*Disclaimer*

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# CHAPTER 7 ISOLATED PARTIAL DEPTH CONCRETE REPAIR

This chapter provides an overview of isolated partial depth concrete repairs. It presents a description of the effectiveness and limitations of this technique, as well as material selection, design considerations, and construction procedures. Also included are a troubleshooting guide and a list of important factors to be considered during design and construction of this treatment.

## 7.1 PURPOSE AND DESCRIPTION OF TREATMENT

Partial depth repairs are preventive maintenance techniques that restore structural integrity and rideability of the pavement, and deter further deterioration, thus extending the pavements service life. Also, partial depth repairs are required to prepare an existing, distressed pavement prior to a structural overlay or restoration project.

### *7.1.1 Partial Depth Repair*

Partial depth repair restores localized surface distresses, which do not extend beyond the upper one-third of a concrete pavement. It involves the removal of small, unsound areas of concrete and their replacement with suitable repair materials. Partial depth repair is commonly used to repair low severity spalling but can also be used for small areas with scaling problems. Table 7-1 illustrates the distress types and severity levels where partial depth repairs should be applied.

Table 7-1 Distresses addressed by partial depth repairs for jointed concrete pavements

| Distress Type | Severity Levels that Require Partial-Depth Repair |
|---|---|
| Spalling of joints | < 6 inches from the joint and < 2 inches in depth |
| Scaling of joints | Low |
| Deterioration adjacent to existing repair | Low |
| Deterioration of existing repairs | Low |

Spalls caused by material problems, such as D-cracking, Alkali-Silica Reactivity (ASR), or by lockup or corrosion of dowel bars at transverse joints cannot be addressed by partial depth repairs. Such spalls usually indicate deterioration beyond the upper one-third of the pavement; therefore in these instances a full depth repair would be more appropriate (see Chapter 8).

## 7.2 MATERIALS AND SPECIFICATIONS

A wide variety of materials are available for partial depth repairs. The selection of an adequate material will depend on the project's environmental, design, and funding requirements. Repair

materials include conventional portland cement concrete mixtures, special cements, proprietary materials, and bituminous materials. These repair materials will be described in more detail in sections 7.2.2 and 7.2.3.

### *7.2.1 Materials Selection*

Repair materials are selected based on available curing time, climatic conditions, material costs, equipment requirements, mixing and placing time, desired service life, and the size and depth of the repair(s). Material properties, such as strength gain, modulus of elasticity, bond strength, scaling resistance, sulfate resistance, abrasion resistance, shrinkage characteristics, coefficient of thermal expansion, and freeze-thaw durability should also be included in the selection process.

Repair materials must be compatible in strength and volume stability with the existing pavement. An adequate bonding between the repair material and the existing slab is critical to obtain an integral slab.

Despite higher costs, special cements and proprietary materials are generally used for partial depth repairs. A good rule of thumb for selecting the material for PCC slab repair is to use the most convenient material that meets the lane closure requirements (Caltrans, 2004).

### *7.2.2 Cementitious Materials*

**Normal Concrete Mixtures**

Portland cement type I, II, or III is typically used for partial depth repairs. Nationally, Type I has been widely used for pavement repairs because of its relatively low cost, availability, and ease of use. Although the rate of strength gain under cool weather may be too slow to allow a timely opening to traffic, insulated layers can be used to reduce the curing time (FHWA, 2001). However, Caltrans most often uses Rapid Strength Concrete (RSC) for partial depth repairs. Some properties of normal concrete mixtures are described in Table 7-2.

FHWA (2001) recommends that the size of the coarse aggregate used must not be larger than one-half the minimum repair thickness. The mix should be a low slump mixture of air entrained concrete having a water-cement ration not exceeding 0.44 (FHWA, 2001).

Caltrans allows the following cementitious materials (Caltrans Standard Specifications Section 90), unless otherwise specified:

- "Type IP (MS) Modified" cement;
- Combination of "Type II Modified" portland cement and mineral admixtures;
- Combination of Type V portland cement and mineral admixtures;
- Type III portland cement shall be used only as allowed in the special provisions or with the approval of the Engineer.

Table 7-2 Properties of normal concrete mixtures used as partial depth repair materials (Patel, Mojab, and Romine, 1993)

| Category | Working time | Installation temperature | Time to open traffic | Moisture condition of | |
|---|---|---|---|---|---|
| | | | | repair surface | aggregate |
| Normal concrete mixtures | 15-30 min. | 40° - 110°F (4° - 43°C) | 4-72 hours | SSD to dry | 1-3% to dry |
| High early strength PCC mixtures | 15-30 min. | 32° - 110°F (0° - 43°C) | 4-6 hours | SSD to dry | 1-3% to dry |

- SSD = saturated surface dry; dry = oven dry

**Specialty Cement Mixtures**

These mixtures contain some kind of cement in place of or in addition to normal Type I, Type II, or Type III cement; this may be hydraulic cement, gypsum-based cement, magnesium phosphate cement, or high-alumina cement, as described below:

- **Gypsum-based cement mixtures** contain calcium sulfates which accelerate strength gain and may be used in temperatures above freezing and all the way up to 110 °F (43 °C). They are not recommended for placement in rainy and freezing weather (NCHRP, 1977), and may promote steel corrosion in reinforced pavements (Good-Mojab, Patel, and Romine, 1993).
- **Magnesium phosphate cement mixtures** are characterized by a high early strength, low permeability, and good bonding to clean dry surfaces. However, this concrete is extremely sensitive to water content and aggregate type (especially limestone); significant strength reduction can be obtained with very small amounts of excess water (Good-Mojab, Patel, and Romine, 1993).
- **High alumina cement mixtures** produces a rapid strength gain concrete with good bonding properties (to dry surfaces) and very low shrinkage. However, they should not be used because a significant strength loss is likely to occur due to chemical conversions in the calcium aluminate cement during curing (ACPA, 1998).
- **Accelerating admixtures/additives** are sometimes used to achieve high early strengths and reduce the time to opening. Premature deterioration can be developed due to insufficient curing time. Calcium chloride ($CaCl_2$) accelerators are not allowed by Caltrans due to detrimental factors such as excessive shrinkage and corrosion of load transfer devices.
- **Alumina powder** has been used as an admixture with Type I, Type II, 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. The use of alumina powder may also decrease the bond strength and patch abrasion resistance.
- **Other rapid setting materials** are also available that may perform adequately. However, some rapid hardening repair materials are affected by high alkaline bearing materials. These materials may react with certain siliceous aggregates to form alkali-silica reactivity (ASR). Therefore, it is important to make sure that no chemical incompatibilities exist between the patch material and the aggregates used in the mixture.

Some properties of specialty cement mixtures are described in Table 7-3.

Table 7-3 Properties of specialty cement mixtures used as partial depth repair materials (Patel, Mojab, and Romine, 1993)

| Category | Working time | Installation temperature | Time to open traffic | Moisture condition of | |
|---|---|---|---|---|---|
| | | | | repair surface | aggregate |
| Gypsum-based cement mixtures | 15-30 min. | 32° - 110°F (0° - 45°C) | 1-2 hours | SSD to dry | 1-3% to dry |
| Magnesium phosphate cement mixtures | 5-45 min. | 32° - 90°F (0° - 30°C) | 1-2 hours | Dry | 1-3% to dry |

- SSD = saturated surface dry; dry = oven dry

### *7.2.3 Specialty Materials*

The application of specialty materials should closely follow the manufacturer's recommendations. The manufacturer's guidelines concerning repair area preparation, bonding, placement, curing, and opening time should also be followed to ensure adequate performance of these repair materials.

**Polymer Concretes**

Polymer concretes are characterized by their quick set in comparison to normal concretes. They are both more expensive and quite sensitive to certain field conditions, such as temperature range. Polymer concretes are a combination of polymer resin, aggregate, and a set initiator. They are categorized by the type of resin used: epoxies, methacrylates, polyester-styrenes, and urethanes.

**Epoxy**

Epoxy mixtures provide a repair material with excellent adhesive properties and low permeability. However, they are not thermally compatible with normal concrete, sometimes resulting in early repair failure. The use of larger aggregate can improve their thermal compatibility with concrete and reduce the risk of debonding.

Epoxies are available with a wide variety of setting times, placement temperature ranges, strengths, bonding capabilities, and abrasion resistance properties. The selection of a particular epoxy mixture should be based on the project's environmental conditions and construction constraints.

Epoxy concrete should not be used to repair spalls caused by reinforced steel because it can accelerate the corrosion of the steel in the adjacent, unrepaired concrete by creating a strongly cathodic area (Furr, 1984).

**Methyl Methacrylate Concrete**

Methyl methacrylate concretes have relatively long working times (30-60 minutes), high compressive strengths, good adhesion to clean dry concrete, and a wide placement temperature range between 40 and 130 °F (5 - 55 °C). A major concern with methacrylates is that many of them produce fumes, which are a health hazard and can ignite if exposed to a spark or flame.

**Polyester-Styrene Concrete**

Polyester-styrene concrete has very similar properties to methyl methacrylate concrete, but posses a much slower rate of strength gain. This limits its usefulness for partial-depth repairs.

**Polyurethane Concrete**

Polyurethane concrete consists of a two-part polyurethane resin mixed with aggregate. They set very quickly (~ 90 seconds). Two types are available: the older type which is moisture sensitive and will foam in contact with water; and the newer ones which claim to be moisture tolerant and can be placed on wet surfaces.

Some properties of specialty materials are described in Table 7-4.

Table 7-4 Properties of specialty materials used in partial depth repairs (Patel, Mojab, and Romine, 1993)

| Category | Working time | Installation temperature | Time to open traffic | Moisture condition of | |
|---|---|---|---|---|---|
| | | | | repair surface | aggregate |
| Epoxy concretes | 5-15 min. | 40° - 90°F (5° - 30°C) | 1-3 hours | Dry | Dry |
| Methyl methacrylate concretes | 30-60 min. | 40° - 130°F (5° - 55°C) | 1-2 hours | Dry | Dry |
| Polyurethane concrete | 1 min. | > 0°F (> -20°C) | 10-20 min. | Dry | Dry |

- SSD = saturated surface dry; dry = oven dry

### *7.2.4 Bituminous Materials*

Bituminous materials are not recommended for permanent repairs of rigid pavements because they allow excessive horizontal movement of the slab, provide no load transfer across the joint, and may lead to rapid deterioration. They should be only considered as a short-term or temporary repair.

### *7.2.5 Bonding Agents*

A bonding agent is required on partial depth repairs to enhance the bond between the existing concrete and the repair material. Sand-cement grouts and epoxy agents have been widely used on these types of repairs.

- Sand-cement grouts – These grouts have performed adequately when the repairs are protected from traffic for 24 to 72 hours. The recommended mixture for the sand-cement grout consists of one part sand and one part cement by volume, with sufficient water to produce a mortar with a thick, creamy consistency (FHWA, 2001).
- Epoxy bonding agents – These bonding agents have proven adequate when repair closure time needs to be reduced to 6 hours or less. They have been used with both PCC and proprietary repair materials.

Caltrans allows the use of the following fast-setting grout material (Caltrans, 2007a):

1. Either of the following magnesium phosphate grouts:
   - Single component water activated
   - Dual component with a prepackaged liquid activator
2. Modified high alumina based grout
3. Hydraulic cement based grout

Caltrans additionally allows the use of polyester grout, consisting of a polyester resin binder and dry aggregate. The resin is an unsaturated isophthalic polyester-styrene copolymer. Additional material requirements are specified in Caltrans SSP No. 41-151.

## 7.3 ENGINEERING CONSIDERATIONS

Partial depth repairs performance can be highly improved through proper design. This section provides important design considerations for partial depth repairs, such as project selection, concurrent work considerations, and repair locations and boundaries.

### *7.3.1 Project Selection*

Partial depth repairs should be used on localized surface distresses, such as low severity spalling or scaling. Deterioration must be within the upper one-third of a concrete pavement slab. Partial depth repairs are not appropriate for moderately severe spalls that generally extend more than 6-10 inches (150-250 mm) from the joint. Such spalls typically indicate further damage which needs to be addressed with a full depth slab repair.

Cracks extending through the full thickness of the slab or spalls with exposed reinforcing steel or load transfer devices cannot be corrected with a partial depth repair. A full depth repair should be used in these cases.

### *7.3.2 Concurrent Work*

For partial depth repairs, when done as part of a comprehensive pavement restoration project, the sequence of repairs is very important. Slab stabilization should be done before partial depth repairs to include any accidental spalling that can occur during slab stabilization. Partial depth repairs should be done before or concurrently with full depth repairs. Diamond grinding should follow partial and full depth repairs, followed by joint resealing as needed.

### *7.3.3 Repair Locations and Boundaries*

A visual survey is needed to identify and mark distressed areas. Engineering judgment, coring, deflection studies, and sounding techniques (such as striking the concrete surface with a hammer or steel rod, or by dragging a chain) should be used to define the extent of the deterioration beneath the surface and determine partial-depth repair boundaries.

Repair boundaries for partial depth repairs must extend 2 to 6 inches (50 to 150 mm) beyond the delaminated or spalled area. Table 7-5 provides the minimum dimensions of repair areas for partial depth repairs (Wilson, Smith, and Romine, 1999b).

Table 7-5 Minimum dimensions of repair area for partial depth repairs

| Location of Spalling | Minimum Dimensions of Repair Area | | |
|---|---|---|---|
| | Depth | Length | Width |
| At one joint | 2 in (50 mm) | 10 in (250 mm) or length of spalled area + 4 in (100 mm) whichever is greater | 4 in (100 mm) or width of spalled area + 2 in (50 mm) whichever is greater |
| At two joints | 2 in (50 mm) | 8 in (200 mm) or length of spalled area + 2 in (50 mm) whichever is greater | 4 in (100 mm) or width of spalled area + 2 in (50 mm) whichever is greater |
| Away from joints | 2 in (50 mm) | 10 in (250 mm) or length of spalled area + 4 in (100 mm) whichever is greater | 5.5 in (140 mm) or width of spalled area + 4 in (100 mm) whichever is greater |

### *7.3.4 Typical Item Codes*

Typical Caltrans item codes for an isolated partial depth concrete repair project are given in Table 7-6.

Table 7-6 Typical item codes for an isolated partial depth concrete repair project

| Item Code | Description |
|---|---|
| 120090 | Construction area signs |
| 120100 | Traffic control system |
| 128650 | Portable changeable message sign |
| 150846 | Remove concrete pavement |
| 150306 | Repair spalled concrete |
| 156515 | Repair spalled and unsound surface area |
| 401108 | Replace concrete pavement (rapid strength concrete |
| 413101 | Repair corner breaks |
| 413111 | Repair spalled joint |
| 413114 | Replace joint seal (existing concrete pavement) |
| 413115 | Seal joint (existing concrete pavement) |
| 420201 | Grind existing concrete pavement |
| 511040 | Concrete surface finish |
| 511055 | Concrete surface texture |
| 515028 | Repair spalled surface area |

*Note: Standard special provision and PS&E must be referred for specific item codes proposed for the project.*

Caltrans Standard Materials and Supplemental Work Item Codes can be found at the following web site:

http://i80.dot.ca.gov/hq/esc/oe/awards/#item_code

Associated specifications for repairing spalled joints are:

- SSP No. 40-150. Repair Spalled Joints
- SSP No. 41-151. Repair Spalled Joints (Polyester Grout)

## 7.4 CONSTRUCTION PROCESS

### *7.4.1 Traffic Control and Safety*

Traffic control is required both for the safety of the traveling public and construction personnel. Traffic control must be enforced before equipment or personnel enter the work zone. Caltrans project specifications and the Caltrans Code of Safe Operating Practice should be followed. Traffic is not allowed on repair areas until the curing period and the joint sealing process are completed.

Depending on the project location, size, and amount of repair work, one of the following types of traffic control alternatives may be considered:

- Complete roadbed closure
- Continuous lane closure
- Weekend closure
- Nighttime closure

### *7.4.2 Equipment*

Equipment requirements vary according to the treatment method and the material selected, and they will be described in more detail in Sections 7.4.3 through 7.4.11. Equipment may be required for:

- Sawing and material removal
- Cleaning
- Repair material placement
- Finishing
- Curing
- Joint sealing

### *7.4.3 Repair Locations*

As mentioned in section 7.3.3, the difficult task of defining the location and boundaries of repairs must be performed by experienced personnel through a thorough field survey. This field survey should be complemented with coring, sounding techniques, and FWD load-deflection studies to define the extent of deterioration beneath the surface and determine repair boundaries. This survey should be performed as close as possible to the proposed repair work and should include additional distressed areas that have developed since the previous pavement inspection. Distressed areas should be examined and repair boundaries identified and marked on the pavement surface (see Figure 7-1).

Figure 7-1 Marking damage area for removal (FHWA, 2006)

### *7.4.4 Concrete Sawing and Removal*

Five different methods have been used nationally to remove deteriorated concrete for partial depth repairs:

- **Saw and patch—T**he saw and patch method employs diamond-bladed saws to define the repair area and light jackhammers to chip out the damaged concrete. The vertical faces and square corners will prevent spalling of the repair material along the perimeter. The saw cut must be at least 2 inches (50 mm) deep. Light jackhammers should be used to chip out the damaged concrete until sound and clean concrete is exposed. Jackhammers heavier than 30 lb. (13 kg) should not be used because of the risk of damage to the underlying, sound pavement.

  Material removal should begin near the center of the repair area and proceed towards (but not up to) the edges. Jackhammers and mechanical chipping tools should be operated at an angle of about 45° to minimize damage to sound concrete. Spade bits are preferable to gouge bits for improved chipping control and less damage to underlying, sound concrete. Material removal near the edges should be performed with lighter equipment (10-20 lb [4.5-9.0 kg]).

- **Chip and patch—T**his procedure differs from the saw and patch procedure in that the repair boundaries are not sawed. Light, 15 lb. (7 kg) jackhammers remove the damaged concrete, starting near the center and proceeding towards the edges. The chisel points should always point towards the inside of the patch area. Light jackhammers and hand tools should be used to remove the material near the edges of the patch area.

  Even though chipping and patching is quicker and provides a rougher vertical face in comparison with the saw and patch procedure, it is generally not recommended. Some disadvantages of this procedure include thin and feathered patch edges which are prone to spalling and debonding, more damage to sound concrete, and the difficulty of achieving vertical sides.

- **Mill and patch.** Carbide-tipped milling machines have been used efficiently and economically on projects requiring the removal of large repair areas. The milling procedure leaves rounded edges that may be made vertical by sawing or jack hammering.

Adequate supervision is required to avoid spalling on adjacent pavement edges by the milling equipment. The bottom surface and repair edges should be checked to ensure that all of the unsound concrete is removed during the milling procedure.

- **Water blast and patch.** A high pressure (15,000 - 30,000 psi [100,000 - 200,000 kPa]) water jet is used to remove damaged concrete. Skilled personnel should set the pressure of the equipment to remove deteriorated concrete only. The jet should reduce most of the damaged concrete to a fine slurry, thus minimizing hauling costs. The resulting slurry and debris must be removed immediately, before the slurry sets.

  Shields should be installed to protect traffic from the high pressure jets. The resulting rough and irregular surface promotes good mechanical interlock between the repair material and the existing slab.

- **Clean and patch.** The clean and patch procedure consists of the removing deteriorated or loose concrete with hand tools and light jackhammers. Loosened material is then removed with a stiff broom before repair material placement. This procedure should only be used for emergency repairs under adverse environmental conditions.

Caltrans requires the outlines of rectangular areas to be cut with a diamond bladed saw to a minimum depth of 2 inches (50 mm); and to 1½ inches (35 mm) for the polyester grout but not greater that one-third of the pavement depth. Unsound and damaged concrete between the saw cut and the joint, and to the depth of the saw cut, shall be removed by methods that will not damage the concrete pavement that is to remain in place. A pneumatic hammer greater than 15 pounds (7 kg) shall not be used for removal of concrete (Caltrans, 2007a and 2007b). Figures 7-2 and 7-3 illustrate part of this process.

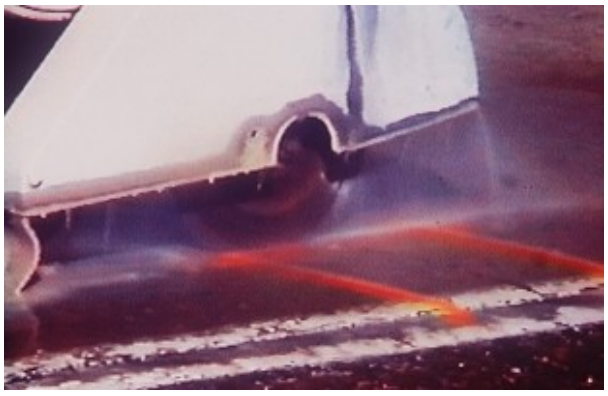

Figure 7-2 Concrete removal using the saw and patch methodology (FHWA, 2006)

Figure 7-3 Concrete removal using the mill and patch methodology (FHWA, 2006)

### *7.4.5 Cleaning and Repair Area Preparation*

The repair surface must be thoroughly clean before the application of repair material. A clean surface will enhance bonding between the repair material and the existing concrete. The use of abrasive blasting, such as sandblasting, is highly recommended (see Figure 7-4). High-pressure water blasting is another alternative which is very useful in urban environments where dust control is enforced. The water blasting equipment for concrete cleaning shall be capable of producing a blast pressure of 2,900 to 5,800 psi (20 to 40 MPa) (Caltrans, 2007a and 2007b).

Figure 7-4 Cleaning the repair area with sandblasting equipment (FHWA, 2006)

Air blasting shall be used to remove all residues from abrasive blasting (Caltrans, 2007a and 2007b). Air blasting equipment must be checked for moisture and oil contamination because of their potential to impede or reduce bonding between the repair material and the existing concrete.

### *7.4.6 Joint Preparation*

Adequate joint preparation is essential to the performance of partial depth repairs. Repairs located next to transverse joints and cracks require sufficient space to minimize the development of compression forces due to thermal expansion of the slabs. Also, a repair material that infiltrates the crack or joint can restrict slab movement and cause the development of compressive stresses at lower depths that will deteriorate the repair. This type of deterioration can also occur along longitudinal joints or at lane-shoulder joints.

Partial depth repair failures can be reduced by placing a bond breaker between the repair material and the adjoining slab (see Figure 7-5). Some examples of widely used compressible materials are polystyrene, polyethylene, and asphalt-impregnated fiberboard. Caltrans specifies that the joint bond breaker shall extend one inch beyond the edges of the patch (Caltrans, 2007a and 2007b). FHWA recommends that the bond breaker extends 1 inch (25 mm) below and 3 inches (75 mm) beyond the repair boundaries (FHWA, 2001).

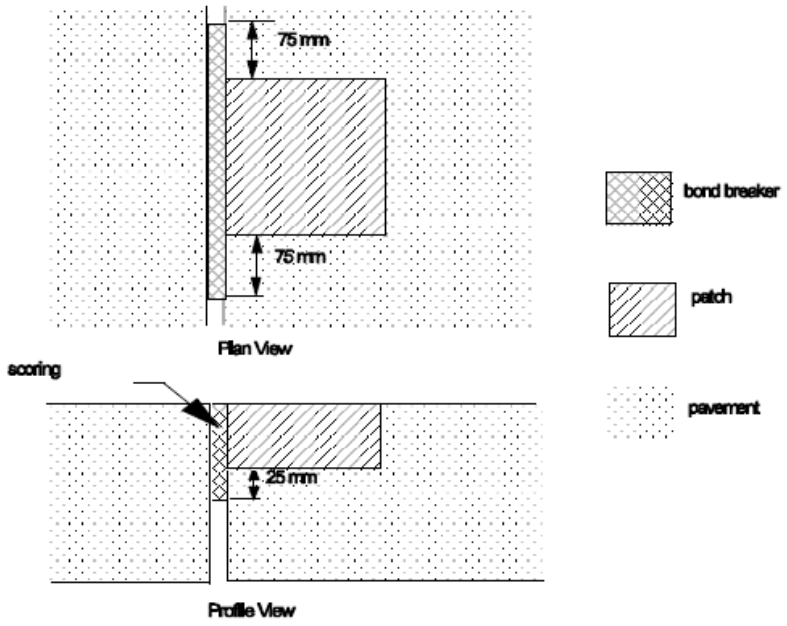


Figure 7-5 Placement of bond breaker at joint (FHWA, 1999)

Once the patch has cured, the insert should be removed and a preformed joint reservoir is ready for joint sealing. A more complete description of joint sealing can be found in section 7.4.10.

Partial depth repairs next to asphalt shoulders can result in damage to the repair or the shoulder, due to the flow of repair material into the asphalt shoulder. The repair material, once hardened, may restrict longitudinal movement and result in deterioration. For these cases, the following procedure is recommended:

- Remove a thin section of the asphalt shoulder along the whole length of the repair.
- Place a wood board or other kind of insert at this location (lane/shoulder joint) to provide confinement during the placement and hardening of the repair material. No flow of repair material is allowed into the shoulder.
- After the curing period, remove the insert and patch the shoulder with asphalt material.

### *7.4.7 Materials Placement*

**Clean Surface**

Before placing the bonding agent and the repair material, make sure the repair area is clean and dry. If debris or dust is present in the repair area, air blow the patch area again.

**Bonding Agent**

It is recommended to apply a thin, even coat of bonding agent over the entire patch area including the side walls. Scrubbing the bonding agent into the patch area with a stiff bristle brush will improve material bonding. The cementitious grout must not be allowed to dry before the placement of the repair material. If the grout is allowed to set, it must be removed by a water jet or sandblasting, and then fresh grout should be reapplied before placement of the repair material. If epoxy or proprietary bonding agents are used, follow the manufacturer's instructions for their proportioning, mixing, and application.

**Placement**

Careful control of mixing times and water content is very important because of the quick setting nature of repair materials. Do not allow the addition of extra water to the concrete mix to achieve better workability because of the resulting reduction in concrete strength and increased shrinkage potential.

Repair materials should be placed under favorable environmental conditions. Portland cement concrete and most proprietary repair materials should not be installed under adverse conditions, such as air or pavement temperatures below 40° F (4º C) or in wet substrates. Placement when temperatures are below 55 °F (13 °C) will required the use of warm water, insulation covers, and longer curing periods.

High frequency internal vibrators with small heads are usually used for partial depth repairs. The vibrator should be held at a slight angle (15-30°) from the vertical, but do not use it to move material from one place to another as this may result in segregation. For very small repairs, hand tools may be used. Cutting with a trowel is recommended over rodding or tamping.

During placement, a slight over-filling of the repair area should be allowed to allow for volume reduction during consolidation. It is also important to ensure that the concrete is well vibrated over the entire repair area, especially around the edges of the repair, and to avoid over-finishing the repair area.

### *7.4.8 Finishing*

A critical aspect of partial depth concrete slab repairs is to obtain a level finish of the repair area with the surrounding pavement. To provide adequate skid resistance and a smooth transition, the surface of the repair should be textured to match that of the existing pavement.

In partial depth repairs, due to their small dimensions, a stiff board can usually be used to screed the repair area. The repair material should be worked towards the perimeter of the repair area, which will enhance bonding to the existing concrete. Finally, a hand trowel can be used to remove minor irregularities.

### *7.4.9 Curing*

Adequate attention to curing will reduce the development of shrinkage cracking and promote more complete hydration by preventing moisture loss from the concrete. Proper curing is even more

important when accelerating admixtures are used. Curing procedures shall be in conformance with Caltrans Standard Specifications Section 90-7, "Curing Concrete."

In hot weather (e.g. greater than 100 °F or 40 °C), the use of pigmented curing compounds is highly recommended over other curing procedures (moist burlap and polyethylene). Caltrans recommends a nominal rate of application of 150 $ft^2$/gal (4 $m^2$/L), unless otherwise specified (Caltrans Standard Specifications Section 90-7). ACPA recommends an application rate of about 200 $ft^2$/gal (5 $m^2$/L). Insulation mats are not necessary in hot weather, and if used can result in concrete cracking (ACPA, 1989).

In cold weather (e.g. less than 50 °F), the use of insulating blankets and tarps can be used to accelerate hydration and promote higher early strengths, thus allowing for earlier opening to traffic. Special care is required during the removal of insulation blankets because rapid cooling of the pavement surface can cause cracking. When large temperature differences (>30 °F) exist between concrete and air temperatures, insulation blankets should not be removed from the repair area.

Curing time and procedures for epoxy and proprietary materials should follow the manufacturer's recommendations.

### *7.4.10 Joint Sealing*

Joint sealing will reduce future spalling and minimize water infiltration. Both longitudinal and transverse repair joints should be sealed. The joints should be sawed or formed, sandblasted, air blasted, and a backer rod should be inserted and joint sealant applied. More detail information on joint sealing can be found in chapter 4.

### *7.4.11 Opening to Traffic*

Repair material must have gained sufficient strength before it is opened to traffic. A compressive strength of 3,000 psi (21 MPa) is generally specified by most agencies before the repair area is opened to traffic. Caltrans requires a minimum flexural strength of 405 psi (2.8 MPa), as determined in accordance with CTM 523 for slab replacement (Caltrans, 2004). It is preferable to have a measure of the actual concrete strength before allowing the repair to be opened to traffic, especially if very early opening is required (e.g. 4 hrs or less curing time). On such projects, maturity meters or pulse-velocity devices may be used to monitor concrete strength (ACPA, 1995).

### *7.4.12 Job Review-Quality Issues*

Quality control and workmanship are critical to the performance and life of partial depth repairs. There must be a cooperative effort between Caltrans and the contractor's representatives to conduct inspections of all construction procedures, materials, and project equipment before and during the partial depth repair project. Project inspections will allow earlier detection and correction of deficiencies in workmanship, equipment and materials, thus resulting in improved performance.

Improper construction and placement techniques, followed by material deficiencies, have been the most frequent quality issues related to poor performance of partial depth repairs. Frequent causes of failure include improper preparation of the repair areas, insufficient consolidation, and improper use of repair materials, as well as incompatibility in thermal expansion between the repair material and the original slab.

## 7.5 PROJECT CHECKLIST AND TROUBLESHOOTING GUIDE

The project checklist and troubleshooting guide, included in this section, provide important information which can help solve difficulties and improve performance in partial depth concrete slab repairs. The project checklist describes important aspects, such as preliminary responsibilities, material and equipment requirements, project inspection responsibilities, and cleanup responsibilities, all of which should be duly considered in order to promote a successful project. The troubleshooting guide describes common problems encountered during construction and their solutions.

### *7.5.1 Project Checklist*

The following checklists are primarily based on guidelines from the FHWA Pavement Preservation Checklist Series (http://www.fhwa.dot.gov/pavement/pub_details.cfm?id=351) and the FHWA / NHI Course entitled "Pavement Preservation Design and Construction of Quality Preventive Maintenance Treatments".

| **Preliminary Responsibilities** | |
|---|---|
| **Document Review** | ✓ Bid/project specifications and drawings<br>✓ Special provisions<br>✓ Agency application requirements<br>✓ Traffic control plan<br>✓ Manufacturers' installation instructions, recommendations<br>✓ Material safety data sheets |
| **Project Review** | ✓ Verify that pavement conditions have not significantly changed since the project was designed and that partial-depth repair is appropriate for the pavement.<br>✓ Verify that the estimated number of partial depth repairs agrees with the number specified in the contract.<br>✓ Agree on quantities to be placed, but allow flexibility if additional deterioration is found below the surface.<br>✓ Note that some partial-depth repairs may become full-depth repairs if deterioration extends below the top third of the slab. |
| **Materials Checks** | |
| **Concrete patch material** | ✓ Verify that patch material is of the correct type and meets specifications.<br>✓ Verify that patch material is obtained from an approved source or as required by the contract documents.<br>✓ Verify that patch material has been sampled and tested prior to installation as required by the contract documents.<br>✓ Verify that additional or extender aggregates have been properly produced and meet requirements of contract documents. |
| **Other materials** | ✓ Verify that material packaging is not damaged so as to prevent proper use (for example, packages are not leaking, torn, or pierced).<br>✓ Verify that bonding agent (if required) meets specifications.<br>✓ Verify that curing compound (if required) meets specifications. |
| **Joint Sealing** | ✓ Verify that joint/crack re-forming material (compressible insert) meets specifications (typically polystyrene foam board, 1/2 in. [12 mm] thick).<br>✓ Verify that joint-sealant material meets specifications. |
| **General** | ✓ Verify that sufficient quantities of materials are on hand for completion of the project. |

| Equipment Inspections | |
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| **Concrete Removal Equipment** | ✓ Verify that concrete saws are of sufficient weight and horsepower to adequately cut the existing concrete pavement to the depth required along the patch boundaries as required by the contract documents.<br>✓ Verify that concrete saws and blades are in good working order.<br>✓ Verify that the maximum rated weight of removal jackhammers is 31 lb (14 kg). |
| **Patch Area Cleaning Equipment** | ✓ Verify that the sand-blaster unit is adjusted for correct sand rate and that it is equipped with and using properly functioning oil/moisture traps.<br>✓ Verify that air compressors have sufficient pressure and volume capabilities to clean patch area adequately in accordance with contract specifications. |
| **Mixing and Testing Equipment** | ✓ Verify that auger flights and paddles within auger-type mixing equipment are kept free of material buildup that can result in inefficient mixing operations.<br>✓ Ensure that volumetric mixing equipment such as mobile mixers are kept in good condition and are calibrated (CT-109) on a regular basis to properly proportion mixes.<br>✓ Verify that the concrete testing technician meets the requirements of the contract documents for training/certification.<br>✓ Ensure that material test equipment required by the specifications is all available on-site and in proper working condition (equipment typically includes slump cone, cylinder molds and lids, rod, mallet, ruler, and 10 ft [3 m] straightedge). |
| **Placing and Finishing Equipment** | ✓ Verify that a sufficient number of concrete vibrators 1 in. (25 mm) in diameter or less are available on-site and in proper working condition.<br>✓ Verify that all floats and screeds are straight, free of defects, and capable of producing the desired finish. |
| **Other Equipment** | ✓ Ensure that a steel chain, rod, or hammer is available on-site to check for unsound concrete around the patch area.<br>✓ Verify that grout-application brushes (if necessary) are available. |
| **Others** | |
| **Weather Requirements** | ✓ Review manufacturers' installation instructions for requirements specific to the patch material being used.<br>✓ Ensure that air and surface temperature meet manufacturer and contract requirements (typically 40 °F [4 °C] and rising) for concrete placement.<br>✓ Ensure that patching does not proceed if rain is imminent. |
| **Traffic Control** | ✓ Verify that signs and devices match the traffic control plan presented in the contract documents.<br>✓ Verify that the set-up complies with the Federal Manual on Uniform Traffic Control Devices or local agency traffic control procedures.<br>✓ Ensure that traffic control personnel are trained and qualified in accordance with contract documents/agency requirements.<br>✓ Ensure that the repaired pavement is not opened to traffic until the patch material meets strength requirements presented in the contract documents.<br>✓ Verify that signs are removed or covered when they are no longer needed.<br>✓ Ensure that any unsafe conditions are reported to a supervisor (contractor or agency). |
| **Project Inspection Responsibilities** | |
| **Patch Removal and Cleaning** | ✓ Ensure that the area surrounding the patch is checked for delamination and unsound concrete. |

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| | ✓ Ensure that the boundaries of unsound concrete area(s) are marked at least 2 in. (50 mm) beyond the area of deterioration.<br>✓ Verify that concrete is removed by saw cutting the boundaries and jack hammering the interior concrete.<br>✓ Verify that concrete removal extends at least 2 in. (50 mm) in depth and does not extend below one-third of the slab depth, and that load transfer devices are not exposed.<br>✓ Verify that, after concrete removal, the patch area is prepared by sandblasting or water blasting.<br>✓ Verify that the patch area is cleaned by air blasting. A second air blasting may be required immediately before placement of patch material if patches are left exposed for a period of time. |
| **Patch Preparation** | ✓ Ensure that compressible joint inserts (joint/crack re-formers) are inserted into existing cracks/joints in accordance with contract documents. Joint inserts are typically required to extend below and outside the patch area by 1/2 in. (12 mm).<br>✓ When a patch abuts a bituminous shoulder, ensure that a wooden form is used to prevent patch material from entering the shoulder joint.<br>✓ Ensure that bonding agent (epoxy- or cement based) is placed on clean, prepared surface of existing concrete immediately prior to placement of patch material as required by the contract documents. If bonding agent shows any sign of drying before patch material is placed, it must be removed by sandblasting, cleaned with compressed air, and re-applied.<br>✓ Verify that cement-based bonding agents are applied using a wire brush; epoxy-based bonding agents are applied using a soft brush. |
| **Placing, Finishing, and Curing Patch Material** | ✓ Verify that quantities of patch material being mixed are relatively small to prevent material from setting prematurely.<br>✓ Verify that the fresh concrete is properly consolidated using several vertical penetrations of the surface with a hand-held vibrator.<br>✓ Verify that the surface of the concrete patch is level with the adjacent slab using a straightedge in accordance with contract documents. Note: To prevent pulling material away from the patch boundaries, work material from the center of the patch outward toward the boundary.<br>✓ Verify that the surface of the fresh patch material is finished and textured to match the adjacent surface.<br>✓ Verify that the perimeter of the patch and saw-cut runouts (if saws are used) are sealed using grout material. Alternatively, saw-cut runouts can be sealed using joint-sealant material.<br>✓ Verify that adequate curing compound is applied to the surface of the finished and textured, fresh patch material in accordance with contract documents.<br>✓ Ensure that insulation blankets are used when ambient temperatures are expected to fall below 40 °F (4 °C). Maintain blanket cover until concrete attains the strength required in the contract documents. |
| **Resealing Joints and Cracks** | ✓ Verify that the compressible inserts are sawed out to the dimensions specified in the contract documents when the patch material has attained sufficient strength to support concrete saws.<br>✓ Verify that joints are cleaned and resealed according to contract documents. |
| **Cleanup Responsibilities** | |
| **General** | ✓ Verify that all concrete pieces and loose debris are removed from the pavement surface and disposed of in accordance with contract documents.<br>✓ Verify that mixing, placement, and finishing equipment is properly cleaned for the next use. |

### *7.5.2 Troubleshooting Guide*

The following guidelines are primarily based on guidelines from the FHWA Pavement Preservation Checklist Series (http://www.fhwa.dot.gov/pavement/pub_details.cfm?id=351) and the FHWA / NHI Course entitled "Pavement Preservation Design and Construction of Quality Preventive Maintenance Treatments".

| Problem | Description and solution |
|---|---|
| More deterioration than expected | Description: more deterioration below surface than is evident above<br><br>Solution:<br>• Extend limits of repair area into sound concrete.<br>• If deterioration extends below one-third of the depth, do a full depth repair.<br>• Ensure that the contractor's removal operations are not damaging the base. |
| Exposed steel | Description: dowel bar or reinforcing steel is exposed during concrete removal.<br><br>Solution:<br>• If steel is in the upper third of slab, remove the steel to the edges of the patch and continue.<br>• If removal extends to mid-depth of the slab, do a full depth repair. |
| Patch material in crack or joint | Description: patch material flows into joint or crack<br><br>Solution:<br>• Ensure joint insert extends far enough into the adjacent joint/crack and below the patch.<br>• Ensure insert is correctly sized for joint/crack width. |
| Patch cracking | Description: patch is cracking or unbonding<br>Solution:<br>• Check that joint insert is being used properly.<br>• Ensure that the insert is correctly sized for the joint/crack width and that it has been inserted correctly.<br>• Check that patch area was cleaned immediately prior to grouting/concrete placement.<br>• Check that grout material has not dried out before concrete placement.<br>• Ensure that curing compounds has been applied adequately.<br>• Check that patch material is not susceptible to shrinkage. |

## 7.6 KEY REFERENCES

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