



Figure 16. Protective shield around waterblasting operation.

the concrete changes (for example, a harder aggregate has been used in one section of the highway). If the concrete does change, the waterblasting machine must be recalibrated using two new trial areas in the section of the highway with the different concrete.

All unsound concrete within a marked spalled area should be removed to a minimum depth of 50 mm with neat vertical faces. Then the repair area must be tested again for soundness. Any additional unsound concrete must be removed by continued waterblasting. A full-depth repair must be used if the deterioration is found to be deeper than the top third of the pavement slab, or if reinforcing bars or mesh are reached.

The debris and slurry that result from the waterblasting operation must be removed using a low-pressure water stream before the slurry dries and hardens on the surface of the hole. If this is not done, the repair area may have to be refaced. Once dried, sandblasting may or may not be able to remove the dried

slurry residue. Some moisture-sensitive materials may require the repair area be completely dry before placing the material.

4.5.5 Clean and Patch

Under adverse conditions, handpicks and shovels should be used to remove loose material. A light jackhammer may sometimes be used for larger areas.

4.6 Cleaning the Repair Area

After all unsound concrete has been removed, the surface of the repair area must be cleaned. Sandblasting, airblasting, and sweeping normally provide a clean, rough surface for the development of a good bond between the patch and the pavement. High-pressure water may also be used to remove dirt, dust, and other contaminants, but sandblasting usually produces better results.

4.6.1 Sandblasting

Sandblasting, shown in figure 17, is highly recommended for cleaning the surface. It removes dirt, oil, thin layers of unsound concrete, and laitance. Sandblasting equipment consists of a compressed air unit, a sand dispenser, hoses, and a wand with a venturi-type nozzle. The compressed air must be free of oil and water, since a contaminated surface will prevent bonding. The air quality can be checked by placing a cloth over the air compressor nozzle and visually inspecting for oil. Sandblasting is generally not used under adverse conditions.



Figure 17. Sandblasting.

4.6.2 Airblasting

After sandblasting, high-pressure airblasting should be used to remove any remaining dust, debris, and loosened concrete fragments. Debris must be blown out and away from the patch so that wind or passing traffic cannot carry it back into the patch. The cleanliness of the repair area must be checked using a black glove or cloth. If the glove or cloth picks up material (dust, asphalt, slurry) when rubbed across the prepared surface, the surface should be cleaned again or poor bonding will result. If there is a delay between cleaning and patch placement, the surface may have to be cleaned again. Airblasting is generally not used with the clean-and-patch procedure under adverse conditions.

Either trailer-mounted air compressors or portable backpack blowers may be used. Backpack blowers need only one laborer and are very mobile. However, trailer-mounted air compressors

are recommended because they provide a higher pressure (greater than 670 kPa). The compressed air unit should have oil and moisture filters; otherwise, it may blow oil or moisture into the repair area and prevent the patch from bonding. When patching with a spray-injection machine (e.g., AMZ, Rosco), the hole may be cleaned with its blower.

4.6.3 Sweeping

Sweeping is most commonly used to clean the repair area when patching under adverse conditions. Under better conditions, sandblasting and airblasting should be used.

4.7 Final Joint Preparation

If a nonflexible repair material is used, a compressible joint bond breaker must be installed as the last step of joint preparation. The type of joint (i.e., transverse, centerline, or lane-shoulder) will determine the type of bond breaker to use. Some flexible materials may not need a bond breaker.

Polystyrene or polyethylene joint bond breakers are placed flush with the pavement surface, between the new (nonflexible) concrete and the adjacent slab to reduce the risk of compression-related failure. They also protect the patch from damage caused by deflection under traffic.

The bond breaker should have a scored top strip as shown in figure 2. It should extend 25 mm below and 75 mm beyond the repair boundaries, as shown in figure 18a. The extension will prevent the repair material from flowing into the joint during placement. Figure 18b shows a bond breaker installed improperly, as there is not enough length to extend beyond the repair boundary along the top (longitudinal) edge of the repair area. The bond breaker should be slightly wider than the joint

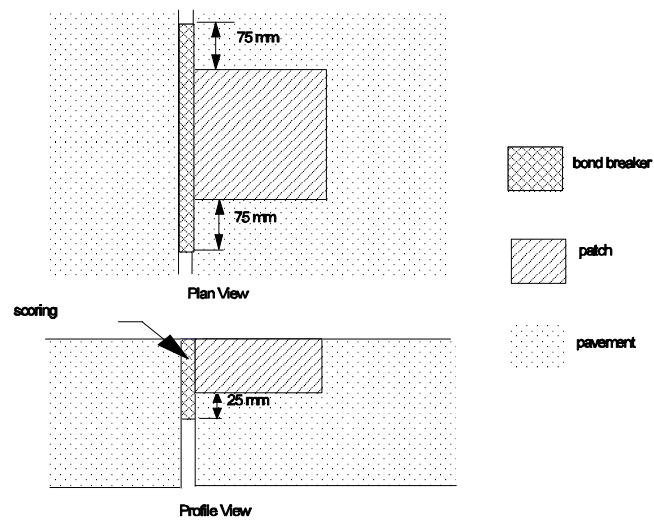


Figure 18a. Correct dimensions of joint bond breaker placement at one joint.

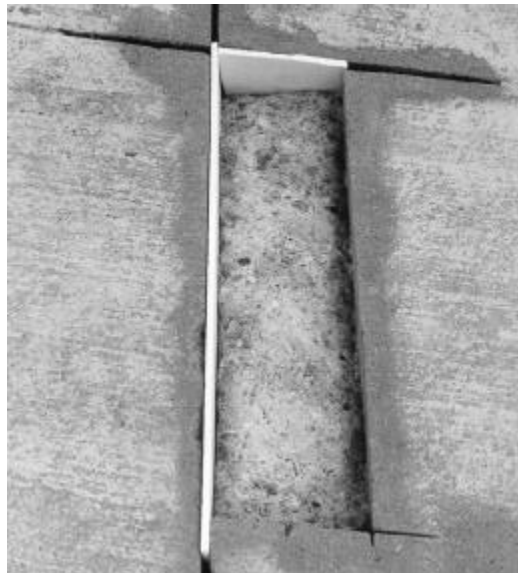


Figure 18b. Incorrectly installed bond breaker at two joints.

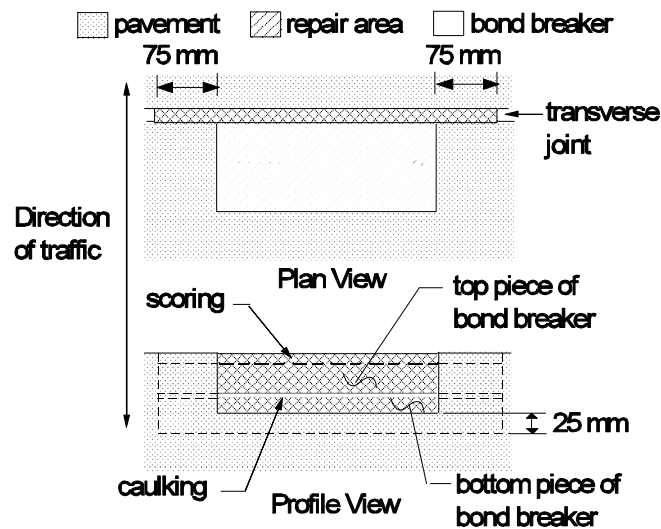


Figure 19. Joint bond breaker that has been stacked and caulked.

so that it is slightly compressed when installed. The scored top strip must later be torn off and the resulting joint reservoir filled with an appropriate joint sealant. Consult the *Materials and Procedures for Repair of Joint Seals in Concrete Pavements—Manual of Practice* for more information on selecting appropriate dimensions for the joint reservoir and joint bond breaker, and for appropriate joint sealing materials and methods (Evans and Romine, 1993b).

4.7.1 Preparing Transverse Joints

A straight joint line should be maintained during bond breaker placement at transverse joints. This may be difficult with back-

to-back patches. Bond breakers of different heights may be installed in patches of different depths. Alternatively, the bond breaker may be stacked to the needed depth, which may be difficult. *Latex caulking* may be used to seal any gaps between layers of bond breaker or between the bond breaker and the joint opening, as illustrated in figure 19. This will prevent the repair material from flowing into the joint or a crack opening below the bottom of the patch.

4.7.2 Preparing Centerline Joints

Partial-depth patches placed at the centerline joint often spall because of curling stresses. To prevent this, a polyethylene strip (or other thin bond-breaker material) must be placed along the centerline joint to prevent the patch from contacting the adjacent lane, as described in section 4.7.1.

4.7.3 Preparing Lane-Shoulder Joints

The joint must be formed using a piece of fiberboard if the repair is at the lane-shoulder joint. Fiberboard is stiffer than a polyethylene or polystyrene joint bond breaker, and it provides the support needed at the lane-shoulder joint when placing the repair material. Like more flexible bond breakers, fiberboard will prevent the repair material from flowing into the shoulder during material placement. If the repair material flows into the lane-shoulder joint, it will restrict longitudinal movement of the slab and damage the repair. Fiberboard must be placed to the same dimensions as the more flexible bond breaker, as shown in figure 18.

4.7.4 Using Flexible Repair Materials

Some proprietary flexible repair materials, such as Percol FL and Penatron R/M-3003, and some bituminous materials, such as UPM High-Performance Cold Mix and spray-injection mix

(e.g., AMZ, Rosco), may have enough compressibility to allow joints to move without needing a joint bond breaker. The manufacturer should be consulted for the appropriate joint treatment when using a flexible spall repair material.

4.8 Pre-Placement Inspection of the Repair Area

After cleaning, the repair area should be inspected to determine if there is any more unsound concrete. If there is, it should be removed, and the repair area should be cleaned again. Sandblasting should never be used to remove unsound material.

If the repair area is sound, it should then be inspected for clean, dry, freshly exposed concrete. Any dust remaining on the pavement surface around the repair area should be removed by sweeping, especially on windy days or when traffic passes alongside the repair. If there is a delay between cleaning and placing the material, the repair area must be inspected again at the time of placement, and must be cleaned again by airblowing if dirt has blown into it.

4.9 Mixing the Bonding Agent

Some partial-depth patching materials require epoxy or proprietary bonding agents. Epoxy bonding agents should be mixed carefully according to the manufacturer's instructions. An electric drill with a Jiffy mixer may be used to mix the two epoxy components for the required time.

Some spall repair materials, such as SikaPronto 11, specify a proprietary bonding agent. The manufacturer's mixing instructions should be followed exactly to ensure good patch performance.

4.10 Mixing the Repair Material

The volume of material required for a partial-depth repair is usually small (0.014 m^3 to 0.057 m^3). Ready-mix trucks and other large equipment cannot efficiently produce small quantities. Small drum or paddle-type mixers with capacities of 0.17 m^3 to 0.23 m^3 and Jiffy mixers are often used. Based on trial batches, repair materials may be weighed and bagged in advance to make the batching process easier. Prebagged cement may also be used; aggregate may be weighed using a precalibrated volume method (i.e., a bucket can be marked by volume for the appropriate weight). Continuous-feed mixers are also widely used.

Mixing times and water content must be carefully observed for prepackaged rapid-setting materials. Mixing for a longer time than needed for good blending reduces the already short time available for placing and finishing rapid-setting materials. Additional water may significantly reduce the strength of the patch.

4.10.1 Cementitious Concretes

Rapid-setting cementitious materials used in partial-depth spall repair, such as Type III PCC, gypsum-based concrete (e.g., Duracal), magnesium phosphate concrete (e.g., Set-45), and high alumina concrete (e.g., Five Star HP), generally are mixed with small drum or mortar mixers, as shown in figure 20.

The proportions of water, aggregate, and cement depend on the type of material selected. A rapid-setting Type III PCC mix generally includes an air-entraining agent, an accelerating agent, and a superplasticizer. In addition to the cement itself, rapid-setting cementitious materials need clean water and a manufacturer-specified gradation of aggregate. Some proprietary materials (e.g., Duracal) also need sand. Most



Figure 20. Adding carefully measured components to a drum mixer.

cementitious materials require that the water be added to the running mixer, followed by the aggregate, and then the cement. Warm water may be needed at air temperatures below 13°C, while ice water may be needed at higher temperatures. The manufacturer's recommendations for proportions, mixing sequence, and mixing times for each component should be followed exactly.

4.10.2 Polymer Concretes

Polymer concretes, such as epoxies (e.g., MC-64), methyl methacrylates (e.g., SikaPronto 11), and polyurethanes (e.g., Percol FL, Penatron R/M-3003), are generally mixed with a

Jiffy mixer or a mortar mixer, as specified by the material manufacturer.

The materials usually consist of two or more premeasured liquid components, or a liquid component and cementitious components. The different components are generally mixed separately and then in combination. Mortar mixers are used for mixing large batches of liquid components and for mixing cementitious components with aggregate. Jiffy mixers are used for mixing small batches of liquid components, as shown in figure 21. Liquid mixtures are either mixed with or poured over a specified gradation of oven-dried aggregate. The manufacturer's recommendations for mixing sequence, component amounts, and mixing times should be followed exactly.

4.10.3 Bituminous Materials

Bituminous cold mixes (e.g., UPM High-Performance Cold Mix) are generally mixed at a local plant using the manufacturer's mix design. They may also come premixed in drums, buckets, or bags. When patching spalls with a spray-injection machine (e.g., AMZ, Rosco), the machine mixes asphalt emulsion heated to approximately 57°C and aggregate. An experienced operator should carefully control the volume of each component. The asphalt and aggregate are sprayed out under pressure. Care should be taken not to overfill or to spill material outside of the repair area.



Figure 21. Using a jiffy mixer.

4.11 Applying the Bonding Agent

A bonding agent should be applied after cleaning the repair area and just before placing PCC repair materials. The manufacturer's directions must be closely followed when using epoxies or other manufactured grouts. The bottom and sides of the repair area must be thoroughly coated by brushing the grout or epoxy onto the concrete as shown in figure 22. Spraying may be appropriate for large repair areas. Excess bonding agent should not be allowed to collect in pockets. The placement of the bonding agent should be timed so that it is tacky when the repair material is placed.



Figure 22. Applying bonding agent.

4.12 Placing the Repair Material

For materials that will be consolidated or compacted, the placement procedure begins by slightly overfilling the repair hole to allow for the reduction in volume. Materials that contain aggregate **must** be placed with a shovel. *Segregation* will occur if these materials are dumped from a bucket or wheelbarrow.

4.12.1 Cementitious Concretes

PCC and most of the rapid-setting proprietary patching materials should not be placed when the air or pavement

temperature is below 4°C. Insulating covers and longer cure times may be needed at temperatures below 13°C. The repair area must be sprayed with water to enhance bonding before placing many cementitious materials (e.g., Duracal, Five Star HP, Pyrament 505). Vibration may be needed during placement to improve workability.

4.12.2 Polymer Concretes

Some polymer concretes may be installed under adverse conditions of low temperatures and wet *substrates* with reasonable success (Stingley, 1977). However, these materials perform better when installed under more favorable conditions.

Due to their high heat of hydration, some polymer concretes, such as epoxies (e.g., MC-64), and methyl methacrylates (e.g., SikaPronto 11) are placed in lifts no more than 38 to 50 mm deep. The time between lifts should be that recommended by the manufacturer. These materials have also been placed in one lift during partial-depth spall repair with no adverse effects.

When placing polyurethane concretes, such as Percol FL and Penatron R/M-3003, the repair area is first filled to grade with washed, oven-dried, and crushed stone of the type and gradation specified by the manufacturer. The polymer is then poured (as in the case of Penatron R/M-3003) or pumped (as in the case of Percol FL) directly over and through the preplaced aggregate until all the aggregate is encased in the concrete and the material is flush with the pavement surface, as shown in figure 23. If specified by the manufacturer, aggregate may then be broadcast over the top of the repair as a friction layer.



Figure 23. Pumping polymer into a patch that was prefilled with aggregate (cover aggregate also being placed).

4.12.3 Bituminous Materials

Some bituminous mixes may be installed under adverse conditions of low temperatures and wet substrates with reasonable success (Stingley, 1977). However, these materials perform better when installed under more favorable conditions.

Bituminous cold mixes, such as UPM High-Performance Cold Mix, must be placed by shovel. When patching using a spray-injection machine (e.g., AMZ, Rosco), a coating of emulsified asphalt should be sprayed into the hole and onto the edges of the pavement around the repair. A mixture of emulsified asphalt and aggregate should then be sprayed directly into the hole. The repair should be filled slightly above level with the pavement surface, and a coating of chip stone should be sprayed onto the patch to prevent tracking.

4.13 Consolidating and Compacting

Cementitious repair materials must be consolidated by vibration during placement to release trapped air from the fresh mix. Failure to do so may result in poor durability, spalling, and rapid deterioration. Voids between the repair material and pavement can cause total debonding and loss of repair material. Percol FL, MC-64, Penatron R/M-3003, and bituminous cold mixes (e.g., UPM High-Performance Cold Mix, spray-injection mixes) do not need vibration.

Three common methods of consolidation are:

- ! Using internal vibrators with small heads (less than 25 mm in diameter).
- ! Using *vibrating screeds*.
- ! Rodding or tamping and cutting with a trowel or other handtools.

The internal vibrator, shown in figure 24, and the vibrating screed give the best results. However, partial-depth patches are usually too small to use a vibrating screed. Internal pencil vibrators are recommended. Very small repairs may be consolidated using handtools. Cutting with a trowel seems to give better results than rodding or tamping. The tools used should be small enough to work easily in the repair area.

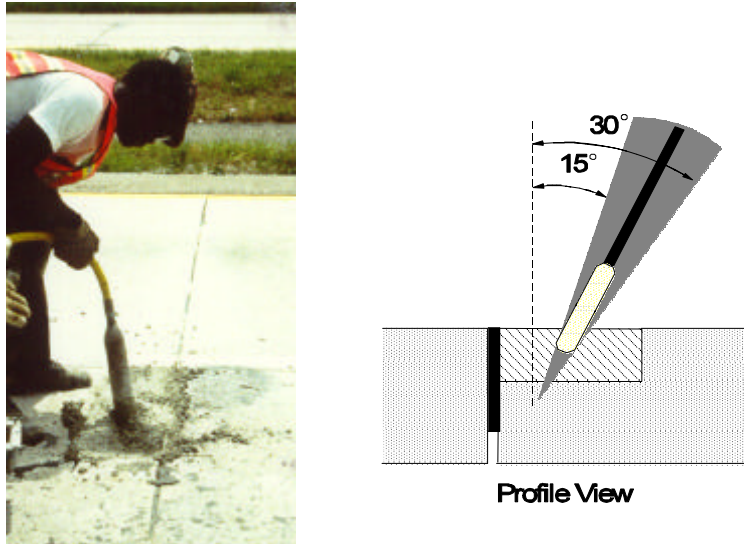


Figure 24. Using an internal vibrator.

The vibrator should be held at 15 degrees to 30 degrees from the vertical, as shown in figure 24, and should be moved through the patch until the entire repair has been vibrated. It should be lifted up and down, but not moved horizontally in the patch. The vibrator should not be used to relocate material within the repair as this may cause segregation. The mix is adequately consolidated when it stops settling, air bubbles no longer emerge, and a smooth layer of mortar appears at the surface.

Bituminous patching materials, such as UPM High-Performance Cold Mix, are generally compacted using a vibratory roller or plate until level with the pavement. The patches should be compacted with three to eight passes. The roller or plate must not bridge the patch.

4.14 Screeding and Finishing

The surface of the patch should be troweled flush with the pavement surface. Vibration may be needed to make the work finishable if the mix is too stiff. Partial-depth repairs are usually small enough that a stiff board resting on the adjacent pavement can be used as a screed. The material should be worked toward the edges of the patch to establish contact and enhance bonding to the pavement, as shown in figure 25. At least two passes should be made to ensure a smooth surface.

The repair surface must be hand-troweled to remove any remaining minor irregularities, as shown in figure 26. The edge of a repair located next to a transverse joint should be tooled to provide a good reservoir for joint sealing. Extra mortar from troweling can be used to fill any saw overcuts at the patch corners. Extra epoxy may also be used, or the saw overcuts may be filled with joint sealant during the joint sealing process.

Partial-depth repairs typically cover only a small portion of the pavement surface and have little effect on *skid resistance*. However, the finished surface of the repair should match that of the pavement as closely as possible.

4.15 Curing

Curing is as important for partial-depth repairs as it is for full-depth repairs. Since partial-depth repairs often have large surface areas in relation to their volumes, moisture can be lost quickly. Improper curing can result in shrinkage cracks that may cause the repair to fail prematurely.

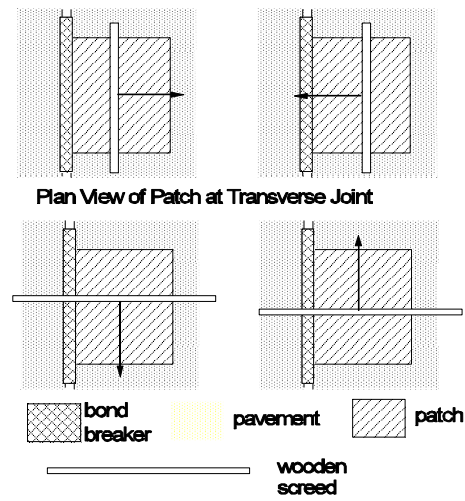


Figure 25. Screeding the patch.



Figure 26. Finishing the patch.

4.15.1 PCC Patching Materials

The most effective curing method when patching with PCC materials in hot weather is to apply a white-pigmented curing compound as soon as water has evaporated from the repair surface. The compound will reflect radiant heat while allowing the heat of hydration to escape and will provide protection for several days. Moist burlap and polyethylene sheeting can also be used, but must be removed when the roadway is opened to traffic. In cold weather, insulating blankets or tarps can be used to provide more rapid curing and to allow an earlier opening to traffic. The required curing time should be stated in the project plans and specifications.

4.15.2 Proprietary Patching Materials

Some proprietary materials may require some form of moist curing after the mix has stiffened (e.g., Five Star HP). Others require the application of a curing compound (e.g., Pyrament 505). Some proprietary repair materials may be air-cured (e.g., SikaPronto 11). Epoxy and proprietary repair materials should be cured as recommended by their manufacturers.

4.16 Joint Sealing

The final step in partial-depth spall repair is restoring the joints. When the recommended scored bond breaker has been used, the tear-off top strip should be removed, as shown in figure 27, and the selected sealant applied (see section 3.4.4). If a scored bond breaker has not been used, joint restoration is accomplished by resawing the joint to a new *shape factor*, sandblasting and airblasting both faces of the joint, inserting a closed-cell backer rod, and applying the sealer. A minimum 1-week cure time should be allowed before joint sealing. Consult

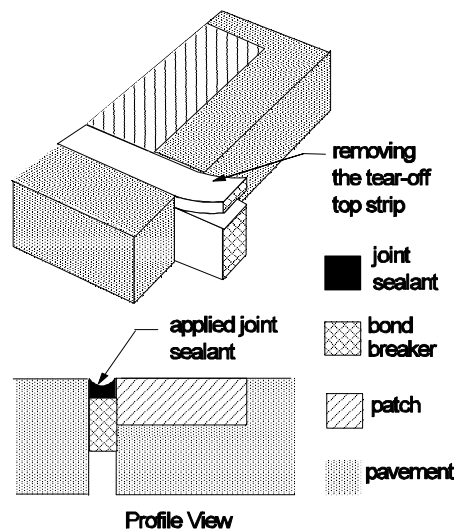


Figure 27. Removing the tear-off top strip of a joint bond breaker.

the *Materials and Procedures for Repair of Joint Seals in Concrete Pavements—Manual of Practice* for more information on proper joint sealing practices (Evans and Romine, 1993b).

4.17 Cleanup Requirements

The material manufacturer's instructions should be consulted for information on cleaning equipment that has been used to mix, place, and finish their material. The cleaning solvent for most cementitious materials is simply potable water. Some proprietary materials may require a special solvent; table 5 shows which of several rapid-setting repair materials require a special cleaning solvent. Equipment must be cleaned

immediately after use so it will not contaminate the next material it contacts.

4.18 Opening to Traffic

Compressive strength requirements for paving concrete are generally specified at 20,700 kPa at 28 days. The repair concrete should develop an equal or greater strength by the time it receives traffic loadings. However, to minimize lane closures, traffic loadings may be allowed on a patched area when the repair concrete has attained the minimum strength needed to ensure its structural integrity. The compressive strength required for the opening of partial-depth patches to traffic may be lowered because of their *lateral confinement* and shallow depth.

The specifications of rapid-setting proprietary mixes should be checked for recommended opening times. Cylinders or beams can be tested for strength to determine what opening time will allow the repair material to develop enough strength. The time to opening to traffic at 21°C for several rapid-setting partial-depth spall repair materials is shown in table 1.

4.19 Inspection

Quality control and inspection of the entire construction process is crucial to the success of the repair. Field experience has shown that each step in the partial-depth spall repair process requires careful supervision and inspection. An inspector must continually observe the various operations to ensure that proper procedures are being followed. Appendix D contains detailed checklists for each step of the inspection process.

5.0 Evaluating Partial-Depth Patch Performance

It is good practice to monitor the performance of partial-depth patches. By doing so, patch performance factors can be determined and used in comparing cost-effectiveness of different material-procedure patch treatments. One method for calculating a performance factor is described in this chapter.

5.1 Data Required

To determine the effectiveness of a given patch type (material-procedure combination), field surveys must be conducted periodically. The highway agency must record the survival life for all patches placed so that the mean service life can be calculated for the patch type. The main emphasis for the field survey is to verify the continued survival of the patches, to document those that have failed, and to note distresses evident in the surviving patches, which may indicate the failure mode of the patch.

For calculating the cost-effectiveness of a partial-depth spall repair patching operation, it is necessary to estimate the expected mean repair life of the patches. Table 8 shows one alternative for documenting survival information and generating a mean repair life value for a situation when the time until repair is to be approximately 48 months. For a situation where the time until repair would be approximately 24 months, the maximum service life recorded for each individual repair would be 24 months.

Table 8. Sample patch performance data.

Patch No.	Survival at Month No.								Life at Month No.		
	1	3	6	12	18	24	36	48	24	36	48
1	U	U	U	U	U	U	U	U	24	36	48
2	U	U	U	U	U	U			24	24	24
3	U	U	U	U	U	U	U	U	24	36	48
4	U	U	U	U	U	U	U	U	24	36	48
5	U	U	U	U	U				18	18	18
6	U	U	U	U	U	U	U	U	24	36	48
7	U	U	U	U	U	U	U	U	24	36	48
8	U	U	U	U	U	U	U	U	24	36	48
9	U	U	U	U	U	U	U	U	24	36	48
10	U	U	U	U					12	12	12
11	U	U	U	U	U	U	U	U	24	36	48
12	U	U	U	U	U	U	U	U	24	36	48
13	U	U	U	U	U				18	18	18
14	U	U	U	U	U	U	U	U	24	36	48
15	U	U	U	U	U	U			24	24	24
16	U	U	U	U	U				18	18	18
17									0	0	0
18	U	U	U	U	U	U	U		24	36	36
19	U	U	U	U	U				18	18	18
20	U	U	U	U	U				18	18	18
Mean Service Life									21	27	33

5.2 Calculations

The mean patch service life is calculated simply by averaging the individual service life values recorded for each patch being monitored. The true mean service life cannot be determined until all of the repairs have failed.

The mean service life for the example shown in table 8 is 33 months. This value is valid for calculating cost-effectiveness for situations where the time until rehabilitation will be approximately 48 months. For situations where the time until rehabilitation will be 24 or 36 months, the mean service life for the data shown in table 8 would be 21 or 27 months, respectively.

Appendix A

Material Testing Specifications

The following specifications for partial-depth spall repair materials are given as a guideline only and should be modified to reflect the conditions and requirements of a particular climatic region or roadway classification.

A.1 Rapid-Setting Cementitious Concretes

The cementitious rapid-setting patching materials and some non-flexible rapid-setting polymer materials (e.g., SikaPronto 11) shall meet the following suggested guidelines for acceptance as approved materials.

Initial set time, minimum	15 min
Compressive strength	
ASTM C 39, 3 hours	6.9 MPa
Compressive strength	
ASTM C 39, 24 hours	20.7 MPa
Bond strength of epoxy-resin systems	
ASTM C 882	1.4 MPa
Bond strength of concrete overlay and patching materials, California test	1.4 MPa
Flexural strength	
ASTM C 78	3.1 MPa
Freeze-thaw resistance	
ASTM C 666, Procedure A (150 cycles)	15 grams
Scaling resistance	
ASTM C 672 (100 cycles)	5
Surface abrasion resistance	
California Test T550	25 grams

Thermal compatibility	
ASTM C 884	pass

A.2 Rapid-Setting Flexible Polymer Concretes

The flexible polymer materials shall meet the following suggested guidelines for acceptance as approved materials.

Initial set time, minimum	15 min
Bond strength of epoxy-resin systems	
ASTM C 882	1.4 MPa
Bond strength of concrete overlay and	
patching materials, California test	1.4 MPa
Freeze-thaw resistance	
ASTM C 666, Procedure A (150 cycles)	15 g
Scaling resistance	
ASTM C 672 (100 cycles)	5
Surface abrasion resistance	
California Test T550	25 g
Thermal compatibility	
ASTM C 884	pass

A.3 Bituminous Materials

Bituminous patching materials shall meet the agency's suggested guidelines for acceptance as approved materials. Tests for workability, stripping, drainage, and cohesion are highly recommended. Additional tests suggested by other agencies and proprietary material manufacturers may also be used. Consult Appendix A of *Materials and Procedures for the Repair of Potholes in Asphalt Pavements—Manual of Practice* for more information on compatibility and acceptance tests for bituminous cold mix materials (Wilson and Romine, 1993).

Appendix B

Sample Cost-Effectiveness Calculations

This appendix contains sample worksheets for cost-effectiveness calculations. Different material and procedure combinations illustrate the financial differences between patching operations.

When using the examples in the following sections, it is important to remember that crew size and productivity differ greatly among agencies. These examples are fictitious and their only purpose is to show how the worksheets are used when completing them with the information relevant to a particular agency.

Each example considers the placement of 200 partial-depth patches with an average finished patch length of 457 mm, width of 229 mm, and depth of 51 mm. Therefore, for all examples, the expected total volume of the finished patches is 1.07 m³. The average daily wage for the maintenance worker is assumed to be \$120 in each example. Other data vary from example to example.

Calculation of the amount of materials needed, such as a patching material, bonding agent, joint bond breaker, or curing compound, is not demonstrated. The examples assume that agencies are already familiar with these calculations based on the number, length, width, and depth of the patches, and a typical waste factor for each material.

B.1 Example 1

Example 1 considers the placement of 200 material "A" patches using the saw-and-patch procedure. Material, labor, and equipment costs can be directly entered on the cost-effectiveness worksheet. However, the average daily productivity, the estimated number of days for the patching operation, and the partial-depth patch survival rate require a few advance calculations.

In calculating the average daily productivity and estimated number of days for patching, the examples assume that the last patch will be placed at the latest possible time and that preparation will stop when there is enough time to place the last patch. Therefore the patch preparation rate will control the number of patches that can be placed per day. The example also assumes that a crew of seven places seven patches per hour, and that the average patch volume is 0.005 m³.

Patches prepared per hour	= 7
Work hours per day	= 8
Material cure time	= 4 hr
Number of hours available for preparation and placement (work hours - cure hours)	= 4 hr
Average preparation rate (7 patches/hr) × (0.006 m ³ /patch)	= 0.042 m ³ /hr
Average daily productivity 4 hr × 0.042 m ³ /hr × (1 patch/0.006 m ³)	= 28 patches
Estimated number of days for patching (rounded up) 200 / 28	= 8 days

The mean patch survival life is estimated at 50 months for a situation where a rehabilitation will be placed in approximately 60 months. Figure B-1 shows the completed cost-effectiveness worksheet for this example.

ESTIMATE OF PROJECT SIZE OR SEASONAL PARTIAL-DEPTH PATCHING NEEDS

	amount	units	
Expected Number of Patches	200		(A)
Average Finished Patch Length	457	mm	(B ₁)
Average Finished Patch Width	229	mm	(B ₂)
Average Finished Patch Depth	51	mm	(B ₃)
Expected Total Volume of Finished Patches [(B ₁ × B ₂ × B ₃ × A) ÷ 10 ⁹]	1.07	m ³	(C)

MATERIAL COSTS (e.g., cold mix, cement, aggregate, sand, bonding agent, joint bond breaker, curing agent, etc.)

Material 1 = Patching Material "A"

Material 1 Purchase Cost	172	\$/m ³	(D ₁)
Expected Material 1 Needs	1.23	m ³	(E ₁)
Material 1 Shipping Cost	0	\$	(F ₁)
Total Material 1 Cost [(D ₁ × E ₁) + F ₁]	211	\$	(G ₁)

Material 2 = Bonding Agent

Material 2 Purchase Cost	12	\$/L	(D ₂)
Expected Material 2 Needs	56.2	L	(E ₂)
Material 2 Shipping Cost	0	\$	(F ₂)
Total Material 2 Cost [(D ₂ × E ₂) + F ₂]	675	\$	(G ₂)

Material 3 = Joint Bond Breaker

Material 3 Purchase Cost	1.075	\$/m	(D ₃)
Expected Material 3 Needs	152.5	m	(E ₃)
Material 3 Shipping Cost	0	\$	(F ₃)
Total Material 3 Cost [(D ₃ × E ₃) + F ₃]	164	\$	(G ₃)

Material 4 = Curing Compound

Material 4 Purchase Cost	2.6	\$/L	(D ₄)
Expected Material 4 Needs	7.7	L	(E ₄)
Material 4 Shipping Cost	0	\$	(F ₄)
Total Material 4 Cost [(D ₄ × E ₄) + F ₄]	20	\$	(G ₄)

Figure B-1. Example 1 cost-effectiveness worksheet.

LABOR COSTS			
	amount	units	
Number in Repair Crew	9		(H)
Average Daily Wage per Person	120	\$/day	(I)
Number in Traffic Control Crew	2		(J)
Average Daily Wage per Person	120	\$/day	(K)
Supervisor Daily Wage	200	\$/day	(L)
EQUIPMENT COSTS			
Material Truck	20	\$/day	(M)
Traffic Control Trucks and Signs	150	\$/day	(N)
Patch Preparation Equipment (e.g., concrete saw, jackhammer, milling machine, waterblaster)	225 60	\$/day \$/day	(O ₁) (O ₂)
Cleaning Equipment (e.g., sandblaster, airblaster)	350 0	\$/day \$/day	(P ₁) (P ₂)
Mixing Equipment (e.g., mortar mixer, Jiffy mixer)	35 0	\$/day \$/day	(Q ₁) (Q ₂)
Consolidation/Compaction Equipment (e.g., pencil vibrator, vibrating screed, vibratory roller)	20	\$/day	(R)
Extra Equipment Truck	0	\$/day	(S)
Miscellaneous Equipment (e.g., spray-injection machine, joint sealing equipment, etc.)	0 0	\$/day \$/day	(T ₁) (T ₂)

Figure B-1. Example 1 cost-effectiveness worksheet
(continued).

SUMMARY COSTS			
	amount	units	
Total Material Cost ($G_1 + G_2 + G_3 + G_4 + \dots$)	1070	\$	(U)
Total Daily Labor Cost [($H \times I$) + ($J \times K$) + L]	1520	\$/day	(V)
Total Equipment Cost [$M + N + (O_1 + O_2 + \dots) +$ ($P_1 + P_2 + \dots$) + ($Q_1 + Q_2 + \dots$) + $R + S + (T_1 + T_2 + \dots)$]	860	\$/day	(W)
User Delay Costs	1000	\$/day	(X)
Average Daily Productivity	28	patches/day (Y)	
Estimated Number of Days for Patching Operation ($A \div Y$)	8	days	(Z)
Total Patching Operation Cost [$U + \{Z \times (V + W + X)\}$]	28,110	\$	(AA)
Expected Mean Life for Partial-Depth Patches ¹	50	months	(BB)
Time to Pavement Rehabilitation	60	months	(CC)
Effective Patching Cost Over Time [$AA \times (CC/BB)$]	33,732	\$	(DD)
¹ Until expected mean life values have been determined, agency experience should be applied. See chapter 5 for calculation examples.			

Figure B-1. Example 1 cost-effectiveness worksheet
(continued).

B.2 Example 2

Example 2 considers the placement of 200 material "B" patches using the chip-and-patch procedure. As in example 1, material, labor, and equipment costs can be directly entered on the cost-effectiveness worksheet. However, the average daily productivity, the estimated number of days for the patching operation, and the partial-depth patch survival rate require a few advance calculations as well.

The same assumptions made in example 1, regarding the calculation of the average daily productivity and estimated number of days for patching, are made here. This example assumes that sawing equipment will be needed to re-establish the joints, and that the chip-and-patch preparation process will have the same productivity as the saw-and-patch preparation process, because the time needed for jackhammering will take up the time not needed for sawing.

The mean patch survival life is estimated at 45 months for a situation where a rehabilitation will be placed in approximately 60 months. Figure B-2 shows the completed cost-effectiveness worksheet for this example.

ESTIMATE OF PROJECT SIZE OR SEASONAL PARTIAL-DEPTH PATCHING NEEDS

	amount	units	
Expected Number of Patches	200		(A)
Average Finished Patch Length	457	mm	(B ₁)
Average Finished Patch Width	229	mm	(B ₂)
Average Finished Patch Depth	51	mm	(B ₃)
Expected Total Volume of Finished Patches [(B ₁ × B ₂ × B ₃ × A) ÷ 10 ⁹]	1.07	m ³	(C)

MATERIAL COSTS (e.g., cold mix, cement, aggregate, sand, bonding agent, joint bond breaker, curing agent, etc.)

Material 1 = Material B

Material 1 Purchase Cost	278	\$/m ³	(D ₁)
Expected Material 1 Needs	1.23	m ³	(E ₁)
Material 1 Shipping Cost	0	\$	(F ₁)
Total Material 1 Cost [(D ₁ × E ₁) + F ₁]	342	\$	(G ₁)

Material 2 = Joint Bond Breaker

Material 2 Purchase Cost	1.14	\$/m	(D ₂)
Expected Material 2 Needs	152.5	m	(E ₂)
Material 2 Shipping Cost	0	\$	(F ₂)
Total Material 2 Cost [(D ₂ × E ₂) + F ₂]	174	\$	(G ₂)

Material 3 = _____

Material 3 Purchase Cost	0	\$/_____	(D ₃)
Expected Material 3 Needs	0	_____	(E ₃)
Material 3 Shipping Cost	0	\$	(F ₃)
Total Material 3 Cost [(D ₃ × E ₃) + F ₃]	0	\$	(G ₃)

Material 4 = _____

Material 4 Purchase Cost	0	\$/_____	(D ₄)
Expected Material 4 Needs	0	_____	(E ₄)
Material 4 Shipping Cost	0	\$	(F ₄)
Total Material 4 Cost [(D ₄ × E ₄) + F ₄]	0	\$	(G ₄)

Figure B-2. Example 2 cost-effectiveness worksheet.

LABOR COSTS			
	amount	units	
Number in Repair Crew	7		(H)
Average Daily Wage per Person	120	\$/day	(I)
Number in Traffic Control Crew	2		(J)
Average Daily Wage per Person	120	\$/day	(K)
Supervisor Daily Wage	200	\$/day	(L)
EQUIPMENT COSTS			
Material Truck	20	\$/day	(M)
Traffic Control Trucks and Signs	150	\$/day	(N)
Patch Preparation Equipment (e.g., concrete saw, jackhammer, milling machine, waterblaster)	225 60	\$/day \$/day	(O ₁) (O ₂)
Cleaning Equipment (e.g., sandblaster, airblaster)	350 0	\$/day \$/day	(P ₁) (P ₂)
Mixing Equipment (e.g., mortar mixer, Jiffy mixer)	35 0	\$/day \$/day	(Q ₁) (Q ₂)
Consolidation/Compaction Equipment (e.g., pencil vibrator, vibrating screed, vibratory roller)	20	\$/day	(R)
Extra Equipment Truck	0	\$/day	(S)
Miscellaneous Equipment (e.g., spray-injection machine, joint sealing equipment, etc.)	0 0	\$/day \$/day	(T ₁) (T ₂)

Figure B-2. Example 2 cost-effectiveness worksheet
(continued).

SUMMARY COSTS			
	amount	units	
Total Material Cost ($G_1 + G_2 + G_3 + G_4 + \dots$)	516	\$	(U)
Total Daily Labor Cost [($H \times I$) + ($J \times K$) + L]	1280	\$/day	(V)
Total Equipment Cost [$M + N + (O_1 + O_2 + \dots) +$ ($P_1 + P_2 + \dots$) + ($Q_1 + Q_2 + \dots$) + $R + S + (T_1 + T_2 + \dots)$]	860	\$/day	(W)
User Costs	1000	\$/day	(X)
Average Daily Productivity	28	patches/day	(Y)
Estimated Number of Days for Patching Operation ($A \div Y$)	8	days	(Z)
Total Patching Operation Cost [$U + \{Z \times (V + W + X)\}$]	25,636	\$	(AA)
Expected Mean Life for Partial-Depth Patches ¹	45	months	(BB)
Time to Pavement Rehabilitation	60	months	(CC)
Effective Patching Cost Over Time [$AA \times (CC/BB)$]	34,181	\$	(DD)
¹ Until expected mean life values have been determined, agency experience should be applied. See chapter 5 for calculation examples.			

Figure B-2. Example 2 cost-effectiveness worksheet
(continued).

Appendix C

Material and Equipment Safety Precautions

This appendix contains some common-sense safety precautions for using materials and equipment in the partial-depth spall repair process. These precautions are not a complete list, nor will they apply to all materials and equipment. **It is essential that the highway agency obtain, review, and follow safety data sheets for all materials and all equipment.** The agency should develop a safety training program that will properly instruct highway workers in the safe use of all materials and equipment involved in partial-depth spall repair.

C.1 Materials

Some common-sense precautions for the safe use of many rapid-setting materials, admixtures, bonding agents, curing compounds, and solvents include the following:

- ! To avoid skin contact during mixing, placing, and cleaning:
 - Ÿ Wear long-sleeved shirts.
 - Ÿ Wear long pants.
 - Ÿ Wear gloves.
 - Ÿ Wear steel-toed boots.

- ! To avoid ingestion during mixing, placing, and cleaning:
 - Ÿ Wear eye protection.
 - Ÿ Wash hands (even if gloves have been worn) before handling anything that will go into the mouth (e.g.,

lunch containers, silverware, food, drinks, tobacco, gum, etc.).

- Ÿ Wash hands before touching the face, eyes, nose, mouth, or any other part of the body.
- Ÿ Avoid inhaling fumes and vapors (use respirators if required).
- Ÿ Use in well-ventilated areas.

- ! To avoid creating additional toxic vapors or fumes, never combine any substances unless following the specific instructions of the manufacturers of those substances. This includes combination by mixing, by cleaning, by adjacent placement, by contamination, etc.

C.2 Equipment

Some common-sense precautions for the safe use of typical partial-depth spall repair equipment include the following:

- ! Wear eye protection, gloves, long-sleeved shirts, long pants, and steel-toed boots during sawing, jackhammering, sandblasting, airblasting, milling, waterblasting, spray injection, and any other operation that could injure the skin, eyes, limbs, etc.
- ! Use ear protection during sawing, jackhammering, sandblasting, airblasting, milling, waterblasting, spray injection, and any other operation that is loud and could permanently damage the hearing.

Appendix D

Inspection Checklists for Construction

This appendix is intended for inspectors of the partial-depth spall repair process. It contains discussions of planning, equipment, and procedures crucial to successfully completing a partial-depth spall repair project. Checklists pertaining to each step of the process—including planning, equipment, material mixing, patch preparation, material installation, and safety precautions—are provided.

D.1 Plans and Specifications

Plans must be prepared and distributed to the inspector and the supervisor of the installation crew. The plans must contain the following information:

- G** 1. Project layout (including stationing, slab lengths, location of spalls to be repaired, etc.).
- G** 2. Original pavement material type.
- G** 3. Location and type of any pre-patching repairs required.
- G** 4. Required patch dimensions.
- G** 5. Required joint reservoir dimensions.

Specifications may be based either on adherence to designated procedures or on achieving a quality end-product. They may also combine the two. **Procedure-based specifications** must contain the following information:

- G** 1. Delivery and storage requirements.
- G** 2. Equipment requirements.
- G** 3. Material requirements.

- G** 4. Material mixing procedure requirements.
- G** 5. Patch preparation procedure requirements.
- G** 6. Installation procedure requirements.
- G** 7. Weather condition limitations.
- G** 8. Traffic control requirements.
- G** 9. Material disposal requirements.
- G** 10. Safety requirements.

End-result specifications must contain the following information:

- G** 1. Delivery and storage requirements.
- G** 2. Required results of mixing procedures and acceptance-rejection criteria.
- G** 3. Required results of each preparation procedure and acceptance-rejection criteria.
- G** 4. Required results of the installation process and acceptance-rejection criteria.
- G** 5. Weather condition limitations.
- G** 6. Traffic control requirements.
- G** 7. Material disposal requirements.
- G** 8. Safety requirements.

Most projects combine procedure-based and end-result specifications. The following inspection process is based on their combination.

D.2 Equipment

All equipment must be inspected and approved before the project begins, as well as during mixing, patch preparation, patch installation, and sealant installation. A list of proposed equipment should be submitted before installation for approval. During the pre-installation inspection, the inspector should check all equipment, ensuring that each piece meets the project

specifications. Suitability of equipment for mixing and placing a particular repair material can be confirmed by contacting the material manufacturer.

The condition and effectiveness of each piece of equipment should be checked at the beginning of each day of patch preparation, mixing, and installation.

D.3 Material Quality

The inspector must confirm that the patching materials, joint bond breaker, bonding agent, curing compound, and so on are from the agency's "approved list" or are from a certified plant, and that samples of the materials have been submitted to the agency's laboratory for testing. The material manufacturer's recommendations for storage and shelf life should also be checked. Materials that are not stored properly or that are old may not meet quality standards.

D.4 Field Installation

After all required slab stabilization and other prepatching rehabilitation have been completed and approved, the partial-depth spall repair process can begin. Inspector(s) and supervisor(s) should meet before work begins to discuss the following subjects:

- G** 1. Exact locations and dimensions of all spalls to be patched. (The boundaries should be clearly marked.)
- G** 2. Traffic control requirements and lane closure time limitations.

- G** 3. Methods for preparing and cleaning repair areas, for mixing and placing the repair materials, and for reinstalling a joint sealant system.
- G** 4. Recommended accessory materials and instructions for their use.
- G** 5. Material properties and working tolerances;
 - G** working times.
 - G** time to traffic at the anticipated mixing and placement temperatures.
 - G** moisture conditions allowable during placement.
 - G** temperatures allowable during mixing and placement.
- G** 6. Mixing times, components, proportions, and sequences.
- G** 7. Criteria for approval of all cleaning and installation equipment and processes.
- G** 8. Criteria for final approval of the repair work.
- G** 9. Any localized variations from the specified methods.
- G** 10. Procedures in the event of hot, cold, and/or wet weather.
- G** 11. Material disposal requirements.
- G** 12. Safety requirements for all equipment and procedures and MSDS's.

D.5 Preparing the Repair Area

Patch preparation includes removing deteriorated concrete and old sealant in the adjacent joint, final cleaning, installing the joint bond breaker, and applying the bonding agent. The following inspection checklist can be used to ensure that spall preparation is completed properly. Not all of these patch preparation procedures are used at one time.

- G 1. Sounding:**
- G** a solid steel rod, chain, or ball-peen hammer is used to sound the spalled area before and after the deteriorated concrete is removed.
 - G** all deteriorated concrete is removed using the specified method until all parts of the repair area yield a clear ringing sound when they are sounded.
- G 2. Sawing:**
- G** the concrete saw is establishing straight, vertical patch boundaries to the required depth, where specified.
 - G** the concrete saw is removing the required amount of concrete and sealant in any adjacent joint.
 - G** the concrete saw is uniformly cutting to the proper width and depth. (Depth and width can be checked quickly using a metal template.)
- G 3.** The **water-wash** equipment is removing all sawing and/or waterblasting slurry from the repair area before it dries.
- G 4. Jackhammering:**
- G** jackhammers of the specified weight are removing all deteriorated concrete to the specified depth, without fracturing the sound concrete below the repair or undercutting or spalling any sawed boundaries.
 - G** chiseling is begun in the center of the repair area and proceeds outward.
 - G** only light jackhammers are used near the patch boundaries.
 - G** if patch boundaries have not been sawed, the hammering is producing rough, vertical edges (not scalloped edges into which the repair material will have to be feathered).

- G** spade bits (not gouge bits) are being used.
- G** jackhammers are being operated at an angle less than 45 degrees from the vertical.
- G** 5. **Milling:**
 - G** the carbide-tipped milling machine is removing all deteriorated concrete to the specified minimum depth.
 - G** any material that remains at the patch corners is removed by light jackhammering or sawing.
 - G** whenever possible, the milling machine is oriented such that the rounded edges of the milling hole are parallel to the direction of traffic.
 - G** if this is not possible, the rounded edges are chipped into straight, vertical edges.
 - G** edge spalling is minimized.
- G** 6. **Waterblasting:**
 - G** a protective shield has been built around the repair area before waterblasting if traffic is passing in the next lane.
 - G** the waterblasting equipment has been calibrated to remove the specified depth of concrete.
 - G** operation parameters are not changed throughout the remainder of the project unless the concrete changes (e.g., the aggregate hardness differs from one pavement section to another).
 - G** the waterblasting equipment is removing all deteriorated concrete to the required depth, and is producing neat, vertical faces at the patch boundaries.
 - G** waterwashing equipment is used to wash the waterblasting slurry from the repair area before it dries.

- G 7.** A **full-depth repair** is used if at any point in the patch preparation process, the deteriorated area of concrete is found to be deeper than the top third of the pavement slab, or if reinforcing bars or mesh are encountered.
- G 8.** **Handtools and shovels** are being used to remove all loose material, when preparing the patch under adverse conditions.
- G 9.** **Sandblasting:**
- G** the sandblasting equipment is uniformly cleaning the faces of the repair area. This typically requires that the nozzle be held 25 mm to 50 mm from the pavement and that several passes be made.
 - G** no old sealant, oil, or dried sawing and/or waterblasting slurry remains in the repair area.
 - G** the sandblasting equipment does not introduce oil or moisture to the repair area.
 - G** after sandblasting, the entire surface area of the patch hole contains freshly exposed concrete.
- G 10.** **Airblasting:**
- G** the airblasting equipment is removing all dirt, dust, old sealant, and sand from the dry repair area.
 - G** the airblaster does not introduce oil or moisture to the repair area.
 - G** after airblasting, the repair area is clean and dry.
- G 11.** **Compressed air** is removing all old sealant, sand, dirt, and dust from the pavement surface so that it cannot re-enter the repair area, especially on windy days or when traffic passes next to the cleaned repair areas.

- G 12. Recleaning:**
- G** the repair area is **re-checked for cleanliness** just before material placement.
 - G** cleaned repair areas that have been recontaminated by rain, dew, dirt, or oil are cleaned again in a manner that restores the original cleanliness. This may require sandblasting and airblasting, or merely airblasting.
 - G** cleaned repair areas that are left overnight are, at a minimum, airblasted again.
- G 13. The repair area** is allowed to dry if a moisture-sensitive repair material will be used. (Water on the surface of the repair area during material installation may severely reduce the ability of the material to bond to the surface, depending on the material type. Watch for heavy dew that may collect in the repair area and remain after the surface is dry.)
- G 14. Scored bond breaker:**
- G** a strip of scored bond breaker is placed at the joint-patch interface 25 mm deeper than the repair, and extends at least 50 mm to 75 mm beyond the repair boundaries.
 - G** the bond breaker is either of the appropriate height or is stacked and latex-caulked when necessary so that there are no gaps through which the repair material can flow.
 - G** a true, straight joint line is maintained when installing the bond breaker.
- G 15. Bonding agent:**
- G** the bonding agent sprayer or brush is applying a thin layer of bonding agent uniformly over the repair area.
 - G** the bonding agent is still tacky when the repair material is placed.

- G 16. Safety:**
 - G** all required **operator safety equipment** is in use.
 - G** all required safety precautions are followed.

D.6 Installing the Patch

Patch installation includes mixing, placing, and finishing the patching material. The following inspection checklist can ensure that patch installation is completed properly.

D.6.1 Mixing

During the mixing of the repair materials, the following items should be regularly checked to ensure that they meet the requirements. Not all rapid-setting partial-depth spall repair materials require mixing.

- G 1.** All **mixing equipment** is clean before use. Some material manufacturers may recommend pre-wetting the mixer so no water is lost when mixing the first batch.
- G 2.** The **water** used for mixing is clean.
- G 3.** The mixing operation results in a **consistently mixed** material.
- G 4.** The **material** is not over- or undermixed.
- G 5.** Any **spilled material** is removed from the pavement surface.
- G 6.** The **mixing temperature** is as recommended. Warm water or ice water is used to raise or lower the mix temperature as needed.
- G 7.** **Mixing time, mix components, mix proportions, and mix sequences** are carefully followed.

- G** 8. The mixing equipment is **cleaned with the solvent specified by the material manufacturer** immediately after use.
- G** 9. The mixing of the bonding agent and repair material is scheduled such that the **bonding agent** is tacky when the repair material is placed.
- G** 10. Disposal of all **wasted materials and solvents** follows the manufacturer's specifications and State ordinances.
- G** 11. All required **operator safety equipment** is in use.
- G** 12. All required **safety precautions** are followed.

Material that has begun to set during mixing, or material that is too wet, should not be placed. It should be discarded, and the mixing process begun again; a *retarding agent* may need to be added. The mixing time or amount of water may also need to be adjusted.

D.6.2 Placement

During placement, the following items should be regularly checked to ensure that they meet the requirements. Not all steps will be required for all materials.

- G** 1. The repair material is placed in a **clean repair hole**, under the **specified moisture conditions**, using the **specified placement methods**.
- G** 2. The **bonding agent** thoroughly coats the bottom and sides of the repair area, but does not collect in any pockets.
- G** 3. The **material** is placed when the bonding agent is still tacky.
- G** 4. The repair hole is **slightly overfilled** with the repair material for those materials that require consolidation or compaction.

- G** 5. A **shovel** is used (**not** a wheelbarrow or a bucket) to place repair materials that contain aggregate, so that segregation does not occur.
- G** 6. The repair **material** is not placed below or above its permissible placement temperature range.
- G** 7. **Deep repairs** are placed in lifts to control heat development, when specified.
- G** 8. A pencil **vibrator or handtools** are used to release trapped air from the mix.
- G** 9. The **vibrator** is held at 15 to 30 degrees from the vertical, and is moved through the concrete by lifting it up and down to vibrate the entire area until the mix stops settling, air bubbles no longer emerge, and a smooth layer of mortar appears at the surface.
- G** 10. A bituminous cold mix patch is compacted to release trapped air using a **vibratory roller or plate** until it is level with the pavement.
- G** 11. Disposal of all **wasted materials and solvents** follows the manufacturer's specifications and State ordinances.
- G** 12. **Field testing** is conducted as appropriate for the patching materials, such as testing beams or cylinders for strength and quality control.
- G** 13. All required **operator safety equipment** is in use.
- G** 14. All required **safety precautions** are followed.

D.6.3 Material Finishing and Curing

During finishing, the following items should be regularly checked to ensure that they meet the requirements. Not all steps will be required by all materials.

- G** 1. The repair material is **troweled** level with the pavement before finishing.
- G** 2. The repair material is **screeded** with a stiff board, using at least two passes.
- G** 3. The repair material is **worked toward** the patch edges to enhance bonding with the existing slab.
- G** 4. The **saw cuts** are filled with excess mortar or epoxy, or are filled with joint sealant during the joint resealing process.
- G** 5. The patch surface is **finished** to match the surface of the surrounding pavement.
- G** 6. Appropriate **curing methods** are used so that shrinkage cracks do not develop.
 - G** **curing agents** are applied uniformly to the patch.
 - G** the **water** used for curing is clean.
 - G** **insulating covers and longer cure times** are used at cooler temperatures, as specified by the material manufacturer.
- G** 7. Disposal of **wasted repair material, curing compound, and cleaning solvents** follows the manufacturer's specifications and State ordinances.
- G** 8. **Traffic** is not allowed on the pavement until the material has developed the strength necessary to carry traffic without being damaged.
- G** 9. All required **operator safety equipment** is in use.
- G** 10. All required **safety precautions** are followed.

D.6.4 Joint Resealing

Consult the *Materials and Procedures for Repair of Joint Seals in Concrete Pavements—Manual of Practice* for information regarding the inspection of the joint resealing process (Evans and Romine, 1993b). In addition to the inspection criteria listed in that manual, when using a scored bond breaker, the following criteria should be met:

- G** 1. **Joint resealing or filling** is conducted after a minimum curing time of 1 week.
- G** 2. Immediately before joint resealing or filling, the **top strip** is torn off of the scored bond breaker, leaving a uniform, clean, dry reservoir.
- G** 3. Before resealing or filling the joints, **low-pressure air cleaning** is used if dust or dirt has blown into the joints after removal of the tear-away top strip.

D.7 Final Inspection

During installation and before approval, the partial-depth patches should be individually inspected, ensuring that the patch meets the highway agency's criteria, and noting the presence and severity of any distresses. The final inspection should include the following:

- G** 1. The patch is **bonded** firmly to the existing pavement and has not separated from the sidewalls.
- G** 2. The patch is **level** with the surface of the existing pavement.
- G** 3. The patch contains **no cracks** (other than fine hairline shrinkage cracks) or bubbles.

- G** 4. All material that has spilled on the pavement has been **removed**.
- G** 5. **No debris** has been left on the pavement.

Consult the *Materials and Procedures for Repair of Joint Seals in Concrete Pavements—Manual of Practice* for information regarding final inspection of the joint sealant system (Evans and Romine, 1993b).

Appendix E

Partial List of Material and Equipment Sources

This appendix contains a partial listing of material and equipment manufacturers. Addresses and phone numbers are provided for manufacturers and/or suppliers who can provide the inquirer with information regarding products, installation practices, safety procedures, costs, and local suppliers.

MSDS's, where applicable, should be available from all manufacturers. Information regarding the safe use of all materials and equipment should be carefully followed to ensure worker safety and the safety of the traveling public.

Inclusion of a particular material, piece of equipment, or supplier in this list does not serve as an endorsement of that material, equipment, or supplier. Likewise, omission from this list is not intended to carry negative connotations for the materials, pieces of equipment, and suppliers omitted.

E.1 Partial-Depth Patching Materials

E.1.1 Manufacturers of Cementitious Concretes

Euclid Chemical Company
19218 Redwood Road
Cleveland, OH 44110-2799
(216) 531-9222
(800) 321-7628
www.euclidchemical.com

Five Star Highway Products, Inc.
425 Stillson Road
Fairfield, CT 06430
(203) 336-7900

Fosroc International Limited
55 Skyline Drive
Planview, NY 11802
(516) 935-9100
www.fosroc.com

Hartline Products Company, Inc.
2186 Noble Road
Cleveland, OH 44112
(216) 451-6573

L&M Construction Chemicals, Inc.
14851 Calhoun Road
Omaha, NE 68152
(402) 453-6600

Master Builders
23700 Chagrin Boulevard
Cleveland, OH 44122-5554
(800) 628-9990
www.masterbuilders.com

United States Gypsum Company
Industrial Gypsum Division
125 South Franklin St.
Chicago, IL 60606-4678
(312) 606-4000
(800) 874-4968
www.usg.com

E.1.2 Manufacturers of Polymer Concretes

Accelerated Systems Technology Corporation
140 Chaparral Court
Suite 100
Anaheim, CA 92808
(714) 263-9074

HC Epoxy Company, Inc.
862 East 19th Street
Tucson, AZ 85719
(602) 624-7929

GeoChem, Inc.
P.O. Box 838
Renton, WA 98057-0838
(425) 227-9312
www.geocheminc.com

Pyrament/Lone Star Industries, Inc.
340 North Sam Houston Parkway, East
Houston, TX 77060
(800) 633-6121

Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
(201) 933-8800
www.sika.com

The Burke Company
P.O. Box 5818
San Mateo, CA 94402
(415) 349-7600
(800) 423-9140

Thoro System Products
Department PWM
7800 N.W. 38th Street
Miami, FL 33166

E.1.3 Manufacturers of Bituminous Materials

Unique Paving Materials Corporation
3993 E. 93rd Street
Cleveland, Ohio 44105-4096
(800) 441-4881
www.upm.com

E.1.4 Manufacturers of Bonding Agents

Master Builders
23700 Chagrin Boulevard
Cleveland, OH 44122-5554
(800) 628-9990
www.masterbuilders.com

The Burke Company
6433 East 30th Street
Indianapolis, IN 46219
(317) 543-4475

E.2 Partial-Depth Patching Equipment

E.2.1 Manufacturers of Sawing Equipment

Cimline, Inc.
2601 Niagara Lane
Minneapolis, MN 55447
(800) 328-3874
www.cimline.com

Target Products Division
4320 Clary Boulevard
Kansas City, MO 64130
(816) 923-5040

Vermeer Manufacturing Company
Route 2
P.O. Box 200
Pella, IA 50219
(515) 628-3141

E.2.2 Manufacturers of Spray-Injection Equipment

Zimmerman Equipment Corporation
1000 South Thompson Lane
P.O. Box 110098
Nashville, TN 37211
(615) 833-5705

Wildcat Manufacturing Company, Inc.
Highway 81
P.O. Box 523
Freeman, SD 57029
(605) 925-4512

Rosco Manufacturing Company
1001 S.W. First St.
P.O. Box B
Madison, SD 57042
(605) 256-0240

Duraco Industries, Inc.
P.O. Box 6127
Jackson, MS 39288-6127
(601) 932-2100

E.2.3 Manufacturers of Waterblasting Equipment

FLOW Services
23500 64th Street
Kent, WA 98032
(800) 446-3569, Ext. 900

E.2.4 Manufacturers of Milling Equipment

Cedarapids, Inc.
916 16th Street, N.E.
Cedar Rapids, IA 52402
(319) 363-3511

Vermeer Manufacturing Company
Route 2
P.O. Box 200
Pella, IA 50219
(515) 628-3141

E.2.5 Manufacturers of Jackhammers

Atlas Copco Berema, Inc.
161 Lower Westfield Road
Holyoke, MA 01040
(800) 284-2373
(413) 536-0600

E.2.6 Manufacturers of Compacting Equipment

Stone Construction Equipment, Inc.
Corporate Offices/Northern Manufacturing Plant
32 East Main Street
P.O. Box 150
Honeoye, NY 14471-0150
(800) 888-9926

Glossary

Admixture—A substance added to a mixture during mixing.

Adverse patching conditions—Climatic conditions in which the air temperature is below 40°F (4°C) and the repair area is saturated with surface moisture.

Bonding agent—A substance that promotes good bonding between the pavement surface and a repair material placed on the surface.

Breaking and seating—The breaking and compaction of a continuously-reinforced concrete pavement, reducing the amount of reflective cracking in the overlay.

Calcium aluminate concrete—A high alumina (Al_2O_3) cementitious concrete.

Chemical conversion—A chemical process that results in a change in the nature, structure, or properties of a substance.

Compact—To release trapped air and reduce volume using compression.

Compression failure—The crushing of a repair due to the expansion of the surrounding pavement during freeze-thaw cycles.

Compression recovery—The property of being able to regain original shape and volume after being compressed.

Compressive strength—The maximum compressive stress a material can withstand before failure.

Compressive stress—A stress that causes an elastic body to shorten in the direction of the applied force and that causes an inelastic body to rupture.

Consolidate—To release trapped air from fresh concrete mix by using vibration.

Cracking and seating—The breaking and compacting of a plain concrete pavement, reducing the amount of reflective cracking in the overlay.

D-cracking—Durability cracking; a pattern of cracks running parallel and close to a joint or linear crack caused by freeze-thaw expansion of large, nondurable aggregate.

Debonding—The partial or complete loss of bond between two materials, such as between a patch and a slab.

Diamond grinding—A surface restoration in which patterns are cut into hardened concrete with closely spaced diamond saw blades to correct surface distresses.

Epoxy concrete—A polymer concrete containing epoxy resin (a flexible, thermosetting resin made by polymerization of an epoxy compound).

Feathering—The thin placement of patching materials because of curved or angled patch edges that do not allow adequate depth of placement.

Free sulfate—A chemical group containing sulfur and oxygen ($-\text{SO}_4$) that is free to react chemically with other chemical groups.

Full-depth spall repair—The removal of an area of deteriorated concrete the entire depth of a pavement slab, and its replacement with a repair material along with the restoration of load transfer devices.

Full lane-width patch—A patch that extends the entire width of a lane.

Gouge bit—A curved chisel tip used in jackhammering that is not recommended for partial-depth spall repair.

Gypsum-based concrete—A cementitious concrete that contains gypsum, a common sulfite mineral.

Heat of hydration—The heat given off when molecular water is incorporated into a complex molecule with molecules such as those found in cementitious mixes.

High alumina concrete—A cementitious concrete that contains a higher amount of alumina (the native form of aluminum oxide) than regular concrete.

High early-strength materials—Patching materials that gain high strength levels early in their curing period.

High molecular weight methacrylate concrete—A cementitious concrete containing high molecular weight methacrylate, an acrylic resin or plastic made from a derivative of methacrylic acid ($C_4H_6O_2$).

Hydration rate—The rate at which molecular water is incorporated into a complex molecule with molecules such as those found in cementitious mixes.

Incompressible—A material that resists compression, such as stones, sand, or dirt, in a crack or joint reservoir that is closing.

Joint bond breaker—A strip of polyurethane, polyethylene, or fiberboard that is placed in a joint to prevent a patch placed at that joint from bonding to the adjacent slab.

Joint insert—A metal or plastic strip inserted into fresh concrete to form a weakened plane and induce cracking at a desired location.

Joint sealant system—All components that function to seal joints, including the sealant material, surrounding concrete, and the sealant-concrete interface.

Laitance—A residue left on a surface, such as the dried residue left on pavement after a wet-sawing operation.

Lateral confinement—Being held in place from the sides.

Latex caulking—The filling and water sealing of a space with a latex material.

Load transfer devices—Devices such as dowel bars that transfer the traffic load from one slab across a joint to the adjacent slab and that reduce the relative deflection across that joint.

Magnesium phosphate concrete—A cementitious concrete that contains magnesium phosphate, a metallic element (Mg) bound to a phosphate group ($-\text{PO}_4$).

Methyl methacrylate concrete—Cementitious concrete containing methyl methacrylate ($\text{C}_5\text{H}_8\text{O}_2$), a volatile, flammable liquid that readily polymerizes.

Opaque—Not transparent to rays of light.

Operating parameters—Equipment settings, such as speed, pressure, and number of overlapping passes.

Partial-depth spall—An area of deteriorated concrete that is limited to the top third of a concrete pavement slab.

Polymer—A chemical compound or mixture of compounds formed by polymerization and consisting of repeating structural units; a substance made of giant molecules formed by the union of simple molecules.

Polymer resin—A resin that is a polymer; see polymer and resin.

Polyurethane concrete—A concrete consisting of aggregate mixed with a two-part polyurethane resin, a resin of repeating structural units of urethane ($C_3H_7NO_2$).

Preformed compression seal—A preformed seal, generally made from neoprene, that can be compressed and inserted into concrete joints for sealing purposes.

Proprietary—Something that is used, produced, or marketed under the exclusive legal right of the inventor or maker.

Radiant heat—Heat that radiates from the sun.

Rapid-setting materials—In the context of this manual, patching materials that set within 30 minutes of mixing.

Resin—Any of a class of solid or semi-solid organic products of natural or synthetic origin with no definite melting point, generally of high molecular weight. Most resins are polymers.

Retarding agent—A substance added to a cementitious material mixture that initially slows down the rate of hydration, allowing a longer period of workability.

Rubblization—The breaking of a concrete pavement into pieces smaller than 304.8 mm in diameter and its compaction, reducing the amount of reflective cracking in the overlay.

Saturated—Full of moisture; having voids filled with water.

Scalloped—Having a series of curves in its edges.

Segregation—The separation of cement and aggregate.

Set initiator—An admixture that triggers the setting of a material.

Shape factor—The ratio of the width to depth of a sealant.

Shrinkage cracks—Fine hairline cracks that develop as a result of water loss and volume reduction during curing.

Skid resistance—The resistance of a pavement to tires sliding over its surface; generally a function of the macro- and micro-texture of the pavement surface.

Slab jacking—The lifting of a slab at a low point to restore it to its original elevation and rideability.

Slurry—The mixture of water, concrete dust, old sealant, and dirt that results from re-sawing a joint in concrete pavement.

Spade bit—A flat, spade-shaped chisel tip used in jackhammering that is recommended for partial-depth spall repair.

Spalling—The cracking, breaking, or chipping away of concrete fragments in a pavement.

Spall—A small broken or chipped segment of concrete normally occurring along a joint or crack.

Substrate—A base layer, such as the repair surface, upon which a material is applied or placed.

Thermal compatibility—Compatibility between the thermal properties of two materials, such as similar amounts of thermal expansion resulting from a given temperature increase in the two materials.

Thermal expansion—The increase in volume of materials due to an increase in temperature.

Undersealing—Filling voids beneath a concrete pavement using a pressurized slurry or hot asphalt material.

Vibrating screed—A leveling device drawn over freshly poured concrete that is vibrated to allow consolidation of the material.

Waterblasting machine—A machine controlled by a mobile robot that produces a high-pressure water jet capable of removing deteriorated concrete.

Weight and volume stability—Structural strength due to sufficient patch weight and volume.

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