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MTI MINETA TRANSPORTATION INSTITUTE

Manual for Asphalt Pavement Repair and Resurfacing Preparation

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California State University Transportation Consortium

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CSU TRANSPORTATION CONSORTIUM

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16. Abstract

Timely repairs of pavement defects are essential in protecting an important investment and asset that public agencies have. These repairs may be made as durable "stand-alone" repairs of isolated problems, or as part of preparations for a total resurfacing. This manual provides basic information on the planning, materials and construction aspects of common pavement repairs such as crack sealing, crack filling, and patching, as well as a broader look at other preparations needed for total resurfacing a pavement, whether the resurfacing is a surface treatment or a thin hot mix asphalt (HMA) overlay.

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Executive Summary

Asphalt pavement repairs are an essential part of an overall pavement maintenance and preservation program, whether repairs are done as "stand-alone" work, or in preparation for a resurfacing project. The purpose of this manual is to provide information and training for agency staff, so that they can understand the needs and benefits of pavement repairs and identify cost-effective repair strategies for preserving their aging asphalt pavements. The manual starts with the most common pavement repair strategies—cracking treatment and patching—and then addresses other pavement repairs or preparation strategies for pavement resurfacing. In summary, this manual provides guidance on quality assurance and troubleshooting crack treatments, patching, and preparation for resurfacing.

This manual provides guidance on *crack treatments*, such as project selection, materials, crack preparation methods, equipment, material placement, and other construction considerations. Crack *sealing* and crack *filling* are two major methods used to repair cracks in pavement surfaces. Crack sealing is generally used to treat working cracks, while crack filling is applied to seal "non-working" cracks. Although most types of cracks are suitable for crack sealing or crack filling, medium or high severity fatigue cracks are not good candidates for crack treatments.

Patching is another major strategy to repair localized pavement failure or disintegration. The primary methods of patching include pothole repairs, large complete removal (dig out) patches, hot and cold leveling or "skin" patches, and edge patches. This manual provides detailed guidance for each patching type including project selection, patching methods ranging from temporary to permanent, patching materials, equipment, and construction considerations.

Studies have shown that crack treatments and patching are also critical *pre-treatments* for pavement resurfacing success, including pavement preservation surface treatments. The most common of these used in California include chip seals, slurry surfacing, Cape seals, and thin asphalt overlays. These treatments all have the ability to extend the life of a pavement via the reduction of aging and oxidation of the existing asphalt material and the prevention of moisture intrusion into the underlying pavement layers. When properly designed and constructed, these preservation treatments can be a cost-effective tool that provides improved life-cycle cost benefits. To ensure the full benefits of these treatments, proper repairs, such as crack treatments and patching, should be performed prior to the placement of these surface treatments.

This manual also covers other special *surface preparation* strategies, such as sweeping, using tack coats, removing pavement markings, using temporary markers, tapered edge milling, milling and micro-milling, as well as raising manholes and valve covers, and other surface utilities in urban environments.

Quality assurance is critical to the success of pavement repair and surface preparation projects. This manual provides information on field considerations and activities to ensure high-quality outcomes and provides information to assist maintenance personnel with *troubleshooting* common problems associated with pavement repair and their recommended solutions.

1. Introduction

1.1 Background

California passed Senate Bill 1 (SB-1) in 2017 to raise revenue for transportation infrastructure improvements through increased fuel tax and other fees. An additional component was the creation of educational materials for workforce training; this manual is part of the SB-1 program.

Since part of SB-1 funds will be distributed back to local agencies and split between all cities and counties throughout California, this manual provides information and training so that local agency staff can recognize and understand pavement repair options as part of cost-effective strategies for preserving their aging hot mix asphalt (HMA) pavements. This manual does not address Portland Cement Concrete (PCC) pavement.

1.2 Purpose of Asphalt Pavement Repair and Preparation for Resurfacing

Pavement repairs are an important part of an overall pavement maintenance program, whether repairs are stand-alone or in preparation for a full resurfacing. This manual is one of several designed to empower local agency staff, in conjunction with training, to choose the right repairs and treatments, at the right time, to optimize their pavement maintenance funds. Most local agencies have deferred road maintenance over many years, and there are thousands of miles of public roads that are currently in poor condition. With the new SB-1 funding available for maintenance and construction projects, the importance of selecting proper road maintenance strategies is paramount.

The most common preservation surface treatments used in California include chip seals, slurry surfacing, Cape seals, and thin asphalt overlays (≤ 1.5 inches). All of these treatments can extend the life of a pavement via the prevention of moisture intrusion into the existing asphalt layer, as well as the base and subgrade. When properly designed and constructed, these preservation treatments can be a cost-effective tool that improves life-cycle cost benefits. Prior to placing these surface treatments, repairs such as crack treatments and patching should be performed. Also, other preparations such as tack coats, micro-milling, and handling existing pavement markings and surface utilities (e.g., manholes) need to be addressed.

However, as part of any preservation program, early *stand-alone* repair maintenance needs to be done using crack treatments or patching as *stand-alone* treatments that will not be covered by a surface treatment. Although an untreated asphalt pavement may still be in generally good condition after several years of use, localized pavement deterioration and defects may have begun, and the timely application of these types of repairs is prudent. However, since general deterioration will continue, it is usually advisable to also place a pavement preservation surface treatment (like a chip seal, slurry surfacing, Cape seal, or thin asphalt overlay) in conjunction with these repairs. This manual addresses all of these strategies.

1.3 Organization of the Manual

This manual is one of five related to pavement preservation published by MTI. The four other companion manuals address 1) Chip Seals, 2) Slurry Surfacing, 3) Cape Seals, and 4) Thin Asphalt Overlays. Chapter 2 of this manual discusses pavement repairs (crack sealing and patching) done either as stand-alone repairs or as preparation for a pavement preservation treatment. Chapter 3 addresses other surface preparations prior to placing a preservation treatment, while Chapter 4 covers Quality Assurance and troubleshooting of repair work. The manual also includes a comprehensive list of references.

More details on the design and construction of chip seals, slurry surfacing, Cape seals, and thin asphalt overlays can be found in the four companion manuals at the following links:

1) Chip seals: transweb.sjsu.edu/sites/default/files/1845A-Chip-Seal-Manual.pdf

2) Slurry surfacing: transweb.sjsu.edu/sites/default/files/1845B-Cheng-Manual-Slurry-Surfacing.pdf

3) Cape seals: transweb.sjsu.edu/sites/default/files/1845C-Cheng-Cape-Seal-Manual.pdf

4) Thin asphalt overlays: transweb.sjsu.edu/sites/default/files/1906-RB-Cheng-Manual-Thin-Asphalt-Overlay.pdf

2. Types of Repairs for Asphalt Pavement

This chapter addresses two common repairs for hot mix asphalt (HMA) pavement: crack treatments and patching, including situations where these repairs are done as a stand-alone treatment or in preparation for a pavement preservation treatment or an HMA overlay.

2.1 Crack Treatments

Cracking in pavements occurs when stress builds in a layer that exceeds the tensile or shear strength of the asphalt pavement materials. Crack *sealing* and crack *filling* are two methods used to repair cracks in pavement surfaces. The cause of the crack and its activity (movement) play a dominant role in determining the success of crack sealing or filling operations. Figure 1 shows a common crack treatment.

Figure 1. Common Crack Treatment (Courtesy of Crafco)

Cracking may be associated with various other distress mechanisms. Crack types include: fatigue or alligator cracks, longitudinal cracks, transverse (thermal) cracks, block cracks, reflective cracks, edge cracks, and slippage cracks as defined by Federal Highway Administration (FHWA, 2014). Cracks provide paths for surface water to infiltrate the pavement structure and cause damage or weakness to base layers. Much of the information for this section comes from a National Center for Asphalt Technology (NCAT) study (Roberts, 1997), an FHWA report on crack sealing (1999), Caltrans Maintenance Technical Advisory Guide (MTAG, 2009), and National Cooperative Highway Research Program (NCHRP) report 784 (Decker, 2014).

2.1.1 Project Selection

Overview

Crack sealing and/or crack filling are selected based on the following general criteria:

- The pavement structure should be sound.
- The cracks are wider than 0.25 inch (6 mm) and up to 1 inch (25 mm).
- The degree of crack activity (movement).
- When tight alligator B or C cracking is extensive a scrub seal should be considered for "mass" crack filling effectiveness and improved aesthetics.

Aesthetics should also be a consideration. Crack sealing can be unattractive as seen in Figure 2, but, if the seal will be covered by a surface treatment or HMA overlay, appearance is less of a concern. For example, crack sealing on a main street or a scenic tourist roadway may only be appropriate if it will be covered up by resurfacing, or, at minimum, "sanded" to soften its look.

Figure 2. Ugly Crack Sealing on a Scenic Street

For fatigue (alligator) cracking, unless the crack treatment is done in early-stage distress development, it does not substantially improve pavement performance. Fatigue cracking is indicative of a structural failure in the pavement system, which can only be remedied by a structural improvement such as an HMA overlay or by removing and replacing the failed materials. Figure 3 shows an attempt at sealing some excessive alligator cracking. Excessive crack sealing may cause a loss of pavement friction, as well as being unsightly. A chip, scrub, or Cape seal could be an interim measure to better hold the pavement together until a structural improvement project is constructed.

Figure 3. Attempt at Sealing Alligator Cracking

Motorist safety must also be considered. Treating longitudinal cracks can pose a safety hazard by creating driver confusion, since the sealant competes visually with the actual lane line as illustrated in Figure 4.

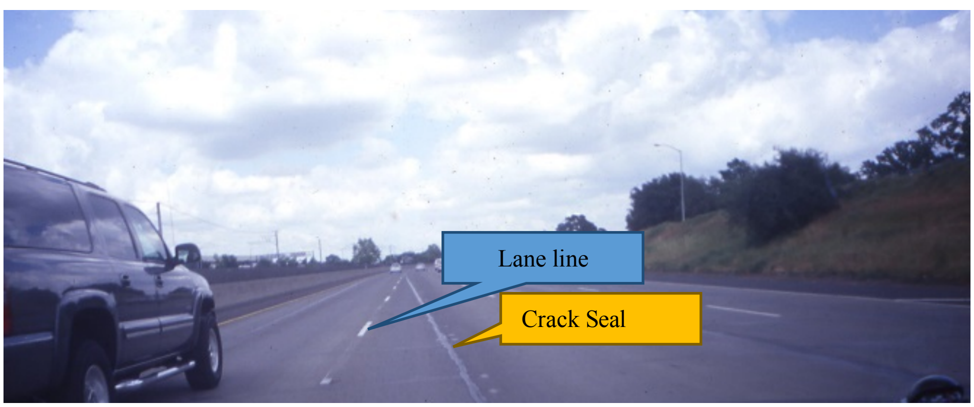


Figure 4. Crack Sealing Appearance Competes with Actual Lane Line

Smaller cracks are difficult to seal, and, usually, do not require crack sealing or filling; larger cracks may require the use of special mastic products. Table 1presents Caltrans's (2009) published guidelines for the type of maintenance to be performed, establishing when one should use crack treatments.

Table 1. Caltrans Cracking Sealing and Filling Criteria (Caltrans MTAG, 2009)

Item	Crack Sealing	Crack Filling
Applicable Width	0.12"–1.00"	0.12"–1.00"
Edge Deterioration	<25%	<50%
Annual Horizontal Movement	>0.12" Working	<0.12" Non-Working
Appropriate Type of Crack	Transverse Thermal Transverse Reflective Longitudinal Reflective Longitudinal Joint	Longitudinal Reflective Longitudinal Cold Joint Longitudinal Edge Block, distantly spaced

Crack development and types

Cracks initiate in asphalt pavements for multiple reasons such as traffic, weather changes, and age. After cracks develop, expansion and contraction of the pavement during hot and cold weather causes movements in the cracks. In cold weather, the crack widens as the pavement mass contracts. This widening allows debris, as well as water, to enter the crack. In hot weather, the pavement expands, thereby closing the crack. However, the debris collected in cold weather restricts closure of the crack in hot weather, resulting in the deterioration of the cracked pavement, often in the form of bumps and a rough ride as well as ravelling at the crack. These cycles cause continued deterioration of the pavement over time.

The Long-Term Pavement Performance Program (LTPP) Distress Identification Manual (FHWA, 2014) identifies six primary types of cracking for asphalt pavements:

- Fatigue Cracking (e.g., alligator)
- Block Cracking
- Edge Cracking
- Longitudinal Cracking (both in and between wheel paths)
- Reflection Cracking from underlying pavement
- Transverse Cracking

While treating any crack may ultimately provide some benefit to the underlying pavement structure through the reduction of moisture intrusion, the most advantageous applications for crack sealing and/or crack filling are to linear cracks in the form of block, longitudinal, reflection, and transverse cracking.

Filling vs. Sealing

The first question to be answered is whether to *seal* or *fill* a crack. Cracks may open and close horizontally with temperature and moisture changes, as shown in Figure 5, and may undergo vertical movements as the result of load applications, as shown in Figure 6. Figure 5 and Figure 6 illustrate the mechanisms of crack movement.

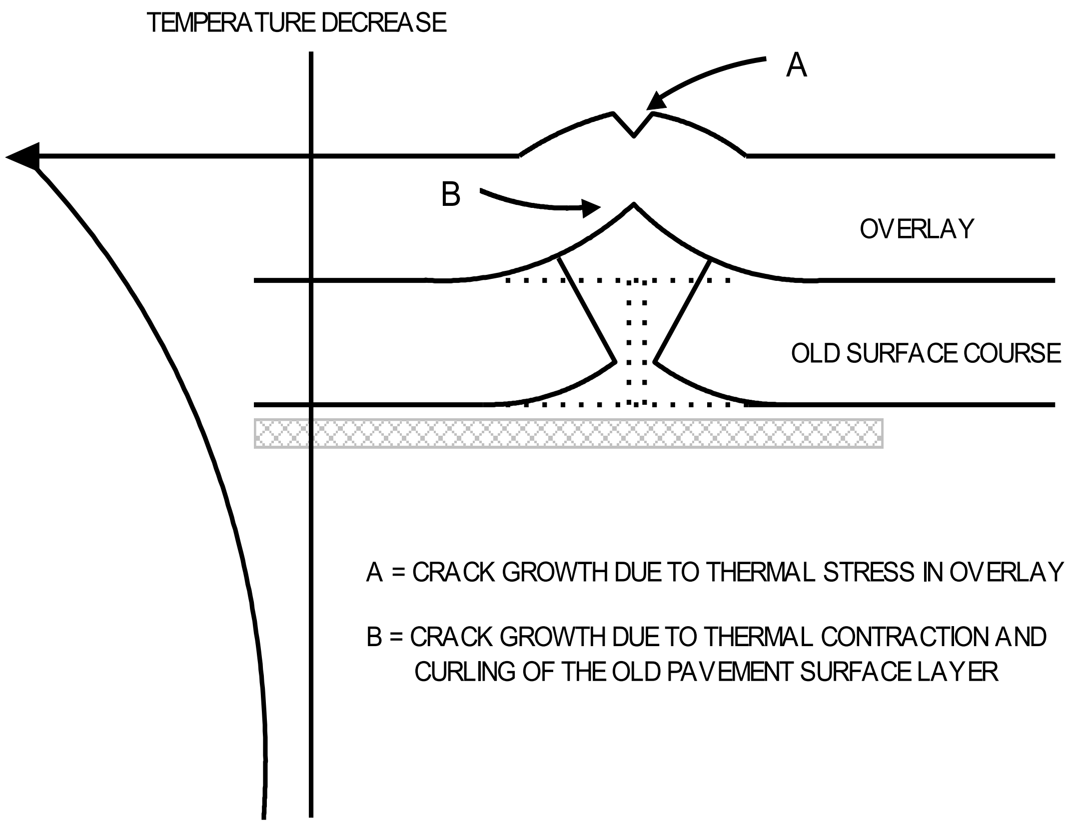


Figure 5. Thermal Effects on Crack Growth (Roberts et al., 1996)

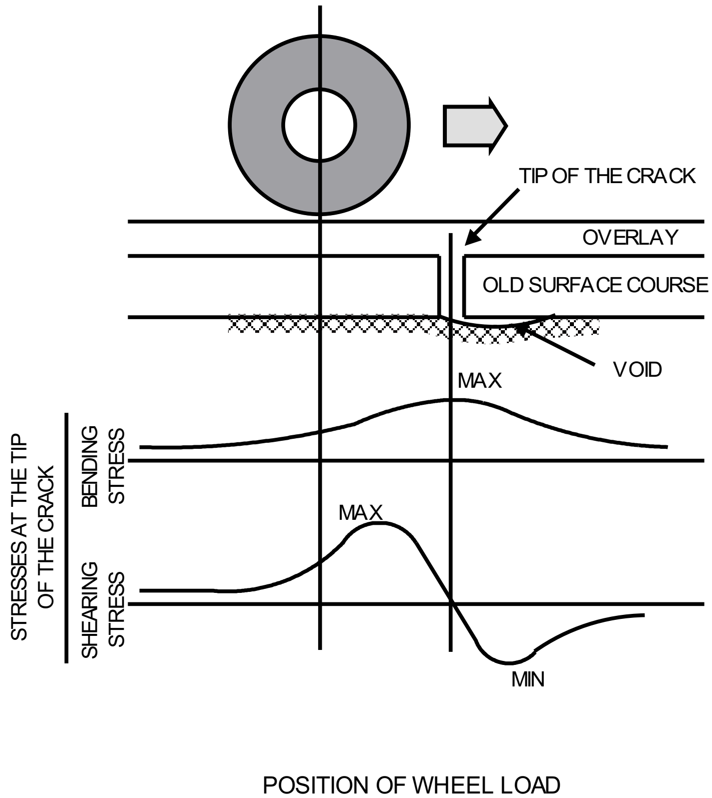


Figure 6. Traffic Load Effects on Crack Growth (Roberts et al., 1996)

To determine whether to seal or fill a crack, it must be established whether the crack is "working" or "non-working," i.e., whether the crack undergoes horizontal or vertical movement. The total horizontal movement of a crack over the period of one year is the primary determining factor of whether a crack is a working or a non-working crack. The Caltrans criterion for a working crack is 1/4 inch of horizontal movement annually (Caltrans, 2009); FHWA requires only 1/8 inch (FHWA, 1999). Horizontal movement is typically related to more severe temperature changes. Vertical movement is not usually considered (FHWA, 1999). Crack sealing is typically triggered when the crack width exceeds 1/4 inch. Also, the type of the crack can indicate whether it is a working crack or not. Working cracks can be transverse or longitudinal to the pavement, but are most often transverse. Working cracks with limited edge deterioration should be sealed, rather than filled. Routing is often done with crack sealing to increase the amount of sealant injected into the crack.

Decker (2014) also defined crack filling versus sealing as follows:

- **Crack sealing:** Materials are placed into and/or above "working" cracks in order to prevent the intrusion of water and incompressibles into the cracks. Crack sealing is commonly used as a transverse crack treatment.

- **Crack filling:** Materials are placed into "non-working" cracks to substantially reduce water infiltration and reinforce adjacent cracks. Crack filling is commonly used as a longitudinal crack or joint treatment.

When the criteria for working cracks are not met, or when cracks are closely spaced and have little movement, crack filling is less expensive (FHWA, 1999). Criteria for deciding whether to seal or fill a crack are listed in Table 1 and are included in NCHRP Report 784 (Decker, 2014). Table 2 shows the criteria for deciding whether to saw or rout a crack.

Table 2. Recommended Crack Routing and Sawing Dimensions (Caltrans MTAG, 2009)

Nominal crack width, inch	Rout or saw width, inch	Rout or saw depth, inch	Width of areas of temperature extremes, inch	Depth in areas of temperature extremes, inch
1/4	1/2	1/2	1	1/2
3/8	1/2	1/2	1	1/2
1/2	3/4	3/4	1	1/2
5/8	3/4	3/4	1.5	3/4
3/4	No routing required	3/4	1.5	3/4
7/8	No routing required	3/4	1.5	3/4
1.0	No routing required	3/4	1.5	3/4

Weather and Timing

Ideally, crack repair treatments should be applied during relatively moderate/cool weather, when the crack is open enough to receive the material. This is usually in the spring or fall. Weather conditions for installation need to be appropriate for the material used, not too cold or too wet. The material manufacturers' guidelines should be followed. Since non-working cracks do not change significantly in width with temperature, the application of crack treatments can proceed at any time of the year when weather conditions are appropriate for the material being used.

Traffic passing over a hot applied sealed or filled crack is usually not an issue; however, traffic control during the application of the treatment should be in force long enough to allow for adequate curing of the product and to prevent tracking. Sanding is typically needed for cold-applied systems to prevent tracking.

Decker (2014) reported that environmental conditions at the time of the sealant placement can significantly impact the sealant's performance. Typically, the temperature should be between 40° and 70°F for both crack sealing and filling. Al Qadi et al. (2014) suggests a range of 40° to 80°F.

2.1.2 Crack Sealing

Both crack *sealing* and crack *filling* prevent the intrusion of water and incompressible materials into cracks, but the methods vary in the amount of crack preparation required and the types of sealant materials that are used.

Crack sealing is the placement of materials into larger "working" (high movement) cracks. Crack sealing requires thorough crack preparation (preferably routing, blowing out, and vacuuming) and often requires the use of specialized high-quality materials placed either into or over working cracks to prevent the intrusion of water and incompressible materials. Crack sealing is generally considered to be a longer-term treatment than crack filling.

Due to the moving nature of working cracks, a suitable crack sealant must be capable of:

- Remaining adhered to the walls of the crack;
- Elongating to the maximum opening of the crack and recovering to the original dimensions without rupture;
- Expanding and contracting over a range of service temperatures without rupture or delamination from the crack walls; and
- Resisting abrasion and damage caused by traffic.

The material manufacturers' guidelines should be followed.

2.1.3 Crack Filling

Crack *filling* is the placement of materials into "non-working" (low movement) cracks to reduce infiltration of water and incompressible materials into the crack. Filling typically involves less crack preparation than sealing, and the performance requirements may be lower for the filler materials. Filling is often considered a short-term treatment to help the pavement perform between major maintenance operations or until a scheduled rehabilitation activity.

A suitable filler material must be capable of:

- Remaining attached to the walls of the crack
- Possessing some elasticity
- Resisting abrasion and damage caused by traffic

2.1.4 Crack Treatment Performance

The performance life of a crack treatment is based on the amount of crack preparation and the type of material used (FHWA, 1999). With the proper amount of preparation and the right material selection, crack sealants can provide up to nine years of service and fillers up to eight years (FHWA, 1999).

In California, excessively "over banded" treatments have contributed to rough rides, ride noise, poor surface appearance, and are not recommended for use unless the material has been squeegeed flush to the surface of the road. Regardless, over bands should be placed only slightly wider than the width of the crack (on both sides of the crack). The excess material on top of the existing pavement expands from the heat when the new HMA overlay is placed. As the crack sealant ages, this becomes less problematic.

Emulsions or hot applied asphalt materials placed in a flush configuration in unrouted cracks can provide two to four years of service, while hot applied rubber, polymer- and fiber-modified asphalt fillers placed in flush or over banded configurations can provide six to eight years of service (FHWA, 1999). Several factors can affect the sealant's life expectancy including the type and density of the cracks, the amount of movement on the crack, the sealant's properties, and the preparation of the crack including routing or blowing out incompressible and deleterious material with compressed air. As a result, it is difficult to give life expectancies.

Treatment Failures

Treatment failures can be attributed to improper treatment selection, improper material selection, poor workmanship, and improper application or lack of post-treatments. Common treatment failures include:

- **Adhesion loss:** The sealant does not adhere to the sides or bottom of the crack.
- **Cohesion loss:** The sealant fails in tension by rupturing/tearing.
- **Potholes:** The crack is not completely sealed, allowing water into the pavement.
- Continued deterioration leads to pumping and pothole formation.

- **Spalls:** The edges of the crack break away as a result of poor routing or sawing.

- **Pull-out:** The sealant is pulled out of the crack by tire action, snowplows, or sweepers.

More information on treatment failures is provided in Chapter 4.

Crack Treatment Effectiveness

There are several methods for evaluating a treatment's performance. Treatment effectiveness is measured as a percentage of the total treatment that has not failed (FHWA, 1999). To determine the condition of a treatment, visual inspections of the treated areas are required. Inspections for treatment failure should be carried out once per year (FHWA, 1999).

The first step in determining a treatment's effectiveness is establishing how much of the treatment has failed in relation to the total length of treatment applied (% failure). Once the amount of treatment failure is determined, the treatment's effectiveness (%) can be calculated using the following equation (FHWA, 1999).

% Effectiveness = 100 - % Failure…………………...………………………………… (1)

Where: % Failure = 100 * [Length of Failed Treatment/Total Length of Treatment]

By routinely monitoring treated areas, a graphical representation of a treatment's effectiveness can be generated, like the one shown in Figure 7. From this figure, the projected life of the treatment used on this cracked area can be projected as the time at which the effectiveness dropped to 50% (as defined above). Graphs like these can be used to determine when additional treatments may become necessary (FHWA, 1999).

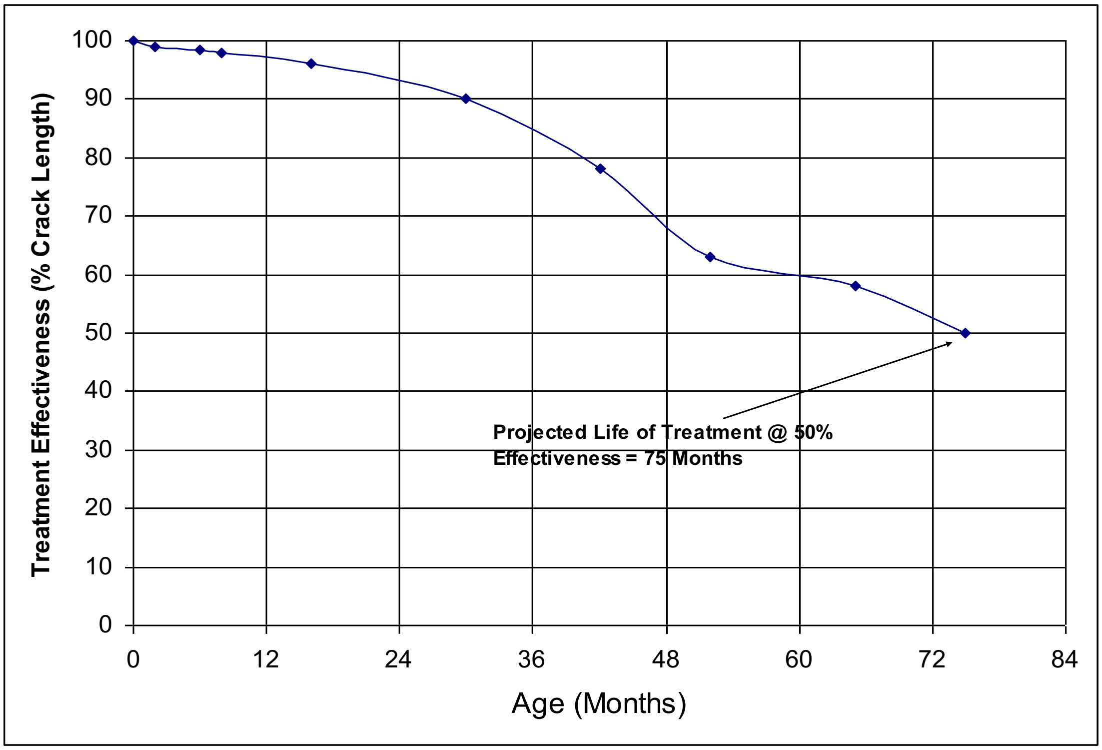


Figure 7. Treatment Effectiveness (FHWA, 1999)

Cost Effectiveness

The cost effectiveness of a treatment can be readily attained once the treatment life has been determined. Cost effectiveness may be converted into an annual cost by dividing the cost effectiveness by the number of years required to reach 50% effectiveness (FHWA, 1999).

Decker (2014) also reported that, to establish the cost effectiveness of crack treatments, the following information is required:

- The performance of the sealant and rout width and depth sizes over times to establish the most efficient products and crack configurations
- The life extension of the pavement by retarding additional crack development and delaying the deteriorations process in the existing pavement
- The influence of time and at which point of the pavement's life cycle the treatment is applied most cost effectively

Crack treatments are unquestionably the most cost-effective treatment in the tool box of pavement preservation (Decker, 2014).

2.1.5 **Materials**

Crack sealing and filling material specifications for Caltrans's flexible pavements fall under Section 37 (Caltrans Standard Specifications, 2018). The materials and methods discussed below only apply to HMA pavements unless stated otherwise. Suppliers and manufacturers should be consulted when choosing materials apt for a specific climate, pavement and/or traffic condition.

Materials for Crack Sealing

Crack *sealing* materials for "working" cracks are designed to adhere to the walls of the crack, stretch with the movement of the crack over the range of conditions and loads associated with the crack location, and resist abrasion and damage caused by traffic. For sealing working cracks, both cold pour emulsions and hot pour sealants have been used. The cold pour emulsions can include polymer modified emulsions on rejuvenating emulsions. The hot pour sealant is usually elastomeric. This means that the sealant has a low modulus of elasticity and will stretch easily to high elongations (usually around 10 times its non-strained dimensions) without fracture. Such sealants also recover over time to close to their original dimensions. The sealants are usually melted and applied at elevated temperatures due to their high viscosity at ambient temperatures, and they set or cure by cooling and reforming into complex structures. These materials are also called thermoplastic. Thermoplastics form physical structures on cooling, but this process is reversible with reheating. Hot application helps ensure a good adhesive bond to the crack's walls. In California, most of the hot pour materials are hot rubber-modified asphalt. However, they must be properly applied to perform as desired.

Hot mastic materials are often used for sealing wide cracks (2–6 inches or more), cupped cracks, fatigue cracks, shoulder cracks, utility cuts, as well as for other applications. They are a hot pour product, which combines engineered aggregate with an asphalt-based polymer modified, thermoplastic binder. The material is easy to apply, adhesive, moisture sealing, and handles pedestrian and rolling traffic, as well as snowplows and weathering. However, the process includes considerable material that takes time to cover much length during a day. For wide cracks, the material is dispensed into a manual box screed or wheeled mastic applicator and slowly dragged across the surface of the cracked pavement to allow maximum penetration and coverage to prevent settling. It is recommended to fill the crack first with a tool just slightly wider than the crack.

Mastics can be designed for cracks wider than 2 inches and 2 inches deep. Routing the crack allows the mastic to better adhere to the crack and helps the material better accommodate drastic movements (Maxwell, 2021).

Materials for Crack Filling

For crack *filling* applications, the cracks are basically inactive (non-working). Crack filling materials are designed to adhere to the walls and resist abrasion and damage caused by traffic.

Crack filling materials may be hot-applied rubber or polymer modified asphalts, or cold-applied polymer modified, or polymer modified rejuvenating emulsion (water-based) products. The emulsion additives assist with forming a good adhesive bond with the crack wall, and additives, such as a rejuvenating agent or a polymer, ensures that the material can endure some degree of movement. In some cases, hot-applied fiber-modified asphalt binders may also be used.

Caltrans Specifications

Table 3 lists Caltrans's specifications for various crack sealants and fillers for different environments. In California, a crack treatment material must be delivered to the job site with the information listed below or with a Certificate of Compliance (Caltrans, 2020):

- Manufacturer's name
- Production location
- Brand or trade name
- Designation
- Crack treatment trade name
- Batch or lot number
- Maximum heating temperature
- Expiration date for cold application only

Hot-applied crack treatment must be delivered to the job site premixed in cardboard containers with meltable inclusion liners or in a fully meltable package. Cold-applied crack treatment must have a minimum shelf life of three months from the date of manufacture.

Table 3. Crack Treatment Materials (Caltrans, 2018)

Climate Region		Deserts, slow moving traffic	Desert	South Coast, Central Coast, Inland Valleys	North Coast, Low Mountain, South Mountain	High Mountain, High Desert
Quality Characteristic (see note 1)	ASTM Test Method (see note 2)	Type 1 Material	Type 2 Material	Type 3 Material	Type 4 Material	Type 5 Material
Softening point (min.)	D 36	102°C	96°C	90°C	84°C	84°C
Cone penetration at 77°F (max.)	D 5329	35	40	50	70	90
Resilience at 77°F, unaged, %	D 5329	20–60	25–65	30–70	35–75	40–80
Flexibility (see note 3)	D 3111	0°C	0°C	0°C	-11°C	-28°C
Tensile adhesion, %, (min.)	D 5329	300	400	400	500	500
Specific gravity (max.)	D 70	1.25	1.25	1.25	1.25	1.25
Asphalt compatibility	D 5329	Pass	Pass	Pass	Pass	Pass
Sieve test (percent passing)	See note 4	100	100	100	100	100

Notes:

1. Cold-applied crack treatment material residue collected under ASTM D 6943, Method B and sampled under ASTM D 140 must comply with the grade specifications.
2. Except for viscosity, cure all specimens at a temperature of 23°C ± 2°C and relative humidity of 50 ± 10 percent for 24 ± 2 hours before testing.
3. For flexibility test, the specimen size must be 6.4 ± 0.2 mm thick x 25 ± 0.2 mm wide x 150 ± 0.5 mm long. Test mandrel diameter must be 6.4 ± 0.2 mm. Bend arc must be 180 degrees. Bend rate must be 2 ± 1 seconds. At least 4 of 5 test specimens must pass at the specified test temperature without fracture, crazing, or cracking.
4. For hot-applied crack treatment, dilute with toluene and sieve through a No. 8 sieve. For cold-applied crack treatment, sieve the product as-received through a No. 8 sieve. If the manufacturer provides a statement that added components passed the No. 16 sieve before blending, this requirement is void.

ASTM Specifications

Table 4 provides a summary of the ASTM specifications for four different environments compared with the five different environments used by Caltrans. The materials used for crack treatments vary widely over the years, ranging from neat liquid asphalt to asphalt emulsions to polymer and/or filler modified asphalt products. The products most commonly used can be broadly characterized as modified asphalt products.

ASTM D 6690 (ASTM, 2021) has been the reference standard for sealants for many years. Sealant manufacturers produce a variety of products to satisfy the ASTM requirements, which includes the following four types of sealants:

- **Type I.** Sealant for moderate climates with low temperature performance tested at -18°C with 50% extension
- **Type II.** Sealant for moderate to cold climates, with low temperature performance tested at -29°C with 50% extension
- **Type III.** Sealant for moderate to cold climates with low temperature performance tested at -29°C with 50% extension. Special tests are also included per ASTM on bond testing and aged resilience
- **Type IV.** Sealant for very cold climates with low temperature performance tested at -29°C with 200% extension

Table 4. ASTM Sealant Requirements (ASTM D 6690, 2021)

	Type I	Type II	Type III	Type IV
Cone *Penetration* at 25 ˚C	90 max.	90 max.	90 max.	90–150
Softening Point, ˚C	80 min.	80 min.	80 min.	80 min.
Bond, non-immersed	Two out of three 25 ± 0.4 mm specimens pass[A] 5 cycles at 50 % ext. at -18 ˚C	Three 12.5 ± 0.2 mm specimens pass[A] 3 cycles at 50 % ext. at -29 ˚C	Three 12.5 ± 0.2 mm specimens pass[A] 3 cycles at 50 % ext. at -29 ˚C	Three 12.5 ± 0.2 mm specimens pass[A] 3 cycles at 200 % ext. at -29 ˚C
Bond, non-immersed	Two out of three 25 ± 0.4 mm specimens pass[A] 5 cycles at 50 % ext. at -18 ˚C	Three 12.5 ± 0.2 mm specimens pass[A] 3 cycles at 50 % ext. at -29 ˚C	Three 12.5 ± 0.2 mm specimens pass[A] 3 cycles at 50 % ext. at -29 ˚C	Three 12.5 ± 0.2 mm specimens pass[A] 3 cycles at 200 % ext. at -29 ˚C
Bond, water immersed	--	--	Three 12.5 ± 0.2 mm specimens pass[A] 3 cycles at 50 % ext. at -29 ˚C	--
Resilience, %	--	60 min.	60 min.	60 min.
Oven Aged Resilience, %	--	--	60 min.	--
Asphalt Compatibility	Pass[B]	Pass[B]	Pass[B]	Pass[B]

(A) The development at any time during the test procedure of a crack, separation, or other opening that at any point is over 6 mm deep in the sealant or between the sealant and concrete block shall constitute *failure* of the *test specimen*. The depth of the crack, separation, or other opening shall be measured perpendicular to the side of the sealant showing the defect.
(B) There shall be no *failure* in adhesion, formation of an oily exudate at the interface between the sealant and asphaltic concrete, or other deleterious effects on the asphaltic concrete or sealant when tested at 60 ˚C.

What do the results of the tests included in Caltrans and ASTM specifications mean? The following provides some guidance on each of the tests:

- **Penetration (ASTM D 5329).** The higher the penetration test results, the softer the crack sealant. For driveway and parking lot applications, it is best to have a low penetration test to withstand the elements of foot traffic and power steering.

- **Resiliency (ASTM D 5329).** Resiliency is the speed with which the crack sealant recovers after a foreign object is dislodged from it. The higher the number, the more the materials have recovered, thus more resilient.

- **Flow (ASTM D 5329).** The flow test measures how likely the crack sealant is to move in the crack at 140°F. The higher the flow, the more the movement.

- **Softening point (ASTM D 36).** A high softening point (anything over 200°F) is desirable when working on parking lots and driveways. Materials with a high softening point generally take longer to melt.

- **Bond and Tensile Adhesion (ASTM D 5329).** The bond tests measure the cohesion and adhesion of the crack sealant at low temperatures. The tensile adhesion test measures these properties at room temperature.

- **Low Temperature Flexibility (ASTM D 3111).** In cool/cold climates, it is important to use a product with at least 0°F low-temperature flexibility. Choosing a material without low-temperature flexibility may result in the sealant cracking in the winter months.

- **Viscosity (ASTM D 4402/2669).** The viscosity is a measurement of the stiffness at liquid stage. The higher the number, the stiffer the material. Additions of recycled crumb rubber tend to increase viscosity. However, it is difficult to use a stiffer product on thinner cracks.

2.1.6 Crack Preparation

Site preparation requirements vary according to the treatment method and materials chosen for the project. The following paragraphs describe site preparation in further detail.

Cleaning and Drying. Dust and debris left in a crack, whether from sawing, routing, or normal pavement use, will affect the adhesion/bond of the sealant or filler. Reduced adhesion normally results in early failures of the treatment, such as the sealant debonding from the crack wall and losing its sealing function. To avoid these bond-related failures, sawed or routed cracks must be cleaned prior to being treated. Several cleaning methods can be used, including:

- Air Blasting

- Hot Air Blasting

- Sand Blasting

- Wire Brushing

Air blasting involves directing a concentrated stream of air into the crack or joint to blow it clean as shown in Figure 8. Air blasting equipment is effective at cleaning cracks, but not drying them. Should a crack require drying, hot air blasting should be used via a hot lance tool. Air pressure should be a minimum of 97 psi (670 kPa) with a flow of 2.5 ft^3/s (0.07 m^3/s). Air blasting equipment must be equipped with moisture and oil traps.

Figure 8. Air Blasting of Routed Crack (Courtesy of Crafco)

Hot air blasting is done using a hot compressed air hot lance as shown in Figure 9. While cleaning and drying the crack, hot air blasting also promotes enhanced bonding associated with the crack edges being warmed. Care must be taken to ensure that the pavement is not overheated or heated for excessive periods of time as this will result in an unnecessary hardening of the asphalt binder in the pavement adjacent to the crack.

Figure 9. Hot Air Lance (Courtesy of Crafco)

Wire brushing or brooming involves the use of a wire broom stock or stiff standard broom to brush out the crack or joint. Wire brushing can be an effective cleaning method. Wire brushing may be done manually, using power driven brushes or with vacuum systems. Figure 10 illustrates the vacuum cleaning method. Figure 11 illustrates that the cracks are not clean and wet before crack sealing, while Figure 12 shows the effect of inappropriate cleaning.

Figure 10. Vacuum Crack Cleaning (Courtesy of Crafco)

Figure 11. Example of a Badly Cleaned Crack (Courtesy of Crafco)

Figure 12. Sealant Peeling as Result of Improper Cleaning (Courtesy of Crafco)

2.1.7 Material Placement Methods

Once a suitable seal or fill material has been selected, the appropriate placement method must be determined. Placement methods vary according to the nature of the distress. When selecting the placement method, one should consider: 1) the type of distress, 2) the dimensions of the crack channel, 3) the type of crack channel (routed or unrouted), 4) the pavement finish requirements (e.g., smoothness, aesthetics, etc.), and 5) whether the pavement will receive a full resurfacing following the crack treatment. Each method carries its own set of job equipment and preparation requirements. Typical placement methods used on flexible pavements include:

- Flush fill
- Overband
- Routed Reservoir
- Combination: Routed w/band-aid
- Combination: Pre Sand Fill w/ recessed finish
- Mastic filling of wide cracks and gaps

Each placement method is briefly discussed below.

Flush Fill Method

In the flush fill method, fill material is forced into an existing unrouted crack, with the goal being to have little or no overband. Once filled, any excess material is struck off flush with the pavement. Figure 13 illustrates this method. When using thermoplastic materials, ideally the crack should be filled to slightly below the surface to allow for expansion when hot. Consistent flush filling is often difficult to obtain by hand crews.

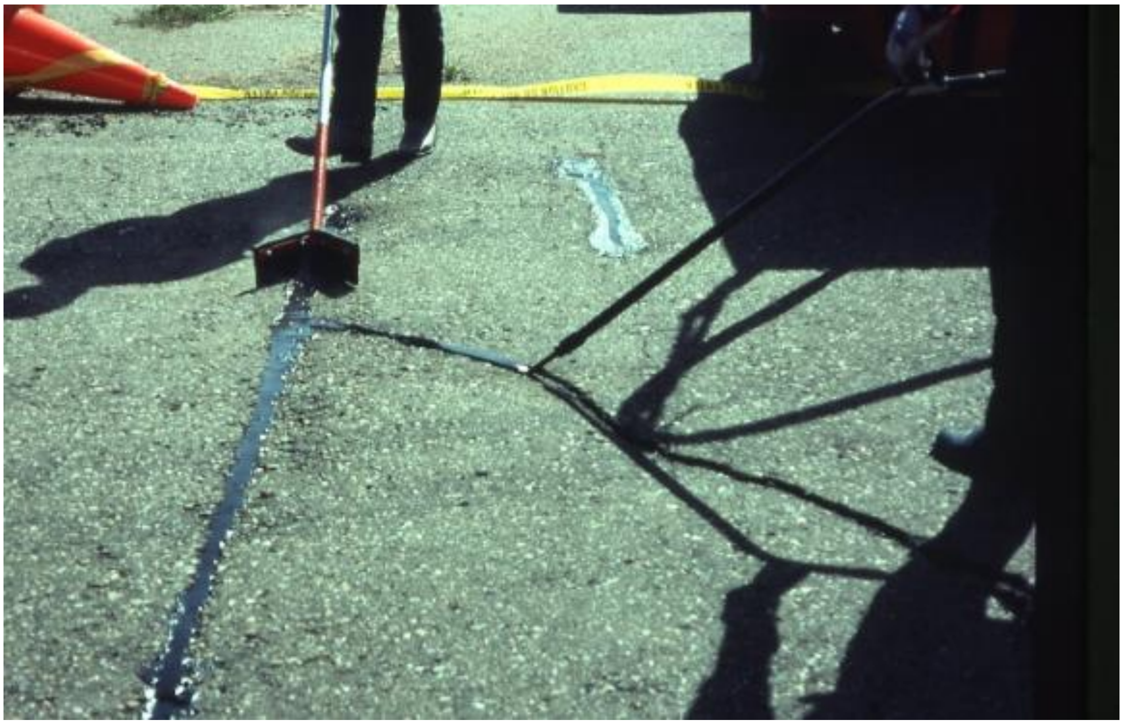


Figure 13. “Flush fill” of Crack

Overband Method

In the overband method, fill material is forced into and placed over an unrouted crack. If the excess fill material is squeegeed flat, it is referred to as a “band-aid”; if not; it is referred to as “capped”. Figure 14 illustrates the overband method with both finishing options. Figure 15 shows a photo of a good overband treatment.

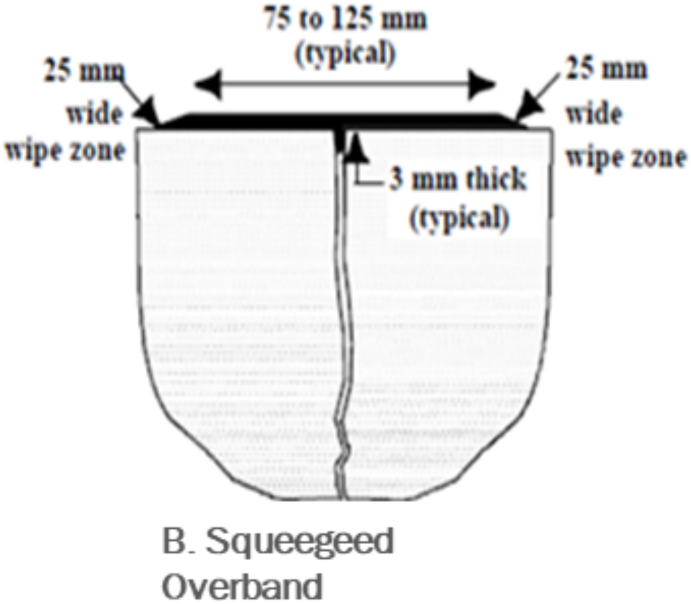


Figure 14. Overband Methods (Courtesy of Crafco, 2021)

Figure 15. Good Overband Method (Courtesy of Roger Smith, 2021)

Caltrans does not recommend the use of overbands and advises that all crack sealing and filling be squeegeed flush if material is left above the surface. Overbanding, if not flush, can create a rough ride and/or excess road noise and causes problems (bumps and fat spots) when placing subsequent overlays, as shown in Figure 16. Excessive squeegeed overbanding, while wasteful and costly, is also aesthetically unpleasing, often making this an unacceptable practice where it will not be covered by a resurfacing. On the other hand, a flush fill relies solely on adhesion to the sides of the crack where an overband does provide an opportunity for better adhesion.

Figure 16. Excessive Overband

Chehovits and Manning (1984) describe the advantages and disadvantages of the overband method (also known as "band-aid") as compared to reservoir configurations. The main advantage of the overband method is the ease and speed of application. Essentially, the procedure is to apply sealant into the crack and level it with a squeegee. However, the disadvantages are the aesthetics, the rough ride, the material waste, the exposure of the surface sealant to environmental and traffic deterioration (including snowplows), and the large and localized tensile strains that develop above the crack.

Based on a pooled fund study, Al-Qadi et al. (2014) recommends the use of overband for crack filling and crack sealing. However, Caltrans (MTAG, 2009) advises against using an overband, preferring a squeegeed approach for any material left above the surface. The concerns are that ride quality on higher speed routes will suffer with the overband bumps and areas of bleeding may form during subsequent overlays. Additionally, during HMA thin blanket overlays, overbanding of transverse cracks can create a wave of crack sealant in front of the breakdown roller that often results in a crack in the new overlay.

Reservoir Method

In the reservoir method, linear cracks are pre-cut or "routed" to form a reservoir that is then filled with a sealant. When pavements are extensively cracked, routing or sawing of cracks may not be appropriate. Some sort of scrub seal or chip seal might be a better solution. Crack routing becomes especially important for crack sealing in climates where crack thermal movement is very high. Crack routing provides better control of the crack channel shape and allows a wider band of material to be used, which will tolerate more movement without failure. Secondary cracks along the primary crack are not usually routed. Routing is only selectively used on HMA pavements in the more extreme climates in California. Routing can cause additional issues such as edge deterioration and spalling. It is recommended that routing be used only if the pavement is in good to fair condition. If it is in poor condition, it should not be used.

The sealant may be left flush or slightly below the surface of the reservoir. The depth and width of the reservoir varies according to job requirements. Saw dimensions will be greatest when working with very active cracks, e.g., in areas of extreme seasonal or day/night climate fluctuation. Crack routing will often depend on the number of cracks and whether the crack is linear enough to allow the router to follow the crack. Typical reservoir widths range from 0.5 to 1.0 inches and even up to 1.5 inches in very cold climates. Reservoir depth ranges from 0.5 to 1.0 inches. Routing use is appropriate for pavements in good condition, without extensive cracking. Crack routing units, when operated by trained, experienced personnel, can follow slightly meandering linear cracks. Figure 17 illustrates the routed reservoir concept.

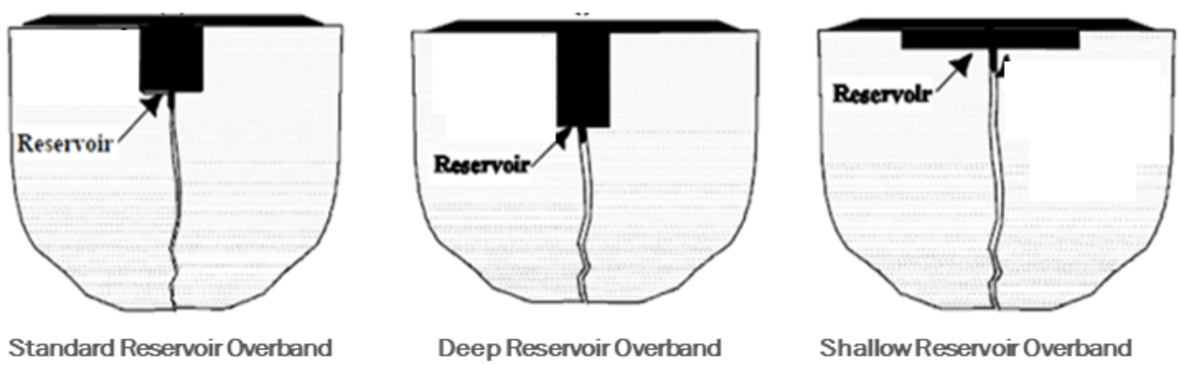


Figure 17. Reservoir Methods

When routing or sawing is used to prepare cracks, special attention to cleaning and drying prior to application of the filler or sealant is necessary. Crack cutting and routing equipment includes vertical spindle routers, rotary blade impact routers, and random crack saws. Damage to the pavement should be kept to a minimum by clean cutting. The use of carbide bits improves the quality of cutting and typically produces clean reservoir cuts. This treatment is meant for the more primary, linear cracks and not for random smaller cracks. Figure 18 and Figure 19 illustrate the method and the equipment used to route the crack.

Figure 18. Routing to Create Crack Reservoir

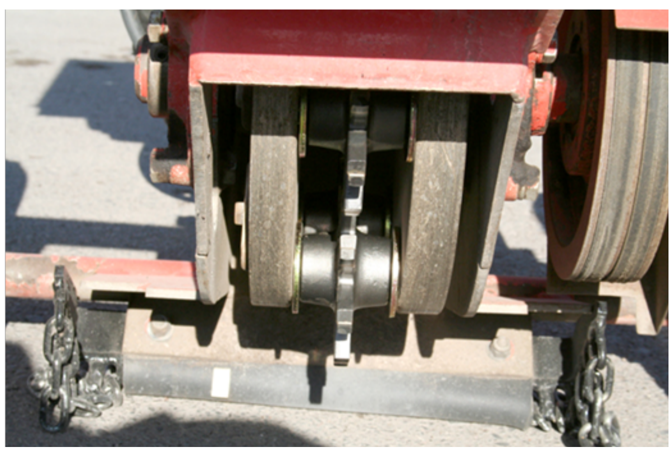


Figure 19. Router Blade

The reservoir applications where routing is performed have the advantages of being more aesthetically acceptable, not being exposed directly to traffic, better adhesion to the vertical faces of the crack, and reduced tensile strains in the sealant. The only disadvantage of the reservoir configuration is the additional work and cost to the project for the routing activity. Johnson et al. (2008) report that routing transverse cracks improved sealant performance, but that routing of longitudinal cracks was not necessary. As with any crack treatment process, the routed crack area should be blown clean by air blasting.

Application of Sealer or Filler

The material selected will, in part, determine the application method. Hot-applied rubber-modified sealants, especially asphalt rubber, have excellent adhesion and when cooled rapidly, do not require the application of a thin sand coating (blotter coat) prior to trafficking. Cold-applied asphalt emulsions are applied directly to the cracks, usually via a pouring tool. But because emulsions are water-based, they require warmer weather, a cure period, and must be blotted with sand prior to being trafficked. Emulsions may be applied via gravity feed devices, such as pour pots, or via pressure hoses. Some emulsions may require heating to achieve appropriate application viscosity.

Hot applied rubberized sealants need to be agitated, heated, and maintained at the correct temperature throughout their application. For polymer and rubber modified materials, temperature control is important to prevent degradation. For hot applied fiber-filled materials, the fiber may settle; therefore, agitation is required. For such materials, indirect oil heating is recommended. Required capacity of sealant or filler application equipment is determined by the job size. Preheating the material before use ensures optimized productivity. Figure 20 illustrates a hot pressure-feed sealing operation and a gravity fed “pour pot” for cold-applied emulsions.

a) Hot Pressure Fed Wand

b) Pour Pot for Cold Sealing

Figure 20. Application Techniques and Equipment

The application rate of a sealant or filler plays an important role in the quality of a crack sealing or filling project. Problems associated with over-applied sealer or filler material include excessive, unsightly smearing or over-banding, rough ride, lowered skid resistance, fat spots, localized tenderness, and later flushing or slippage when treated areas are overlaid with hot mix.

Finishing techniques will vary depending on the application and type of material chosen. Flush finishes and controlled over-banding methods require the use of a special squeegee tool. In some cases, a preformed strike-off plate on a hand lance controls the overband width and assists in making the required flush result. Figure 21 shows three typical flat (flush) finishing techniques. As stated earlier, all remaining sealant on the surface should be squeegeed flush to prevent a rough ride. This is the only method recommended by Caltrans.

a) Squeegee b) Flat Plate Use c) OverBanding

Figure 21. Typical Flat Finishing Techniques

Blotter coats of clean, dry sand are usually only used with emulsion crack filling to prevent pick-up by traffic of any overband upon re-opening to traffic. Blotter coats of sand may also be used on hot-applied treatments to reduce their visibility, where aesthetics is a concern, or where treatments of longitudinal cracks look like lane lines and cause driver confusion as shown earlier in Figure 4.

Figure 22 illustrates the brooming of a blotter coat over a freshly treated crack. This practice is not recommended by Caltrans, as it leaves broom marks and voids in the sealant. Local agencies sometimes prefer blotter coat to reduce the visibility of crack sealing.

Figure 22. Brooming Blotter Coat over a Treated Crack

Loose sand must be swept up prior to opening to traffic, since it will pose a safety hazard, especially to two-wheeled vehicles.

Other blotter methods, including toilet paper, have been tried, but are not recommended. The problems with this unlikely blotter material are shown in Figure 23.

Figure 23. Improper Blotting Techniques Using Paper

Mastic Filling of Wide Cracks and Gaps

Mastics are used for wide cracks, cupped cracks, fatigue cracks, shoulder cracks, utility cuts, and other applications. They are hot-pour products, which combines finer engineered aggregate with an asphalt-based polymer modified, thermoplastic binder. The adhesive material is easy to apply, seals out moisture, handles pedestrian and rolling traffic, snow plows, and weathering.

For wide cracks, the material is dispensed into a manual box screed or wheeled mastic applicator and slowly dragged across the surface of the cracked pavement to allow maximum penetration and coverage. To prevent settling, fill the crack first with a tool just slightly wider than the crack. After the initial application settles, apply a second pass with a tool wide enough to form a flush surface or a slight overband.

This product is designed for cracks wider than 2 inches and 2 inches deep. Routing the crack allows the mastic to better adhere to the crack and helps the material better accommodate drastic movements. Figure 24 and Figure 25 show this use of mastics in wide cracks.

Figure 24. Application of Mastic in Wide Cracks (Courtesy of Maxwell Products)

Figure 25. Mastic Placed in a Wider Crack (Courtesy of Maxwell Products)

Placement Method Considerations

The appropriate placement method should be based on the project's main parameters, including:

- Type and extent of the sealing or filling operation
- Traffic conditions
- Crack characteristics
- Material requirements
- Desired performance (expectations)
- Planned future projects
- Aesthetics
- Cost

Table 5 outlines placement issues in relation to governing project considerations. Figure 26 shows photos of improper sealant applications.

Table 5. Placement Method Considerations (FHWA, 1999)

Project Consideration	Method applicability
Type and Extent of Operation	Most filling operations, and some sealing operations, omit crack cutting operation. However, many northern states have found crack cutting necessary and desirable for cracks exhibiting significant movements.
Traffic	Overband configurations experience wear and, subsequently, high tensile stresses directly above the crack edges, leading to adhesive edge separations. Avoid overband configurations for sealing cracks on heavily trafficked roads.
Crack Characteristics	If no overlay is planned, overband configurations may be appropriate for cracks having a considerable amount of edge deterioration (> 10 percent of crack length); because the overband simultaneously fills and covers the deteriorated segments in the same pass. However, if it is possible that the pavement may be overlaid in the future, a scrub seal should be considered as an alternate method to address edge deterioration without overbanding.
Material Type	Materials such as emulsion and asphalt cement must be unexposed to traffic due to serious tracking or abrasion problems.
Desired Performance	For long-term sealant performance flush reservoir and recessed band-aid configurations provide the longest life.
Aesthetics	Overband and combination configurations detract from the general appearance of the pavement.
Cost	Omission of crack cutting operation reduces equipment and labor costs, but may decrease treatment longevity. Combination configurations require significantly more material than reservoir configurations, resulting in higher costs. The placement method impacts the type of material used, so costs may be higher for specialty materials.

Figure 26. Improper Project Selection

2.1.8 Other Construction Considerations

Contracting Procedures

Two significant schools of thought exist for the installation of crack treatments (Decker, 2014): 1) the agency will self-perform the crack treatment installation, and 2) the agency will contract for the crack treatment services. The decision is usually based on perceived cost-effectiveness. If done in-house by small agencies, oversight of the process is often not well-defined. Employees are directed to do crack sealing, the directive is followed, and often little is done to verify installation quality. If contractor services are employed, owners use a variety of techniques for the purchase of crack sealing services. These techniques include unit price-low bid, lump sum/fixed price, cost plus, indefinite delivery/indefinite quantity, and warranty.

Safety

The Resident Engineer can examine and approve the contractor's traffic control plan prepared in accordance with the Caltrans Safety Manual (Caltrans, 2020) and the Caltrans Code of Safe Operating Practices (Caltrans, 2020). The signs and devices used must match the traffic control plan. The work zone must conform to Caltrans's practice and requirements set forth in the above-mentioned Caltrans Safety Manual and the Caltrans Code of Safe Operating Practices.

All workers should have the required safety equipment and clothing since they will be working with very hot materials. Examples of unsafe Personal Protective Equipment (PPE) and the consequence of not using gloves are shown in Figure 27.

Figure 27. Examples of Poor PPE and the Consequence of Not Wearing Gloves
(Courtesy of Crafco)

Signage for traffic warnings shall be removed or covered when it no longer applies.

Sampling Sealant

Some specifications have sampling requirements. Samples may be taken: a) from the plant or warehouse prior to delivery, b) from the melter at the time of delivery, or c) from the applicator nozzle. As with any sample, documenting the sample project name, date, product, and location is critical for proper record keeping. As an alternative to sampling, agencies should require a Certificate of Compliance (COC) to verity that the material meets specifications.

Curing and Open to Traffic

Sealants and fillers undergo a curing cycle depending on the type of material used. Hot applied materials are thermoplastic; they set when they cool provided no diluents, such as solvents, are used in their formulation. These materials produce a non-tacky finish once the material reaches ambient temperature. A blotter coat (e.g., sand) can assist in this process and prevent tracking by vehicles. In addition, hot applied sealants require a three- to four-month cure time prior to being covered with a HMA overlay or surface seal.

Cold-applied sealants are asphalt emulsions, water-based products. Emulsions cure by evaporation and water loss and, therefore, reduce in volume. Depending on air temperature and humidity, this process usually takes several days and creates a concave surface in the crack. Generally, cracks filled with these materials should not be overlaid until fully cured, which could take months. Crack sealing with rejuvenating emulsions should typically be done the season before overlaying or seal coat for best results. Trafficking should not be allowed until after the emulsion has set sufficiently so that tires passing over the sealant/filler won't pick it up. Caltrans normally sands these sealers prior to opening to traffic. Whenever sand is used, the excess should be swept up prior to opening to traffic so as not to be a skid hazard—especially to two-wheeled vehicles.

Blotter coats of clean, dry sand are usually only used with emulsion crack filling to prevent pick-up by traffic of any overband upon re-opening to traffic. Blotter coats of sand may also be used on hot-applied treatments to reduce their visibility, where aesthetics are a concern, or where treatments of longitudinal cracks can look like lane lines and cause driver confusion. Figure 28 shows an excessive application of sand that was not broomed. Local agencies sometimes prefer blotter coat to reduce the visibility of crack sealing.

Figure 28. Excess Sand Must Be Removed Prior to Traffic

2.1.9 Crack Treatment Done in Preparation for Resurfacing

The pavement designer can select the appropriate pre-treatment for a surface treatment or a thin asphalt overlay surfacing if they have a good understanding of the following:

- Existing conditions of a pavement structure,
- Existing variations in structural section and subgrade strength,
- The expectations of their agency regarding funding and performance,
- The construction capabilities of the supplier and contracting community,
- The expected performance of the pre-overlay treatment materials,
- Associated costs of a pre-overlay treatments, and
- The principals of structural pavement design.

An HMA pavement structure that exhibits very few low-severity surface cracks versus a pavement structure that exhibits extensive high-severity cracking should be handled in a completely different manner regarding pre-overlay treatment before any resurfacing. Does the pavement designer decide to do nothing in a given distressed area or do they designate areas to be locally removed and replaced? Are there areas in which the entire HMA surface should be partially or completely milled off or will either cold or hot in-place recycling be used for the pre-overlay treatment? Other decisions that may need to be made have to do with whether the surface should just be crack sealed, chip sealed, scrub sealed, micro-surfaced, or slurry sealed. If rutting or shoving exists, will rut-filling be done, or will the top of the ruts and shoved areas be milled off, or can they remain as is in-place? All of these decisions will come with an associated cost and will affect the future performance of the resurfacing over the existing HMA pavement structure. Also, because the pavement will get a resurfacing, the crack treatment's aesthetics are not of concern, so the treatments can be more extensive and not require sanding to reduce visual impact. Crack sealant must be applied after any planned milling operations. Otherwise, the sealant may be pulled out of the cracks by the milling operations.

Crack Treatments for Surface Treatments

Designers should be aware that problems can arise if placing a thin surface treatment such as a chip seal or slurry seal too soon after placement of crack sealant. In the case of hot crack sealers, the lighter oils of the sealant may bleed through the fresh surface treatment and be visible as a pattern on the new surface. This can usually be remedied by requiring a waiting period of several months between crack sealing and placing the surface treatment.

Crack Treatments for Thin HMA Overlays

There are also some pre-overlay treatment decisions that need to be made a significant time before the actual construction of the thin HMA overlay, especially those less than 2 inch thick. A case in point is the timing of when HMA crack sealing operations are done relative to when the HMA overlay is placed. If the thin HMA overlay is placed too soon, many crack sealing materials will swell up within the confines of the sealed cracks during the placement of an HMA overlay, and may cause a significant bump in the surface of the HMA overlay. To prevent this from occurring, the pavement designer needs to ensure that all maintenance crack sealing operations allow enough time for the crack sealant material to cure and fully harden before the scheduled placement of the thin HMA overlay. This could be up to 3–6 months prior to placing the overlay.

2.2 Patching

Patching can be one of the most expensive of the maintenance procedures for HMA pavements, (per unit of measure such as cost/ton, cost/in^2, or cost/yd^2). It is important that the correct methods, equipment, and materials be used to do it right the first time. (McDaniel, et al., 2014). Although patching is often done in preparation for various forms of resurfacing, it can also be done as a "stand-alone" repair of localized problem areas in an otherwise sound pavement.

The primary methods of patching include:

- Quick "safety" replacement of materials that have been lost due to localized pavement distress or disintegration (e.g., potholes),
- Complete removal (dig out) and replacement of larger localized areas of failed pavement, or
- Application of a thin layer of new leveling material over segments of pavement that exhibit surface-related distress/distortion.

Once patched, the distressed area should be able to carry a significant traffic level safely, with improved performance and lower rates of deterioration.

Patching may be temporary for safety, or a more permanent treatment. The appropriate method to be used depends on the type of problem, traffic level, urgency, the time of the year during which the repair is carried out, the time until scheduled rehabilitation, and the availability of equipment, materials, personnel, and funds.

Selecting the proper type of patch involves engineering judgement, so within an agency there should be guidelines for consistency in the process (McDaniel, et al., 2014). This involves consideration of purpose, materials, and timeliness of construction.

2.2.1 Project Selection

Types of Patches—Overview
This section addresses the following four primary types of patches and their appropriate uses:

1) **Pothole patching:** Potholes occur when the pavement material in a highly distressed, localized area has broken up and disappeared, leaving a distinct hole in the roadway. In pothole patching, the distressed area is removed and replaced, or additional material is simply added to fill up the pothole. Merely filling a hole will not prevent the development of further distress adjacent to or within the patch, but for safety reasons, it is important to promptly fill the pothole using a "quick patch" process until a more permanent repair (e.g., small digout) can be made. Potholes left unfilled pose a safety threat to motorists, especially motorcycles and bicycles. Potholes are more of a problem in colder, freeze-thaw climates. Various types of pothole repairs are discussed in section 2.2.2 below.

2) **Larger "digout" patches:** Where pavement defects are more extensive than the single pothole area, but still localized in nature, larger "digout patches" may be needed (Asphalt

Institute, MS 16, 2009). These types of problems are usually confined to wheel path areas and may take the form of:

- Alligator cracking (areas of structural failure)
- Rutted areas
- Severely raveled areas
- Coarse rock pocket areas
- Delamination
- Fuel spillage areas

These larger digouts often address areas of structural weakness and involve the removal of all or part of the asphalt layer and some of the base layer to restore adequate structure. These patches are more costly and should be done correctly (McDaniel, et al., 2014) to maximize performance and to possibly be considered permanent. These larger patches may be done in conjunction with a structural overlay strategy. Details are given in section 2.2.3.

3) Levelling and "skin" patching (hot and cold patches): For local areas of wheel path rutting or roughness, leveling and/or skin patching are often used to restore a uniform surface (Caltrans MTAG, 2009, Asphalt Institute, 2009). Skin patching can take two forms:

- The filling and leveling of wheel path rutting using an asphalt mix. This work involves placing a leveling layer of hot or cold asphalt mix, using either a "blade" (e.g., motor grader) or a paving machine. Microsurfacing can also be used for minor leveling. (To repair extensive rutting in the wheel paths, the "mill and fill" approach should be considered as an alternative to leveling.) Wheel ruts, if not repaired, can trap water and contribute to hydroplaning (WSDOT, 2020).
- The arresting of ravelling by sealing localized small areas of rough or raveling pavement without rutting. This can involve the application of a sealcoat (e.g., chip seal) or a parking area sealcoat product.

4) **Edge cracks:** These are longitudinal cracks that occur within 1 to 2 feet of the outer edge of the pavement. Most of the time the distress will include longitudinal cracking with or without some drop off. This could be due to narrow pavement width, lack of edge support, poor drainage, steep side slopes, fill settlement, soils with high plasticity (Shuler, 2005) and trees or other vegetation close to the pavement edge. Other factors that could contribute to edge failures include abnormal climate conditions such as drought or heavy

wheel loads running close to the pavement edge. Although edge failures are usually outside of the primary wheelpaths, their presence can accelerate the deterioration of the entire pavement. Edge failure repair may also involve the correction of drainage problems (e.g., restoring cross-slope, removing shoulder vegetation dams) and restoration of shoulder-backing material for support of the pavement edge.

Cost Effectiveness of Patching

Materials are usually a minor component of the cost of patching. The main costs of patching work are in the labor, equipment and traffic control. (McDaniel, et al. 2014). So it's important to do it right the first time by selecting proper materials and using proper techniques. Patching can be one of the more expensive treatments used.

When considering the patching repair, the cost and expected performance should be considered. Statements concerning performance are included in the discussion of each patch type.

Cost effectiveness calculations are affected by the patch "survival rate." To determine the patch survival rate, repairs should be monitored for at least one year. Monitoring consists of checking for the presence of repairs and noting the survival or failure of each pavement section. Figure 29 shows typical survival rate curves, where A, B, and C represent three separate patch locations. The area under the curve represents the patch survival rate.

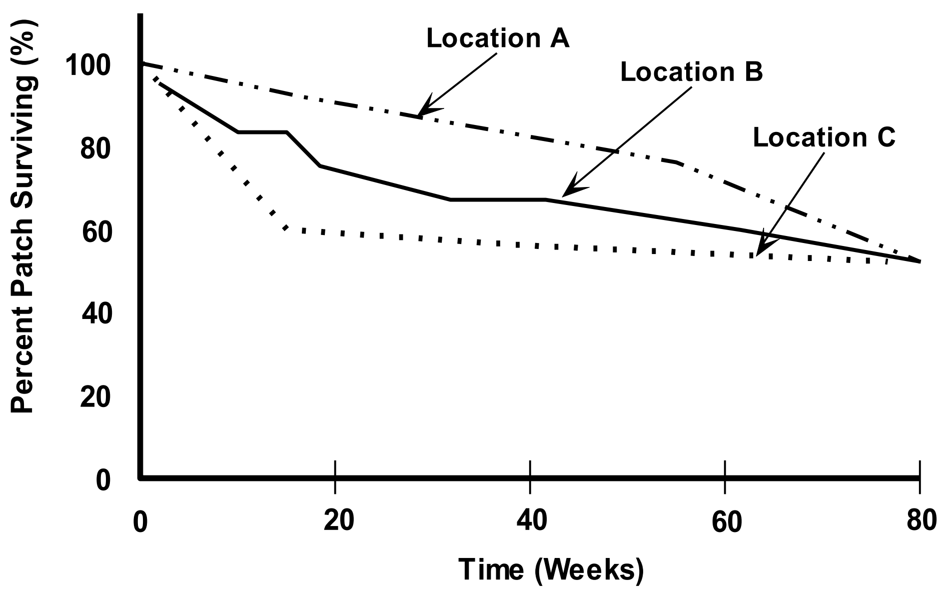


Figure 29. Typical Survival Rate Curves (FHWA, 1999)

Cost effectiveness can be assessed in different ways, but the above FHWA reference presents examples using patch survival rate to determine cost effectiveness in terms of cost per original volume of a pothole.

2.2.2 Pothole Patches

Potholes are a form of disintegration of the pavement that may be associated with poorly compacted material, raveling, cracking, base failure or aging of the pavement. Potholes often appear after rain or during thaw periods when pavements are weaker (Caltrans MTAG, 2009). A typical pothole is shown in Figure 30. Single or infrequent potholes may be the only pavement distress to occur in an area, and, beyond the treatment of the individual pothole, no other pavement repair work may be required (WSDOT, 2020).

Potholes pose a serious safety hazard, especially to motorcycles and other two-wheeled vehicles. The urgency and importance of patching potholes is reflected in the fact that many agencies have set up "Report-a-Pothole" programs with "1-800" phone numbers.

Figure 30. Typical Pothole

Not only are potholes detrimental to the integrity of the roadway and user safety; they are also a huge economic burden for transportation agencies (Dailey, 2017).

The generally accepted mechanisms for pothole formation (Caltrans MTAG, 2009) are:

- Localized raveling, stripping, or cracking occurs in the pavement surface.
- Water penetrates the surface layers of the pavement, softening the underlying pavement layers, which increases deflections by traffic.
- Ice formation and heaving in the pavement occurs (in some climatic areas).
- Fines from the underlying pavement layers are eroded and lost, reducing overall structural strength and support for the pavement surface.
- Once a pothole is formed, it will continue to grow until it is repaired.

Potholes occur when the material in a highly distressed localized area has broken up and disappeared, leaving a distinct hole in the roadway. In pothole patching, the distressed area is either removed and replaced, or additional material is simply added to fill up the pothole. While merely filling a hole will not prevent the development of further distress adjacent to or within the patch, it is important to promptly fill the pothole using a “quick patch” process until a more permanent repair can be made. Potholes left unfilled pose a safety threat to motorists, especially for motorcycles and bicycles.

The primary methods used to perform pothole patching include:

- Quick-patch products (throw-and-roll)
- Small digout patches
- Heater patching
- Spray injection patching
- Hot mastic patching

Each of these methods is discussed below.

Important references relating to potholes include Caltrans MTAG (2009), the Asphalt Institute Manuals (MS-16 and MS-22), FHWA Tech Brief (1999) and a report by R. Hajj, et al. (2021) and D. Hein et al. (2019). Each patching method is discussed in the following sections.

“Quick-Patch” Method for Potholes

General

The preferred procedure for addressing smaller potholes is to fill them in a fast-response mode using the “quick-patch” method (Figure 31) using specialty pothole patching cold mixes. This is the method most appropriate when urgency is paramount, or when either weather conditions are too poor for an HMA dig out patch to be placed, HMA material is not readily available, or the road is due to be rehabilitated soon. Only smaller (<2 feet square), deeper (>2 inches) potholes should be patched with these special mixes, which can be placed even into wet potholes during emergencies. Because these quick patch methods only address the immediate pothole hazard, they are usually not considered permanent and should be followed by a more permanent repair of the larger defective area. But, as a rule, these products work well when used for their intended purpose. (Asphalt Institute MS-16, 2009)

a. Put Mix in and Compact b. Completed Product

Figure 31. Quick Patch Material in Pothole

Materials & Equipment

The preferred materials for rapid patching of smaller potholes are the proprietary "quick-patch" cold mix products, which are specifically designed for pothole repair (McDaniel et al., 2014). Various commercial proprietary brands of quick-patch products are available in most areas of California. These products are available in bulk, and also in plastic bags or 5-gallon pails—even from the "big box" home stores. Fortunately, there are many good "quick-patch" products commercially available in California for this type of simple pothole repair. A few ccommon brand names used in California include QPR, UPM, Crafco HP, GranitePatch, EZ Street, and Aquaphalt. No generic specification is available.

These specialty cold mixes can simply be deposited in the pothole (even a wet one) given minimum compaction by hand or truck tire and then opened to traffic. Where practical, the material should be placed and compacted in 2 to 3 inch lifts. Maintenance crews can carry bags or buckets of this material and rapidly fill potholes as they find them. Manufacturer's guidelines should be followed.

Some non-proprietary cold (cutback) mixes can also be used, but they will require a longer cure (hardening) period and may ravel out under heavier traffic. They also require bulk mixing and outdoor stockpiling and have a limited "shelf life." They are considered temporary patches (Dailey et al., 2017). The old "throw & go" approach using conventional cold mix products is not an effective way of addressing potholes.

HMA can also be used, but only if it can be kept hot in the field. This usually requires a special patching truck or trailer with an enclosed, heated box as shown in Figure 32. Use of this equipment and HMA may also trigger the need for more traffic control.

a. Obtaining Hot Patching Materials from Heated Trailer by Hand

b. Unload Patching Material from Patching Truck

Figure 32. Hot Patch Trailer/Truck (Courtesy of Michigan LTAP)

(Safety Note: Cold mix products involving cutbacks with lower flash points should not be transported and held in closed, heated patching vehicles.) Equipment for these quick patches is normally limited to shovels and hand tampers. Compaction is often done by tamping or truck tires.

Construction

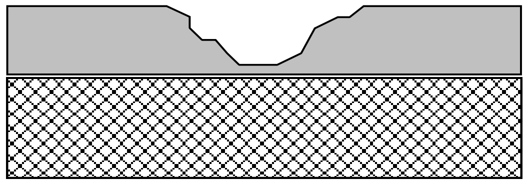
Only minimal preparation is required for using the specialty "quick-patch" products in potholes. These products may even be placed into a wet pothole. It is usually the fastest, least expensive and least labor-intensive method for patching a pothole in an emergency. Pothole patching by the "place-and-roll" method involves the following steps:

- Debris and loose material is removed from the hole.
- Patching material is placed into the hole, without drying of the hole.
- The material is shaped with a rake or shovel.
- The material is compacted using a hand tamper or the truck tires.
- The finished patch should have only a slight crown to help avoid ponding water.
- Loose debris should be cleaned up.

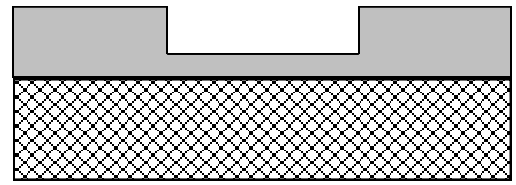
Small Digout Patches of Pothole Areas

General

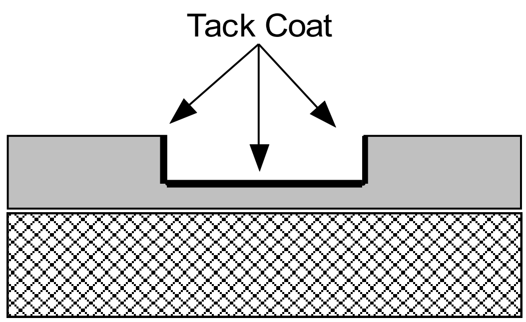
A more permanent repair is often the follow-up to a pothole repair, usually done when weather permits. For these smaller digout patches, the boundaries of the adjacent distressed area are properly marked and cut, the failed material is removed, the remaining (underlying) base material is re-compacted and new material is added. Figure 33 provides an overview of the steps involved in smaller digout patching. This digout cutting process is shown in Figure 34.



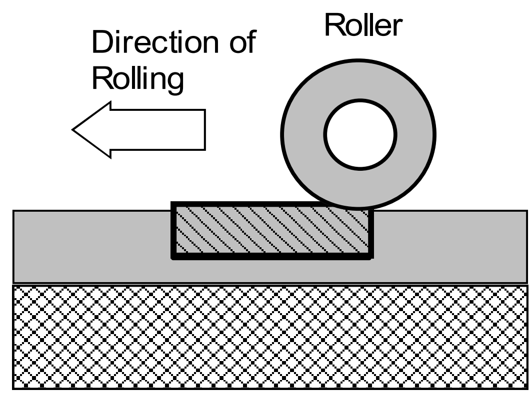
Pothole Area



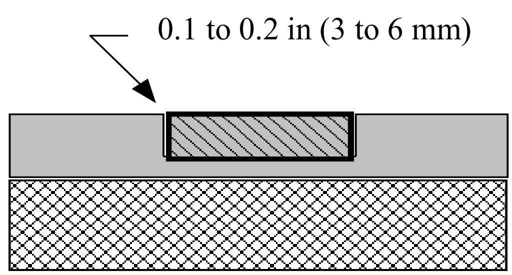
Surface and Base of Pothole Prepared for Treatment



Tack Coat Applied to All Asphalt Faces (not to aggregate base)



Patch Material Placed and Compaction in Progress



Finished Patch with a 0.1 to 0.2 in (3 to 6 mm) Crown

Figure 33. Semi-permanent Patching Procedure (Caltrans MTAG, 2009)

a. Cutting wheel

b. Jack hammer

Figure 34. Small Dig-out Patching

Done properly, these smaller digout patches can be considered permanent repairs and should last for 5–10 years.

Materials & Equipment

The main materials used for smaller digout patches are:

- Hot Mix Asphalt (HMA)—preferred
- Bulk cold-mix asphalt—if HMA is unavailable; emergency fix only
- Aggregate base (AB)—if needed for deeper repairs

For these digout patches, where possible use HMA meeting the Caltrans Section 39 Standard Specifications (Caltrans, 2018). Appropriate "Green Book" HMA mixes may also be used (Greenbook, 2021). In hotter climates, under heavy vehicle traffic, a harder grade of asphalt binder (e.g., PG 70–10) should be used in the HMA patching mix.

The equipment required is a pavement saw, or a jackhammer with spade bit, or possibly a very small milling machine. Vibratory plate compactors or small static steel-drum rollers will be needed, along with lutes and push-brooms and a straight edge.

Construction

For maximum performance of small digout patches, the following steps should be performed (Asphalt Institute, MS-16, 2009, MS-22, 2020):

- Mark the boundaries (cut lines) of the distressed area (Figure 35), at least 1 foot beyond the visible distress into sound pavement (Asphalt Institute, MS-22, 2020). Keep cut lines out of the direct wheel path areas. The repair boundaries should be as square or rectangular as possible, and take into consideration the dimensions of the equipment that will be used for removal of the old material and compaction of the new material.

Figure 35. Marked Cut Lines for Small Digout

- Cut the boundaries of the patching either a diamond saw, cutting wheel, or pneumatic hammer with a spade bit (Figure 36). In the case of the latter, care should be taken avoid rocking the hammer to not damage the HMA in the surrounding sound pavement. Milling out the area is another option. Saw cutting and jackhammering is used for complete removal of the HMA section. Partial depth digouts of the HMA section require the use of a milling machine.

Figure 36. Cut the Boundaries of the Patch and Tack Coat on Vertical “cut” Edges

- The depth of the digout/patch should be to sound material, and-at least 50% thicker than the thickness of the failed HMA layer in order to avoid a repeat failure (Caltrans

MTAG, 2009) and the need for costly re-patching. This will usually require removal of some or all of the aggregate base layer.

- Remove water and debris from the hole. Depending on the size of the pothole, this may be accomplished manually with a pick and shovel or with various combinations of power equipment, i.e., a pneumatic hammer and shovel, backhoe, or front-end loader. Smaller cold milling/grinding equipment can also be very effective for this operation.

- Apply a heavy tack coat of asphalt emulsion to the vertical edges of the cut asphalt layer using a slow- or rapid-setting emulsion (Figure 35). The tack coat should either be sprayed or brushed on the edges of the repair, not poured. Tack the bottom of partial depth HMA dig outs.

- Place the patch material in the hole (Figure 37). If the patch is placed manually, use a shovel (not a rake) to distribute the HMA material, taking care to avoid aggregate segregation. The hole should be overfilled by 20–25% of its depth to provide adequate material for compaction. Place enough extra material so that it will require three to four passes of the roller to be flush with the surrounding pavement. Use a lute to push the material back to edge of the dig out. Do not use a lute to feather and blend the material around the dig out edges to match the existing HMA surface prior to rolling. This method will result in roller bridging and leave uncompacted lower density material around the edge of the dig out and will lead to early dig out failure.

Figure 37. Spreading Patch Material into the Digout

- Compact the patch material with a hand device or a small vibratory roller. It is preferable to use compaction equipment whose surface is smaller than the size of the patch. It is very difficult to achieve satisfactory compaction with equipment that bridges the repair area. This is why the entire patch must be 25% high, edge to edge, prior to rolling. Vibratory rolling should not be used when roller comes in contact with the surrounding "good" (cold) pavement (Figure 38), since the intense vibratory energy can cause cracking

Figure 38. No Vibratory Rolling on Surrounding Good Pavement

The finished patch should have a slight crown (0.1 to 0.2 inch or 3 to 6 mm) as shown in Figure 39. This allows for slight compaction by traffic and prevents water from ponding in the patch area. However, excessive crown should be avoided as it will cause a rough ride. This is especially important for patching on higher speed routes.

For areas with significant amounts of rainfall, or if the patch will be resurfaced with a chip seal or slurry, the new patch surface and edges should be fog sealed.

Figure 39. Completed Digout Patch using HMA (Caltrans MTAG, 2009)

Heater Patching of Pothole Areas

General

Heater (infrared) patching is another form of localized patch whereby a small area of the old HMA pavement is indirectly heated and softened 2 to 3 inches deep with a portable heating device fueled by propane (Asphalt Institute MS-16, 2009). The softened HMA is then raked to break up any crack patterns and to re-level the material, and a rejuvenating spray is applied. New HMA may also be added for pothole filling or for leveling (McDaniel et al., 2014). The area is then compacted. This process is more appropriate for areas that do not appear to have structural problems, but only exhibit localized distress (e.g., shallow potholes, raveling, bumps, and depressions). This method has also been used to finish off the tops of utility patches that have been exposed to traffic and compacted (Asphalt Institute MS-16, 2009). Done properly, it can be considered a permanent repair.

Materials and Equipment

Infrared heater patching involves heating a small, distressed area with a propane fueled indirect heater device or intermittent radiant heating as shown in Figure 40. To minimize smoking, no flames should directly touch the asphalt surface. The heating device can be truck mounted or a towed trailer. Heating equipment comes in various sizes, rectangular or square. For heater patching, the equipment manufacturer's instructions should be followed.

a. Heater Patching Truck (Rose Paving, 2013)

b. Heater Patching Trailer

Figure 40. Heater Patching Machines

Liquid rejuvenators, appropriate for the equipment and process, are often applied to the heated material before compacting.

Construction

Heater patching (Asphalt Institute, MS-16, 2009) involves the following steps:

- Heating/softening the distressed pavement to a depth of 1 to 3 inches.
- Scarifying and raking the surface to break up the crack pattern and re-level it.
- Applying a rejuvenator spray, and possibly adding new asphalt mix for leveling.
- Re-compacting the patched area with a plate compactor or small steel drum roller.

Some of these systems, if used improperly, can produce large amounts of smoke, so may not be appropriate for some locations.

Spray Injection Patching of Pothole Areas

General

The "spray injection" process may also be used for pothole patching (Figure 41). This involves specialty equipment, either truck-mounted or trailer-mounted that mixes and injects an asphalt emulsion-aggregate mix into a pothole area, much like a "gunite" process for cement mixes. These patches can perform very well, but are not structural and are usually considered temporary. Performance will depend largely on the skill of the operator (McDaniel, et al., 2014). Lane closures and follow-up sweeping may be required for this process on urban, heavy traffic roadways.

Figure 41. Spray Injection Patch Truck

Materials & Equipment

Spray injection patching involves specialty equipment, asphalt emulsion, and clean, dry aggregate. The common type of emulsions used are Rapid Set (e.g., CRS-2, RS-2). The equipment can be truck or trailer mounted. Materials, equipment and process should be as directed by the equipment manufacturer and demonstrated for approval on a test area. Lane closures or shadow trucks may be required for safety in heavy traffic areas.

Construction

The operation may require lane closures, or at least a shadow vehicle with warning lights and signage in heavier traffic areas. The steps for injection patching using a single spray patching machine are described below (Caltrans MTAG, 2009). All materials are applied through a common hose on a boom, operated either by a worker on foot or from the driver's cab.

- Prepare the site for patching by blowing debris and water from the hole with air from the application nozzle (Figure 42a).

- Spray a tack coat of asphalt emulsion onto the sides and bottom of the hole at a rate of approximately 0.2 gal/yd^2 (Figure 42b).

- Blow an asphalt emulsion/aggregate mixture into the hole, filling the hole to the top (Figure 42c).

- Finish with a light layer of dry aggregate to minimize pick up by traffic (Figure 42d). (It is usually not necessary to roll a pothole patched using this method. This is one advantage of the injection method.)

- If necessary, sweep any loose aggregate that might be a hazardous to motorists.

a) Site Preparation

b) Application of Tack Coat

c) Filling the Prepared Hole with a Mixture

d) Application of Finish Coat of Aggregate

Figure 42. Spray Injection Patching (Caltrans MTAG, 2009)

Hot Mastic Patching

General

This type of pothole patching involves the placement of hot asphalt mastic products directly into the pothole or wide gap (Figure 43). They can also be used for leveling patches. Done properly they can be considered a permanent repair.

Figure 43. Hot Mastic Patching (Courtesy of Maxwell)

Materials & Equipment

These hot patching materials are proprietary blends containing polymer-modified asphalt binder and fine aggregate (passing No. 4 sieve). The material can be flexible yet stable enough to support heavy wheel loads. The specific grade of product used must be appropriate for traffic levels and climate, per manufacturer's guidelines. The material comes in meltable blocks, which require a special melter kettle (Figure 44) and, possibly, smaller "buggys" for transporting the material to the patch area. Tools for hand work are also required.

Figure 44. Material Blocks and Melter Kettle for Mastic Patch Material (Courtesy of Maxwell)

After melting per manufacturer's instructions, the molten material flows via a chute into the patch area, or into a small buggy for transport to the patch site. It is spread and leveled using hand tools before cooling and becoming unworkable.

2.2.3 Larger Digout Patches

General

Larger digout patches involve the milling or cutting and removal of the entire distressed area and replacing it—often with a thickened HMA layer (Figure 45). These larger patches, which can involve the full-lane width, are also referred to as a "dig out," "mill-and-fill," "remove & replace" (R&R), "plugging," and "base repair."

a. Milling Out the Distressed Area

b. Paving HMA on a Tacked Surface

Figure 45. Full Lane Width “mill & fill” Patch

These patches are used when the pavement has failed in localized areas to an extent that the underlying support materials have weakened from water, become infiltrated with fine-grained materials, or otherwise lost their load-carrying capacity. These patches could also be used where there’s significant cracking of the HMA that would quickly reflect through a new surface course. Unlike quicker pothole patching, dig outs may require the removal and replacement of much (if not all) of the underlying aggregate base (AB) layer. Due to the thorough nature of this method, it has sometimes been referred to as “spot reconstruction” or “full-depth” repair.

These larger patches can be done as stand-alone repairs, as preparation for a full surface treatment, or as an HMA overlay. Since the recommended material for the patch is HMA, the proximity to a hot mix plant should be considered. Lane closures are usually required for this type of patching.

Structural design work may be necessary for larger dig out patches, since these are structural repairs of loaded wheel path areas. The patch materials and thickness must be appropriate for the type of traffic. The new HMA patch should be thick enough to reach stable material (Asphalt Institute, MS-16, 2009; MS-22, 2020), and as a general rule-of-thumb, at least 50% thicker than the HMA layer that failed (Caltrans MTAG, 2009). Done properly, with proper structural design, these larger digout repairs can be considered permanent.

Materials & Equipment

The main materials used for larger dig out patches are:

- Hot-mix Asphalt (HMA)—preferred
- Cold-mix Asphalt—if HMA is unavailable; emergency fix only
- Aggregate Base (if needed)
- Emulsion Based Tack Coat

For these larger patches, use HMA meeting the Caltrans Standard Specifications, Section 39 (Caltrans, 2018), the Green Book specifications (2021), or the newer HMA-LG specification (CCPIC, 2021). Choose a mix appropriate for the climate and the anticipated traffic loading or instability problems may result (Figure 46). Also, pave according to Caltrans Standard Specs, Section 39, "Method" process.

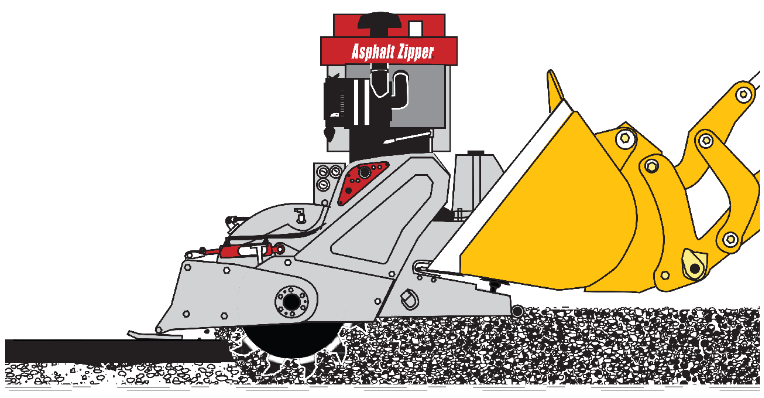
Figure 46. Weak, Unstable Asphalt Mix Used in Patches on a City Bus Lane

In hotter climates, under heavy vehicle traffic, a harder (e.g., PG 70-10) asphalt binder should be used in the HMA mix, but it could be difficult for hand work.

Primary equipment includes a pavement saw, a jackhammer with spade bit, a small backhoe or front-end loader, a dump truck, a steel drum roller, and a straightedge.

Alternatively, for more extensive digout work, milling machines would be used. A small pulverizing machine (Figure 47), usually from 2 to 4 feet wide, can also be used. These smaller units are especially appropriate for longer partial or full depth wheel path digouts. A disadvantage of these types of machines is that they don't remove the grindings from the dig out like a full-sized milling machine would do, so production is slowed.

a. Photo



b. Schematic

Figure 47. Small Pulverizer Unit Mounted on Front Loader (Courtesy of Asphalt Zipper, Inc.)

For milling larger full-lane areas and for partial depth milling of HMA layer, larger, dedicated milling machines should be used.

Construction

These larger digout patches will require a lane closure. Details of construction "best practices" are outlined below and involve the same steps depicted in Figure 49. The general construction steps for larger digouts are outlined below (Caltrans MTAG, 2009; Asphalt Institute MS-22, 2020):

- Marking and cutting of the boundaries
- Removal of material - using a milling machine when possible
- Or manual cutting, breaking-up and removing of the HMA pavement layer and any affected base/subbase layers
- Placement and compaction of any new base/subbase layers
- Application of tack coat on the vertical cut faces and the bottom of partial depth dig outs.
- Placement and compaction of the new HMA (usually in multiple lifts)
- Checking the finished surface with a straightedge
- Application of a fog seal (asphalt emulsion) if a surface treatment is to follow

More specific practices and guidelines for these larger digout patches include the following:

- Using paint or chalk, mark the cut lines for the distressed area (Figure 48a), taking care to encompass a larger area than the actual distress. A good rule of thumb is to go at least 1 foot beyond any visible cracking. Use straight edges and square corners. Where practical, layout a cut wide enough to accommodate a small roller.
- Where practical, keep the longitudinal cutline out of the direct wheel path areas.
- If a milling machine is to be used, mark "cut lines" to match the width of the milling machine. The milling path should be straight and parallel to centerline. Avoid meandering patterns.
- If no milling machine is to be used,
- Cut along the boundaries of the patch using either a diamond saw, cutting wheel, or jack hammer with a spade bit. Avoid rocking the hammer on these perimeter cuts which damages the surrounding "good" material.

- Make additional cross-cuts within the patch area, if necessary, to further break up the failed material for removal.

- Remove the old pavement pieces, debris and any water from the hole. Depending on the size of the dig out, this may be accomplished manually, with a pick and shovel or with various combinations of power equipment, i.e., a pneumatic hammer and shovel, small excavator, or front-end loader.

- It is recommended that additional material (e.g., existing aggregate base) be removed to allow the new HMA patch thickness to be at least 50% thicker than the old HMA layer (Figure 48b). The goal is to provide a thickened HMA layer over this localized weak area, hopefully eliminating the need to do repeat patches in this same area in the future. If the hole is extremely wet, limit the depth of material removal (and the thickness of new HMA) to about 12 inches. (Further investigation will be needed to determine the source of the water.)

- Re-compact the exposed base material with a roller (if the cut is wide enough) or with a vibratory plate compactor.

- Apply a "tack coat" of asphalt emulsion to the vertical cut faces of the old HMA pavement at a rate of approximately 0.2 gal/yd^2 using an emulsion. The tack coat should either be sprayed or brushed onto the edges of the repair, not poured. Apply tack coat to bottom of partial depth dig outs as shown previously in Figure 33. Do not apply to aggregate base surface. Figure 48c above illustrates the tack coat application areas.

- The thickness of any lift of HMA should be at least 3 times the maximum aggregate size. For thicker patches, say >4 inches, the HMA should be placed in more than one lift. In very thick patches, the thickness of any lower lift of HMA should not exceed 5 inches, with the final (surface) lift not exceeding 3 inches. (In thicker lifts, it is often difficult to attain the required smoothness.)

- Place the hot HMA patching material into the hole. Place enough excess material (about 25%) so that it takes at least three passes of the roller to become flush with the surrounding old pavement. This should ensure:

- good compaction and stability of the patch so that it will not compact further under traffic, and

- a smooth ride (no bump).

- Compact the patch material with a vibratory device, preferably a small vibratory roller. (Note: use only in "static" mode when roller is touching the surrounding old pavement.)

If the ends of dig outs cannot be cross rolled, then a vibratory plate should be used to ensure good compaction at the digout ends.

- A straight edge should be used—in both the transverse and longitudinal directions—to make sure that the finished patch surface is within 1/8 inch of flat.

- For areas with higher rainfall, or where the patched area will later be covered by a surface treatment (e.g., chip seal, slurry seal), the entire patch surface should be fog sealed, possibly followed by a light sand application to avoid pickup by tires. Any excess sand is a safety hazard and should be swept prior to opening to traffic.

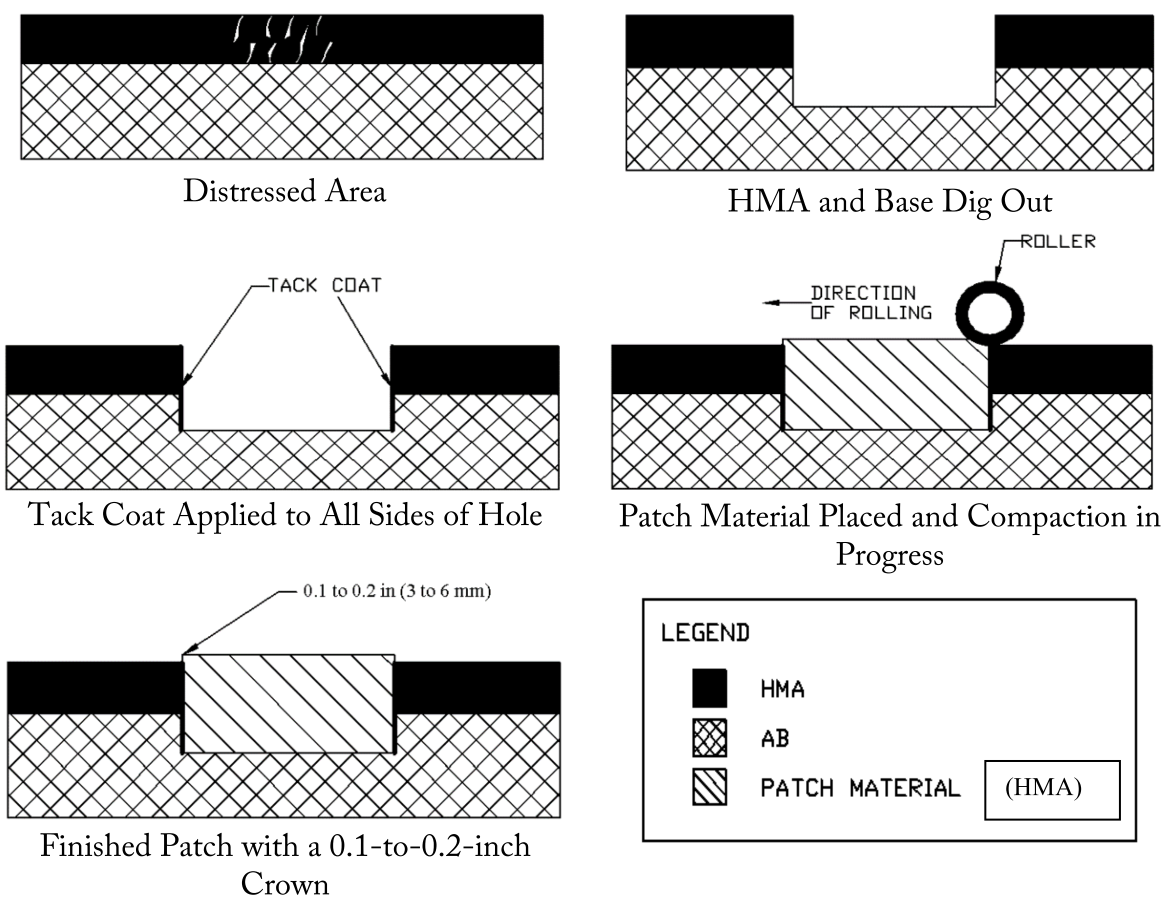


Figure 48. Digout Project Construction Procedure (Caltrans MTAG, 2009)

2.2.4 Leveling/Skin Patching

General

Surface "skin" patches are appropriate for areas that do not have a structural problem. They involve laying down a thin asphalt mix layer over an existing pavement in the distressed areas to improve the ride and reduce pavement roughness (Dessouky, et al., 2012; Papagiannakis, et al., 2018). They can be used to level depressions, arrest raveling or seal course “rock pocket” areas. They are often viewed as temporary fixes or possibly as a preliminary treatment for a full surface treatment.

For local areas of wheel path rutting, ravelling, or roughness, skin patching is often used to level and restore a uniform surface. Skin patching can take two forms:

a) The use of asphalt mix to fill ruts or provide leveling. This work involves laying a leveling layer of hot or cold asphalt mix, using either a “blade” (e.g., motor grader) or a paving machine, followed by rubber-tired rolling. (To repair extensive rutting in the wheel paths, the mill and fill approach should be considered). Layered microsurfacing can also be used.

b) The application of a seal (e.g., fog seal or chip seal) or parking area sealcoat to seal localized small areas of rough or raveling pavement without rutting. A pavement that is ravelling must be sealed as soon as reasonably possible since unsealed pavements will continue to ravel, age, and harden much faster than normal resulting in difficult maintenance problems (WSDOT, 2020).

Materials and Equipment

For surface skin patches—two types of materials can be used:

1) Use HMA with smaller maximum size aggregate (e.g., 3/8 inch-max). Where available, cold mixes made with certain liquid asphalt (cutback) binders can also be used. An asphalt emulsion tack coat on the old pavement surface should be specified (Caltrans Standard Specifications – Section 39, 2018). Equipment will usually involve a paving machine or small tailgate spreader. Motor graders are also sometimes used. Compaction should involve a light steel wheel, rubber-tired roller, or truck tire rolling.

2) For ravelling areas (not leveling) small-area sealcoat (chip seal) patches can also be used following good chip seal practices (e.g., Caltrans Standard Specifications, Section 37, “Sealcoats”, 2018), but without the requirement for mechanical chip spreaders and emulsion distributor trucks. Other material options include parking area sealcoats, hot mastic patch materials, and fog seals.

Construction

Skin patching may involve asphalt mixes (hot or cold) or a localized seal application (Caltrans MTAG 2009). Typically, one of two methods is used, as follows:

- A thin layer of HMA (or certain cold mixes) can be applied to the existing surface, and rolled with truck tires or a light roller. The process can involve up to 10 steps:
    - Setting the traffic control at both ends of the project site.
    - Milling the upper 0.5 to 1 inch to remove the distressed material.
    - Scraping off raised markers by blading.
    - Cleaning the pavement surface of debris and dirt using a broom machine.
    - Distributing tack coat over the existing surface using an asphalt distributor truck.
    - Transporting the patching mix (keeping HMA hot).
    - Mix placement using either a paving machine or a "blade."
    - Roller compaction—using rubber-tired (pneumatic) for rutted areas.
    - Visual inspection and ride test.
    - Set temporary asphalt markings and open for traffic.

Figure 49 shows the hand leveling of a skin patched area, and Figure 50 illustrates the final rolling of the skin-patched area. (Use pneumatic rollers for rutted areas.)

Figure 49. Hand Leveling of a Skin Patched Area

Figure 50. Rolling of a Skin Patched Area

- A localized small-area seal (chip seal or fog seal), parking area sealcoat product or hot mastic material can be used for sealing a porous area (e.g., rock pocket) or to arrest raveling. This localized treatment must usually be done by hand. For a chip seal, this means without typical chip sealing equipment, as follows. After sweeping the repair area, an asphalt emulsion binder is applied heavily by a hand sprayer, and then aggregate chips are applied by hand, followed by immediate rolling with a small roller or with truck tires. Excess aggregate must be removed before opening the lane to uncontrolled traffic. Target application rates for the hand spraying of asphalt emulsion and for the hand spreading of chips should be specified. A final flush coat of asphalt emulsion over the chip seal should also be specified, per Section 37 of Caltrans Standard Specifications.

CAUTION: The use of small-area chip seals as a form of skin patch may not be appropriate, especially on high-speed routes where they can create differential surface friction between wheel paths, which can pose a special skid hazard in wet weather. Choosing the appropriate skin patching method will also depend on what materials and equipment are available (e.g., proximity to a hot mix plant).

2.2.5 Edge Patches and Repairs

General

Edge cracks are longitudinal cracks and occur within 1 to 2 feet of the outer edge of the pavement (Figure 51). Over time, as vehicles pass over the weakened area, further cracking or breakout can take place (Shuler, 2005). Edge repairs are used when the pavement has failed along the edges due to the action of traffic and the loss of edge support that occurs due to vehicle off-tracking and loss of shoulder backing lateral support, the presence of water poor surface drainage (pavement and shoulder), and aggressive growth of vegetation. Lower density and higher moisture than optimum of the subgrade beneath the edge cracks appears related to edge cracking (Shuler, 2005). Done properly, they can be considered permanent repairs.

Figure 51. Example of Edge Cracking of a Pavement

Materials and Equipment

The main materials and methods used in edge repairs are the same as those associated with patching and digouts, with HMA being the preferred material. Aggregate base material can be used for restoring shoulder backing. The work often involves only hand tools and small rollers.

Construction

The basic construction steps associated with a repair along the edge of the pavement depend upon the severity and depth of the deterioration. If the distress is confined mainly to the HMA surface, the steps associated with surface skin patching (Section 2.2.5 above) should be employed. If, on the other hand, the deterioration is structural and extends well below the surface, then the steps associated with a larger dig out patches (Section 2.2.3 above) are more appropriate. In both cases, the intent is to provide leveling, improved lateral support and drainage along the pavement' s edge. Accordingly, extra precautions should be taken for achieving adequate compaction and maintaining good surface drainage at that interface with the shoulder. Work on the shoulder area to promote good surface drainage is often necessary, and reinstatement and grading of shoulder backing material may also be required.

2.2.6 Patching in Preparation for Full Resurfacing – Special Practices

General Guidelines

When pavement patching is done as a preparation for full resurfacing—either surface treatments (e.g., chip seals, slurry seals) or HMA overlays—the patch will be completely covered and disappear, so aesthetics of the patch areas is not a maj or concern. But structural adequacy and ensuring good bond with the resurfacing become very important. When it comes to structural HMA overlays, proper pre-treatment can enhance the structural performance of the overlay (Tenison, et al., 2009)

Here are some general guidelines that apply, whether the final resurfacing will be a surface treatment or an HMA overlay:

- Make the patched area structurally adequate by making it deep enough to reach stable material (Asphalt Institute MS-22, 2020), or, as a general guideline, make the HMA layer thickness at least 50% thicker than the HMA thickness that failed (Caltrans MTAG, 2009)

- Use HMA (not cold mix) for the patch material

- Use a stable HMA mix that won't deform under the expected traffic loading

- Check old pavement for rutting and do a leveling patch, if needed.

- Make the final patch surface flush or slightly overfilled

- Consider sealing the patch perimeter on the surface (a.k.a. "picture framing") with tack coat materials or crack sealant.

- If a proper patching treatment is used before construction of the structural overlay, the expected performance of an HMA overlay may be enhanced (Tennison, et al., 2009).

Specific guidelines—pertinent to the type of re-surfacing planned—are as follows:

a. Patching as Preparation for *Surface Treatments*

    - Apply a fog seal (asphalt emulsion) to the surface of the new HMA patch, if the surface treatment will be a chip seal or any slurry seal. The fog seal will fill the surface voids in the new HMA patch. Without the fog seal the surface treatment may not bond well.

    - Take care to make the patch even with the old HMA surface (i.e., no bump or dip).

b. Patching as Preparation for *HMA Overlays*

    - Consider testing larger patches for compaction /density.

    - Apply a pre-tack coat (asphalt emulsion) fog seal to the surface of the new patch—this is in addition to the usual tack coat that will be applied to the entire surface prior to the HMA overlay.

- Dig outs, patching, and crack sealing of existing pavement prior to placement of HMA overlays should not exceed 20% of the project's cost (Caltrans 2001). More detailed guideline on patching prior to overlays are provided in "Caltrans Guidelines for Identifying and Repairing Localized Areas of Distress in AC Pavements Prior to Capital Preventive Maintenance or Rehabilitation Repairs" (Caltrans, 2001).

3. Other Preparations for Resurfacings

3.1 Overview

While crack treatments and patching done as preparations for resurfacings are covered in the previous chapter, this chapter deals with other actions sometimes used in preparation for the full resurfacing of pavements (Heitzman, et al. NAPA, 2018). In discussing *resurfacings*, we will differentiate between surface treatments (e.g., chip seals, slurry seals) and thin HMA overlays. Table 6 summarizes the common preparation options that should be considered, and each option is discussed in more detail below.

Table 6. Special Preparations for Surface Treatments and Thin Asphalt Overlays

	Sweeping	Tack Coat	Remove Markings[1]	Milling & Micromilling	Leveling Course	Raise Iron
Fog Seal	✓					
Scrub Seal	✓		✓		3	
Chip Seal	✓		✓	3	3	
GRCS[2]	✓		✓	3	3	
Slurry Seal	✓		✓	3	3	
Microsurfacing	✓		✓	3		4
Thin Asphalt Overlay	5	✓	✓	3	3	✓

Notes:
- All except painted striping
- GRCS = Geosynthetic Reinforced Chip Seal
- Typically, not done. May be required in special cases for smoothness or rut removal, or for correction of cross slope or crown.
- For thicker applications (i.e., >3/4 inch)
- When pavement surface is dirty.

Common surface preparations for asphalt pavement preservation treatments were summarized in NCHRP Synthesis 565 (Peshkin and Duncan, 2021), as well as NCHRP Report 388 (Tenison, et al. 2009)

3.2 Sweeping

Perhaps the simplest, common preparation action is cleaning the old pavement surface. Sweeping by power brooms or sweepers (see Figure 52), should be required prior to surface treatments, but is usually not necessary for thin HMA overlays unless the pavement surface is dirty or contaminated, since a tack coat is always used on the old pavement surface, as discussed below.

Figure 52. Sweeping Prior to Resurfacing

Muddy surfaces may need to be cleaned by power washing, possibly in combination with sweeping. Sweeping is especially important after surface preparations involving milling or micro-milling. Vacuum sweepers are recommended for rougher, dusty surfaces, such as those recently milled.

3.3 Tack Coats

Tack coats (Figure 53) are meant to provide bond between the old pavement surface and a new HMA overlay and must be used even with thin overlays. Proper tack coat applications are critical to the successful long-term performance of flexible pavements. Tack coats are <u>not</u> commonly used with surface treatments.

Tack material is usually asphalt emulsions applied in uniform manner by a distributor truck. Since these emulsions are water-based, a cure ("break") time should be allowed before placing the HMA overlay. It should be noted that excess tack coat can reduce bonding (Heitzman et al., NAPA, 2018) and can create a slippage failure in areas of braking or sharp tuning (e.g., intersections). Hot "PG" Grade asphalt can also be used for tack coat in cooler climates or night work when climate conditions aren't appropriate for the curing of emulsions. Standards for tack coat materials and procedures are addressed by Caltrans (Caltrans Standard Specifications, Section 39, 2018 and the Caltrans Tack Coat Guidelines, 2009). Figure 54 shows an example of a fresh emulsion tack coat (before break), while Figure 55 shows an example of a sparse tack coat after break (with the emulsion water evaporated).

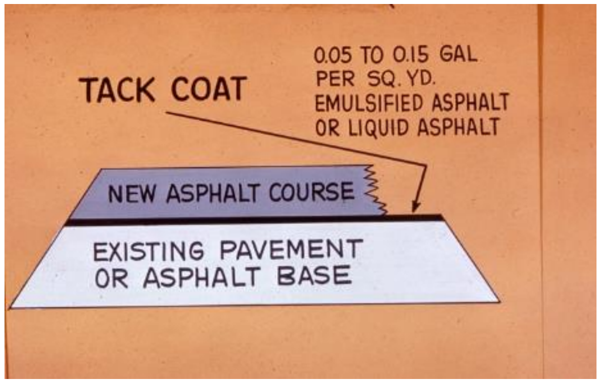


Figure 53. Tack Coat Is Required to Help Bond the Overlay

Figure 54. Photo of a Good Tack Coat (Courtesy of RoadResource.com)

Figure 55. Sparse Tack Coat after Break

Since any traffic can "track" the tack coat onto surrounding pavement, care should be taken to control traffic movements—including haul trucks—coming off of tack coat, especially in areas where aesthetics is very important (e.g., downtown areas, color-coded surfaces, etc.). In those areas, reduced tracking tack coat products should be used.

Tack coat is usually paid by the ton, and it is paid on the residual binder in emulsions. It is important to know the dilution rate of both the original emulsion and the diluted emulsion used for tack coat in order to calculate the residual asphalt and make the proper payment to the supplier or the contractor. The dilution rates may vary, but the most common dilution rate is 50 percent emulsion and 50 percent water.

3.4 Markings Removal/Temporary Markers

Raised markers and thermoplastic lines and legends should be removed prior to any form of resurfacing. Painted stripes can usually remain and should not affect the performance of the resurfacing. Most raised marker can be scraped off with an equipment blade, as long as it doesn't cause damage to the old asphalt surface. Recessed markers should be removed by hand, usually with a pick. Thermoplastic markings are usually removed by grinding, but water blasting methods are gaining popularity (Pike, et al., 2013).

For surface treatments, temporary reflective lane markers are often used, as shown in Figure 56. They will provide delineation until permanent raised markers or striping can be installed. The "peel-and-stick" type of temporary markers should be placed prior to placing the surface treatment, with their clear protective covers left intact. These clear covers should be removed only after placement of the surface treatment.

Figure 56. Temporary Lane Markers in Place Prior to Surface Treatment

For thin overlays, instead of temporary markers, lane lines should be referenced to offset stakes or to other solid reference points (e.g., curbs, guard rail) to simplify re-painting of striping. Some contracts specify using temporary painted striping. Temporary painted striping may be used with or without the temporary raised markers.

3.5 Edge Milling

Tapered milling of the existing pavement edge near the gutter line (a.k.a. edge milling, key cutting) (Figure 57) is needed for thicker treatments, such as HMA overlays or thicker microsurfacing to eliminate feathering and ravelling. It is especially advisable in pedestrian areas to provide a flush edge with gutters and avoid trip hazards and bicycle hazards, or to be compliant with American Disability ACT (ADA) requirements at ramp locations. It also facilitates street/gutter sweeping. The specified HMA overlay thickness must be maintained even at the high points in the tapered milled surface (Heitzman et al., NAPA 2009). Edge milling is usually not required for thin treatments such as chip seals or slurry seals. Since edge milling leaves a dusty surface, vacuum sweeping should be required to promote bonding prior to any resurfacing. For HMA overlays, a tack coat must also be required. More information can be found on the Asphalt Reclaiming and Recycling Association's (ARRA) website (www.arra.org/).

Figure 57. Edge Milling/Key Cutting

3.6 Milling & Micro-milling

Conventional milling (a.k.a. cold planing) usually denotes removal of some major thickness of older HMA material using a heavy-duty, coarse-toothed grinding machine having a drum with approximately 170–200 teeth for a 5/8-inch pattern (Figure 58). This may be done for various reasons:

- Removal of excessive crown
- Restoration of cross-slope

- Edge milling (discussed above)
- Smoothing the old surface for rideability
- Replacing old HMA with new HMA (mill & fill)

Figure 58. Milling Drum

Milling depths can range from 1 inch to as much as 12 inches.

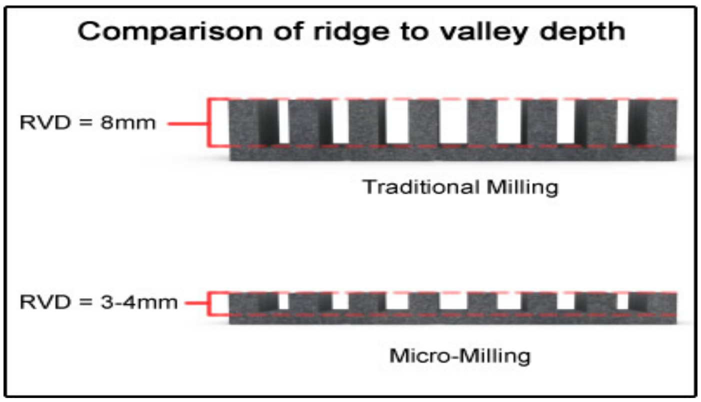
The resulting surface (Figure 59) will be too rough for placing a surface treatment such as a chip seal or slurry seal. Conventional milling is followed by sweeping and placement of an HMA overlay—with a heavy tack coat of asphalt emulsion. A side benefit of milling is that the large quantities of milled material produced can be further processed to become reclaimed asphalt pavement (RAP) for use in recycling processes such as cold in-place recycling, or hot/cold central plant recycling. These millings are also often used as Class 2 Aggregate Base (AB). Guidelines for milling of asphalt pavements have been developed by the ARRA (2016).

Figure 59. Milling of Entire Street to Reduce High Crown

Micro-milling refers to a finer, more precise, abrasive removal of minor amounts (less than 3/8 inch) of surface material—for minor pre-leveling or smoothing. It is an effective treatment for old surfaces prior to applying a thin resurfacing such as a chip seal or slurry seal, primarily to improve smoothness (ARRA, 2012; ARRA, 2016).

Micro-milling involves equipment fitted with drums having approximately 800 smaller teeth for a 1/8-inch pattern (Figure 60).

a. Micro-milling Drum in Foreground



b. Micro-milling versus Traditional Milling Patterns

Figure 60. Micro-milling Drum (foreground) and Milling Patterns
(Courtesy PR Systems and Wirtgen)

Used in advance of a new surface treatment, micro-milling of the existing pavement can result in improved smoothness and rideability of the surface treatment. (ARRA, 2012). This less aggressive form of milling is also less prone to producing spalls in the old surface, and it leaves a smoother surface texture that's easier to sweep clean, which reduces the risk of windshield damage from milling debris (Figure 61). Micro-milling was also found to be more cost effective than conventional milling (Tsai et al., 2018)

Figure 61. Micro-milling Operation (Courtesy P.R. Systems, Inc.)

The finer, smoother surface texture of micro-milling is suitable for placing a thin surface treatment (or an HMA overlay). Using micro-milling, smoothness (IRI) levels of less than 40 inches per mile (the smoothness required by Caltrans for Interstates) can be achieved.

In another strategy, smoothing by micro-milling can be followed by a paving fabric, then the placement of a chip seal, to create a Geosynthetic Reinforced Chip Seal (GRCS). The Asphalt Interlayer Association's (AIA) website (www.aia-us.org/) has more information on the GRCS process. Microsurfacing or thin HMA overlays can also be used as a follow-up to micro-milling. Micro-milling asphalt surface pavements should result in improved smoothers after the final treatment. If an HMA overlay is to be done on a micro-milled surface, sweeping and a tack coat at normal rates should be required. Micro-milling has also been used successfully on open graded asphalt surfaces (e.g., OGFC), in advance of placing another layer of open graded HMA (Lai et al., 2009)

3.7 Leveling Course

For all types of resurfacing, a leveling course/layer should be required where the old pavement is rutted (due to consolidation of HMA or pavement wear in the wheel tracks) or otherwise uneven as shown in Figure 62. Leveling is not appropriate for unstable HMA mixes, which should be removed and replaced. Leveling work usually involves HMA with finer aggregate gradation (Asphalt Institute, MS-22, 2020). These mixes can be "blade-laid" with a motor grader or placed with a conventional asphalt paving machine. Dump trucks (end-dump) and belly dump trucks (bottom dump) are best suited to both blade and laydown operation. Tack coats should always be used (Dessouky et al., 2012).

Figure 62. Rutting Requiring a Leveling Course Prior to Overlaying

Wheel path rutting greater than 0.5 inch can cause problems with the new resurfacing as follows:

- *Chip Seal*: Ruts can result in ponding of the emulsion binder in the rut areas causing chips to "drown" in the emulsion and leaving a slick, unsafe surface (see Figure 63) and a return of the rutting condition. A thin, feathered leveling course of HMA should be applied to the rutted areas and rolled with a rubber-tired (pneumatic) roller.

Figure 63. Chip Seal Placed over Rutted Pavement

- *Slurry Seal*: The slurry mixture will end up too thick in the rut areas and displace under wheel loads resulting in re-rutting and bumps. A thin, feathered leveling course of HMA should be applied to the rutted areas and rolled with a rubber-tired (pneumatic) roller.

- *Microsurfacing*: Microsurfacing has more stability than conventional slurry seal and can be used to fill and level ruts as shown in Figure 64. But ruts deeper than about 1 inch may require multiple lifts of microsurfacing. Rut filling must be performed using a special rut box attachment prior to the application of the microsurfacing surface.

Figure 64. Rut Filling Using Microsurfacing Rut Box

- *Thin HMA Overlay*: Prior to placing the HMA overlay, ruts should be pre-paved with a thin, feathered leveling course of HMA, and rolled with a rubber-tired (pneumatic) roller. Failure to pre-level ruts will result in re-rutting of the new overlay.

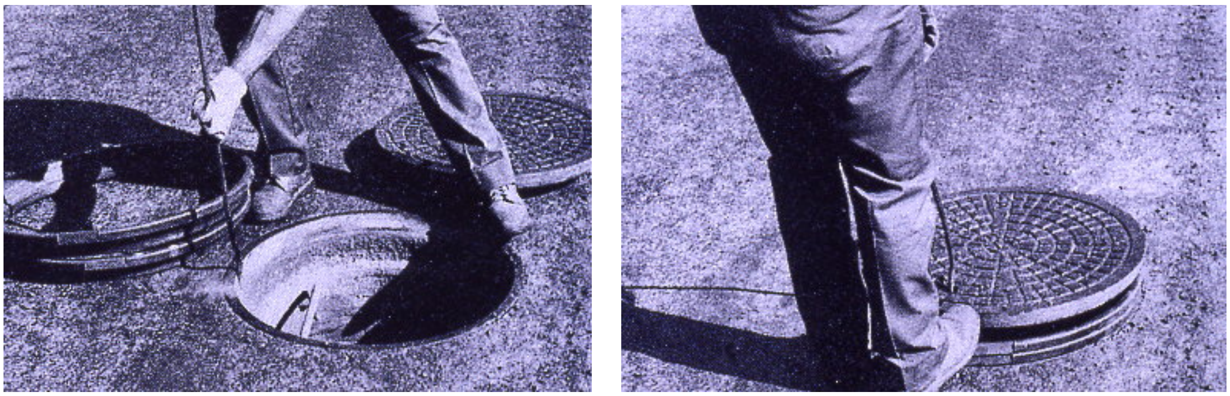
3.8 Raising Street Fixtures

When resurfacing is done on pavement containing iron appurtenances, such as manhole rings, valve boxes, drain inlets, these street fixtures (a.k.a. "iron") may need to be raised to the elevation of the new pavement surface so a depression /bump will not exist after the surfacing (Asphalt Institute MS-22, 2020). This is typically only done for the thicker treatments such as HMA overlays and microsurfacing treatments that exceed about 1 inch.

This raising of the "iron" typically requires digging out the old steel ring and raising and re-setting it (with mortar) and paving around it to be flush with the elevation of the new overlay surface (Figure 65). The utilities are raised to grade after the HMA is placed. The manholes and valve covers are referenced by the surveyors prior to the overlay. The manhole or valve cover location may be double checked by using a metal detector prior to digging out the location. If the surface is milled full-width, no vertical adjustment may be needed.

Figure 65. Manhole Iron Raised after Overlay

One of the negative impacts associated with this process is the need for a second lane closure and disruption of traffic. One way to avoid this is to use spacer ring inserts that match the thickness of the new resurfacing as shown in Figure 66. These spacers are simply placed into the old ring and anchored into place, and the lid is replaced prior to resurfacing. Then the resurfacing is done over and around them. This saves the time and cost of relocating and raising the old hardware, and—perhaps most importantly—avoids a second disruption of traffic.



a. Clean Up Existing Manhole Ring & Cover

b. Install Manhole Riser Ring

Figure 66. Manhole Riser Ring Placed Prior to Overlay

3.9 Public Notification

Although not a technical item, notifying the public is an important part of preparations for street repair or resurfacing work. This is especially true for work on streets in neighborhoods and commercial areas, where the street work will affect people's ability to come and go from homes and businesses. These notifications must also give warning that cars normally parked on the street are expected to be moved. Notifications can take the form of news releases to local media outlets and through social media. Also, temporary signs and door-hanger notifications are common practices. Some agencies go a step further and use the notification process as an opportunity to distribute educational brochures about the agency's pavement management program and any special taxes or funding that is being put to work.

4. Quality Assurance and Troubleshooting

The purpose of this chapter is to discuss the need for a Quality Assurance (QA) program and to provide troubleshooting tips for any problems that can be encountered during pavement repairs or preparations for resurfacing. The information and tables provided are primarily from the Caltrans Maintenance Technical Advisory Guide (MTAG), but they have been modified with information from the FHWA checklists and the experience of the authors.

4.1 Quality Assurance

The following field considerations are a guide to the importance of performing pavement repairs. The information below should be considered in order to promote a successful job outcome. As thoroughly as possible, the answers to these questions should be determined before, during, and after construction, as appropriate. The staff and equipment needed to do this work will vary by job type and size. Some topics may need attention from several staff members and disciplines. Field supervisors should also be acquainted with this information. The intention of the tables is not to form a report, but to highlight important aspects and components of the project's process. Some information is product specific and, therefore, is contained in the relevant standard specifications, special standard provisions, or special provisions.

The information is presented in three sections:

1) Crack Treatments

2) Patching

3) Special Preparations for Resurfacing

4.1.1 Crack Treatments

Quality Control of a crack treatment operation consists of: (a) inspection of the operation, (b) sealant sampling and testing, (c) calibration of the equipment, and (d) inspection of the equipment. This section contains a brief discussion of each activity.

Unfortunately, pavement preservation activities often do not command an adequate amount of attention by inspection services. With millions of dollars going towards a pavement reconstruction/rehabilitation project, hundreds of thousands to a surface treatment project, and only tens of thousands to a crack treatment project, it is easy to understand how an agency prioritizes the activities of their limited inspection personnel with limited budget.

Likewise, training is often not a high-priority activity for crack treatment operations. Personnel need to understand the importance of their activities and the proper method of application; and training is critical. Many organizations depend on on-the-job training, and in some cases, this approach works well. However, it is all too easy for uniformity of on-the-job training to suffer due to time constraints and limited manpower. In addition, if bad habits are developed, generations of employees can inherit them.

Training resources on crack treatments are available, for example, through ISSA and FHWA/PPRA. Many states require inspectors to be certified for construction inspection. The development of an appropriately scoped certification program for crack treatment operations should be considered. "Just-in-Time Training" is an approach that has been used in a variety of situations ranging from safety training to materials handling and could be a viable option.

When sampling any material for evaluation, it is critical that the sample truly represent the materials being evaluated. A bad sample provides bad information on the material.

The key calibration component for crack sealing equipment is to ensure that the temperature control on the melter is working properly. Based on research by Masson et al. (2008), overheating may cause damage to the sealant material.

Equipment should be visually inspected for obvious defects prior to the start of each workday. Equipment manufacturers include maintenance recommendations with their specific equipment, and these recommendations should be followed.

Table 7 summarizes some of the preliminary considerations for crack treatments. Table 8 describes the inspection considerations before crack seal activities, while

Table 9 summarizes the items on the inspection of equipment for cracking sealing. Table 10 summarizes project inspection items. This information is primarily a compilation of information from the Caltrans MTAG (2009) and the FHWA checklist for crack treatments (2019).

Table 7. Preliminary Considerations for Crack Treatments

PRELIMINARY CONSIDERATIONS	
PROJECT SELECTION & DESIGN	• Is the project a good candidate for crack sealing or filling? • What type of cracking exists? Severity? Quantity? • Are there base failures? • How much bleeding or flushing exists? • Is the pavement raveling? • What is the traffic loading? • Is the base sound and well drained? • Would an overlay or surface treatment (e.g., scrub seal) be a better solution for widespread cracking? • Crack survey done? • Determine bid/plan quantities.
DOCUMENT REVIEW	• Crack activity (movement) & climate information • Application specifications & procedures • Special provisions for project • Traffic control plan
DETERMINING APPLICATION TYPE	• What type of application should be used? • Are agency guidelines and requirements being followed? • Should the cracks be pre-sawn/routed? • Should a hot lance be required?
MATERIAL CHECKS	• Has a crack survey been done? • Quantity of material needed? • Material from an approved source? (if required) • Is the material appropriate for the climate and traffic level? • Application temperature and the safe heating temperature? • What special handling requirements are needed: flash point, heating rate, allowable storage time at high temperatures, cold application? • Should the material sampled and submitted for testing? • Will sanding be required?

Table 8. Pre-Crack Seal Inspection Considerations

PRE-CRACKSEAL INSPECTION CONSIDERATIONS	
SURFACE PREPARATION	• Are cracks routed per specifications (if required)? • Are secondary cracks to be sawn or routed? • Have the cracks been cleaned? • Is a hot lance required for the climate?
WEATHER REQUIREMENTS	• Have air and surface temperature been checked at the coolest location on the project? • Do air and surface temperatures meet agency and sealant/filler manufacturer requirements? • Weather forecast? Application should not begin if rain is likely. • Application should not begin if freezing temperatures are expected.
TRAFFIC CONTROL	• The signs and devices used must match the traffic control plan. • Flaggers should not hold the traffic for extended periods of time. • Unsafe conditions, if any, must be reported to a supervisor. • Signs must be removed or covered when they no longer apply.

Table 9. Equipment Inspection and Considerations for Crack Sealing

EQUIPMENT INSPECTION AND CONSIDERATIONS	
SAWING/ ROUTING UNIT	• Is the routing unit fully functional? • Are the cutting bits sharp to avoid spalling or cracking? • Are replacement cutting bits available? • Are the routing head the correct size (width)? • Is all equipment free of leaks? (hydraulic oil, diesel, motor oil etc.) • Is there a dust collector (if required)?
CRACK SEALING UNIT	• Is the sealing unit functional? • Does the unit have temperature control (for hot applied sealants)? Is the temperature controller working properly and is the measuring device calibrated? • Does the sealing unit provide adequate pressure to deliver material to the crack at an appropriate rate? • Is a kettle applicator being used? Is the kettle being kept at least partially full at all times? • Is the applicator unit re-circulating sealant during idle periods? • What applicator is being used to ensure that the material is flush with the pavement surface? • Is all equipment free of leaks? (hydraulic oil, diesel, motor oil etc.)

Table 10. Project Inspection Considerations for Crack Sealing

PROJECT INSPECTION CONSIDERATIONS	
CRACK SEALING OR FILLING APPLICATION	▪ Does the operator have safety gear appropriate for the job? ▪ Are sealant blocks being put into the hot kettle safely? ▪ If routing, does it follow the cracks closely? ▪ Are the routed dimensions (width and depth) correct? ▪ Are the cracks dry at the time of sealing? ▪ Does the sealing operation follow directly behind the routing/cleaning/drying operations? ▪ Does sealant flow evenly, with no surging? ▪ Is kettle kept at least part full at all times? ▪ Is the material at the correct application temperature? ▪ Is the squeegee shape correct; clean and free of build-up, correct width and used centered on the crack? ▪ Is sealant not been reheated more than the allowable number of times and for the recommended periods of time? ▪ Are there excessive bubbles in the material (caused by water)? ▪ Is the crack channel filled from the bottom up and not overfilled? ▪ Is the final surface smoothed to be flush with the pavement surface? ▪ Is over-banding and smearing minimal, not wasteful? ▪ Is sealant re-applied to any areas that are under filled? ▪ Is application stopped as soon as any problems are detected? ▪ Does the sealant pick-up or track under traffic?
CLEAN UP	▪ All material spills are cleaned up. ▪ All loose sand (if used) is removed from the traveled way prior to opening to traffic.

4.1.2 Patching

Table 11 through Table 16 summarize the important aspects of Quality Assurance (QA) for performing a patching project. They include information from the Caltrans MTAG (2009) and FHWA Checklists (2019). Table 11 describes the preliminary responsibilities for patching; Table 12 shows the material checks for patching; Table 13 describes the pre-patching inspection responsibilities; Table 14 discusses the equipment inspection for patching; Table 15 shows the weather and traffic control for patching activities; while Table 16 describes project inspection responsibilities for patching.

Table 11. Preliminary Responsibilities for Patching

PRELIMINARY RESPONSIBILITIES	
PROJECT REVIEW	▪ Are pothole "quick-patches" adequate, or are digouts required? ▪ Extent of the potholes? ▪ Cause? ▪ Is base failure extensive? ▪ Will a resurfacing be applied after the repair? ▪ Traffic level? Heavy vehicles? ▪ What time of year will repairs be performed? ▪ Types and quantities of materials required.
DOCUMENT REVIEW	▪ Material specifications; appropriate for climate and traffic? ▪ Dig out/patching methods & procedures ▪ Special Provisions for project ▪ Traffic Control Plan (TCP)

Table 12. Material Checks for Patching

MATERIAL CHECKS	
SPRAY INJECTION OR COLD-MIX PATCHING	**SPRAY INJECTION PATCH** ▪ Is the emulsion produced by an approved source? ▪ Has the emulsion been sampled and submitted for testing? ▪ Does the aggregate meet all specifications? Is it clean? ▪ Is the tack emulsion suitable for the climatic conditions? **COLD MIX PATCH** ▪ Is the cold-mix binder appropriate for climate & traffic? ▪ Is the cold-mix workable at the required temperatures? ▪ Is the ambient temperature high enough for materials used?
SPECIAL COLD-MIX QUICK PATCH	▪ Are materials compatible with the job requirements? ▪ Are the materials appropriate for climate (per mfgr.)? ▪ Is the pothole small and deep enough for this material to work?
HMA DIGOUT PATCHING	▪ Is the tack emulsion the correct grade? ▪ Is the HMA type appropriate for traffic loading? ▪ Is the HMA asphalt binder correct for the climate conditions? ▪ Is there equipment for keeping the HMA hot until used?
EDGE REPAIRS	▪ Is the tack emulsion correct grade? ▪ Is the HMA Type correct for the traffic loading? ▪ Is the new base course material (if used) within specification?
LEVELING / SKIN PATCHING	▪ Is the HMA aggregate gradation correct for the rut depth and traffic loading? ▪ Is the tack coat emulsion correct grade ▪ If a sealcoat, is the tack emulsion correct grade? ▪ If a sealcoat, is the aggregate clean, dry, and properly graded?

Table 13. Pre-patching Inspection Responsibilities

PRE-PATCHING INSPECTION	
SURFACE PREPARATION	▪ If quick-patch material is option (smaller pothole patches), little or no prep is required. ▪ For digouts, has all loose material and debris been removed? ▪ Will saw-cutting or jackhammer be used for any digout? ▪ Are the cut edges of dig outs in sound material? ▪ Are there surface drainage problems (x-slope? shoulder?) ▪ Has the base material been re-compacted? ▪ Have cut faces received a tack coat?

Table 14. Equipment Inspection for Patching

EQUIPMENT INSPECTIONS	
INJECTION PATCHING MACHINE	▪ Is the equipment free of leaks (hydraulic oil, motor oil, etc.)? ▪ Does the aggregate flow freely? ▪ Does the emulsion flow freely? ▪ Is the compressor working properly?
DIG OUT COLD PLANERS	▪ Is the milling head the proper size (width)? ▪ Are the cutting tips sharp and do they make a clean cut without spalling the edges? ▪ Is the equipment free of leaks (hydraulic oil, motor oil, etc.)?
POTHOLE PATCHERS HMA/COLD MIX	▪ Are heating systems working to control mix temperature? ▪ Are all conveyors working? ▪ Is the equipment for applying tack coat working properly? ▪ If cold mix is used, and heated, is the unit properly vented?
SKIN PATCHING	▪ Are the heating systems working to control mix temperature? ▪ Is spreader box properly adjusted? ▪ **For sealcoat applications:** ▪ Is the emulsion spray rate properly controlled? ▪ Is aggregate spreading being properly controlled? ▪ Is full sweeping done prior to traffic?
COMPACTION DEVICES	▪ Is the equipment free of leaks (hydraulic oil, motor oil, etc.)? ▪ Do rollers meet specification requirements? ▪ If using a rubber-tired roller, use proper tire pressure? ▪ If required, are compaction measurement devices (e.g., nuclear gages) calibrated and in working order?

Table 15. Weather and Traffic Control for Patching

WEATHER REQUIREMENTS	▪ Have the air and surface temperatures been checked at the coolest location on the project, and do they meet agency requirements? ▪ Are ambient temperatures warm enough for products used? ▪ Patching should not begin if rain or snow is likely. ▪ Emulsion applications should not start in cold weather
TRAFFIC CONTROL	▪ The signs and devices used match the traffic control plan. ▪ Traffic speed control, if necessary ▪ Flaggers do not hold the traffic for extended periods of time. ▪ Signs are removed or covered when they no long apply.

Table 16. Project Inspection Responsibilities for Patching

PROJECT INSPECTION RESPONSIBILITIES	
INJECTION PATCHING	▪ Does the operator have the correct safety equipment? ▪ Is the weather going to be warm enough for at least 48 hours after patching? ▪ Are the aggregate and emulsion within specification? ▪ Is there enough emulsion and aggregate available? ▪ Is the aggregate clean and dry and within specification? ▪ Are the holes to be patched dry? ▪ Is the tack coat applied evenly to vertical cut faces and at an appropriate rate? ▪ Does the aggregate flow evenly into the hole? ▪ Does the emulsion evenly coat the aggregate? ▪ Is the hole finished with a layer of clean aggregate?
COLD-MIX PATCHING	▪ Is an approved "quick-patch" product being used? ▪ Is the cold mix within specification? ▪ Is weather appropriate for the cold mix? ▪ Is there enough mixture available? ▪ Is the mixture workable at the temperatures of application? ▪ Does the mix fill the holes evenly? ▪ Are multiple lifts required (hole depth >4inches; 100 mm)? ▪ Does the mixture compact satisfactorily? ▪ Is the surface finish even and uniform? ▪ Do tires pick up the final surface? If so, is sand available?
HMA DIG OUTS AND EDGE REPAIRS	▪ Is the weather going to be warm enough for patching? ▪ Is the HMA mix and tack emulsion within specification? ▪ Is there enough emulsion and HMA available? ▪ Is the HMA at the proper temperature for compaction? ▪ Are the areas clean and dry, and in a stable pavement? ▪ Is the pavement cut edge clean and sound? ▪ Is the tack coat on the cut face at an appropriate rate? ▪ Does the HMA mix fill the holes evenly? ▪ Are multiple HMA lifts required (hole depth >4 inches) ▪ Does the mixture compact satisfactorily? ▪ Is vibratory roller turned off when contacting the old pavement? ▪ Are at least three repeat passes made with the roller? ▪ Is the final surface even and uniform? Not a bump or depression? ▪ Do tires pick up the final surface? If so, apply sand and sweep.

PROJECT INSPECTION RESPONSIBILITIES	
OPENING THE PATCHING TO TRAFFIC	▪ Patch must have time to cool (HMA) or cure (cold mix) before opening to traffic. ▪ Have density tests been done (if required) ▪ Sweep if sand is used. ▪ Reduced speed limit signs or pilot cars needed? ▪ Remove all construction-related signs when opening to normal traffic.
CLEAN UP	▪ All loose patching material and sand should be removed. ▪ Remove binder application or spills from all areas including curbs, sidewalks, and radius applications.

4.2 Troubleshooting Guide

This section provides information to assist maintenance personnel with troubleshooting problems with crack treatment and patching projects. The Tables include information from the Caltrans MTAG (2009). Troubleshooting checklists are also available through the Federal Highway Administration (FHWA, 2019) for both crack treatments and patching.

4.2.1 Crack Treatment

The troubleshooting information presented in Table 17 associates common problems with their potential causes. For example, a sealant separating from the sides of a crack may be caused by application to a wet crack surface, dirty crack surface, poor material finishing technique, application of cold sealant, insufficient material, rain during the application, or application during cold weather. In addition, Table 18 lists some commonly encountered problems and their recommended solutions.

Table 17. Trouble Shooting Crack Sealing and Filling Projects

CAUSE	PROBLEM						
	ALL SEALS			EMULSION SEALS ONLY			
	TACKY PICKS UP	RE-CRACKS QUICKLY	BUMPY SURFACE	SEPARATION FROM CRACK SIDES	EMULSION SEALER NOT BREAKING	EMULSION SEALER BREAKS TOO FAST	EMULSION SEALER WASHES OFF
Crack Wet					•		•
Sealant Not Cured	•			•		•	
Crack Dirty	•	•		•		•	
Insufficient Sanding	•			•		•	
Poor Finish, Wrong Tools	•	•	•	•		•	
Sealant Too Cold		•	•				
Sealant Too Hot	•			•			
Application Too High	•		•	•			
Application Too Low		•	•				
Sealant Degraded Due to Overheating	•	•	•	•	•	•	•
Rain During Application					•		•
Cold Weather		•			•		
Hot Weather	•		•	•		•	

Table 18. Common Problems and Related Solutions for Crack Sealing

PROBLEM	SOLUTION
Tracking	• Reduce the amount of sealant or filler being applied. • For hot applied materials, allow to cool or use sand or other blotter. Sweep up loose sand. • Allow sufficient time for emulsions to cure or use a sufficient amount of sand for a blotter coat. Sweep up loose sand. • Ensure the sealer/filler is appropriate for the climate in which it is being placed.
Pick out of Sealer	• Ensure cracks are clean and dry. Use hot lance? • Increase temperature of application. • Use the correct sealant for the climate. • Allow longer cure time before trafficking. • Apply light sanding; sweep up excess.
Bumps	• Check squeegee and ensure it is leaving the correct flush finish. • Have squeegee follow more closely to the application. • Decrease the viscosity of the sealer. • Apply sealant in fall or spring and strike off excess. • Use a low expansive crack sealant. • Change the rubber on the squeegee. • Stop or minimize using overbanding.

4.2.2 Patching

Table 19 provides information to assist maintenance personnel with troubleshooting problems with patching and edge repair projects. It outlines common problems and related solutions.

Table 19. Common Problems and Related Solutions for Patching

PROBLEM	SOLUTIONS
POTHOLE PATCHES	▪ ● **Loss of patch material** – Wrong material used; poor compaction; little or no preparation ▪ ● **Hump or Depression** – too much/little patch material used, poor compaction ▪ ● **Spray Injection patch ravels out** – dirty aggregate; not enough emulsion applied
DIG-OUT HMA PATCHES	▪ **Distortion/ Shoving** – low stability mix for heavy traffic level ▪ **Depression** – too little material placed, poor compaction ▪ **Bump** – too much material placed ▪ **Raveling** – poor compaction; "dry" asphalt mix ▪ **Cracking** – patch too thin; week pavement structure; "dry" mix ▪ **Surface Flushing** – "rich" asphalt mix
LEVELING PATCHES (HMA)	▪ **Re-ruts under traffic** – poor compaction; steel drum roller used (instead of rubber-tired); low stability mix ▪ **Raveling** – poor compaction; mix cools before rolling
SEAL COAT LEVELING PATCHES	▪ Loss of Cover Aggregate o incorrect emulsion rate is sprayed o dirty/dusty aggregate o aggregate isn't spread while the emulsion is still brown o aggregate isn't promptly rolled o emulsion "breaks" before traffic was allowed o allow longer cure time before traffic
EDGE PATCHES	▪ ● Cracking – unstable base; patch too thin; not enough tack coat applied to vertical face at cut edge ▪ ● Distortion – low stability mix; poor compaction ▪ ● Water ponding – cross-slope inadequate

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Terminology

Base Layer: Supporting layer beneath HMA surfacing; aka. aggregate base (AB)

Cape Seal: This multi-layer treatment type is a combination of a chip seal with a slurry seal or microsurfacing seal as the top layer. The chip seal may have an emulsion binder or a hot applied binder such as an asphalt rubber. Cape seals typically increase the durability of the road and produce a smooth surface.

Chip Seal: A bituminous binder is applied followed by aggregate (chip) application and rolling to embed the aggregate into the binder.

Cold Mix Asphalt: A "cold" mixture of aggregate and asphalt binder (cutback or emulsion) usually produced in a central mixing plant and able to be stockpiled for use at a future time.

Corrective Maintenance: This maintenance type is conducted in response to defects that affect operations of a facility and integrity of pavement sections. This form of maintenance is also known as reactionary maintenance and can be conducted throughout the lifespan of a pavement. It is typically used to fix localized defects and return a pavement to an acceptable service quality. Maintenance activities include patching of potholes and replacement of concrete slabs.

Crack Treatments: Cracking occurs when a stress is built up that exceeds the tensile or shear strength of the pavement materials. Crack treatments are used to repair cracks in pavement surfaces.

> **Crack sealing:** "Working crack" undergoes significant horizontal or vertical movement over a year. Caltrans uses ¼ inch or more horizontal movement annually as the "working crack" criterion, while FHWA requires only 1/8 inch per year. Crack sealing is used to treat working cracks to prevent the intrusion of water and incompressibles into the cracks.
>
> **Crack filling:** Materials are placed into "non-working" cracks to substantially reduce water infiltration and reinforce adjacent cracks. Cracking filling is commonly used as a longitudinal crack or joint treatment.

Distresses: Deterioration resulting from factors including the environment, construction and design practices, material selection, or load on pavement. There are two distinct categories of distresses: functional and structural.

- **Functional distress:** Deterioration affecting the pavement's ability to serve its function of being a safe, smooth, and quiet surface for comfort while driving. Using preservation treatments, minor functional problems can be addresses as long as there are no structural problems.

- **Structural distress:** Deterioration resulting from excess weight and loading, lack of thickness and support for the pavement structure. Considerable deterioration does not allow for the distresses to be addressed using preservation treatments.

Flush coat: Also known as a fog seal, a flush coat is a light application of asphalt emulsion over a new chip seal to lessen the loss of chips and help protect motorists from broken windshields.

Hot Mix Asphalt: A high quality mixture of aggregate and asphalt binder produced in a closely controlled hot mixing plant.

Microsurfacing: This treatment type relates to slurry seals; however, the main variation between the two is the quality of the materials. With this treatment, the polymer and asphalt residual content is greater than that of slurry seals, and the aggregate quality is better. In addition, the cost is greater than slurry seals; however, the cure time is more time-efficient than slurry seals.

Minor Rehabilitation: The distresses addressed are non-structural enhancements to improve the lifespan, surface cracking, and restore the pavement to serve its function. The distresses could be a result of environmental factors. These are typically referred to as pavement preservation techniques occurring midway in a pavement's lifespan when the quality of the roadway begins to diminish.

Patching: Patching is used to replace the localized pavement distresses or disintegration with new asphalt paving materials. Patching may be temporary for safety, or a more permanent treatment.

Pothole patching: Potholes occur when the pavement material in a highly distressed, localized area has broken up and disappeared, leaving a distinct hole in the roadway. In pothole patching, the distressed area is removed and replaced, or additional material is simply added to fill up the pothole.

Digout repairs: Where pavement defects are more extensive than the single pothole area, but still localized in nature, larger "digout patches" may be needed. These larger digouts often address areas of structural weakness and involve the removal of all or part of the asphalt layer and some of the base layer to restore adequate structure.

Edge Cracks: Although edge failures are usually out of the primary wheel paths, their presence can accelerate the deterioration of the entire pavement. Edge failure repair/patch is used to fix this type of distresses and may also involve the correction of drainage problems (e.g., restoring cross-slope, removing shoulder vegetation dams) and restoration of shoulder-backing material for support of the pavement edge.

Levelling: Leveling course is used to filling and levelling local areas of wheel path rutting or roughness. leveling (a.k.a. "skin patching") is often used to restore a uniform surface.

Pavement Preservation: The practice of utilizing a cost-effective system that allows for the tracking and recording to extend and enhance the quality and life of a pavement. In addition, preservation would serve as a way to improve safety and provide good ride quality. The system primarily focuses on preventive maintenance as a cost-effective way to treat roadways and improve the quality of the road.

Pre-treatments: Anything done to a pavement in preparation for a resurfacing.

Preventive Maintenance: Cost-effective strategy for treatment to roadway system accounting for ways to preserve the roadway and prevent deterioration in addition to improving or maintaining the condition of the roadway. This is typically performed early, before significant structural deterioration can appear. Some activities include joint sealing, crack sealing and filling, as well as utilizing chip seals and slurry seals.

Quality Assurance (QA): It is defined as all those planned and systematic actions taken by the Agency and Contractor to provide the necessary confidence that the procured material and workmanship will satisfy the quality requirements of the contract. QA includes Quality Control (QC), Agency Acceptance, and Independent Assurance (IA).

Quality Control: QC is the system used by the Contractor to monitor, assess and adjust production and placement processes to ensure that the material and workmanship will meet the specified quality. QC is the responsibility of the Contractor.

Agency Acceptance: Acceptance is the system used by the Agency/ Engineer to measure the degree of compliance of the quality of the materials and workmanship with the Contract requirements by inspection or evaluation. Acceptance is the responsibility of the Agency/Engineer and will be conducted in accordance with these Specifications.

Independent Assurance: IA is an unbiased and independent system used to assess all sampling, testing and inspection procedures used for QA. IA is the responsibility of the Agency/Engineer and is conducted in accordance with these Specifications.

Routine Maintenance: Maintenance performed routinely to preserve the roadways condition or to return the roadway to a proper level of service. Some maintenance activities include crack filling and/or sealing, as well as maintaining the drainage system, both of which are performed throughout a pavement's life.

Slurry Seal: Combination of emulsion and aggregate spread with a slurry paver which is used for public roads, highways, airport runways, parking lots, and a multitude of other surfacing projects throughout the world. It has been accepted and incorporated into many maintenance programs as a cost-effective maintenance treatment.

Slurry Surfacing: Is a generic term which includes slurry seals and microsurfacing, as a pavement preservation treatment which provides an economical means for maintaining and improving the functional condition of an existing pavement while sealing it from water intrusion. Microsurfacing is a more durable product than slurry seals and should have a longer life as a maintenance treatment.

Subgrade: The soil supporting a pavement structural section.

Surface Treatment: A thin, non-structural asphalt surfacing usually applied as a pavement preservation treatment with the intent of sealing the underlying pavement against water intrusion (e.g., slurry seal, chip seal)

Surface Type: Surface type is the uppermost layer of a pavement structural section and is dependent on the type of material used, whether it be HMA or Portland cement. The surface type also depends on the functional class (arterial, collector, residential).

Treatment Type: A certain treatment used to treat specific distresses on a roadway. These treatments would include chip seals, slurry seals, microsurfacing, Cape seals ad thin HMA overlays. For some situations, treatment combinations are required to ensure quality performance of the roadway.

Acronyms

AASHTO: American Association of State Highway and Transportation Officials

AB: Aggregate Base

ADA: American Disability Act

ADT: Average Daily Traffic

AEMA: Asphalt Emulsion Manufacturers Association

AI: Asphalt Institute

AIA: Asphalt Interlayer Association

APWA: American Public Works Association

AR: Asphalt Rubber

ARRA: Asphalt Recycling and Reclaiming Association

ASCE: American Society of Civil Engineers

ASTM: American Society for Testing and Materials

Caltrans: California Department of Transportation

CCPIC: City and County Pavement Improvement Center

CIR: Cold In-place Recycling

CP2C: California Pavement Preservation Center (CSU Chico)

DOT: Department of Transportation

FHWA: Federal Highway Administration

HMA: Hot Mixed Asphalt

GRCS: Geosynthetic Reinforced Chip Seal

IRI: International Roughness Index

ISSA: International Slurry Surfacing Association

LCCA: Life Cycle Cost Analysis

MTAG: Maintenance Technical Advisory Guide (Caltrans)

MTI: Mineta Transportation Institute

NAPA: National Asphalt Pavement Association

NCAT: National Center for Asphalt Technology

NCHRP: Nation Cooperative Highway Research Program

OGFC: Open Graded Friction Course

PCC: Portland Cement Concrete

PCI: Pavement Condition Index

PME: Polymer Modified Emulsion

PMS: Pavement Management System

PPE: Personal Protective Equipment

PPRA: Pavement Preservation and Recycling Alliance

QA: Quality Assurance

QC: Quality Control

RAP: Reclaimed Asphalt Pavement

TCP: Traffic Control Plan

TRB: Transportation Research Board

WSDOT: Washington State Department of Transportation

About the Authors

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