. [10] However, if the depth of the patch exceeds about one-third to one-half the slab thickness or exposes any dowel bars, switch to a full-depth repair.

Chipping—Spalled or delaminated concrete has also been removed by chipping without first sawing the patch boundaries. The deteriorated concrete in the center of the repair area is removed with a light jackhammer. The deteriorated concrete near the edges of the repair area is then removed using a light jackhammer and hand tools. The work should progress from the center of the repair area toward the edges, and the chisel point of the jackhammer should be directed toward the center of the repair area.[11]

Though chipping alone has been used, it is not recommended to use it without first sawing the patch perimeters. Past experience with partial-depth repairs constructed using chipping has shown that thin or feathered concrete along the repair perimeter is prone to spalling and debonding. [9, 15, 21]

Milling — Removal of the spalled or delaminated concrete by cold milling is especially efficient for pavements that need partial-depth spall repair across most or all of the full width of the transverse joints. A milling machine equipped with carbide-tipped bits is illustrated in Figure 9. The machine must be equipped with a device for stopping at a preset depth to prevent excessive concrete removal and possible damage to dowel bars or reinforcing steel.

Depending on the equipment and the lane closure scenario, milling may be done either longitudinally across the joint or transversely along the joint (Figure 10). Transverse milling is effective for spalling along an entire joint. Transverse milling produces more vertical boundaries, but can be a less efficient operation and can potentially interfere more with traffic move-

Figure 9. Removal of material within repair area using a cold-milling machine.

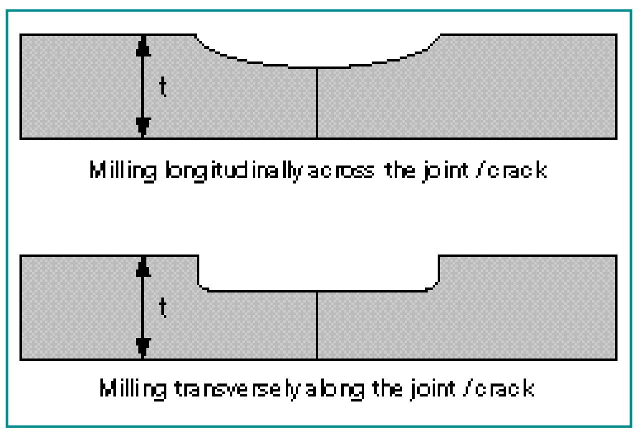


Figure 10. Profile of a partial-depth repair using milling equipment in removal.

ment in the adjacent lane. For small individual spalls, either milling direction is effective.

After milling, the bottom of the repair area should be checked by sounding to ensure that all unsound material has been removed. Any unsound material must be chipped out. If the depth of unsound concrete approaches or exceeds one-half of the slab thickness, place a full-depth repair.

Spalling has not been a problem with tapered edges produced by longitudinal milling. This is attributed to a gradual transfer of load through the repair material. The state of Minnesota has used both milling procedures very effectively.

Cleaning —

The exposed faces of the concrete should be thoroughly cleaned by abrasive blasting, such as sandblasting, to remove loose particles, oil, dust, and joint-sealant materials. These and any other contaminants interfere with bonding between the repair material and the existing concrete. Furthermore, the rough texture produced by abrasive blasting enhances bonding.

High-pressure water blasting is an alternative to abrasive blasting where controlling dust is critical in urban environments. Waterblast equipment for concrete removal should be capable of producing a blast pressure of 20-40 MPa (3000-6000 psi). However, to avoid damage, the equipment must be capable of adjustments that will allow removal of only weakened concrete.

All residue from abrasive blasting should be removed by airblasting just prior to placement of the bonding agent. The air compressor should deliver air at a minimum of 3.4 cu. m/min. (120 cu. ft/min.) and develop 0.63 MPa (90 psi) nozzle pressure. Even if the equipment has a filter, occasionally check the air for oil and moisture contamination. Oil sprayed onto the concrete will impede bonding of the repair material to the concrete. The equipment can be checked by placing a dry, clean cloth over the nozzle and blowing through the cloth. Any discoloration indicates moisture or oil residue.

Portable backpack blowers also are acceptable for removing dust and dirt from the repair area. However, air compressors with oil and moisture filters are preferred because of the higher pressure. Figure 11

Figure 11. Repair area being cleaned by sandblasting.

shows a photo of a repair area being cleaned by airblasting just prior to placement of the patch.

Joint Preparation —

Partial-depth repairs placed at longitudinal, transverse, or shoulder joints require special joint preparation work prior to placement of the repair material.

Joint Inserts — Partial-depth patches that cross or abut a working joint or crack require a compressible insert. The compressible insert reforms the joint or crack and makes a uniform face that is helpful when resealing. However, the most important function of the insert is to keep the adjacent concrete from bearing directly on the new patch. Bearing on the new patch has been the primary reason for failure of partial-depth repairs.

Bearing occurs in hot weather when the adjacent slab expands and pushes directly on the patch material instead of the full face of the joint. This is termed "point bearing." It causes the patch to fail by popout or delamination, as depicted in Figure 12. [9, 15, 20, 21] The joint insert eliminates point bearing by creating space for the slab to expand into.

Common compressible insert materials are Styrofoam or asphalt-impregnated fiberboard. [9] The insert width should match the width of the existing joint or crack. It should also be sized to extend about 25 mm (1 in.) below and 75 mm (3 in.) beyond each end of the patch area (Figures 13 and 14). An additional saw cut through the joint or crack may be necessary to allow the insert

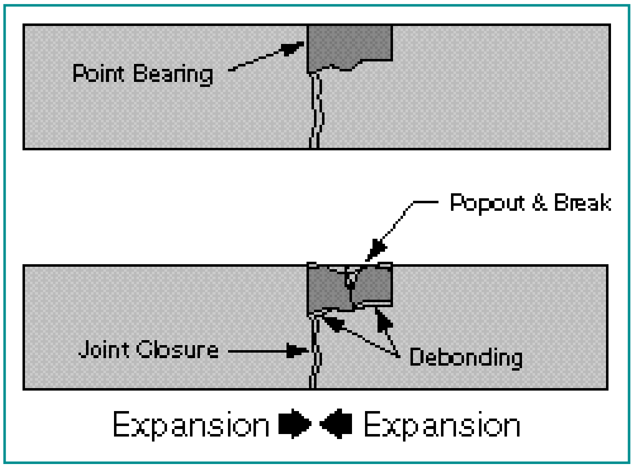


Figure 12. *Popout of partial-depth repair due to point bearing.*

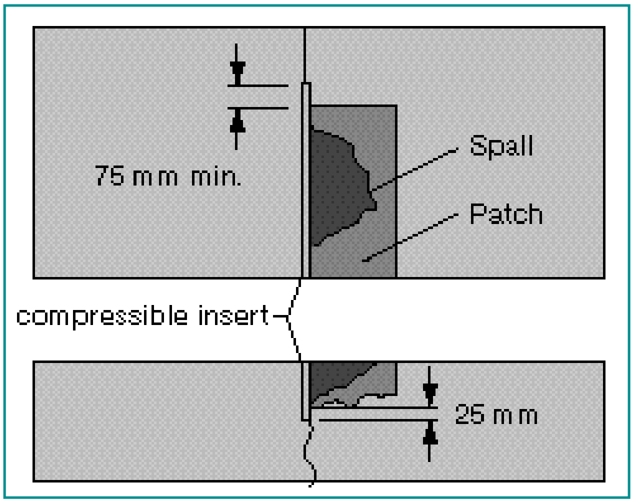


Figure 13. *Recommended placement of compressible*

Figure 14. *Properly placed compressible insert.*

to fit properly. If large gaps exist around the insert, either cut a new piece or fill the gaps with latex caulk.

At no time should the patch material be permitted to flow into or across the joint or crack. Bonding to the concrete in the adjacent lane or slabs will cause spalling of the repair.

When the repair material has hardened, the joint or crack reservoir may be reformed and resealed. In the case of transverse and longitudinal joints, this will often require sawing of a new joint sealant reservoir along the joint before new sealant is placed.

Shoulder Joint — If the shoulder is portland cement concrete, a compressible insert should be placed and sealed as previously described. However, if the shoulder is asphalt, special steps must be taken to insure that the repair material does not flow into the lane/shoulder joint or into the shoulder. If this happens, it may restrict longitudinal movement and result in damage to the repair or the shoulder. [15]

To place a partial-depth repair next to an asphalt shoulder, remove a small area of the asphalt shoulder surface adjacent to the repair material, and insert a thin piece of plywood or other insert in the lane/shoulder joint. This confines the repair material in the patch area so that it cannot flow into the lane/shoulder joint or into the shoulder. After the repair material has hardened, the plywood insert is removed and the asphalt surface is patched.

Material Placement —

The repair material should be placed as quickly as possible after preparing the patch area while the exposed concrete is clean and dry. It is a good idea to check the patch area for any dust or sandblasting residue before placing a bonding agent. Wiping the area while wearing a dark brown or black cotton glove will easily indicate a dust problem. Airblow again if the dust has settled back in the patch area.

Placing Bonding Agent — When placing the bonding agent or cementitious grout, apply the material in a thin even coat. The best results are obtained when the material is scrubbed into the surface with a stiff bristle brush. The material should cover the entire area including the patch walls and should overlap the pavement surface to ensure adequate bond.

Figure 15. Placing partial-depth repair materials.

Figure 16. Consolidation of partial-depth repair material.

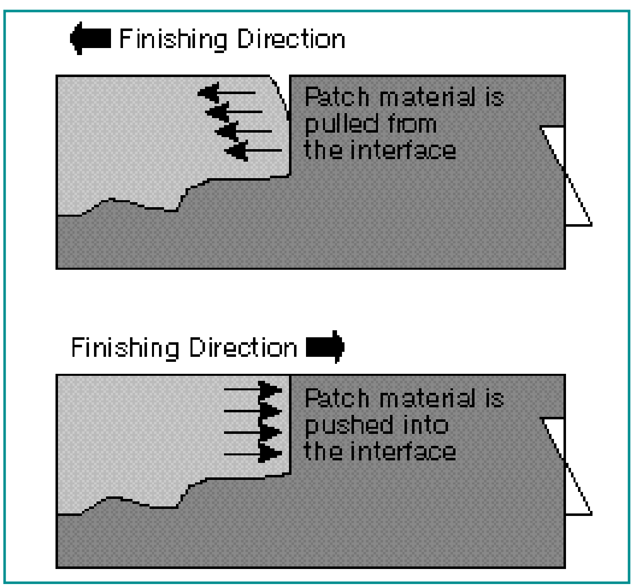


Figure 17. Effects of direction of finishing of repair material.

Cementitious grouts must not be allowed to dry before the repair material is placed.

Some partial-depth repair materials require epoxy or proprietary bonding agents. Epoxy bonding agents should be mixed carefully according to the manufacturer's instructions. Bonding agents and grouts should be mixed on site in small quantities.

Mixing — The volume of partial-depth repairs is typically very small. Therefore, partial-depth repair materials are usually mixed on site in small mobile drum or paddle mixers. On-site mixing avoids wasting material and may improve quality. If the quantity of patches is large, ready-mix trucks can speed placing operations.

Material Placement and Consolidation — Place concrete into the repair area from wheelbarrows, buggies, or other mobile batch vehicles (Figure 15). For small patches, shovel the patch material. Where the patch material is mixed in ready-mix trucks, direct the concrete into the patch area with the truck's chute. [9]

The repair area should be slightly overfilled to compensate for consolidation of the patch material. Once the repair material is placed, vibrate the fresh concrete with a small spud vibrator to remove entrapped air and eliminate any voids. This is especially important at the interface of the patch and existing concrete.

The vibrator should be held vertically and inserted into the repair material. The vibrator should not be dragged through the repair material, nor should it be used to move the repair material. These actions may cause segregation of the mix and loss of entrained air. Consolidation of a freshly placed partial-depth repair is illustrated in Figure 16. On very small repairs, hand tools should be sufficient to achieve adequate consolidation.

Finishing — The repair material should be finished flush with the surface of the existing concrete. It is recommended to finish the patch outward from the center of the repair toward the edges. This pushes the repair material into contact with the repair faces, rather than pulling it away, as illustrated in Figure 17. This technique provides a smooth transition and enhances the bond at the repair faces.

Texturing — The repair material should be textured in a manner similar to that of the surrounding concrete. However, because of the small size of partial-depth repairs, the surface texture will not have any significant effect on the overall friction characteristics of the pavement surface. Burlap drag, broom and transverse tine surfaces are common.

Sealing Patch Perimeter and Sawcut Run-outs — For cementitious repair materials, an important step of partial-depth repairs is sealing the repair/slab interfaces and saw cut run-outs, as illustrated in Figure 18. Sawcut run-outs are the sawcuts extending beyond the repair boundaries. They are made because sawing to the appropriate depth along the full repair boundary causes the blade to extend beyond the patch perimeters.

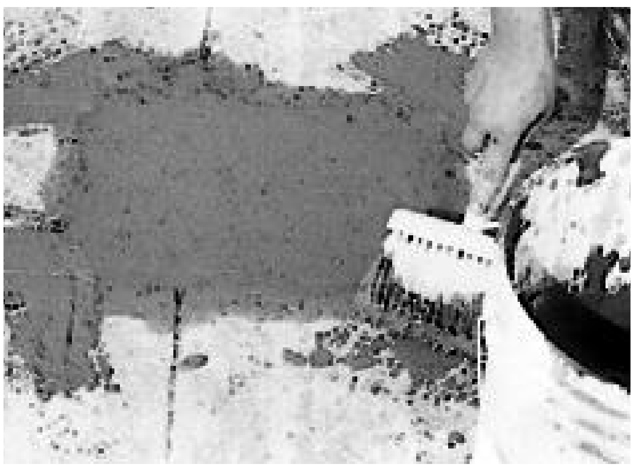


Figure 18. Sealing repair boundaries with cement-water grout.

Sealing is done with a thin 1:1 cement-water grout, which is painted along any repair edges that do not abut joints or cracks. The grout should cover the entire patch perimeter and fill the sawcut run-outs. The grout will form a moisture barrier over the perimeter and impede delamination of the repair. If water is able to infiltrate the interface along the repair perimeter, it can freeze and spall the repair.

Curing — Curing is very important because of the partial-depth repair's large surface-area-to-volume ratio makes them susceptible to rapid heat and moisture loss. Neglecting to cure the patches, or waiting too long to apply the compound, will likely result in excessive material shrinkage and possible patch delamination.

When using a cementitious repair material, a liquid membrane-forming curing compound that meets ASTM C 309 [22] material requirements is adequate. The compound creates a seal that limits mix water evaporation and contributes to thorough cement hydration. Some agencies specify a white-pigmented compound (Type 2, Class A) that is easy to see after application. Other agencies specify a resin-based curing compound that meets ASTM C 309, Type 2, Class B requirements and may not contain a white pigment, but can produce a more effective evaporation barrier. An application rate of about 5 sq. m/L (200 sq. ft/gal) is sufficient for either material. When specialty repair materials are used, curing should be done according to the manufacturer's recommendations.

Where early opening to traffic is required, it may be beneficial to place insulation mats over the repairs. This will hold in heat from hydration and accelerate strength gain in cementitious materials. To prevent moisture loss and to protect the surface, a layer of polyethylene sheeting should be placed on the patch surface under the insulation mats.

Insulation mats may not be necessary — and may cause cracking — in hot weather. The purpose of insulation is to aid early strength gain in cool temperatures. After removing the insulation, thermal shock may induce shrinkage cracks if the insulation retained excessive heat in the concrete.

Smoothness—

A good finishing technique can develop an adequate transition between the repair and the surrounding concrete. However, if the pavement contains many closely spaced repairs, it may be difficult to achieve acceptable surface smoothness. In these cases, consider specifying a ride quality comparable to the local ride standards for new concrete pavements. Repaired pavements that do not meet the specified ride requirement will require correction by diamond grinding. Grinding should precede joint sealing operations.

Joint Sealing—

After the repairs have gained sufficient strength, the joints should be resealed. Resealing should be done in accordance with the requirements of the specifying agency. It is important that the joint faces are clean and dry for good sealant performance. Sawing, to provide the proper shape factor, and abrasive blasting, to remove dirt and saw laitance from the joint face, are essential. Resealing the joint is extremely important, because it will help prevent moisture and incompressibles from causing further damage. Figure 19 shows a completed patch after joint resealing. For more information on joint sealing, see ACPA publication *Joint and Crack Sealing and Repair for Concrete Pavements (TB012P)* [5].

Figure 19. Completed patch after joint resealing.

OPENING TO TRAFFIC-

There are two methods to determine when to open partial-depth repairs to traffic: [23]

- Specified minimum strength.
- Specified minimum time after completing placement.

For most concrete pavement applications, it is preferable to measure the concrete strength to determine when it is acceptable for traffic. This is not always true for concrete repairs, particularly where quick opening is not critical. Most repair mixtures fall into one of three categories for opening to traffic: 4 to 6 hours, 12 to 24 hours, and 24 to 72 hours (conventional). Contractors often use conventional mixtures in repairs on large projects, in low-traffic areas, or in other situations where quick opening is not necessary. For these situations, specifying a minimum time after placement is reasonable. [23]

For the 4- to 6- hour mixtures and 12- to 24- hour mixtures, a strength test using portable cylinder test devices, maturity meters, or pulse-velocity devices are preferable to a specified time requirement. [23]

PERFORMANCE

The key factors influencing the performance of partial-depth spall repairs are the appropriateness of their use, the quality of construction, and the behavior of the repair material.

Partial-depth repairs should only be used to repair surficial spalls that do not extend to more than one-third to one-half of the slab depth. Partial-depth repairs are not appropriate for some types of concrete deterioration such as D-cracking that are usually not confined only to the surface. Likewise, they should not be used if dowels or reinforcing steel are uncovered during construction.

Partial-depth repairs may be constructed successfully across working transverse joints or cracks, but they will crack and fail if the joint or crack is not reestablished through the repair. Finally, partial-depth repairs may perform well but may not be cost effective for a pavement that has little or no remaining structural life and will soon need resurfacing or reconstruction.

The performance of partial-depth repairs is highly dependent on the quality of the construction operations. The construction steps described in this bulletin are those used by several agencies that have had several years of good experience with partial-depth repairs.

Performance reviews of various partial-depth spall repair materials typically have compared the performance of conventional Type I or III cement-based patch materials with proprietary materials. In most cases the conventional concrete mixtures have performed as well or better than most of the proprietary mixtures and specialty blends. [17]

ADDITIONAL INFORMATION

Additional information on partial-depth repair can be obtained by contacting the American Concrete Pavement Association.

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