Sealing and Filling of Cracks for Bituminous Concrete Pavements

Selection and Installation Procedures

Michigan Department of Transportation

Developed by Michigan Technological University in cooperation with the Michigan Department of Transportation

Acknowledgments

This manual is intended to provide basic guidelines to assist field personnel in the identification of candidate pavements for crack sealing and/or filling operations. It is also intended to provide guidelines to aid in the selection of the proper treatment. The guidelines and procedures described in this manual are supported by The Michigan Department of Transportation (MDOT). This manual was produced from materials provided by both MDOT and Michigan Technological University (MTU) by Michigan's Local Technical Assistance Program (LTAP). Non of the above mentioned parties warrant the material in this manual.

The primary source of information for this manual was the *Development of a Laboratory Screening Test for Asphalt Pavement Crack Sealants and Fillers, June 1998*. The report was submitted by:

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I INTRODUCTION

Background

Cracking is one of the most common distresses encountered on asphalt concrete (AC) pavements. Cracking can occur as single or multiple, transverse, longitudinal, block, or alligator cracks. Transverse and longitudinal cracking is usually addressed by sealing or filling the cracks with an asphalt-based material to reduce infiltration of moisture. Prevention of moisture infiltration will help mitigate the occurrence of further distresses, such as stripping of asphalt cement from aggregate particles and weakening of the pavement structure. Many methods are currently used to seal or fill cracks, and it is difficult to know which method and material will be the most cost-effective for a given situation.

Cracking in an asphalt pavement is caused when traffic and temperature fluctuations create strains that the pavement cannot accommodate. Several factors influence crack development, including temperature extremes and rate of change, pavement structural design, construction quality, temperature susceptibility, aging characteristics of the asphalt cement, and traffic characteristics (SHRP 1993). Cracking can occur as transverse, longitudinal, alligator, and block cracking.

Cracks are inevitable, and neglect will lead to a more rapid deterioration of the road surface. Preventative maintenance can help extend the life of the road and provide a smoother road surface. Maintenance activities can range from crack sealing and filling, to other, more involved surface treatments. Crack sealing and filling activities have been performed for quite some time. When performed properly, crack sealing and filling can extend the life of the pavement to the point where the cost of the activities is outweighed by the cost-benefit of the additional pavement life (SHRP 1993).

Importance of Sealing and Filling

Crack sealing and filling of asphalt pavements is a necessary and important maintenance activity that is required to mitigate the infiltration of water and incompressibles into a pavement system. Sealing/filling operations should be instituted when pavement cracks first develop, as timely treatment will help prevent further pavement deterioration. The effects of not sealing/filling cracks include increased pavement deterioration, including raveling, tenting, and migrating of cracks, along with potholes and frost heave damage.

Crack sealing and crack filling are two different activities, and the difference between them must be understood to effectively treat a pavement. Crack sealing is a rigorous operation, intended to prevent water from entering the pavement structure. It involves thorough crack preparation followed by the placement of a high-quality material in a specific configuration. Please refer to Figure 1.1 for an example of an AC pavement crack suitable for sealing. Crack sealing is normally used on working cracks. Working cracks are de-

Figure 1.1 - AC pavement crack suitable for sealing

fined as those that experience considerable horizontal and/or vertical movement as a result of temperature changes and/or traffic loading. Working cracks typically have horizontal and/or vertical crack movements of 2.5 mm or more (Smith et al. 1991).

Crack filling is an activity designed to reduce the amount of water infiltrating into a pavement and reinforce the adjacent pavement. Please refer to Figure 1.2. This crack is unsuitable for sealing due to the high degree of spalling and secondary cracking present, but is a good candidate for filling. Crack filling is normally applied to cracks unsuitable for sealing and to non-working cracks. Non-working cracks are defined as those that experience relatively little horizontal and/or vertical movement as a result of temperature changes and/or traffic loading. Non-working cracks typically have horizontal and/or vertical crack movements of less than 2.5 mm (Smith et al. 1991).

Cracking can be repaired in a variety of ways, ranging from pavement maintenance activities, such as surface treatments and crack filling, to full-scale pavement rehabilitation projects, like resurfacing (Smith and Romine 1993). Alligator and longitudinal cracks in the wheel paths are indicative of structural deficiency, and require at least partial reconstruction for an effective solution (Turgeon 1989). Proper pavement design and drainage can help control these types of cracks. Transverse and longitudinal cracking are most often caused by thermal changes and are related to the cold temperature and age stiffening characteristics of the asphalt concrete, which in turn is directly related to the properties of the asphalt binder. This type of cracking should be treated soon after initiation to minimize the infiltration of water that can cause further deterioration.

Transverse and longitudinal thermal cracks can be treated through crack sealing and filling. The goal is to reduce or eliminate the infiltration of moisture into the pavement structure, and prevent incompressible materials from entering the crack. Water can lead to accelerated fatigue, stripping, pumping, and other pavement damage. It is commonly believed that sealing and filling are justified because they extend pavement life. The earlier these detrimental effects can be prevented, the better the chance that a pavement's life will be extended (Turgeon 1989).

Figure 1. 2 - AC pavement crack suitable for filling

Selection Criteria for Sealing and Filling

General Overview

The first step of any crack treatment operation is an evaluation of the pavement to assess the extent and type of cracking present and to determine the appropriate treatment(s). If a pavement is badly deteriorated, has large quantities of closely spaced or random cracking, or other major deficiencies are present, crack filling or sealing may not be appropriate and another repair should be used. Good pavement condition data is essential for proper treatment selection.

Most highway agencies have developed policies and criteria that specify the type of maintenance to be performed on cracked pavements. These criteria are often based on an assessment of the overall pavement condition and crack characteristics. These policies also specify when cracks should first be filled or sealed.

Requirements exist at most highway agencies regarding air temperatures and the seasons when crack filling/sealing operations should be conducted. In cold temperatures, the pavement contracts and the cracks open to their widest. In hot temperatures, the pavement expands, closing the cracks. To limit failures due to excessive expansion and contraction, it is preferable to perform the crack treatment activities during the moderate spring and fall temperatures when the cracks are midway between the extremes. However, given the environmental conditions that Michigan encounters, conducting these operations in the spring and fall may put the operation in the middle of a wet period. As such, care must be taken so that the sealing and filling operations are conducted in dry conditions. If a treatment is placed too early in the spring or too late in the fall, moisture may be present in the pavement creating frost action that will render a seal or fill ineffective. It is important to keep moisture out of the base for this reason. Additionally, it is important that when performing a seal/fill operation, the crack is clean. Having a clean crack permits adhesion and provides for a better overall treatment.

Although MDOT currently has no set criteria of when to perform crack sealing and filling, they typically initiate crack sealing within 2 to 3 years of a bituminous overlay over concrete, and within 3 to 8 years after a full-depth bituminous pavement construction or a bituminous overlay over a bituminous pavement.

Determining Crack Density and Edge Deterioration

The first step in the treatment selection process is to characterize the density of cracking and level of edge deterioration using the basic definitions presented in the *SHRP Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements – Manual of Practice* (Smith and Romine 1993).

Crack density thresholds are not defined in the SHRP Manual "because experienced personnel can usually make reasonable assessments of density" (Smith and Romine 1993). Although this may be true, some guidance regarding the determination of crack density is necessary. As a starting point, the threshold between moderate and high density will be established at the point where transverse and longitu-

Linear Crack Length per 100 m Pavement Section	Density
< 10 m	Low
10 m to 135 m	Moderate
> 135 m	High

Table 2.1 - Determination of Crack Density

dinal cracking will be classified as block cracking. According to the SHRP publication entitled *Distress Identification Manual for the Long-Term Pavement Performance Project* (SHRP 1993), this transition occurs at a crack spacing of 3 m. This approximately translates to 10 full width transverse cracks and one full-length longitudinal crack in a 100 m long pavement section. In a 3.5 m wide pavement lane, a total of 135 m of linear cracking in a representative 100 m of pavement is thus assumed to be a reasonable threshold value between moderate and high density. The demarcation between low and moderate density is less clear. Generally, two to three transverse cracks within a 100 m long pavement section would justify a sealing operation, and thus a reasonable threshold is 10 m of linear cracking in a representative 100 m length of pavement. Table 2.1 can be used as a general guideline when determining crack density.

Figures 2.1 - 2.6 illustrate various degrees of crack densities and edge deterioration.

Once a reasonable determination of crack density and edge deterioration is made, Figures 2.7, 2.8, and 2.9 outline the appropriate course(s) of action for low, moderate, and high density cracking, respectively. *These flow charts are meant to give a general overview of the appropriate actions. These are not hard-and-fast rules, and good engineering judgement is needed in each situation to verify that the correct course of action is being taken.*

Figure 2.1 - Example of low density cracking

Figure 2.2 - Example of cracking with low edge deterioration

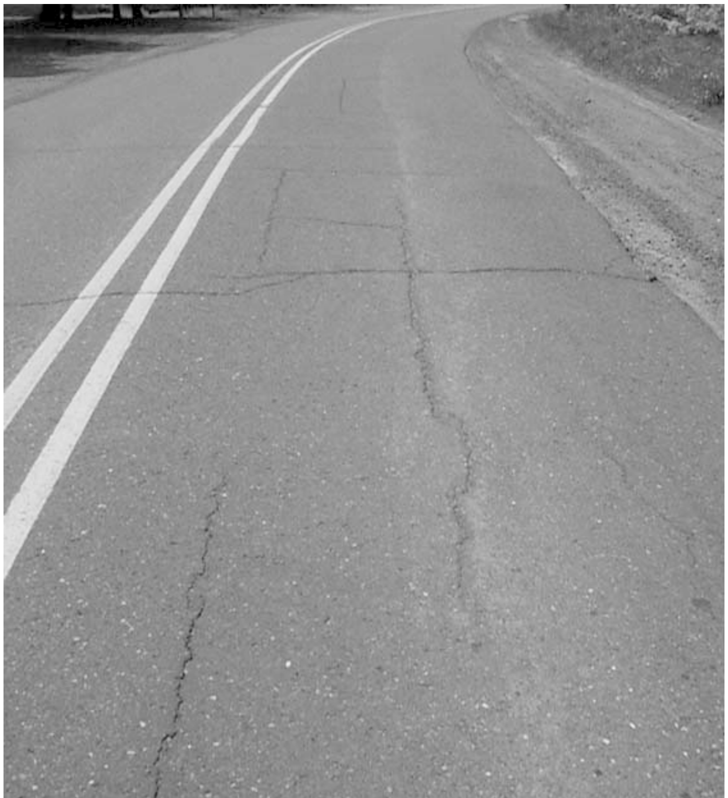

Figure 2.3 - Example of medium density cracking

Figure 2.4 - Example of cracking with medium edge deterioration

Figure 2.5 - Example of high density cracking

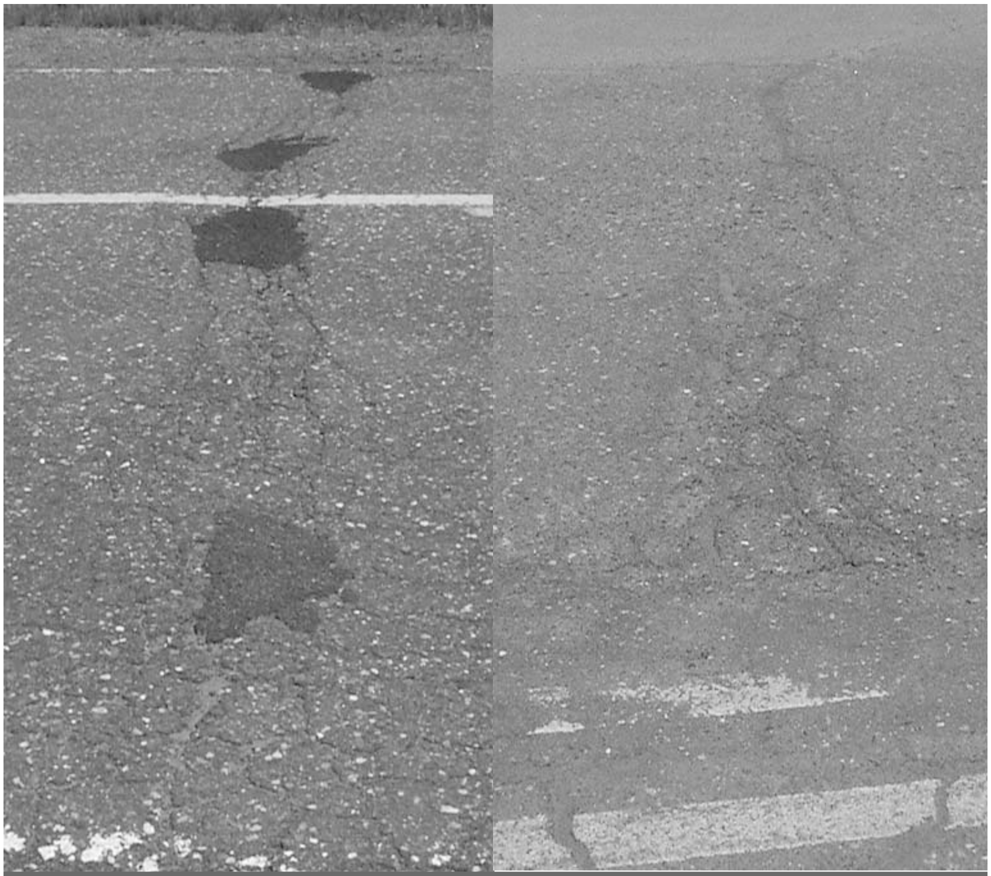

Figure 2.6 - Examples of cracking with high edge deterioration

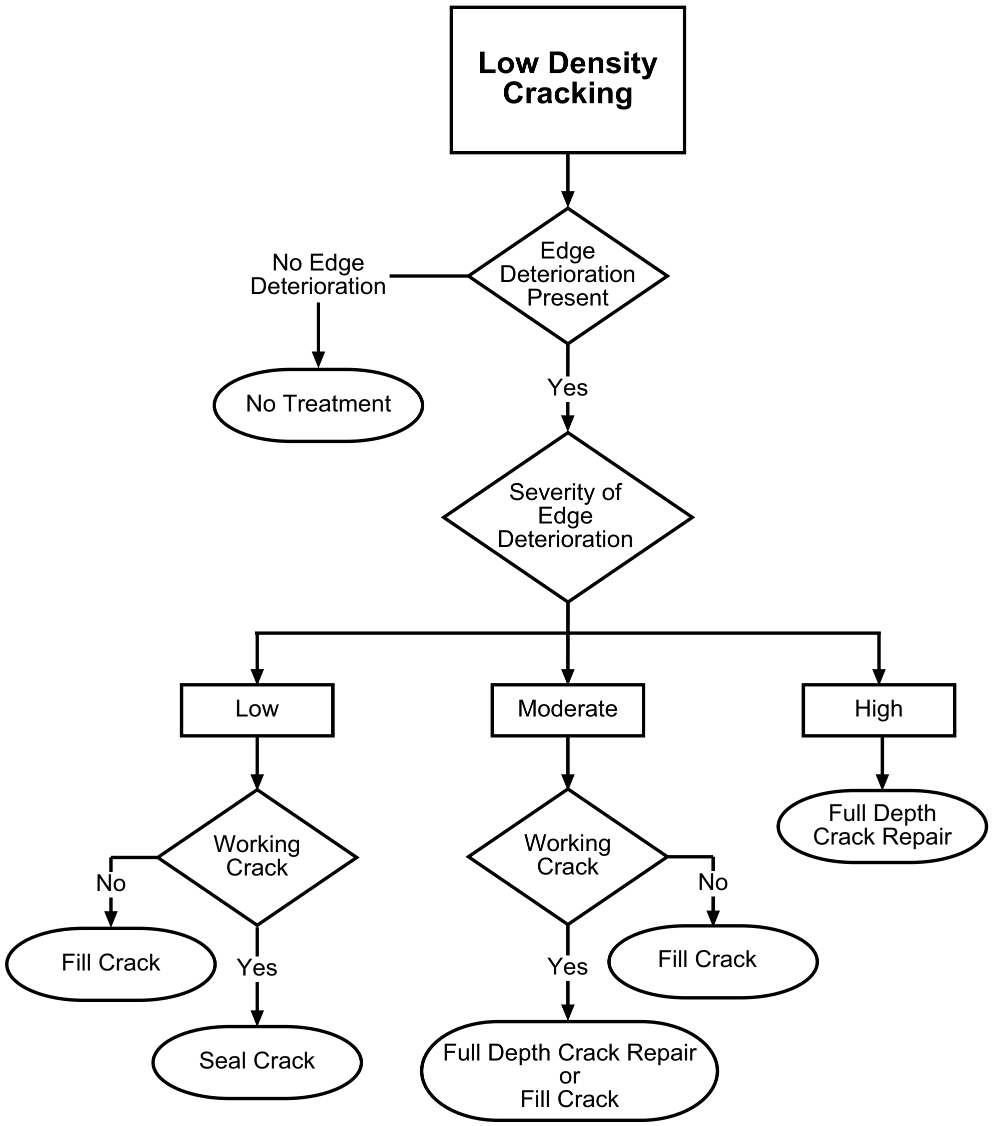

Figure 2.7 - Appropriate treatment for low density cracking

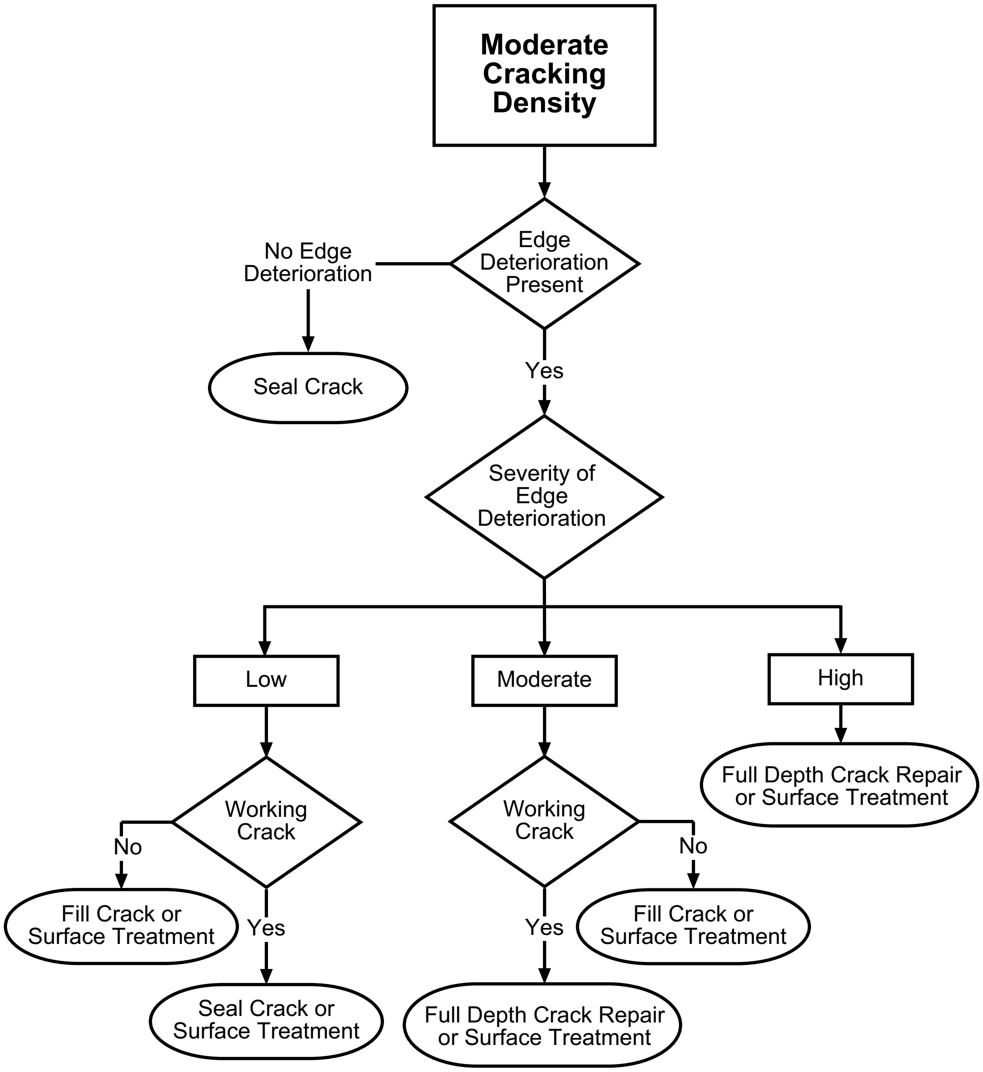

Figure 2.8 - Appropriate treatment for moderate density cracking

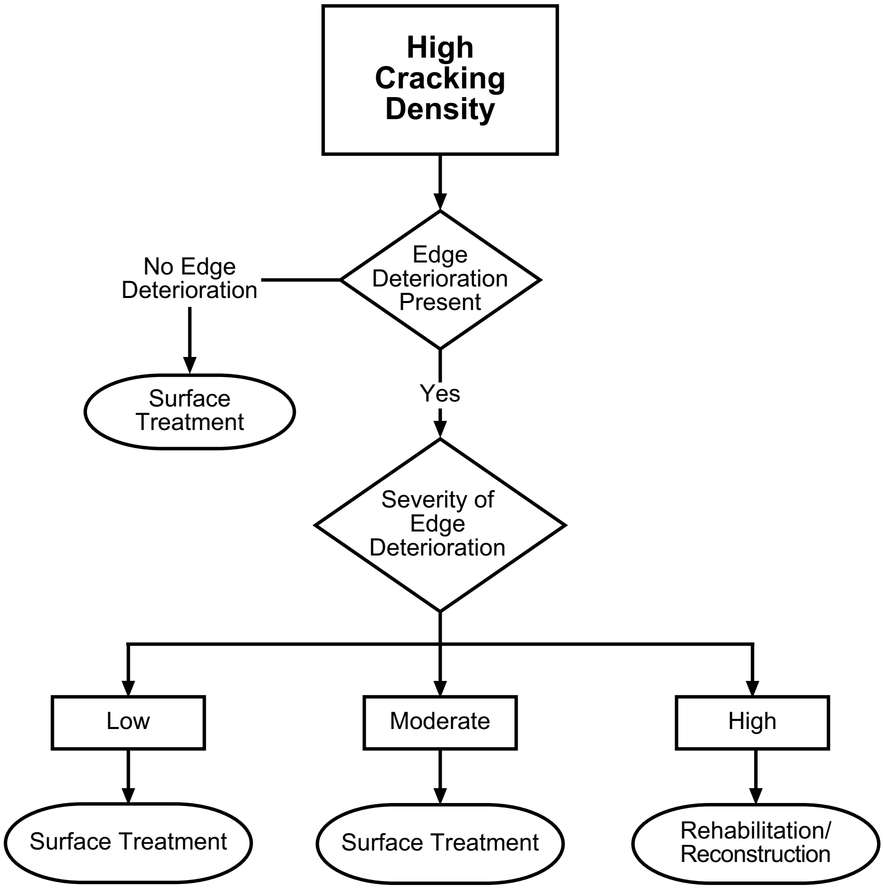

Figure 2.9 - Appropriate treatment for high density cracking

As shown in these figures, crack sealing is primarily used to address working cracks of low to medium density with low edge deterioration. Crack filling is used on low to moderate density non-working cracks with low to moderate edge deterioration, or on working cracks of low to medium density with moderate edge deterioration.

Other treatments listed include crack repair and surface treatment. Crack repairs typically involve the partial or full depth removal of the cracked material. The area is replaced with new bituminous materials. Surface seals include chip seals, slurry seals, and microsurfacing. In depth descriptions of these treatments is beyond the scope of this manual, and the above descriptions are for reference only.

Sealing and Filling Procedures

Traffic Control and Worker Safety

Traffic control in the work zone is a vital part of any crack treatment, whether it is a stationary or a moving operation. Proper work zone operations will ensure both the safety of the work crew and motorists. The materials and equipment used in crack filling and sealing operations also present safety concerns for workers. Proper safety attire should be worn and workers should be made aware of all safety precautions related to the material and equipment used in the operation. **Please note: It is beyond the scope of this manual to instruct current MDOT policies regarding work zones and worker safety. Please refer to the appropriate MDOT publications for a detailed overview of these practices.**

Installation Procedures

Procedures vary between crack sealing and filling operations. *Regardless of the operation performed, proper execution of the procedures and quality workmanship are essential and cannot be overemphasized.* Crack sealing and filling operations consist of at least two and up to five steps, depending on the type of treatment. In order to determine the proper procedures for a particular situation, review current MDOT specifications. Given a situation where all five steps are necessary, the typical order is:

1. Crack cutting
   crack sealing only
2. Crack cleaning and drying
   crack sealing and filling
3. Material preparation
   crack sealing and filling
4. Material placement
   crack sealing and filling
5. Blotting
   possible in both crack sealing and filling

Crack Cutting

Crack cutting is performed during crack sealing operations and is done to create a uniform, rectangular reservoir, centered as closely as possible over a particular crack, while inflicting as little damage as possible to the surrounding pavement (Smith and Romine 1993). Crack cutting is done with either a diamond saw or rotary impact router. Please refer to Figures 3.1 and 3.2 for an example of a rotary impact router and to Figures 3.3 and 3.4 for an example of a diamond blade saw. The saw has a wide, small diameter blade to cut a reservoir, while a router has multiple impacting blades or teeth. The saw creates a smooth walled reservoir, while the router creates rougher edges. The saw creates a more rectangular reservoir and a higher percentage of aggregate surface area, while the router is more maneuverable, which allows it to follow the contours of the crack more closely. The router also has a higher production rate than sawing. A diamond saw can have production rates of 1.2 to 2.1 m/min, while a rotary impact router can have production rates of 3.6 to 4.6 m/min. (Smith and Romine 1993). However, the rotary

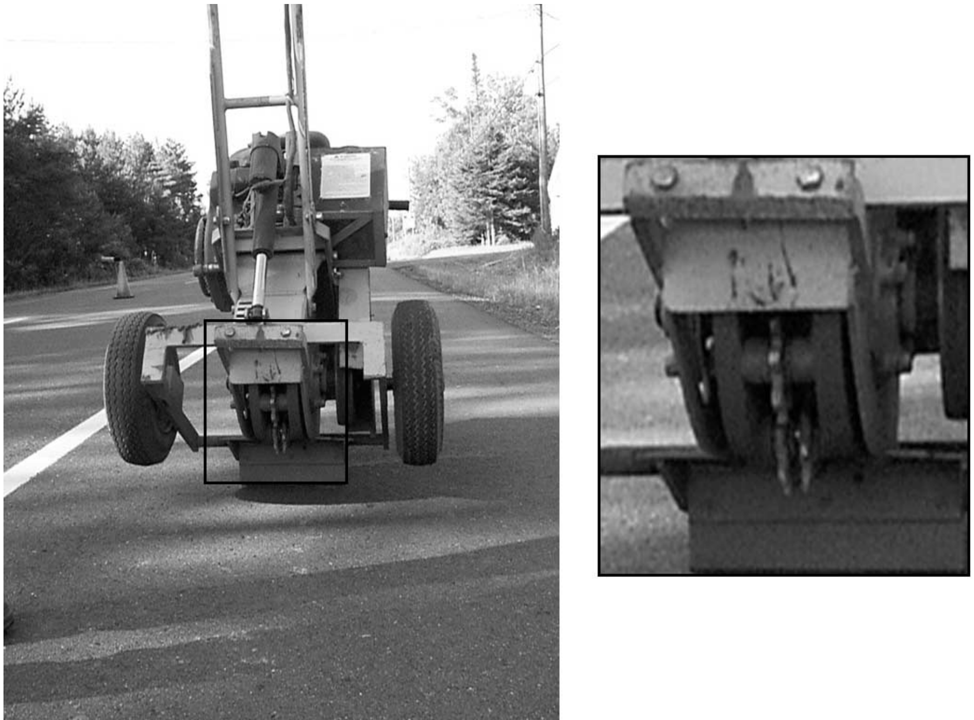

Figure 3.1 - Rotary impact router with close-up of blade

Figure 3.2 - Crack cutting using rotary impact router

Figure 3.3 - Close-up of diamond saw blade

Figure 3.4 - Example of diamond saw

impact blades wear faster, and poor reservoir configurations result from worn blades. It is important to closely follow the crack when creating a reservoir to maximize the effectiveness of the operation. Figures 3.5 and 3.6 are examples of properly cut cracks. Widths and depths of the cut will vary depending on the configurations.

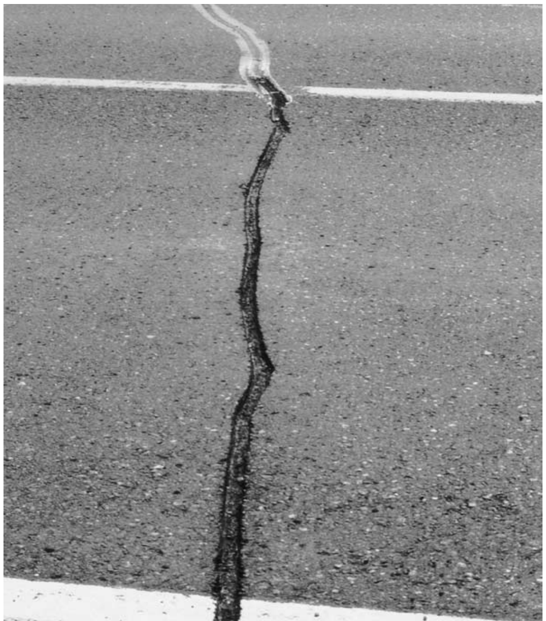

Figure 3.5 - Properly cut crack

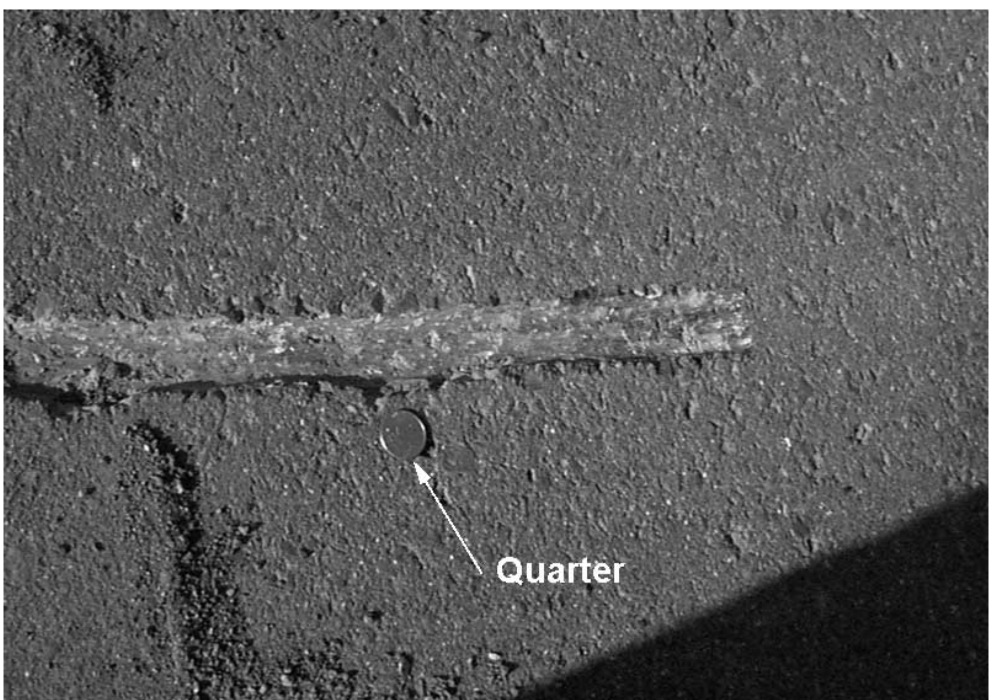

Figure 3.6 - Example of relative width of cut crack

Crack Cleaning and Drying

Crack cleaning and drying is done to provide a clean, dry crack channel and to remove any loose materials from the crack. A clean, dry crack is extremely important, as a large percentage of sealant failure is caused by adhesion failure with the crack wall. Crack cleaning can be done by hand tools, brushing or sweeping, airblasting, hot airblasting, or sandblasting.

High-Pressure Airblasting

Airblasting with compressed air is an effective method of removing particles and dust. High-pressure airblasting equipment must be able to provide a continuous, high-volume, high-pressure airstream delivering 620 kPa (90 lb/in^2) and 4.3 m^3/min (150 ft^3/min) flow (Smith and Romine 1993). Refer to Figure 3.7 for an example of high-pressure airblasting followed by hot airblasting. Please note that the worker in front is performing the high-pressure airblasting and the worker following is performing the hot airblasting. Working in tandem enables the team to effectively clean and dry cracks more quickly than performing these operations separately.

Due to the fact that most modern air compressors introduce water and oil into the air supply, it is essential that the compressors are equipped with moisture and oil filters. The presence of either water or oil in the crack will inhibit the sealing and filling material's bond (Smith and Romine 1993).

Figure 3.7 - Crack cleaning through high-pressure airblasting followed by hot airblasting

Hot-Airblasting

Hot airblasting with a hot compressed-air lance, or heat lance, is effective for both cleaning and drying a crack. The heat lance must be able to produce 1370°C (2500°F) and a blast velocity of 600 m/s (1970 ft/s). The heating provides two unique benefits. Moisture is quickly evaporated, improving potential for bond, and if the material installation follows closely behind, the heated surface can enhance the bonding of hot-applied materials (Smith and Romine 1993). Overheating is a danger and must be avoided, as it can scorch and weaken the edge of the crack or reservoir. Typically, hot airblasting is not required.

Sandblasting

Sandblasting operations should be conducted during dry weather conditions and should be followed up by airblasting to remove the sand from the crack reservoir and roadway. Sandblasting not only removes dust and debris, but also strips away any loose particles. It is a specialized procedure that is usually more costly due to the equipment and materials needed. Refer to Figure 3.8 an example of the sandblasting operation.

Figure 3.8 - Crack cleaning through sandblasting

Material Preparation

Proper material preparation is necessary for an effective seal. The specific material preparation requirements provided by the manufacturer should be followed. These include the minimum placement temperature, material heating temperatures, prolonged heating guidelines, recommended pavement temperature and recommended moisture conditions.

It is important that the specific recommendations from the material manufacturer are followed, as overheating of the material should be avoided. Overheating the material may alter the material's properties significantly. This can have a detrimental effect on the operator's ability to install the material, and adversely affect the performance of the material. If the material is overheated, it should be discarded and new material should be prepared. This will cause delays that will effect the entire operation. Furthermore, it may also necessitate repeating previous crack cleaning activities.

Material Placement

There are several configurations commonly used for the application of fillers and sealants. These configurations range from simply filling unprepared cracks, to cutting a specific size of reservoir for sealant placement . Typical placement configurations are shown in Figure 3.9. Reservoirs are generally associated with sealing operations, and simple overbands are usually used with filling operations, though this is not always the case.

Once the filling or sealing operation commences, it is important that the entire operation moves at a steady pace. It is vital that the kettle operator regularly monitors the temperature and quantity of material in the kettle. As mentioned earlier,

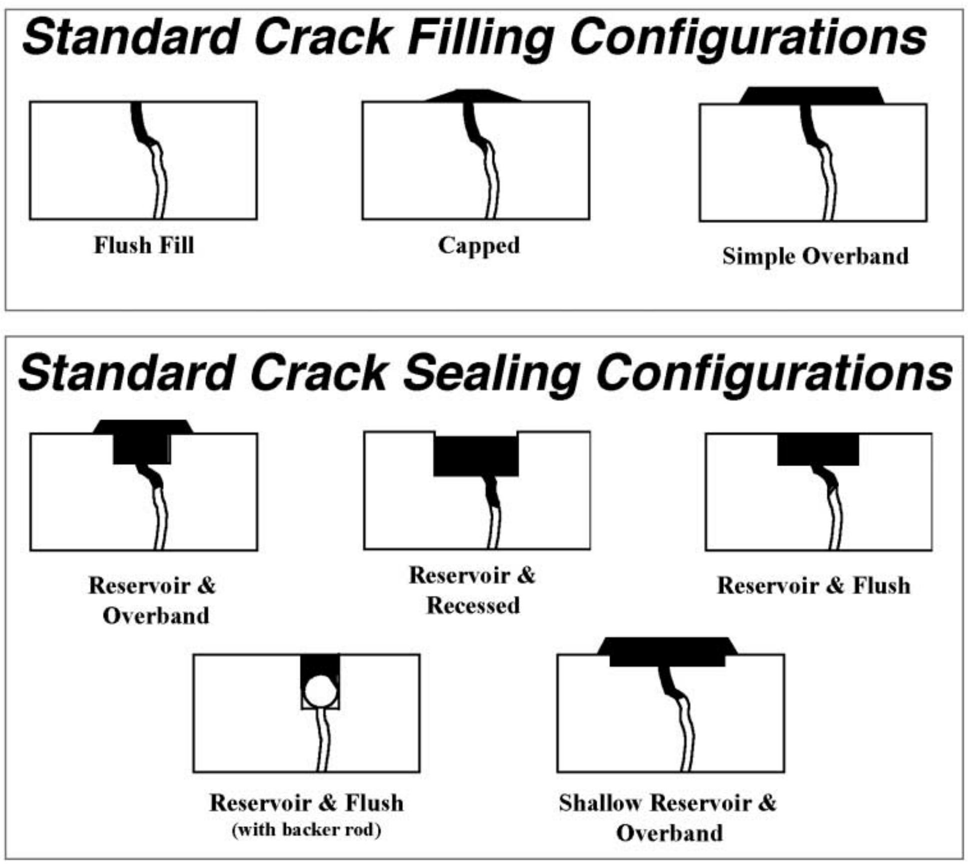

Figure 3.9 - Typical placement configurations

overheating can suspend the entire operation. Under-heated material can also produce problems as the material may not flow correctly, and it may not bond properly. This is another benefit of applying the material in the relatively mild weather of spring and fall, as maintaining material temperature in cold and hot weather is more difficult.

The application procedures for all crack sealing and filling materials are basically the same. The material should be applied in a continuous motion from the bottom of the crack up to reduce the chance of trapping air beneath the material. Enough material should be applied to provide the desired configuration. Occasionally, additional material must be applied to ensure proper coverage.

Filling Configurations

Crack filling involves either a one or two person team placing the filling material and then spreading it out over and into the crack(s) with a squeegee. Squeegees are typically U or V shaped to push the material and concentrate it over the crack. One person installation is done using an attachment to the material application wand. Refer to Figure 3.10 for an example of a filling operation. Advantages of filling include the need for less equipment and smaller installation crews.

Figure 3.10 - Single operator using application wand and attachment to apply fill material

Sealing Configurations

In a sealing operation, sealant is placed either flush with the surface or slightly recessed within a cut reservoir. The purpose of the reservoir is to create room for enough material to be applied, create a desirable sealant shape, and provide a uniform surface for the sealant to adhere to. The sealant also may be recessed to prevent plow and traffic damage.

Chehovits and Manning (1984) give the following advantages of a typical sealant configuration:

> First the sealant is applied only to surface level, resulting in a neat appearance when compared with the band-aid configuration. Second, the sealant is not on top of the pavement surface, and therefore it is not directly exposed to abrasion by vehicle tires. The crack widening operation also cleans the crack faces, which provides intact surfaces for the sealant to adhere to. Another advantage when compared with the band-aid configuration is that the sealant is subjected to a lesser amount of strain when the pavement contracts in cold weather because of the increased width of the sealant.

A combination reservoir overband configuration exists in which the material is placed in a reservoir and also above the reservoir in an overband. Refer to Figure 3.11. This configuration attempts to combine the advantages and eliminate some of the disadvantages of the reservoir and overband configurations. A combined overband and reservoir will limit cohesive failures and reinforce the edges of the reservoir (Turgeon 1989).

Figure 3.11 - Combination of reservoir and overband

The sealant is usually placed directly into the reservoir or crack. For cracks greater than 10 mm wide, a bond breaker, such as polyethylene foam backer rod, may be placed in the bottom of the crack. The purpose of this backer rod is to prevent the material from running down in the crack, prevent a three-sided bond, and control the shape factor (Smith and Romine 1993). A backer rod is installed after the crack has been properly cleaned and before sealant application. The backer rod should be non-absorptive, flexible, and compatible with the sealant material being used. The size should be about 25 percent larger in diameter than the crack width (ERES 1993). Refer to Figure 3.12 for example of backer rod installation.

Figure 3.12 - Installation of backer rod

The shape factor is the ratio of the width to the depth of the sealant. The shape of the sealant can be controlled by using a backer rod or by specifying the dimensions of the crack reservoir. The shape factor influences stress development in a sealant, and thus the performance of the sealant system. A sealant experiences tensile stress as the pavement contracts and the crack widens. As the ratio of depth to width increases, so does the stress on the sealant/crack interface. This can lead to adhesive failure. A reservoir that is wider than it is deep will lessen the stress on the sealant (Turgeon 1989).

Reservoir dimensions may vary depending on location and/or specifications. Typical dimensions for an overband are 75-100 mm wide and a thickness of 3 mm. Reservoir dimensions are controlled by the shape factor. Typical standard reservoir widths are 12.5 – 40 mm , and 12.5 – 20 mm deep. The shallow reservoir is typically about 40 mm wide and 4 mm deep. The cutting depth may be greater for a reservoir if a backer rod is used.

Blotting

Blotting protects the uncured crack treatment material from tracking under traffic. Blotting material is typically used in areas where traffic has to travel on the material before it has had time to cure. Blotting material is also frequently used in areas of stop-and-go traffic and where there may be traffic turning on the material.

The blotting material should be applied immediately after the material is placed and finished. Toilet paper, talcum powder, lime, sand, and limestone chips are commonly used as blotting materials.

Figure 3.13 - Installation of toilet paper as blotting material

Figure 3.14 - Installation of sand as blotting material

Estimating Costs and Quantities

Estimating material requirements is a difficult task, as each situation is unique. A reliable estimate of the required materials can be the deciding factor in whether or not a certain section of road receives the appropriate maintenance activities. Table 4.1 can be used to help determine the material requirements

Determining Material Quantity Requirements	
A. Length of roadway to be treated	____________ m
B. Length of sample segment inspected	____________ m
C. Amount (length) of targeted crack in sample segment inspected	____________ lin m
D. Amount (length) of targeted crack in roadway [D=C x (A/B)]	____________ lin m

Table 4.1 - Determining material quantity requirements

Sealing costs range from $3.94 to $8.20 per meter of crack, while filling costs range from $0.50 to $3.61 per meter of crack. When estimating costs, it is strongly recommended that you use a representative 100 m section (minimum) of roadway per kilometer as the sample segment. This representative section can then be used to calculate an estimate using the pay item in the specifications. If the work will not commence until the following season, it may be necessary to add 25% or more to the determined quantity.

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