Applied Research and Innovation Branch

COLORADO DEPARTMENT OF TRANSPORTATION HOT MIX ASPHALT CRACK SEALING AND FILLING BEST PRACTICES GUIDLINES

Carrie Truschke, P.E.
David Peshkin, P.E.
Kelly L. Smith, P.E.
Kurt D. Smith, P.E.

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Carrie Truschke, David Peshkin, Kelly L. Smith, and Kurt D. Smith

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115 West Main Street, Suite 400
Urbana, IL 61801

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16. Abstract

Crack sealing and filling on hot mix asphalt (HMA) pavements are cost-effective pavement preservation techniques that improve pavement performance and extend the life of existing pavements. If performed in a timely and effective manner, crack sealing can extend the life of HMA pavements.

The Colorado Department of Transportation (CDOT) supports the sealing of cracks on HMA pavements. Under Study No. 11.40, CDOT Pavement Crack Seal and Fill Best Management Practices, CDOT sponsored this study to update its procedures and guidelines for crack sealing and filling of HMA pavements. The draft Guidelines included in this report reflect CDOT experience, current state-of-the-practice, and the most recent research findings, and address where and when to perform crack sealing and filling, material selection, installation methods, construction inspection, and follow-up evaluation.

Three primary tasks were undertaken to meet the project objective including a literature review and survey of agencies, a draft of recommended best practices guidelines, and recommended procedures for monitoring, evaluating, and documenting the effectiveness of crack sealing and filling methods and materials.

Implementation

Once the final guidelines are developed, CDOT will broadly communicate the existence of the new guidance, highlighting any changes and how they will contribute to improved performance. Developing and presenting a 2- to 4-hour workshop and training session on improved crack sealing practices would also benefit all maintenance crews engaged in the activity.

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Prepared By:

Applied Pavement Technology, Inc.
115 W. Main Street, Suite 400
Urbana, Illinois 61801

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Colorado Department of Transportation
DTD Applied Research and Innovation Branch
4201 E. Arkansas Avenue
Denver, Colorado 80222
(303) 757-9506

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- Phillip Anderle, R-4 Maintenance
- Donna Harmelink, CO Div. FHWA
- Frank McCoy, R-6 Maintenance
- Mark Mueller, Staff Maintenance and Operations
- Mike Stanford, Materials and Geotechnical Branch

CDOT's Study Research Managers were Richard Griffin and Roberto De Dios.

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EXECUTIVE SUMMARY

Research Needs

Crack sealing and filling are pavement preservation techniques applied to in-service hot mix asphalt (HMA) pavements to reduce moisture infiltration into the pavement structure, thereby preventing weakening of the underlying layers and the potential for accelerated deterioration. If performed in a timely and effective manner, crack sealing is expected to improve pavement performance and extend pavement life.

The Colorado Department of Transportation (CDOT) supports the sealing of cracks on HMA pavements throughout its network. However, CDOT's most recent guidance on crack sealing and filling was published in 1991 and 1994, and in need of review and updating. Under Study No. 11.40, *CDOT Pavement Crack Seal and Fill Best Management Practices*, CDOT sponsored research to update its procedures and guidelines for crack sealing and filling of HMA pavements. The draft Guidelines developed under this study reflect not only CDOT's experience, but also current state-of-the-practice and the most recent research findings; the guidelines address such critical item as where and when to perform crack sealing and filling, material selection, installation methods, construction inspection, and follow-up evaluation.

Completion of Research

Three primary tasks were performed under this project:

- Conduct a literature review and survey of practice.
- Prepare a draft of recommended best practices guidelines.
- Prepare recommended procedures for monitoring, evaluating, and documenting the effectiveness of crack sealing and filling methods and materials.

The literature review focused on published and current research on crack sealing and filling in HMA pavements, including materials, procedures, and performance. In addition, two surveys of practices were performed: one a national survey (which yielded 22 agency responses) and the other a survey of CDOT maintenance engineers and managers (which included 7 responses).

During this process, it was observed that many agencies distinguish between crack sealing and crack filling, but CDOT noted that for in-house sealing operations it is problematic to distinguish between crack sealing and crack filling activities within a project. Therefore, CDOT uses a single operation for its in-house sealing contracts, one that generally conforms more to a "filling" activity than to a "sealing" activity. In the context of the guidelines document, the use of the term "crack sealing" is generically used to refer to CDOT's in-house practices, regardless of whether it actually refers to a crack sealing or crack filling operation.

Use of Research by CDOT

The primary product of this study is the Guideline Recommendations in Chapter 3 and the guidance on evaluating crack sealing failures in Appendix D. It is envisioned that the final guidelines adopted by CDOT would be extracted from this guidance and disseminated as a stand-alone document.

The proposed guidance presented in Appendix D can be used by CDOT to monitor, evaluate, and document the effectiveness of crack sealing and filling practices. This guidance can then be used to evaluate practices covered in the Guidelines so that these can be improved over time.

Implementation Statement

In order to improve the overall performance of crack sealing operations in Colorado, CDOT is encouraged to consider the following recommendations:

- Develop guidance on project selection to include identification of appropriate windows of opportunity to seal non-load related cracking.
- Where feasible, differentiate between crack sealing and crack filling operations. Transverse cracks that open and close with temperature changes present the greatest challenge for successful crack sealing and would benefit most from the use of more rigorous crack preparation procedures and high-quality sealant materials.
- Apply sealant in the spring and fall when cracks are opened a moderate amount and before deicing applications have started, but avoid times when dew may develop within the crack.

- Link sealant material selection to the temperature limits and performance requirements identified in ASTM D6690.
- For enhanced sealant performance in working cracks, consider the creation of a uniform crack reservoir specifically dimensioned for the sealant to be applied. The reservoir can most easily be created using a rotary impact router; however, if the cracks are quite straight, a diamond-blade crack saw may be used.
- Encourage the adoption of self-inspection procedures in which crack conditions are verified, and sealant is placed in clean and dry pavement.
- Use troubleshooting guidance to identify the cause and to resolve any premature failures.

Once the final Guidelines are developed, CDOT is encouraged to broadly communicate the existence of the new guidance, highlighting any changes and how they will contribute to improved performance. Developing and presenting a 2- to 4-hour workshop and training session on improved crack sealing practices would also benefit all maintenance crews engaged in the activity.

Benefits of Research

It is expected that the results of this research can be used to improve CDOT's crack sealing practices. This should contribute to better sealed roads and longer lasting crack sealing projects, which in turn would result in an increased return on the investment in sealing cracks in HMA pavements in Colorado.

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CHAPTER 1. INTRODUCTION

Crack sealing and filling on hot-mix asphalt (HMA) pavements are cost-effective pavement preservation techniques applied to in-service hot-mix asphalt (HMA) pavements to reduce moisture infiltration into the pavement structure, thereby preventing weakening of the underlying layers and the potential for accelerated deterioration. If performed in a timely and effective manner, crack sealing is expected to improve pavement performance and can extend the life of HMA pavements life. As an operation, crack sealing may be performed either as a stand-alone activity or in preparation for an existing pavement to receive an overlay.

The Colorado Department of Transportation (CDOT) supports the sealing of cracks on HMA pavements. However, CDOT's most recent guidance on crack sealing and filling was published in 1991 and 1994 and is in need of updating.

Under Study 11.40, *Procedures and Guidelines for Crack Sealing and Filling HMA Pavements*, CDOT sponsored research to update agency practices related to HMA crack sealing and filling. The results of that research are incorporated into this document.

Project Objective

The objective of this study is to update CDOT's procedures and guidelines for crack sealing and filling of HMA pavements. Guidelines will reflect current state of the practice and the most recent research findings, and will cover where and when to perform crack sealing and filling, material selection, installation methods, construction inspection, and follow-up evaluation.

Project Approach

Three primary tasks were undertaken to meet the project objective. These are briefly described below.

Literature Review (Task 1)

A literature review was made of published and current research on crack sealing and filling in HMA pavements, including materials, procedures, and performance. Sources included the

Transportation Research Information Service (TRIS) database, the Transportation Research Board (TRB) Research in Progress (RIP) database, and the online libraries and publication directories of various highway agencies, industry organizations, and academic institutions, including the following:

- TRB/NCHRP.
- American Association of State Highway and Transportation Officials (AASHTO).
- Federal Highway Administration (FHWA) and National Highway Institute (NHI).
- Other national research programs/foundations.
- Selected state Departments of Transportation (DOT).

As part of this work, a survey was also developed and delivered to state highway and other roadway agencies with environments similar to Colorado's to document their policies and procedures with respect to crack sealing. Finally, interviews were conducted with selected CDOT maintenance superintendents, materials engineers, and managers to document current CDOT practices and experiences.

The results of the literature review and the national and CDOT surveys are summarized in chapter 2, along with CDOT's current policy for crack sealing. An annotated bibliography covering the collected literature is provided in Appendix A. Results from the national survey are summarized in Appendix B, while internal CDOT responses are presented in Appendix C.

Draft Recommended Best Practices Guidelines (Task 2)

The primary product of this study is the *Best Practices Guidelines*, presented in chapter 3 of this report. The *Guidelines* were developed from the information collected in task 1, including the literature search, information collected from other agencies, and input provided by CDOT staff. The *Guidelines* used previous CDOT guidance as a starting point (CDOT 1991; CDOT 1994).

Recommended Procedures for Monitoring, Evaluating, and Documenting the Effectiveness of Crack Sealing and Filling Methods and Materials (Task 3)

In this study the research team has proposed guidance that CDOT can use to monitor, evaluate, and document the effectiveness of crack sealing and filling practices. This guidance can then be used to evaluate practices covered in the *Guidelines* so that these can be improved over time. This guidance is found in Appendix D.

Report Organization

This report is intended to provide all of the deliverables associated with the study objectives. In addition to this introductory chapter, it includes the following chapters:

- Chapter 2. Summary of Reported Information.
- Chapter 3. CDOT Guidelines.
- Chapter 4. Conclusions and Recommendations.
- Appendix A. Literature Review.
- Appendix B. External Survey Results.
- Appendix C: CDOT Survey Responses.
- Appendix D. Procedures for Monitoring, Evaluating, and Documenting the Effectiveness of Crack Sealing and Filling Methods and Materials.

Terminology

A glossary of terms is commonly found as an appendix in similar documents. Because a common understanding of certain terms is central to the reading of this report, key terms are briefly explained and defined here. One set of terms bears special explanation: crack filling and crack sealing. These terms are often used interchangeably to describe the same activity, and this is the case in much of the literature described in Chapter 2, as well as in CDOT's previous policy on the topic. However, it is best practice to distinguish between the two, reserving the term "sealing" to describe the use of materials and practices on cracks that experience movement (opening and closing) and "filling" to describe the placement of sealant (generally of a lower quality) in wider and non-moving cracks.

Adhesion: the bond between the sealant and the sides of the crack or crack reservoir. An adhesion failure is the loss of bond between the sealant and the pavement.

Cohesion: the internal integrity of the sealant material. A cohesion failure occurs when the sealant remains bonded to the sides of the pavement but develops an internal rupture.

Crack filling: the placement of sealing materials into non-working cracks (i.e., cracks that undergo <1/8 inch of annual horizontal movement) to substantially reduce the infiltration of water into the pavement structure. Crack filling also reinforces the adjacent pavement and helps to keep incompressibles out of the pavement structure.

Crack sealing: the placement of higher quality materials into working cracks to reduce the infiltration of water into the pavement structure, reinforce the adjacent pavement, and keep out incompressibles. Crack sealing is differentiated from crack filling in that the sealant material used must adhere to the crack walls while the crack is opening and closing. Crack sealing therefore often includes more extensive crack preparation methods than crack filling, and employs higher quality sealant materials.

Flush fill: a sealant placement configuration in which the sealing material fills the crack up to and even with the surface of the pavement.

Hairline crack: a crack that is visible to the eye but so tight that a knife blade cannot be inserted into it.

Hot-air lance: also referred to as a hot compressed air lance, a device that applies hot, compressed air to both blow clean and to dry a crack.

Non-Working crack: a crack that experiences very little movement due to thermal cycling. Non-working cracks are usually oriented parallel to the pavement centerline, and a common example of a non-working crack is a longitudinal paving joint.

Overband: a sealant placement configuration in which the sealing material both fills the crack and extends onto the surface of the pavement. An overband is centered on the crack and will vary in width and thickness.

Recess: a sealant placement configuration in which the sealing material fills the crack just below the pavement surface. A typical recess is 1/8 inch.

Reservoir: a routed or sawed cut in the pavement surface over a crack to create a channel into which sealant may be placed. Routing a reservoir is associated with crack filling and is more common in HMA pavements than sawing a reservoir.

Router: a mechanical device usually equipped with a rotary spinning blade that is used to cut and widen cracks in order to create a reservoir.

Sealant configuration: the shape of the sealant plug used in a crack. Examples of sealant configurations include: flush fill, overband, recess, rout and fill, rout and overband, and rout and recess.

Working crack: a crack that opens and closes due to thermal cycling. Working cracks are usually oriented perpendicular to the pavement centerline.

CHAPTER 2. SUMMARY OF REPORTED INFORMATION

Many different resources were consulted in order to document current crack sealing practices. A comprehensive review of literature was first performed, followed by a national survey of state highway agencies (SHA) and a local survey of CDOT Maintenance Superintendents. The national survey was divided into four areas of questioning—definitions and policies, materials, procedures, and performance—and yielded responses from 22 agencies. There were seven responses to the CDOT survey, which covered similar topics but included fewer questions. During the surveys, CDOT policy documents governing the practice of crack sealing in Colorado were obtained and reviewed.

This chapter summarizes the results of the literature review and agency practice surveys. The information is presented according to various crack sealing subtopics, such as material selection, sealing procedures, and seal performance. At the end of the chapter is a short summary of the CDOT crack sealing policies unearthed in the study.

Crack Sealing and Filling Definitions and Policies

The distinction between crack sealing and crack filling has long focused on the crack's cyclic movement (daily and annual) and the quality and properties of the material placed in the crack. A large nationwide study of surface maintenance treatments conducted in the 1990s under the Strategic Highway Research Program (SHRP) (Projects H-105 and H-106) produced the *Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements Manual of Practice* (Smith and Romine 2001), which provided the following definitions for the two activities:

- Crack Sealing—The placement of specialized treatment materials above or into *working* cracks (i.e., cracks that undergo ≥ 1/8 inch of annual horizontal movement) using unique configurations to prevent the intrusion of water and incompressibles into the crack.
- Crack Filling—The placement of ordinary treatment materials into *non-working* cracks (i.e., cracks that undergo < 1/8 inch of annual horizontal movement) to substantially reduce infiltration of water and to reinforce the adjacent pavement.

They further distinguished between the two and provided general criteria for their use through a summary table that is presented in table 1.

More recent literature indicates slightly different perspectives on the subject of sealing versus filling. For instance, the Texas DOT (TXDOT) equates crack sealing with placing material in a routed channel and crack filling with the placement of material in or on an uncut crack (Yildirim, Qatan, and Prozzi 2006). They use the criteria given in table 1 and recommend that both operations take place during the winter months when ambient temperatures are between 45 and 65 °F, so that the applied material can more easily penetrate the crack.

Table 1. Recommended criteria for determining whether to crack seal or crack fill (after Smith and Romine 2001).

	Crack Treatment Activity	
Crack Characteristics	**Crack Sealing**	**Crack Filling**
Width, inches	1/5 to 3/4	1/5 to 1
Edge Deterioration (i.e., spalls, secondary cracks)	Minimal to None (≤ 25 % of crack length)	Moderate to None (≤ 50 % of crack length)
Annual Horizontal Movement, inches	≥ 1/8	< 1/8
Type of Crack	Transverse Thermal Transverse Reflective Longitudinal Reflective Longitudinal Cold-Joint	Longitudinal Reflective Longitudinal Cold-Joint Longitudinal Edge Distantly Spaced Block

The Minnesota DOT (MnDOT) uses both a clean-and-seal and rout-and-seal approach for crack sealing, with the former using a good-quality adhesive sealant material targeted for longitudinal cracks, and the latter using a higher quality (greater resilience) sealant targeted for transverse cracks less than or equal to 3/4 inch wide (MnDOT 2008). Crack filling uses a lower quality material and is most often reserved for more worn pavements with more random cracking that is usually wider than 3/4 inch. Spring and autumn are the recommended timeframes for both types of operations.

The working crack criterion used by the California DOT (Caltrans) in its Maintenance Technical Advisory Guide (MTAG) is 1/4 inch of annual movement (Caltrans 2008). In addition, crack sealing is triggered when the crack width exceeds 1/4 inch. Caltrans also makes the general distinction that sealing is considered to be a longer-term treatment while filling is considered a short-term treatment to help hold the pavement together between major maintenance operations or until a scheduled rehabilitation activity.

In the national survey conducted in this study, agencies were asked several questions regarding their definitions and policies for crack sealing or filling, including the circumstances appropriate for each activity, the allowable weather conditions, personnel training requirements, and so on. Since terminology varies from agency to agency, the survey first asked whether or not the agency distinguishes between crack sealing and crack filling. Based on the responses provided, it was found that Colorado and seven other states do distinguish between the two, whereas 15 agencies do not (notwithstanding the fact that Colorado does not employ different methodologies or materials for sealing and filling). The methods of distinguishing included crack characteristics, treatment method, or both.

In terms of how agencies determine whether to seal or fill based on specific crack characteristics, crack width was the most common response, as shown in figure 1 (respondents were allowed to select all options that applied). Furthermore, as illustrated in figure 2, a majority of agencies have set a minimum crack width for sealing, but most have not set a maximum crack width.

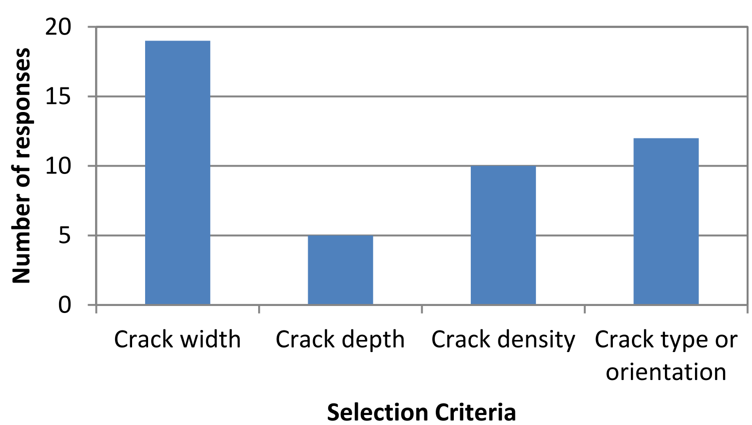


Figure 1. Selection criteria for crack sealing from survey responses.

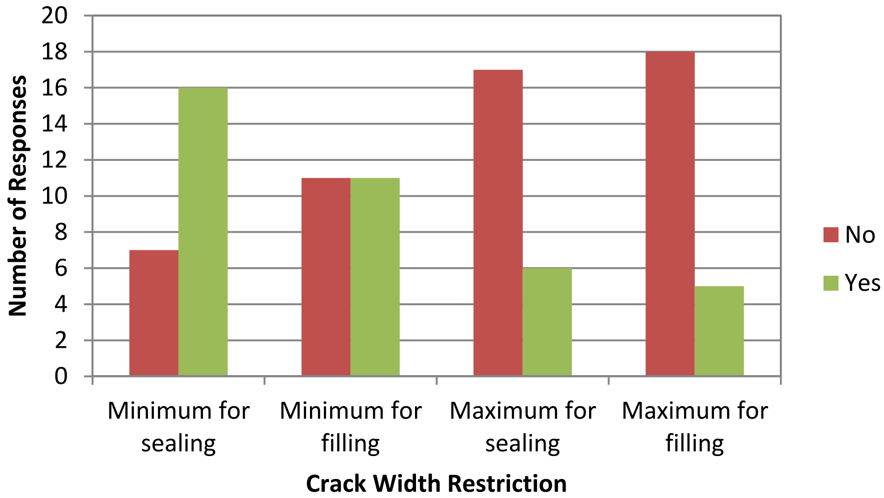


Figure 2. Policy restrictions on crack width for filling and sealing from survey responses.

With respect to the allowable timing of crack sealing and filling, only six of the responding SHAs reported using a particular season for crack sealing, while the other seventeen respondents reported allowing the work throughout two or more seasons (see figure 3). Also, as shown in the first four sets of columns in figure 4, more agencies use minimum allowable temperatures than maximum temperatures. If the results for air and temperature are combined, as seen in the right two columns, most states have a minimum for either air or pavement temperature, although most states still do not specify any maximum temperature.

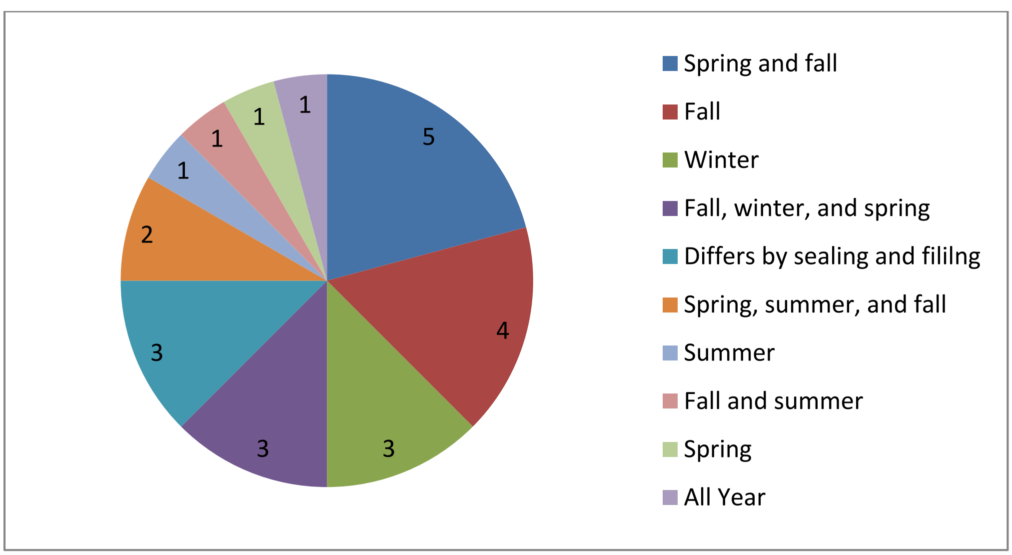


Figure 3. Typical season for crack sealing or filling from survey responses.

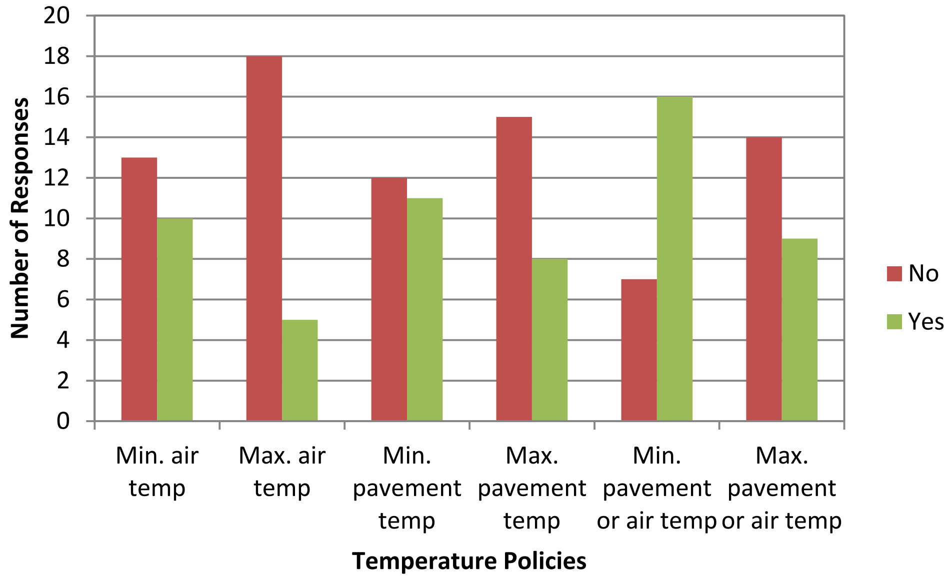


Figure 4. Placement policies for air and pavement temperatures from survey responses.

Among the eight agencies that distinguish between sealing and filling, three seal by contract only, two seal using in-house forces only, and three seal by both methods. Of those same agencies, two fill by contract only, three fill with in-house forces only, two fill by both methods, and one does not fill. Of the fifteen states that do not differentiate between filling and sealing, three seal or fill by contract only, four seal or fill in-house only, and eight seal or fill by both methods. For states that seal and/or fill in-house and by contract, half of them use the same material and installation specifications for both types of work.

Only five of the respondents indicated that they have performance or experience qualifications for their crack sealing or filling contractors. Six of the agencies have training or certification programs for crack sealing or filling inspectors, applicators, or contractors.

Nine agencies restrict sealing or filling based on recent rainfall; four agencies restrict by expected future rainfall. Eleven agencies restrict by other weather conditions, including requiring that the cracks must be clean and dry, that there should be no snow or ice, or no wind. Idaho respondents reported that they do not have specific requirements but that results are better under certain conditions and that the products are used in conjunction with the manufacturer's recommendations. Since manufacturers generally have temperature and weather restrictions stated on their products, they essentially have such restrictions but they are not explicitly stated in their policies.

Eleven states have different crack sealing or filling practices based on the roadway's classification, age, or other criteria, while ten states do not. Two agencies did not answer this question.

Results of the CDOT Maintenance survey provide additional insight into crack sealing and crack filling practices. When asked what criteria are used to select crack sealing projects, all seven respondents said that pavement condition plays a part. Other commonly reported criteria, as shown in figure 5, include pavement age, crack type or orientation, and crack width (Note: as before, respondents were allowed to select all options that applied). Two respondents indicated that the timeline of other upcoming projects, such as overlays and chip seal applications, should also be considered.

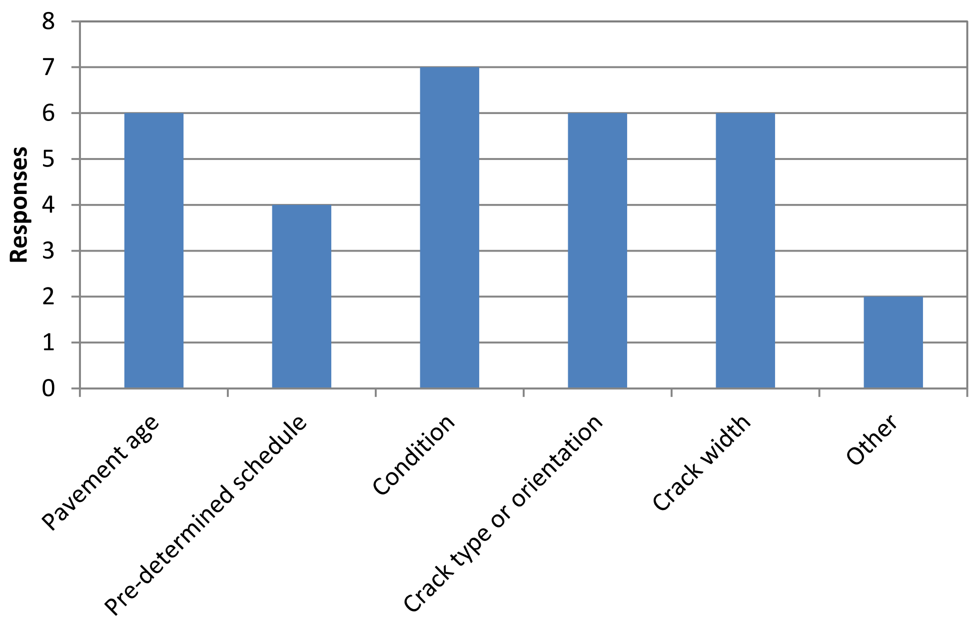


Figure 5. CDOT-identified criteria for crack sealing project selection.

Concerning minimum crack widths for sealing, four CDOT respondents reported that a crack width of 1/4 inch would be the narrowest crack that is typically sealed, while one each reported values of 1/16 inch and 1/8 inch. One respondent noted that the minimum crack width depends on the type of product used, the type of crack to be sealed, and the goal for crack sealing.

As figure 6 shows, the reported maximum crack widths varied more significantly. Two respondents each indicated criterion of 1/2 inch and 3/4 inch, and one respondent stated sealing all widths of cracks for the reason that sealing even a wide crack is better than not sealing at all. Moreover, two respondents indicated that if a stone mastic product could be used, they would consider sealing even wider cracks.

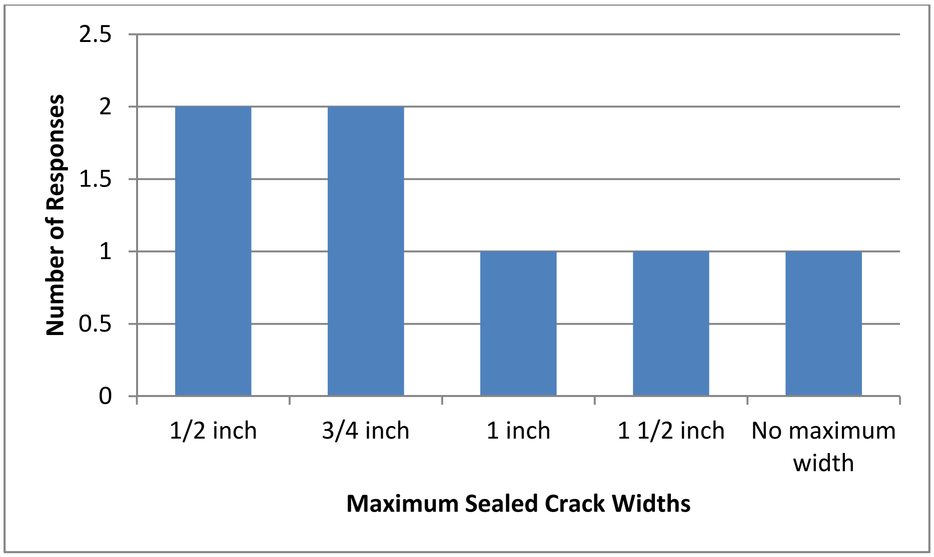


Figure 6. Maximum crack widths for sealing identified by CDOT respondents.

Asked about the timing of crack sealing, the CDOT survey participants overwhelmingly indicated the fall and winter, as seen in figure 7. All seven respondents use one of these two seasons as the primary time for sealing operations, with three also performing the work in spring or summer. One of these latter respondents noted that they usually seal in September, after the rain has washed away residue from the road, but while there is still expansion and contraction from daily temperature variations. Another reported following the Schaffer memo (CDOT 1991) and saying that as long as the cracks are dry, the sealing is effective.

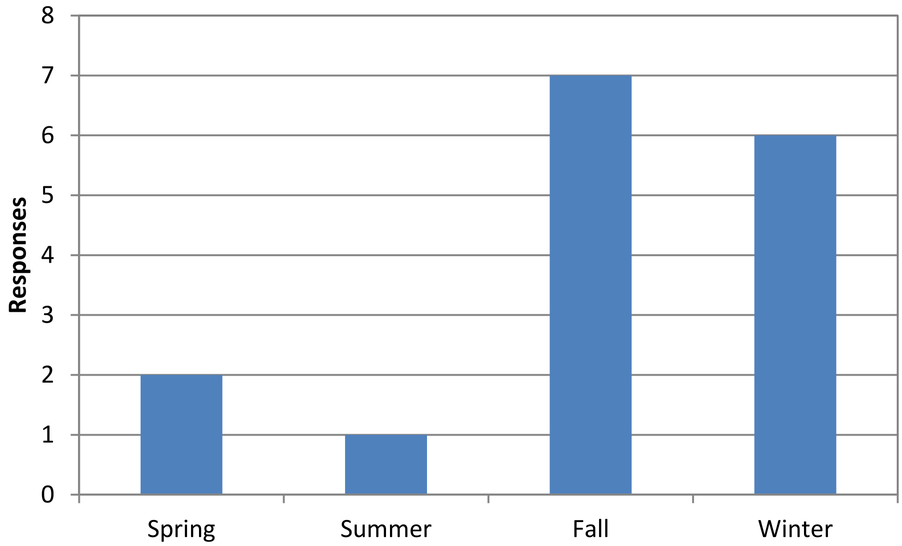


Figure 7. CDOT-identified seasons in which crack sealing is performed.

Material Use and Selection

When planning a crack sealing or filling project, one of the main design considerations is the selection of an appropriate treatment material. Material selection is dependent on a number of factors, including climate conditions (at the time of installation and during the life of the treatment), crack characteristics and spacing/density, traffic loadings, and material availability and cost.

Critical material properties that significantly affect the performance of the treatment material (particularly sealants) include the following:

- Durability—Ability of the sealant to withstand the effects of traffic, moisture, sunshine, and climatic variation.
- Extensibility—The ability of the material to deform without rupturing.
- Resilience—Material's ability to fully recover from deformation and to resist stone intrusion.
- Adhesiveness and Cohesiveness—Materials with good adhesive and cohesive qualities minimize the stress levels developed when elongated and thus the potential for separation from the crack sidewall (adhesive failure) or for internal ruptures (cohesive failure).

As outlined in the SHRP *Manual of Practice*, the materials used to seal and fill cracks can be subdivided into the following families and types (Smith and Romine 2001):

- Cold-applied thermoplastic bituminous materials.
  - Liquid asphalt (emulsion).
  - Polymer-modified liquid asphalt.
- Hot-applied thermoplastic bituminous materials.
  - Asphalt cement.
  - Fiberized asphalt.
  - Asphalt rubber.
  - Rubberized/polymerized asphalt.
  - Low-modulus rubberized/polymerized asphalt.
- Chemically cured thermosetting materials.
  - Self-leveling silicone.

In general, cold-applied thermoplastics and lower quality, hot-applied thermoplastics (e.g., asphalt cement, fiberized asphalt) are used for crack filling, whereas the higher quality, modified hot-applied thermoplastics and silicone materials are used for crack sealing. Because of its substantially higher cost compared to the modified hot-applied sealants, however, silicone is rarely used.

Rubber- and/or polymer-modified asphalt is the sealing industry standard. Today these materials are governed by ASTM D 6690 (or AASHTO M 324), which includes the following four classes of sealants established to match low-temperature performance with climate:

- Type I: Moderate climates, 50% extension at 0 °F.
- Type II: Most climates, 50% extension at -20 °F.
- Type III: Most climates, 50% extension at -20 °F, with other special tests.
- Type IV: Very cold climates, 200% extension at -20 °F.

ASTM D 5329 describes the procedures for most of the tests performed on these materials. These tests include cone penetration, flow, non-immersed and water-immersed bond, resilience, asphalt compatibility, artificial weathering, tensile adhesion, and flexibility. At least one sealant/filler manufacturer provides usage guidelines for its products, based on high- and low-temperature performance grades (e.g., 64-28 for pavements that experience an average 7-day maximum temperature of 64 °C and a minimum temperature of -28 °C).

Recognizing that many SHAs have varied the limits of the ASTM D 6690 specification to better fit their conditions, and that several past studies showed little or no correlation between test results and field performance, Al-Qadi et al. (2009) undertook a pooled-fund study to develop performance-based tests and guidelines for selecting hot-applied crack sealants. Based on extensive laboratory testing and limited field testing, a new battery of tests for fundamental sealant properties was developed and recommended for consideration as AASHTO provisional standards. The tests have subsequently been adopted and include the following:

- TP 85-10, *Apparent Viscosity of Hot-Poured Bituminous Crack Sealant Using Brookfield Rotational Viscometer RV Series Instrument*—Apparent viscosity at the recommended installation temperature.
- TP 86-10, *Accelerated Aging of Bituminous Sealants and Fillers with a Vacuum Oven*—Simulates sealant weathering in the field.
- TP 87-10, *Measure Low Temperature Flexural Creep Stiffness of Bituminous Sealants and Fillers by Bending Beam Rheometer (BBR)*—Evaluate a sealant's creep properties at low temperatures.
- TP 88-10, *Evaluation of the Low-Temperature Tensile Property of Bituminous Sealants by Direct Tension Test*—Characterize a sealant's low-temperature extendibility.
- TP 90-10, *Measuring Interfacial Fracture Energy of Hot-Poured Crack Sealant Using a Blister Test*, and TP 89-10, *Measuring Adhesion of Hot-Poured Crack Sealant Using Direct Adhesion Tester*—Evaluate the bonding between sealant and its substrate.

The new "Sealant Grade" (SG) system embodied by these tests is currently being validated and implemented as part of the second phase of the study.

For sealing working cracks, Caltrans typically uses rubber-modified hot-applied thermoplastic products with a low modulus of elasticity for easy stretching and high elongation (Caltrans

2008). For crack filling, the agency allows the use of both cold-applied emulsion-based products and hot-applied, rubber- or polymer-modified asphalts. Caltrans specifications outline the material tests to be performed (e.g., softening point, cone penetration at 77 °F, resilience at 77 °F, flexibility, tensile adhesion, asphalt compatibility) and the quality characteristics criteria to be achieved for use in different climatic regions in the state (e.g., desert, south or north coast, low or high mountain).

Emulsified asphalt is the most common crack filler used in Texas, having the advantages of safety (no heating required), application in moist conditions, and the ability to penetrate into cracks (Yildirim, Qatan, and Prozzi 2006). For crack sealing operations, the material of choice is hot-applied, rubber-modified asphalt.

Minnesota uses different material specifications for different applications (MnDOT 2008). The specifications include a variety of performance-based tests, such as low-temperature adhesion and cohesion, viscosity at installation temperature, and tracking under high pavement temperatures. For rout-and-seal crack sealing, the MnDOT 3725 material with low-temperature resiliency properties is typically required. The MnDOT 3723 material, which has good adhesion qualities, is primarily used for the clean-and-seal crack seal method, but may also be used with the rout-and-seal method. And lastly, the MnDOT 3723 material is most commonly used for crack filling, but may also be used for clean-and-seal crack sealing. The use of asphalt cement (AC-3) and polymer-modified emulsion for crack sealing is not recommended due to their brittle nature at cold temperatures.

The national survey of SHAs included several questions regarding materials selection, specification, and acceptance. Although the types of materials or material products used in sealing and filling operations were not specifically asked, some information was provided along this line. The materials cited were generally referenced by a particular ASTM or SHA specification, or by a generic material term (e.g., asphalt emulsion, hot-applied asphalt sealer). While a full breakdown of the types of materials used was not possible, the general consensus follows the descriptions above.

When asked if one material is used under all conditions or if different materials are used for different purposes, 8 of the responding SHAs stated the former and 15 stated the latter. However, one of the agencies reporting the latter explained that they use one material for hot mix asphalt pavements and another for portland cement concrete pavements, meaning that they really use one material for asphalt crack sealing. Hence the number of states that use different materials for different applications is actually fourteen.

Figure 8 summarizes the procedures used by agencies to determine qualified suppliers or products. As can be seen, supplier certification is the most common procedure, followed by field performance testing. Among the "other" procedures reported by agencies are in-house testing, state experience, approved contractors, and a few specific requirements for specific material or application types.

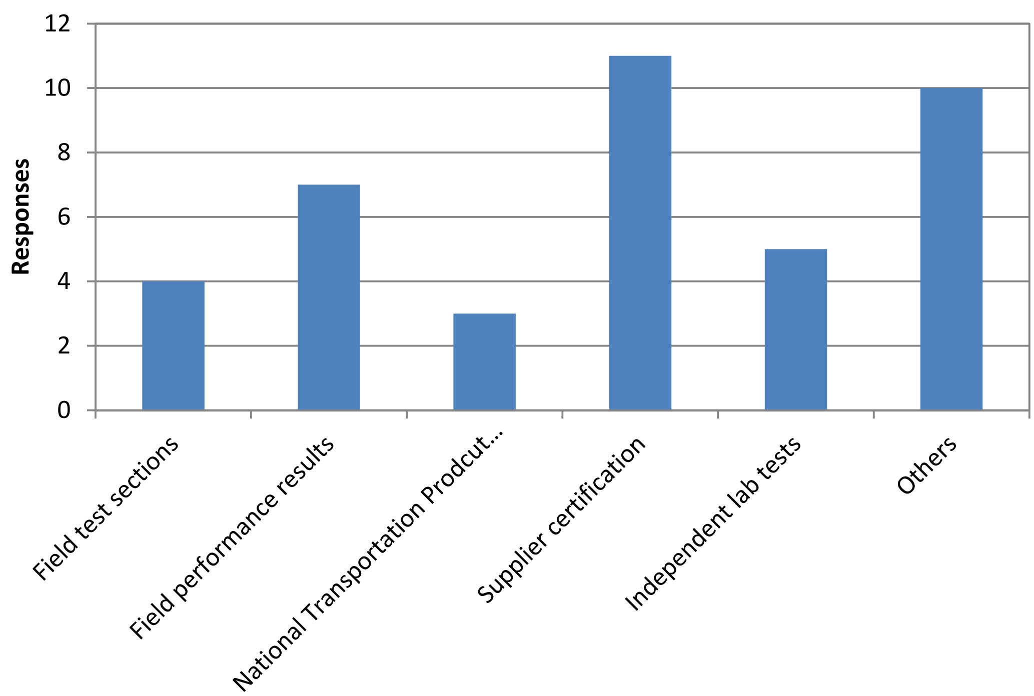


Figure 8. Procedures used to identify qualified suppliers or products from survey responses.

A breakdown of the material acceptance tests used by SHAs is provided in figure 9. It can be seen that the cone penetration, softening point, adhesion/bond, and resilience tests are all commonly used, and that no new performance-based tests were reported. Two of the responding agencies who replied "other" were not certain which tests are used since the materials lab does the testing. When asked if they have any other material selection not previously mentioned, four agencies said they have additional requirements.

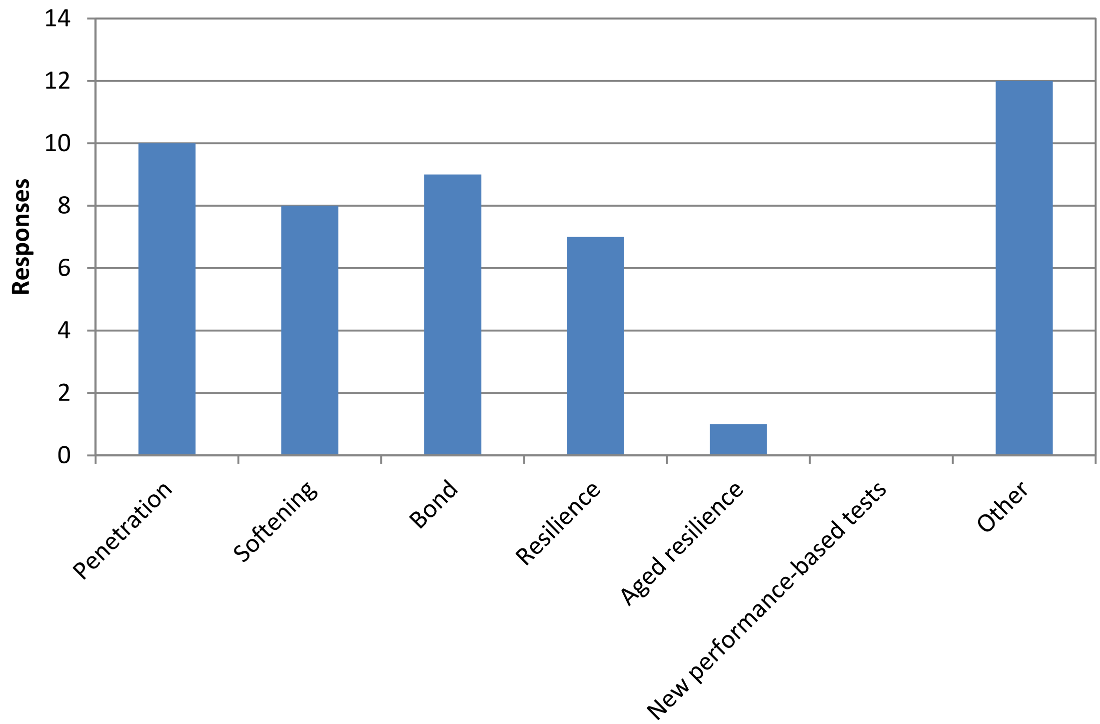


Figure 9. Material acceptance tests from survey responses.

Eight of the responding SHAs sample material in the field and test it to verify that it is the specified material, whereas 14 do not. One agency did not respond. The responses related to evaluating materials in the field to verify that the proper sealant was used are summarized in figure 10. When asked if field acceptance tests, such as an adhesion test, are used, 18 agencies do not use them, while four do. One agency did not respond.

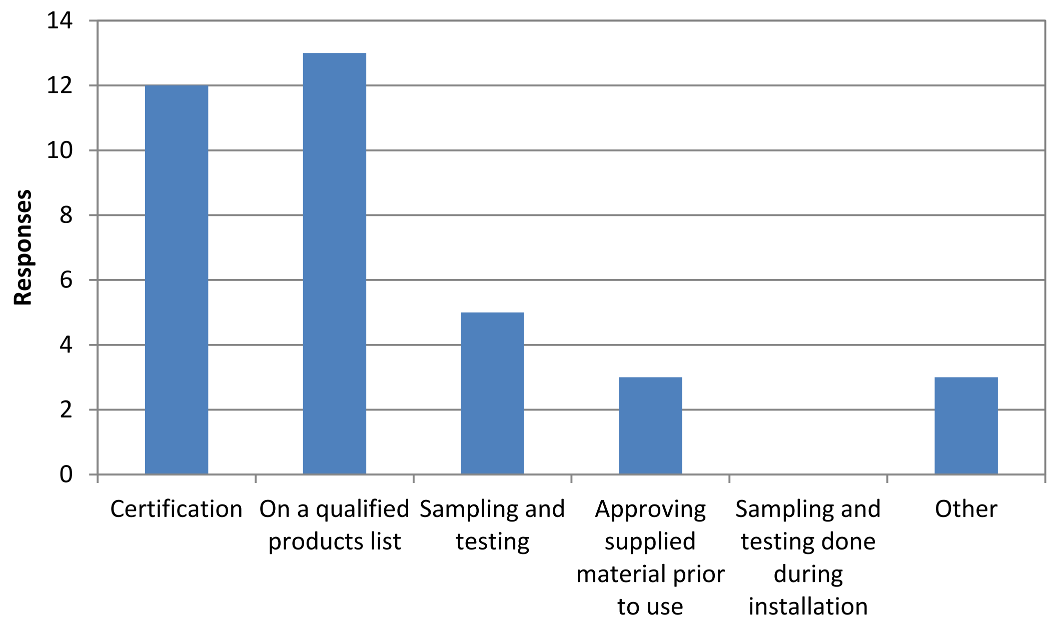


Figure 10. Survey responses of methods of evaluating material in the field to verify that the proper sealant was used.

The CDOT Maintenance survey inquired about crack sealing materials used and the process for selecting sealant materials. Tables 2 and 3 summarize the responses provided. As can be seen in table 2, the material types reported include specific products or the applicable ASTM specifications. And, as table 3 shows, the crack sealant material selection process is primarily based on a combination of state-allowed material and local requirements, such as altitude, climate, and cost.

Table 2. CDOT responses of crack sealing material used.

Respondent	What crack sealing material do you currently use?
D'Wayne Gaymon	Material and vendor is off the state award. D6690-II, Deery 102 and other vendor-related products that are equivalent.
TJ Blake	Maxwell products
Greg Hayes	
Byron K Rogers	Maxwell products and CRS2P
Phillip Anderle	ASTM D6690, D5078
Robert Madrid	ASTM D6690-06
Larry Dungan	Deery Brand Hi Elevation; not sure of the numbers on it.

Table 3. CDOT responses on crack sealant material selection process.

Respondent	Describe your crack sealant material selection process.
D'Wayne Gaymon	By number of material that is best for the altitude, and by vendor that has the state award.
TJ Blake	Brand is chosen by state award and then material type is selected by elevation of road and temperature ranges.
Greg Hayes	Approved Product List (APL)
Byron K Rogers	It needs to have some polymer properties to bend but not break down in cold temperatures, but yet still have a quick cure time in the early fall when temperatures are still warm. Also we want Performance (Longevity).
Phillip Anderle	It is done through our procurement department and based on past specifications and materials that are on the approved products list. We typically use the lowest bid product that is awarded.
Robert Madrid	I go off of studies that have been performed with different types of materials and which holds up the best; also we have a state bid so we are limited to the materials that are available.
Larry Dungan	This year I have a large amount given to me from a project off of I-70.

Crack Sealing and Filling Procedures

The SHRP *Manual of Practice* describes in detail the various methods and equipment available for sealing and filling cracks in existing asphalt pavements (Smith and Romine 2001). It presents twelve different ways a material can be applied into and/or above a prepared crack, based on whether or not the crack is cut, whether or not a bond-breaker is used, what the dimensions of the crack channel are (if cut), how the material is struck off or finished, and what the dimensions of the overband are (if used). It also describes the types of equipment that are appropriate in preparing the cracks and installing and finishing the sealant/filler material, and provides step-by-step procedures and guidance in the entire process.

The literature collected and reviewed in this study indicates general adherence to the SHRP *Manual of Practice*, but some degree of customization to incorporate each agency's unique conditions, experiences, and knowledge base. For example, MnDOT recommends use of a standard 3/4-inch by 3/4-inch cut reservoir for their rout-and-seal crack sealing procedure, and cautions against excessively wide reservoir cuts (i.e., rout width-to-depth ratios substantially greater than 1). While the agency advocates the use of routers and saws for crack cutting and high-pressure air and heat lances for crack cleaning, the specifications placed on the equipment are somewhat different than the specifications given in the SHRP *Manual of Practice*.

Depending on the material used, TXDOT recommends that crack fillers placed in uncut cracks be finished either in a flush configuration or an overband configuration (Yildirim, Qatan, and Prozzi 2006). Likewise, the agency recommends that crack sealers placed in routed cracks be placed either in a flush or overband configuration. Recommendations for routed channel dimensions and overband dimensions are not given.

Caltrans describes and illustrates various material configurations in its MTAG and notes that the selection of a placement method must consider (a) the type of distress accompanying the crack, (b) the dimensions of the crack channel, (c) the type of crack channel (cut or uncut), and (d) the finish requirements. It recommends against use of the overband configuration due to added roughness and noise, and the possible development of bumps in subsequently placed overlays. It recommends the creation of reservoirs for projects with working cracks and allows the use of variable channel dimensions to fit the job requirements. Table 4 shows the recommended channel dimensions corresponding to nominal crack widths.

Table 4. Caltrans recommendations regarding crack routing and sawing dimensions (Caltrans 2008).

Nominal Crack Width*	Rout or Saw Width	Rout or Saw Depth**	Width in Areas of Temperature Extremes	Depth in Areas of Temperature Extremes
1/4 inch	1/2 inch	1/2 inch	1 inch	1/2 inch
3/8 inch	1/2 inch	1/2 inch	1 inch	1/2 inch
1/2 inch	3/4 inch	3/4 inch	1 inch	1/2 inch
5/8 inch	3/4 inch	3/4 inch	1.5 inches	3/4 inch
3/4 inch	No routing required	3/4 inch	1.5 inches	3/4 inch
7/8 inch	No routing required	3/4 inch	1.5 inches	3/4 inch
1 inch	No routing required	3/4 inch	1.5 inches	3/4 inch

* Nominal crack width is the approximate width for 80% of the length of the crack
** If using recessed fill method, add 1/4 inch
*** Use sand fill or backer rod to limit material depth to 3/4 inch

The survey of SHA practices included a variety of questions on crack preparation and sealing/filling procedures. The first question was about the units used in putting out crack sealing or filling bids. A summary of the responses provided is shown in figure 11. Most of the responding agencies base the bids on the estimated quantity of material or on the number of lane-miles of pavement to be treated. Of the three agencies responding OTHER, two of them do all their sealing or filling in-house, and the third has not done enough projects to have a standard method. Four agencies selected multiple options and provided details on when each option is used. Three of them leave it up to the region or engineer's preference, while the fourth varies their method depending on the job size and contract setup.

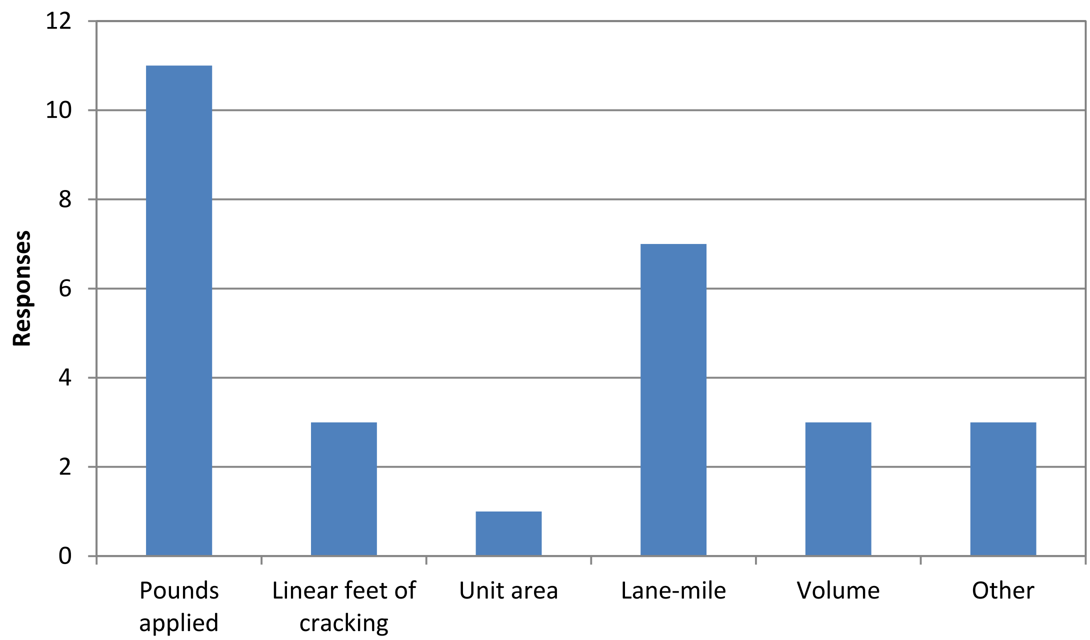


Figure 11. Survey responses on crack sealing or filling bid methods.

SHAs were asked to provide information on their crack preparation methods, including crack reservoir creation (if used) and crack cleaning and heating. The specific responses provided are shown in table 5. Although a mix of agencies reported routing cracks in preparation for sealing/filling, most all agencies reported blowing out the cracks with high-pressure air. Where moisture may be an issue, a hot-air lance is typically used to dry out the crack.

Table 5. Crack preparation procedures from survey responses.

State	Response
MI	Routing or sawing: 1:1 width to depth ratio, 7.5 cubic inches/foot minimum. Air blasting: 100 psi at continuous 150 cfm air flow, moisture and oil separators. Hot-air lance: can be used to remove surface moisture, not used to dry wet pavement.
IN	Crack sealing – routing, air blasting Crack filling – air blasting
ND	No answer
NM	Routing and air blasting
NC	We rout concrete and a few high volume asphalt primary routes. All others we use hot compressed air lance.
CT	Hot compressed air lance, wire brush are used (wire brush for cracks that are filled with dirt, vegetation, or debris within 1.5 inches of the surface) for both sealing and filling
IA	**Crack Sealing** 3/8-inch or less – Rout or saw to a minimum reservoir of 3/8 inch wide by 1/2 inch deep. Crack must be clean and dry before sealing. Larger than 3/8-inch – Clean cracks to necessary depth to accommodate the sealer and backer rod. Cracks must be clean and dry before sealing. **Crack Filling** 1/4-inch to 1-inch cracks – Clear with air pressure or high-pressure water to remove foreign debris. Clean to a minimum of 1 inch and down to sound material. 1/4 inch or less – Clean sufficiently to remove sand and other foreign debris.
TN	All cracks shall be thoroughly cleaned with high pressure, dry compressed air removing all vegetation, debris, moisture and foreign materials, as directed by the Engineer.
WA	All the above, depending on Region preference
SC	Cracks 1/4-inch or greater are blown out with a hot-air lance and the sealant is then applied. We do not rout our cracks at this time. We are in the beginning process of developing more detailed and refined crack sealing and filling specifications.
MN	See special provisions for crack preparation
FL	Crack filling: air blasting; Crack sealing: routing, air blasting A hot compressed air lance is used to dry cracks when they are moist.
MT	**403.03.2 Routing** Rout all existing cracks that are between 1/8 inch (3 mm) and 1 inch (25 mm) wide. Rout all longitudinal cracks to produce straight 3/4-inch (19-mm) vertical walls and a 3/4-inch (19-mm) wide flat bottom reservoir. Rout the transverse cracks to produce straight 1/2-inch (13-mm) vertical walls and a 1 1/2 inch (40 mm) wide flat bottom reservoir. Rout when the roadway is dry. Remove and dispose of the routed material from the roadway before opening the roadway to traffic. **403.03.3 Cleaning** The reservoir and crack must be dry and free of dust, dirt and loose materials immediately before placing the backer rod, if applicable, and applying the sealant.
WY	See specification 403 and Contract Administration Manual for details.

Table 5. Crack preparation procedures from survey responses (continued).

State	Response
PA	Air blasting, hot compressed air lance
NV	Air blasting
NJ	Routing, then air blast to clear water and particles, then fill. Crafco super shot melter is used.
UT	A. Apply sealant to designated joints as shown on the plans. B. Cleaning and Drying 1. Asphalt joints – Clean 6 inches on both sides of the joint of foreign matter and loosened particles with a hot compressed air (HCA) heat lance immediately before sealing the joints. Adequate cleaning is determined by surface darkening at least 12 inches wide, centered on the joint. 2. Concrete joints – Clean joints and surface in portland cement concrete by sand blasting before applying the sealant. C. Fill the joints following the Relief Joint Crack Sealing detail on the plans. D. Use an appropriate backer rod, compatible with the sealant and all components of the joint sealant system, in the joint opening where the depth and width of the joint opening are greater than 2 inches and 1/2 inch, respectively.
ID	117.01 Procedure. If needed, rout out the crack to the sealant manufacturer's specifications for width-to-depth ratio. Clean the crack using high-pressure air, sandblasting, wire brushing, or hot-air blasting. This is a key step to crack sealing. If the crack is not thoroughly cleaned the sealant will not adhere to the sides. Hot-air blasting is the preferred method because it helps dry the crack and if the sealing operation closely follows the hot-air drying, the heated crack surface helps the sealant adhere to the crack. After cleaning the crack, sealant should be applied from bottom to within 1/8 inch of the top of the crack to prevent air bubbles from forming and creating a weak spot in the sealant. Fill the crack to no more than 1/8 inch from the top. Overbanding, or the application of sealers up to the top of cracks and out onto the pavement surface, has been shown through research to be ineffective, wasteful, and reduces the friction values of the roadway, and is therefore not to be done.
GA	Compressed air from an air compressor is used to blow the cracks out prior to material being placed
AR	Clean cracks using compressed air. Fill cracks. Surface may be sprinkled with a layer of fine sand to prevent tracking.
KY	Routing
CO	Air blasting, air lance

The national survey inquired about the use and dimensions of the three different crack seal configurations (recessed, flush fill, and overband) shown in figure 12. The responses provided are summarized in table 6. Two agencies provided reservoir dimensions for a recessed configuration; they typically use 3/4-in by 3/4-in for all cracks. One agency did not provide a recess depth and another specifies a 1/4-in recess depth.

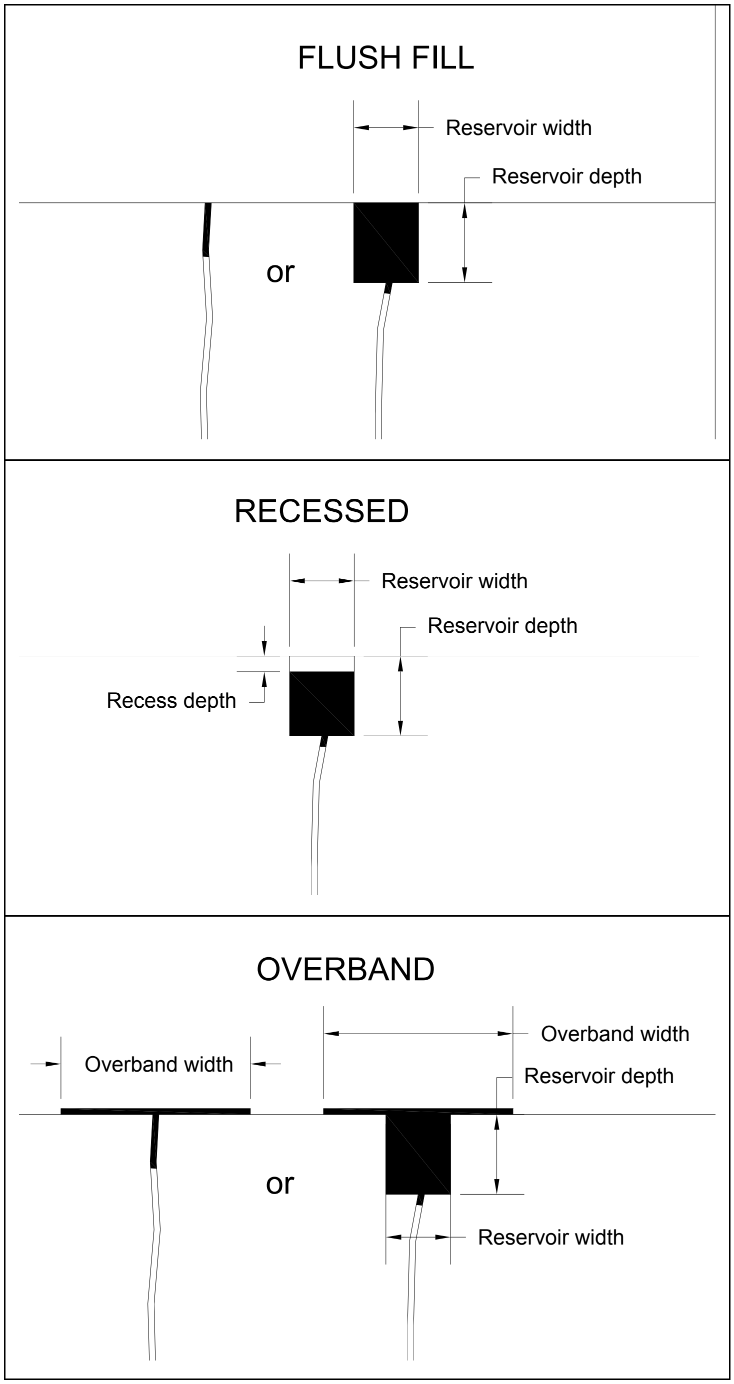


Figure 12. Crack sealing and filling configurations.

Table 6. Summary of survey responses of situations in which each crack seal or fill configuration is used.

State	When is each configuration used?		
	Recessed	Flush Fill	Overband
MI	All sealing using recessed or flush		All filling
IN	All sealing with routing	-	-
ND	-	All	-
NM	All	-	-
NC	-	High-volume primary roads	Other primary roads and secondary roads
CT	Pre-overlay (no routing)	Most situations	-
IA	-	Typical	Allowed but not required
TN	-	All	-
WA	-	Typical	When used as a surface treatment
SC	-	-	All
MN	-	-	All sealing
FL	-	-	Used on one project
MT	-	Typical	Considered if cold in-place recycling
WY	Typical	If engineer recommends	-
PA	-	Used in all situations	
NV	Typical	-	Only unintentional
NJ	-	-	All
UT	Only unintentional	Typical	Only unintentional
ID	No answers		
GA	-	All	-
AR	-	All	-
KY	-	-	Use routing if crack is at least 1/4-in wide
CO	No answers		

With the flush fill configuration, four agencies do not typically rout or create a reservoir, one agency stated that the dimensions vary depending on location, and two did not provide enough details to determine their typical dimensions. One agency reported using a 3/4-inch by 3/4-inch reservoir for all cracks, while another reported using a 3/8 inch wide by 1/2-inch deep reservoir. A third agency uses 3/4-in by 3/4-in for longitudinal cracks and 1 1/2-in by 1 1/2-in for transverse cracks, while a fourth uses widths between 1/4 inch and 1 inch.

Most reported overband widths were between 2 and 3 inches, and if cracks are routed, the typical dimensions are 3/4-in by 3/4-in. One agency that does not rout noted that they require a 1/8-inch depth of sealant.

Figure 13 shows the types of equipment used by SHAs for sealing and filling cracks. Most use an air compressor to clean the cracks, a sealant applicator to install the material, and a squeegee to finish the material at the surface. Fewer than half use a router to create a crack reservoir for the material. Other devices reported include hot-air lances, high-pressure waterblasters, wire brushes, and all-in-one units.

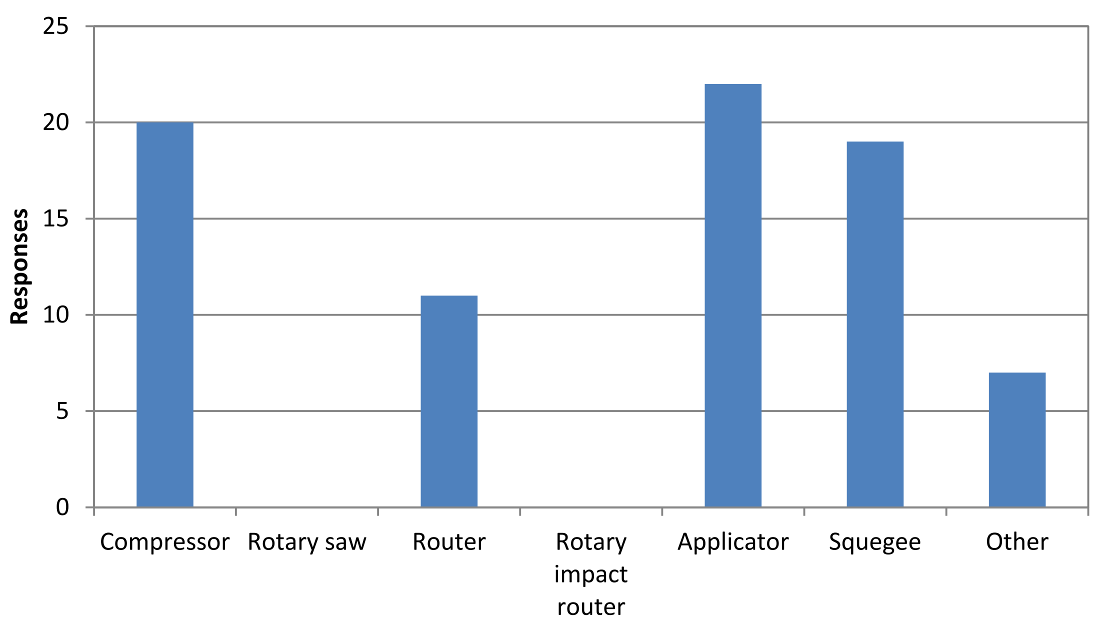


Figure 13. Typical equipment used in the crack sealing process from survey responses.

Nineteen of the responding SHAs take steps to prevent pull-out or tracking of sealant/filler material after it is installed. The methods they use are summarized in figure 14. As can be seen, more than half apply a blotter material. Less than half either delay the opening to traffic until the material has set or use a combination of delaying traffic and using blotter material.

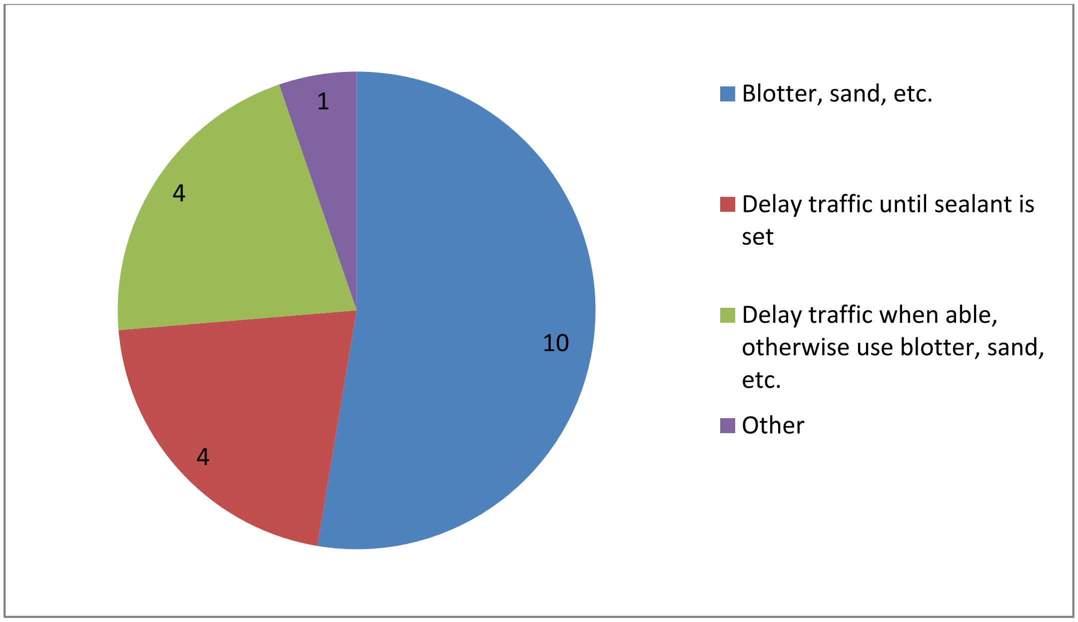


Figure 14. Methods used to prevent pull-out or tracking from survey responses.

Because sealing cracks before placing an overlay can significantly affect overlay performance, SHAs were asked if any procedures are specified regarding this issue. Thirteen agencies indicated having no special procedures, while nine did indicate having procedures. Among the procedures reported were placing sealant no less than 3 months to 1 year or more before the overlay, only sealing wide cracks, recessing the crack sealant, and considering an isolation lift if there is too much sealant on the surface. In the case of sealing cracks before a surface treatment, only four agencies indicated having special procedures. These generally consisted of using a flush fill configuration, only sealing large cracks, or using a different type of sealer.

The CDOT Maintenance survey also requested information on crack sealing procedures, including crack preparation, cleaning, placement, and any other steps that may be taken. The responses received are provided in table 7.

Table 7. CDOT-identified crack sealing preparation steps.

Respondent	Please briefly describe your standard crack sealing procedure, including crack preparation, cleaning, placement, and any other steps that you may take.
D'Wayne Gaymon	Blow out crack with air compressor, ensure it is dry, in the fall when temps are not too hot or cold, tar pot with material heated to manufacturer's recommendations, poured using buggies, squeegeed off. Heat lanced as needed to dry crack and router used in mastic applications only.
TJ Blake	We blow the crack free of debris and moisture with air then fill and squeegee off excess.
Greg Hayes	Blow them out- heat lance- material
Byron K Rogers	Pre plan 3 year to 5 year plan know the performance of your roads. Timing is critical. Blow cracks use heat lance depending on surface temp. Apply with wand from tar pot. Use squeegee no wider than a 4-inch band. Oil temp very important: go by company recommendation for application.
Phillip Anderle	Above freezing temps, heat material to recommended temp, prep the crack with a heat lance, apply the material with a heated wand, and strike off the excess.
Robert Madrid	Crack sealing on newer pavements is considered a high priority and the cracks should be filled as soon as possible after detection, preferably the first fall after they appear. Cracks should be blown or routed to remove all debris at least 1/2-inch below the surface, asphalt should be dry and clean of any water or other materials so that the sealant will bond to the surface. The best time for crack sealing is during fall and winter.
Larry Dungan	We blow the cracks out with the compressor and wand. We are using a rented tar pot from Vance Brothers. We will be working on Hwy 72, Hwy 74, Hwy 119 and 40 through September and you are welcome to look at our operation and give us ideas.

Inspection and Troubleshooting

In addition to providing step-by-step guidance for conducting crack sealing and filling operations, the SHRP *Manual of Practice* contains a construction inspection checklist for maximizing workmanship in the field (Smith and Romine 2001). The checklist covers several individual activities, including crack cutting, crack cleaning and drying, material preparation and installation, material finishing and shaping, and material blotting. The TXDOT likewise provides guidance in sealant application procedures and includes a quality control checklist that covers climatic conditions at time of application, routing, material preparation, crack cleaning, sealant application, and sealant protection (Yildirim, Qatan, and Prozzi 2006).

The Caltrans MTAG includes the troubleshooting guide presented in table 8 (Caltrans 2008) for crack sealing and filling operations. The information provided links common problems to their potential causes.

Table 8. Troubleshooting guide for crack sealing and filling projects (Caltrans 2008).

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	●		●	●		●	

The MTAG also presents the following common problems and recommended solutions for sealing and filling:

- Material Tracking
  - Reduce the amount of sealant or filler being applied.
  - For hot-applied materials, allow to cool or use sand or other blotter.
  - Allow sufficient time for emulsions to cure or use a sufficient amount of sand for a blotter coat.
  - 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.
  - Increase temperature of application.
  - Use the correct sealant for the climate.
  - Allow longer cure time before trafficking.
- 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.
  - Change the rubber on the squeegee.
  - Stop using overbanding.

Results of the survey on crack sealing and filling show that more than half of the SHAs (12 of 21 respondents) inspect the quality of the prepared crack reservoir prior to sealant placement. Most of the agencies that do inspect for channel dimensions, cleanliness, and/or dryness, perform a simple visual evaluation. Other reported means of inspection included the use of a reservoir gage and the use of duct tape. Two respondents replied that experience is used, and another simply said that cracks are sealed during dry conditions. Two agencies provided portions of their specifications regarding crack sealing or filling in response to this question.

More than half of the surveyed agencies (12 of 21) do not have required equipment inspections. One of these agencies stated that they service equipment at the beginning of the sealing season and units are serviced as needed throughout the year. Responses from the nine agencies that do perform inspections ranged simply from following FHWA guidance to providing detailed excerpts from their specifications.

With respect to the quality of the final crack seal product, six of the responding SHAs stated that they use a visual field inspection or acceptance procedure, while five others provided additional details on what is noted and inspected during the process. Seventeen respondents said performance guarantees are part of their acceptance procedures.

Performance

The SHRP *Manual of Practice* highly recommended that crack sealant and filler projects be closely monitored over time to determine performance life (Smith and Romine 2001). The *Manual* directed that the following failure-type distresses be identified and quantified during each field evaluation:

- Full-depth adhesion loss.
- Full-depth cohesion loss.
- Complete pull-out of material.
- Spalls or secondary cracks that extend below the treatment (i.e., sealant or filler) material.
- Potholes.

The *Manual* recommended that treatment failure or treatment effectiveness be established in terms of the percentage of total crack length that is either failed or effective (i.e., not failed). After a few time-series evaluations, a graph of treatment effectiveness like the one shown in figure 15 can be created. And, by establishing a minimum allowable effectiveness level (say 50 or 75 percent), the projected life of the treatment can be determined.

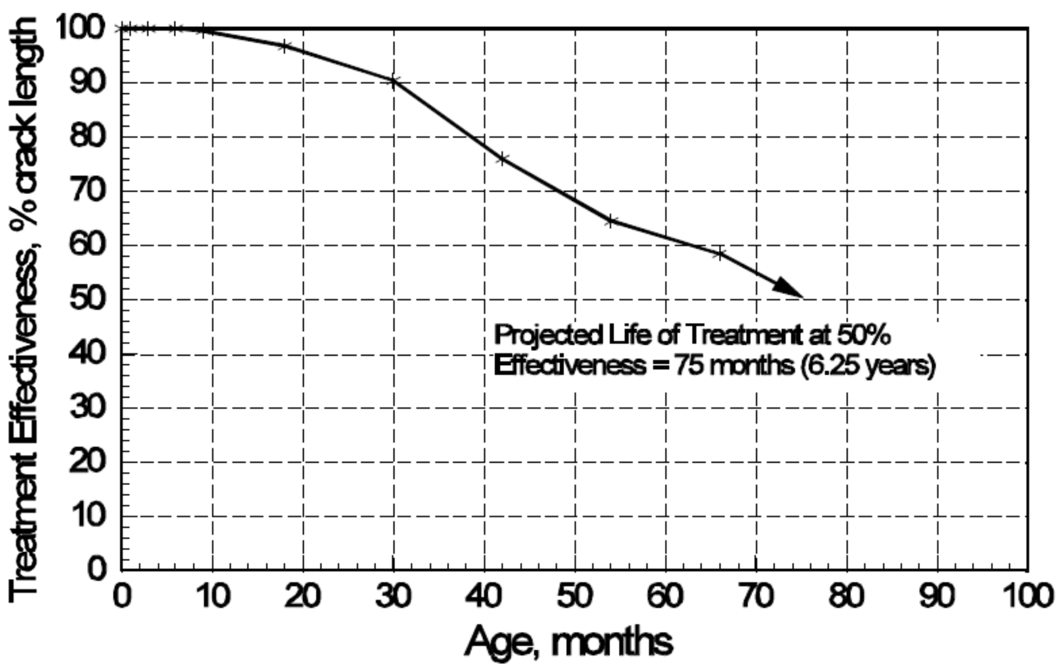


Figure 15. Example graph of treatment effectiveness versus time (Smith and Romine 2001).

Although the nationwide SHRP H-106 crack treatment experiment was completed in 1999, it resulted in service life estimates for a variety of sealant and filler products placed in different configurations on HMA roads in four different climates (Smith and Romine 1999). The service life estimates were based on the time until a 75 percent effectiveness level was reached (i.e., 25 percent of treated crack length exhibited failure). The average service lives of hot-applied rubberized asphalt sealants largely ranged between 4 and 7 years, with some treatments lasting only 2 years and others lasting as long as 10 years. The performance of a silicone product in the experiment ranged between 3 and 9 years.

Since the H-106 study, several highway agencies have also undertaken performance evaluations of crack sealing and filling activities. Some of the studies relevant to Colorado include a Montana crack sealing cost-effectiveness study (Cuelho and Freeman 2004), a Wyoming laboratory and field evaluation of crack surfacing material (Carter, Ksaibati, and Huntington 2005), and a recent CDOT study of pavement preservation treatments (Shuler 2010).

In the Montana study, four crack seal test sites were installed throughout the state between 1995 and 1998 (Cuelho and Freeman 2004). The two sites located in north central Montana (I-15 near Conrad and I-15 near Dutton) were installed in October 1995 and May 1996, respectively. The two site in west central Montana (I-15 near Helena and I-90 near Tarkio) were installed in July and August 1998, respectively. Performance evaluations were conducted through 2001 for the Conrad, Dutton, and Tarkio sites, and through 2003 for the Helena site.

Crack seal performance at the Helena site was among the best observed. At the end of the 5-year evaluation period, only 12 of the 25 material/technique combinations at this site had reached a 50 percent failure level. Forecasting of the life expectancy of the remaining 13 treatments indicated that that 10 of the treatments would have lives of at least 7 years. Table 9 shows the rankings of these 10 material-technique combinations.

Table 9. Ranking of best material/technique combinations at the Helena, Montana crack seal test site (Cuelho and Freeman 2004).

Rank	Forecasted life (months)	Material-Technique Combination
1	175	Crafco 522 — Square Reservoir & Flush
2	163	Crafco 522 — Square Reservoir & Band-Aid
3	151	Crafco 522 — Shallow Reservoir & Flush
4	139	Crafco 231 — Shallow Reservoir & Flush
5	127	Maxwell 72 — Shallow Reservoir & Flush
6	103	Crafco 231 — Square Reservoir & Band-Aid
		Crafco 231 — Square Reservoir & Flush
		Maxwell 71 — Shallow Reservoir & Flush
		Maxwell 71 — Square Reservoir & Flush
7	91	Maxwell 72 — Square Reservoir & Flush

The Wyoming crack surfacing study (Carter, Ksaibati, and Huntington 2005) looked at two different hot-applied overband mastic products composed of asphalt, fine aggregate, synthetic rubber polymers, and other materials. The products were installed at three different locations (WY 93, US 26, and I-25) in Wyoming between 1999 and 2002. High percentages of adhesion and cohesion failure (> 40 percent) were observed at the WY 93 site after 4 years and at the US 26 site after 2 years. Nearly all the treatments applied at the I-25 site had experienced adhesion failure after 2 years.

The CDOT pavement preservation treatment study looked at the performance of two crack sealants placed at two locations (SH 7 south of Estes Park and SH 66 east of Lyons) in Colorado in 2005 (Shuler 2010). The primary focus of these two crack seal projects was to determine the impacts of de-icing salts on sealant performance. Four years of performance monitoring resulted in the development of the crack seal effectiveness trends shown in figures 16 and 17. With the exception of one product at the Lyons site, the effectiveness has dropped well below the 75 percent level after 4 years. Moreover, the impact on performance of de-icing chemical applied to the pavement prior to crack sealing, was shown to be positive in some cases.

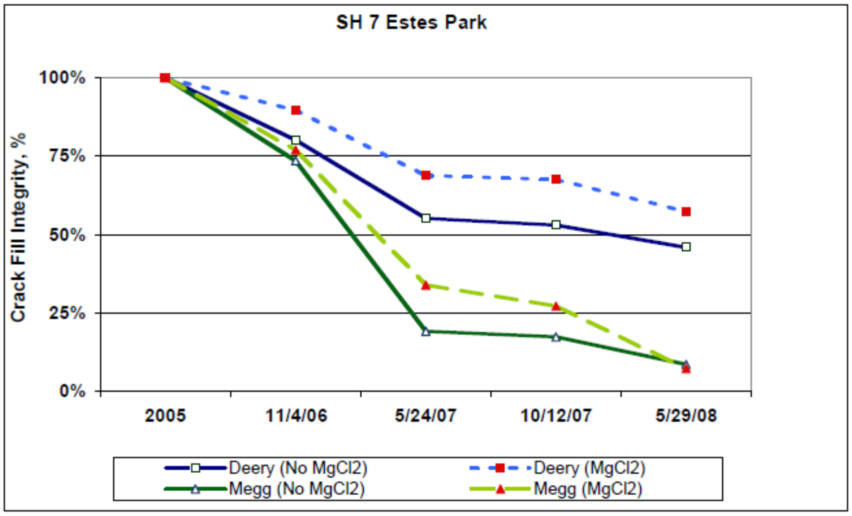


Figure 16. Crack seal effectiveness over time at SH 7 Estes Park (Shuler 2010).

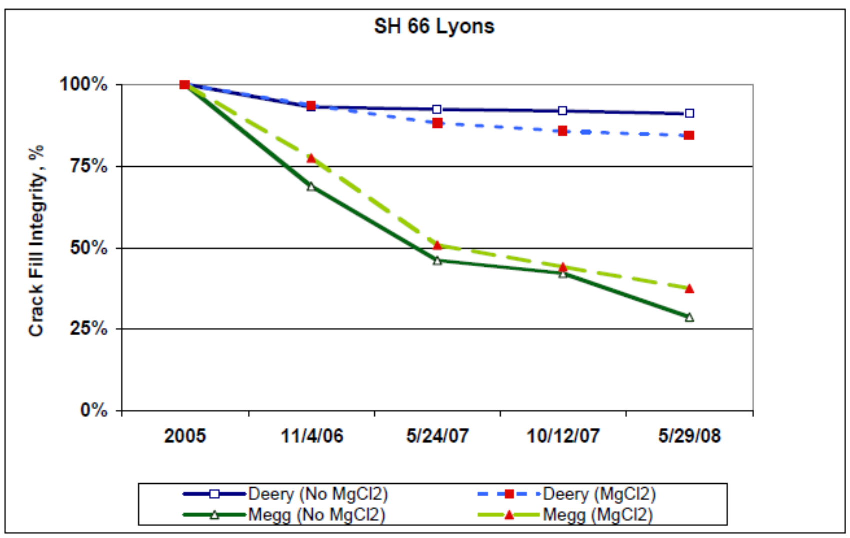


Figure 17. Crack seal effectiveness over time at SH 66 Lyons (Shuler 2010).

The survey of SHA crack sealing/filling practices included a series of questions regarding the performance of these treatments. The questions addressed the frequency of the activity and how long the treatment lasted. With respect to the former, ten agencies reported having a typical maintenance schedule for the first crack seal application following new pavement construction. The schedules provided are summarized in table 10. Three agencies stated that crack sealing is done as needed or by warranty.

Table 10. Typical maintenance schedule for the first crack seal application from survey responses.

State	Response
MI	Composite pavements usually have a contract crack treatment project 2 to 3 years after the overlay.
IN	3 to 5 years
ND	On new or mine and blend projects the transverse cracks should be sealed early in the life of the pavement, suggest within 3 years after construction… On thin lift overlay projects the reflective cracks should be poured every other year. If the cracks in the old existing pavement were sealed in the past, the reflective cracks in the new overlay should also be sealed rather than poured… On existing pavements, where the transverse cracks have not been sealed in the past, the cracks should be poured.
NC	After constructing an overlay we recommend that section of roadway be reviewed for crack sealing each year following two winters.
CT	Aim is for 4-6 years after bituminous-concrete placement for crack treatment (filler if only paving joints or non-working cracks, sealant if working cracks).
MT	3-4 years
NJ	3-5 years after pavement is placed, it is evaluated for the need for crack sealing.
GA	Routes that rate between 75 – 85
KY	Five years
CO	4 to 5 years

With respect to the lifespan of crack sealing and filling treatments, responses are summarized in table 11. Although 3 to 5 years was frequently cited, the full range extended between 1 and 10 years and was based on factors such as road type, construction type, and material used.

Table 11. Typical lifespan of crack sealing and filling from survey responses.

State(s)	Response
ND, IA, TN, WA, MN, FL, NV, ID, KY	No answer / unknown
MI	Composite pavements or thin overlays vary depending on the condition of the pavement that is overlaid (1 to 4 years). Full depth HMA depending on thickness (5 to 8 years).
IN	Crumb rubber - 3-5 years emulsion- 1-2 years
a	Approximately 3 years
NC	5 years
CT	After a hiatus of 5 years, crack sealant was first placed in 2009 (four years ago). It still does not need to be replaced. Crack filler was also used in these projects and depending on the project there are minor areas where crack treatment is needed (mostly delamination OUTSIDE where the filler had been placed), but no areas requiring re-application of filler because of material failure.
SC	3 to 5 years
MT	Depends on surface and environment.
WY	Maintenance plans reseal operations in 8 to 10 year time period. Still also based on roadway performance
PA	3 years
NJ	Cracks are generally not re-sealed.
UT	After new construction of asphalt pavement. It typically requires a crack sealant in 3 to 4 years depending on the traffic loads. The concrete pavements may go 10 to 15 years before needing to seal the cracks.
GA	This depends on ADT along a route, weather, etc. Typically around 3 to 5 years.
AR	1 to 2 years
KY	Unknown.
CO	10 years

The survey also inquired about the definitions and methods used for determining sealant failure. As shown in table 12, the primary definitions given for failure included adhesion or bond failure and pull-out of the material. And, as table 13 shows, the most common method for evaluating failure is visual inspection. Only one agency (Connecticut) provided criteria regarding the overall amount of failure (i.e., percent of crack seal length) that is considered unacceptable.

Table 12. Sealant failure definitions from survey responses.

State	Response
MI	Adhesion or cohesion failure are the main focus. Plow wear/abrasion and stone intrusion are other failures that are observed.
IN	Cohesion or adhesion failure
ND	No standard definition
NM	Pull outs, loss of adhesion, extended cracking
NC	Debonding from one side of crack.
CT	Adhesion, cohesion failures, tracking (at the time of construction); adhesion and cohesion failures will be our failure criteria (25% or more of the length) (considering; not needed yet)
IA	When sealant no longer adheres to the sides of the crack.
TN	Loss of sealant or bond failure
WA	Unknown
SC	When the sealant is pulled from the cracks by traffic or is torn by excessive crack movement.
MN	Bond failure, pull-outs
FL	I would define sealant failure as the point at which the sealant no longer provides a water proof seal to prevent water and debris from entering into the crack.
MT	Pulling from edges, pulling from the crack with traffic.
WY	Bond failure.
PA	Pulling out, recracking
NV	No answer.
NJ	Not defined.
UT	When the crack sealant material pulls out of the crack and not bonded or if the crack itself is not filled at all
ID	We don't.
GA	Not bonding, no elasticity.
AR	Visual cracks.
KY	We have only been doing crack sealing for about 6 years. We haven't had any failures so far.
CO	Loss of adhesion.

Table 13. Method of determining crack sealant failure from survey responses.

State	Response
MI	Visual determination that usually occurs when there is also new cracking that has not yet been treated in the pavement section.
IN	Visual inspection
ND	Operator experience
NM	District decision
NC	When the material is not adequately bonded to both sides of crack.
CT	25% of the length not performing its function (considering this definition; not needed yet)
IA	If sealant is missing or no longer adheres to either side of the crack.
TN	Bond failure.
WA	Unknown.
SC	There have not been any formal procedures developed.
MN	No answer.
FL	We don't.
MT	Visually.
WY	Visual inspections by maintenance during annual budgeting process. Roadways are reviewed and seal contracts recommended. There is also review by Materials program with Pathview analysis that can give recommendations.
PA	Water getting into the roadway and causing more cracking or the sealant coming out.
NV	No answer.
NJ	Not done.
UT	Visual failures during inspection of the roads.
ID	No answer.
GA	N/A
AR	Visual observation.
KY	I think the pavement would be overlaid prior to having to replace the crack sealant.
CO	Budget availability.

Only three of the responding SHAs have quantified the effect of sealing cracks on pavement life. In addition, as figure 18 shows, a large majority of the responding agencies believe that pavement condition, placement or preparation procedures, and placement conditions affect sealant performance. Traffic, environment, and material quality were also commonly noted as performance factors.

As both figures 18 and 19 show, only a few SHAs think that deicer applications prior to sealing affect sealant performance. Most of the responding agencies were unsure. Several agencies noted that deicer application and sealant application do not overlap in timing, or that crack preparation procedures adequately remove the deicer so that it does not have an effect.

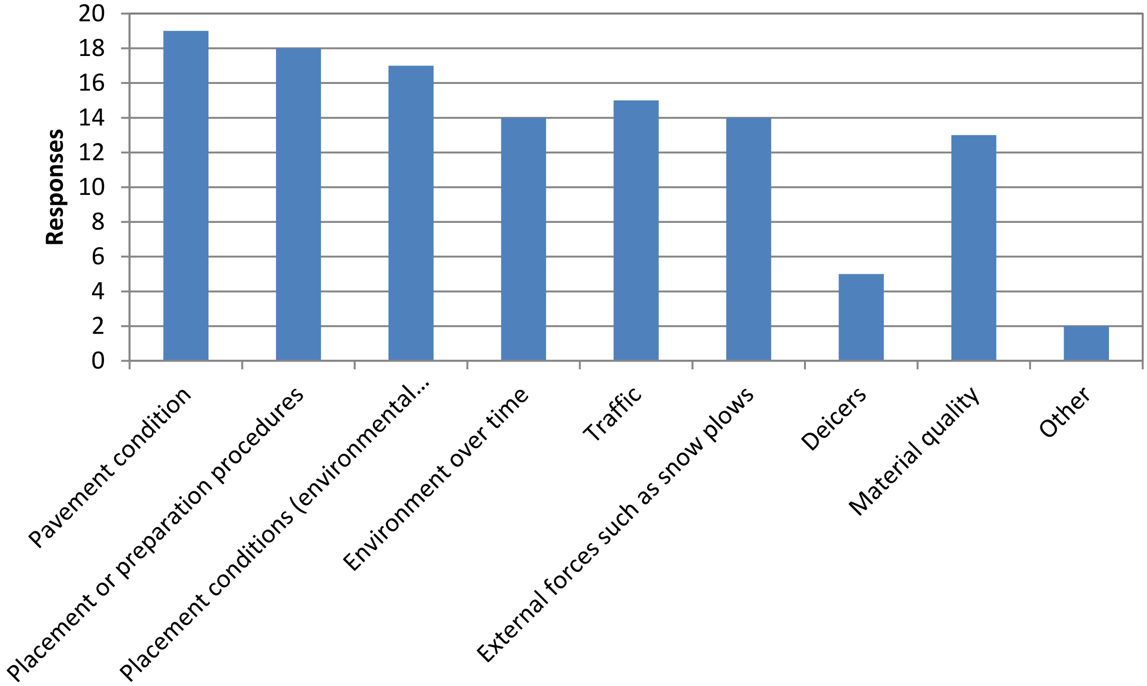


Figure 18. Survey responses of factors affecting sealant performance.

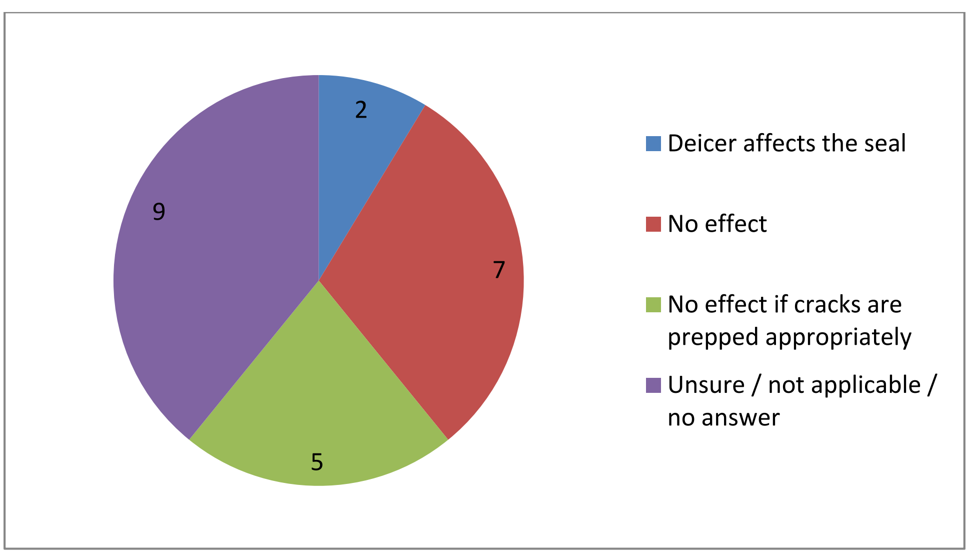


Figure 19. Survey responses of the effects of deicers on sealant performance.

Survey respondents identified a variety of issues that affect the successfulness of crack sealing and filling projects. Table 14 lists the problems conveyed by the 23 responding agencies. The most common problems include inappropriate project selection and/or timing, inadequate crack preparation, improper material installation procedures, and poor decisions regarding opening of the pavement to traffic.

Table 14. Typical crack seal/fill problems from survey responses.

State	Response
MI	There have been several reasons for premature failures that include project selection, workmanship quality, and material selection.
IN	Improper application procedures being followed, poor project selection.
ND	No answer.
NM	No answer.
NC	Contracts apply to much sealant or fail to squeegee properly
CT	1. Pre-overlay crack filling paid by the pound, even though spec is clear on crack selection and application technique (massive over-application and bumps in the overlay, even when no rubberized material was used). (Happened on one project due to over-application at properly selected cracks, on one more project due to improper crack filling selection [all cracks were filled regardless of width]): have discontinued this practice. 2. Minimum ambient temperature becomes a restriction quickly in the fall, particularly on night filling/sealing projects.
IA	The first problem we have is getting the projects let in a timely manner. Often districts wait too long to get the first crack sealing project let, so cracks deteriorate due to the delay. The second problem is being able to estimate the quantity of filler material needed on a project. The actual amount used can vary significantly from the engineer's estimate, both high and low.
TN	The main point is insuring that the cracks are cleaned well before sealing. Most of the time this is not a problem, but can be on occasion. In Tennessee, work on the Interstate system must be done at night and ensuring that moisture in the crack is blown out may be an issue.
WA	Joints not being cleaned prior to placement. Bumps develop when hot-poured material is used beneath HMA. Occasional tracking issues.
SC	Prior to changing to lane miles as the pay item we would have too much sealant applied because the contractor was being paid by the pound. The change in pay item and better project selection have reduced the typical problems encountered. We may have the occasional issue with sealant being pulled from the cracks, but this is rare.
MN	Poor workmanship. Lack of inspection.

Table 14. Typical crack seal/fill problems from survey responses (continued).

State	Response
FL	Having only had one project, it is hard to say what is typical. One major problem that we encountered during construction of our recent research project was when we were routing two cracks that intersected each other. One specific section of roadway had portions of the friction course "pop-out" as wedges between the two routed cracks. Measurements indicated that the friction course thickness on that roadway was only 1/2 inch. Another issue that we had was in determining when the cracks were adequately cleaned. Not having much (any) experience with crack filling/sealing, we were counting on the contractor to use the proper equipment to adequately clean out the cracks. The material supplier who was on site during construction was not happy with the cleanliness of the cracks, but I couldn't really hold up construction and demand that they get a bigger air compressor.
MT	Product running to low side. Contractor fails to flush fill. Traffic returned to road too quickly, resulting in rubber pulling from crack. Toilet paper blotter is sometimes bad public relations.
WY	Over-application of sealant by contractors; making sure cleaning and joint preparation is done properly; material quality issues.
PA	Crews filling alligator cracks; too wide of bands; poor squeegee methods.
NV	Too much overband on a dirty surface will come right up as traffic drives over it and can pull material from crack.
NJ	We have not experienced any in the last 8 to 9 years.
UT	Too soft, doesn't stay in the cracks; over filling; Motorcycle Association complains about crack seals causing them to have accidents; when cars drive over some cracks the tires pull out the crack sealant; too brittle.
ID	No answer.
GA	Most common problem is with the equipment breaking down; personnel not knowing what temperature to heat material to.
AR	Traffic control, tracking.
KY	If water is bleeding up through a joint, the material will not adhere to the pavement.
CO	Overlay bumps occurring at sealing location. Need better sealant replacements for concrete pavement.

The CDOT Maintenance survey also inquired about the performance life of crack seals. As table 15 shows, the responses varied substantially between 3 and 15 years, with factors such as location, road type, and traffic level cited.

Table 15. CDOT responses of typical performance life of sealed cracks.

Respondent	What is your typical performance life of a sealed crack? i.e., how long (in years) after you seal a crack will you need to return to re-seal that same crack?
D'Wayne Gaymon	Varies, depending on the road, AADT, conditions when applied, etc. Hope to get 2 to 5 years out of a good crack seal.
TJ Blake	Depends on location. In higher elevations roads we are re-sealing around 8 to 10 years and at lower elevations around 10 to 15 years. Then road base under the pavement makes a big difference on the movement of the asphalt and how often re-sealing must be done.
Greg Hayes	Hard to determine, it varies on traffic volume.
Byron K Rogers	3 to 5 years, maybe 7 years depending on how old the actual surface is. Also depending on the infrastructure of the road, in conjunction with your Chip seal program they run together hand in hand. Have a plan, monitor the performance of your roads, know your roads. Always evaluate and monitor.
Phillip Anderle	3 years or more.
Robert Madrid	This will depend on the road surface and where in its life cycle the roadway is at the time of sealing. I would say the normal life of crack pouring would be around 5 to 8 years.
Larry Dungan	3 years.

The CDOT survey also asked participants to describe any crack sealant installation or performance problems that have been experienced, along with identified causes and proposed or implemented solutions if applicable. As table 16 shows, more than half of the respondents cited issues with performance after application of deicing materials.

Table 16. Installation and performance issues, causes, and solutions from CDOT responses.

Respondent	Describe any crack sealant installation or performance problems you've experienced, along with identified causes and proposed or implemented solutions if applicable.
D'Wayne Gaymon	If put down after road is sprayed with liquid snow melt products it doesn't seal or stay in the crack well. If crack is wet it doesn't perform as needed. If too cold or too hot it works, but not as well as it should, creates lost product or seal. Quit crack sealing roads that have been sprayed by liquid product or use heat lance to get product to seal. Don't crack seal when crack is wet or use heat lance. Most of our work is scheduled for the fall to avoid these issues.
TJ Blake	Our biggest issue is with roads that have been treated with deicer products. No product that we have found will stay down in these conditions.
Greg Hayes	Traffic pulling material out of the cracks.
Byron K Rogers	Again your Oil Temp when applying is important as well as the surface being clean. Mag [magnesium chloride] treated roads can be a problem as well. Know the roads you are going to do. Plan your attack and use your strategy by crack pouring your heavy liquid areas early fall then go to your secondary roads. Ensure your equipment at the end of the year (spring, summer) such as your tar pot is clean out and all preventive maintenance is done so it is ready to go. Record air temperature, surface temperature, and oil temperature every hour for documentation. Sometimes products fail.
Phillip Anderle	Product not sticking because of too cold of material temperature or too cold of air and surface temperature or the crack not being heat lanced to burn off road contaminants that reduce the bonding ability of the material being applied.
Robert Madrid	We did have problems with the performance of a material that would not set up and stayed very soft, causing the materials to be pulled from the crack. We also had material that was too hard when it set up the crack opened up within a month of pouring. Both situations we looked at the material and changed the type to fit our needs.
Larry Dungan	The material peeling up from the roadway. Make sure the crews are cleaning the areas well.

One of the final questions in the CDOT survey pertained to the use of any non-standard crack sealing materials or practices. Table 17 shows the responses provided.

Table 17. Nonstandard crack sealing practices from CDOT responses.

Respondent	In the past, have you tried anything other than your standard crack sealing materials or practices, and what was the result? Is there anything unique that you do that you feel improves performance, increases efficiency, etc. Please provide as much detail as possible to share your knowledge with the rest of the state.
Byron K Rogers	Use the correct product for the type of cracks you have. Example alligator cracks use CRS2P oil and apply w/tar pot buggies and squeegee and apply a fine blotting sand. Or look at an Armor coat seal. I realize this is old school and is labor intensive, but it works. In the past I have seen the wrong type of crack pour being used in the wrong application.
Phillip Anderle	We have used mastic material for wide cracks and it works fantastic. I wish we could get it on our APL. We try to pour cracks above freezing. We heat lance everything. We follow manufacturer's recommendations on heating and handling the material. We use heated wands and we try to use large capacity kettles so we can pour most of the day without having to add material that would cool the product down. We try to pour at least twice the depth of the width of the crack.
Robert Madrid	The most important process of crack pouring is to have a clean dry surface, the crack must be blown out to at least a half an inch. Mag [magnesium chloride], apex or other winter materials can affect the ability of the materials to bond to the asphalt.

CDOT Policy

CDOT's current policy for crack sealing is provided in a March 1, 1991 memo to District Engineers from Doug Shaffer, titled "Policy and Procedures for Crack Filling and Joint Resealing in Colorado." This document is sometimes referred to as the "Shaffer memo." For project selection, the policy distinguishes between crack filling on newer and older pavements. On newer pavements "cracks should be filled as soon as possible after detection, preferably in the first fall crack filling period after they initially appear." Crack filling on older pavements is more complex, and requires an evaluation of the pavement and the condition of the cracks, as well as an evaluation of the potential for moisture-related damage, among other factors. In any case, a pavement evaluation is recommended "to determine if crack filling will be cost-effective." The overall objective of the evaluation is to determine if some other blanket treatment, such as a chip seal or slurry seal, may be a better alternative. In any case, crack sealing may still be a useful pre-treatment. Crack filling should take place in the fall or spring, "when the pavement is dry and air temperatures are above 35 °F." Fall crack filling is preferred. Hot-air lances are identified as an effective tool to dry out moist cracks immediately prior to sealing.

Sealant material recommendations are based on crack width. "For cracks 1/4-inch or less, an ASTM D1190 or a CDOH-approved cold pour sealant" is recommended. Sealant should be applied under pressure and not by a pour pot… For cracks greater than 1/4-inch, use either an ASTM D1190, D3405, or D5078 rubber asphalt material. Cracks in excess of 1 inch wide can be filled with 1/2-inch minus road mix or suitable patching material." [Note: since the publication of this memo ASTM has changed its designations for sealant materials.]

The cornerstone of a good crack filling operation is "clean and dry." Compressed air may be used to remove "moisture, dirt, and sand, and will usually provide a clean face for bonding. A heat lance can be used to dry cracks." Crack routing is discouraged because it adds cost and doesn't improve performance. It may also damage the surrounding pavement and be difficult to accomplish on randomly oriented cracks without creating more cracks. The following additional guidance is provided in this memo (CDOT 1991):

- Crack filling should be performed well in advance and independent of any type of overlay operation.
- If sealant tracking occurs, sand may be used as a blotter. A squeegee used over freshly filled cracks and limiting the width of the overband to 4 inches are also helpful.
- Filling cracks 1/2-inch wide and less can be easily accomplished with maintenance forces while using higher quality materials and specialized equipment can suggest the need for contracting out this work.

In a subsequent document, *Guidelines for Pavement Surface Treatment* (CDOT 1994), crack sealing, as well as joint resealing, seal coats, asphalt overlays, and chip seals are discussed. The guidance in the 1994 document is essentially identical to that contained in the 1991 memo.

CHAPTER 3. CDOT GUIDELINE RECOMMENDATIONS

This chapter outlines recommendations for revised crack sealing guidelines for CDOT. It is based on CDOT's previous guidance on this topic, most notably the 1991 Shaffer memo (CDOT 1991), but is updated to reflect current practices, material designations, and recent experiences. Important information is provided on the purpose of crack sealing, project selection, construction timing, materials selection, construction and installation techniques, and construction inspection.

As noted previously, many agencies make a distinction between crack sealing and crack filling. CDOT has noted that for in-house sealing operations it is problematic to distinguish between crack sealing and crack filling activities within a project. The primary reason for this is that it is not practical to use different sealing methods and materials on the same project (unless the work is done by contract). There is also an inherent difficulty in trying to differentiate between a working crack and a non-working crack in the field. As a result, CDOT uses a single operation for its in-house sealing contracts, one that generally conforms more to a "filling" activity than to a "sealing" activity (as described by the above definitions). In the context of this document, the use of the term "crack sealing" is generically used to refer to CDOT's in-house practices, whether they are crack sealing or crack filling.

Purpose of Crack Sealing

Crack sealing serves several purposes. Its primary purpose is to keep moisture from entering into the pavement structure or to reduce the amount of moisture that infiltrates into the pavement through the surface. This in turn helps to maintain the integrity of the pavement structure and prevent base failures, pothole development, crack deterioration, and increased roughness levels. Sealing may also provide additional benefits, such as producing a more uniform ride, mitigating reflection cracking when placed prior to an HMA overlay, or improving the performance of a subsequent surface treatment by reducing the occurrence of bumps or humps at each filled crack. Crack sealing also keeps incompressibles out of cracks, reducing crack deterioration. When performed in a timely and effective manner, crack sealing is expected to extend the life of an HMA pavement (Peshkin et al.). In an established maintenance program, crack sealing will be performed on a regular and periodic basis over the life of the HMA pavement.

Project Selection

In order to ensure the overall effectiveness of the treatment, a number of factors should be considered when selecting candidate projects for crack sealing. A summary of these important factors are listed below:

- Pavement condition. Unless being considered for an overlay, a pavement that is a good candidate for crack sealing is one that is generally in good condition. The surface is not excessively worn or oxidized, there is little to no structural (alligator or fatigue) cracking, and little to no block cracking. As a whole, the pavement has adequate strength to carry the current and future traffic loadings.
- Pavement age. By itself, pavement age is not a deciding factor in selecting a project for crack sealing. For example, new pavements exhibiting cracking immediately after construction are suitable candidates for crack sealing. And older pavements, say more than 20 years old, may still be candidates for crack sealing, provided other conditions are met. However, generally speaking, older pavements are likely to have more significantly deteriorated cracks or a higher density of cracks that would otherwise diminish the effectiveness of the crack sealing treatment.
- Time to rehabilitation. It is not recommended that cracks be sealed on a pavement during the last several years prior to a major rehabilitation. In this instance crack sealing is unlikely to provide much of a benefit, especially if load-related failures are observed.
- Crack condition. Cracks to be sealed should be well defined and should not exhibit excessive secondary cracking or breakdown (e.g., raveling) of the crack walls.
- Crack density. While maintaining sealed cracks on a pavement provides tangible benefits, crack sealing is not a cost-effective strategy when there is an excessive amount of cracks. As a general rule, a pavement with transverse cracks spaced more closely than 20 to 30 feet may not be a good candidate for crack sealing unless there is no viable alternative. Such pavements are likely to have a rough ride even if the cracks are sealed.

Furthermore, a pavement with more than approximately 20 percent of the surface area[1] needing crack sealing or filling should be considered a candidate for a different treatment.

- Crack width. Transverse and longitudinal cracks between 1/4 and 3/4 inch wide are good candidates for crack sealing. Although wider transverse cracks can be sealed, the existence of these wide cracks will negatively affect the pavement ride. Sealing very wide cracks also requires a different sealant material.

- Traffic: While crack sealing is appropriate for pavements subjected to all traffic levels, the performance and life of a crack sealing treatment may be affected by traffic volumes. In addition, the cost of installation may be greater on higher volume roadways where more rigorous traffic management techniques are required.

Seasonal and Ambient Conditions

In general, cracks can be sealed any time the ambient temperatures are above the material manufacturer's recommended minimums and the crack itself is clean and dry. However, in practice certain times of the year are better than others, and other environmental factors (such as humidity, precipitation) also come into play. The following summarizes the conditions recommended for performing crack sealing.

- Time of year. Ideally, it is recommended that cracks be sealed in the spring or fall during a period of moderate temperature. This is because transverse working cracks are at their widest in the winter (as the pavement contracts in response to the cold temperatures) and at their narrowest in the summer (as the pavement expands in response to the warmer temperatures). Placement of the sealant under either of these temperature extremes will place additional stress on the sealant and on the pavement, leading to reduced performance. Working cracks that are sealed mid-course in their annual movement cycle (typically in the spring or fall) do not experience excessive compression or expansive stresses, and sufficient sealant is able to adequately fill the crack (Smith and Romine 1999). Non-working cracks (such as longitudinal cracks) do not experience significant movement and can be sealed almost any time the temperature and crack conditions are

[1] Percent sealed area can be calculated by multiplying the number of linear feet of cracking by 1 foot, dividing the result by the surface area of the pavement, and multiplying by 100.

met, but as a practical matter would be sealed at the same time as the working cracks on a given project.

Another time-of-year consideration is the presence of deicers if crack sealing is undertaken after deicers have started to be used in the fall or before they have been washed away in the spring. Some research (e.g., Shuler and Hessling 2011; Shi et al 2009) and anecdotal experience indicates that the presence of deicers may inhibit sealant performance. In Colorado, this suggests that sealing should take place either in the spring, after the use of deicers is no longer necessary and spring rains have flushed residue out of cracks, or in the fall before deicers have been used.

- Ambient temperatures. The placement of the crack sealant material should be performed under ambient temperature conditions in accordance with the recommendations provided by the sealant manufacturer; as a general guideline, the air temperature should be above 40 °F. Although lower temperatures may be tolerated when a hot-air lance is used to prepare the crack reservoir, this extra step and cost do not necessarily ensure the desired performance and should be considered a last resort rather than the preferred approach.
- Other environmental factors. Several other environmental factors should be considered when performing a crack sealing project:
  - Sealing during a period of seasonal rains will make it more difficult to dry out the crack. The crack and pavement must be dry for crack sealing to perform well.
  - Excess pavement moisture may be present in the spring as the underlying foundation materials thaw out. If this is noted to be a prevailing problem on a project, it is best to defer crack sealing until later in the spring or early fall.
  - In the fall, dew may form on the cracks when the pavement temperature is less than the ambient temperature. This may require delaying the crack sealing until later in the day or using a hot-air lance.

Material Selection

There is a wide range of materials available for sealing cracks on HMA pavements. Broadly speaking, these generally are classified as either hot-poured thermoplastic materials or cold-poured emulsified asphalt materials. For most crack sealing operations, hot-poured thermoplastic materials are preferred because of their increased flexibility and extensibility. This is especially important where cracks experience movement from temperature fluctuations or deflection.

By definition, thermoplastic sealants are bitumen-based materials that soften upon heating and harden upon cooling. Although a number of different thermoplastic sealant types have been used, in the past several decades rubberized or polymer-modified asphalt has become the sealing industry standard. This type of sealant is produced by incorporating various types and amounts of polymers and melted rubber into the asphalt. Softer grades of asphalt are sometimes used to further improve low temperature extensibility. These materials, referred to as low-modulus rubberized asphalt sealants, are used for crack sealing operations in many northern states. Overall, rubberized asphalt sealant materials possess a desirable working range with respect to low temperature extensibility and resistance to high temperature softening and tracking.

Most rubberized asphalt materials are described by ASTM D 6690 (equivalent to AASHTO M 324), which defines four different grades of material:

- ASTM D 6690, Type I: For moderate climates, 50% extension at 0 °F.
- ASTM D 6690, Type II: For most climates, 50% extension at -20 °F.
- ASTM D 6690, Type III: For most climates, 50% extension at -20 °F, along with other special tests.
- ASTM D 6690, Type IV: For very cold climates, 200% extension at -20 °F.

In selecting a crack sealant material, key characteristics important to the specific project must be identified; example considerations include the following (Smith and Romine 1999):

- Preparation time.
- Workability and ease of placement.
- Curing time.
- Adhesiveness
- Cohesiveness.
- Resistance to softening and flow.

- Flexibility.
- Elasticity.
- Resistance to aging and weather.
- Abrasion resistance.
- Cost.
- Performance/life.

Actual experience and field performance should be considered when selecting a sealant material.

Sealing materials available for use by Colorado DOT are identified in the DOT's Approved Product List (APL) in the Sealant [Joint and Crack] category, Joint/Crack sub-category. Three different types of materials are found in three base categories: ASTM D 5078 (a hot-applied crack filler product), ASTM D 6690 Type II, and ASTM D 6690, Type IV.

Installation Techniques

A fundamental tenet of achieving effective performance from a crack sealant installation is "clean and dry." That is, a deliberate preparation process should be followed that results in a crack that is clean and dry: this provides the greatest probability that a strong, permanent bond will be formed between the pavement and the sealant material. The presence of dirt, debris, and moisture detract from obtaining a strong bond. Key aspects of the installation process that contribute to an effective crack sealing project are summarized below.

- <u>Crack routing</u>. Although not used by CDOT, many highway agencies use a router on working cracks less than 3/4 inch wide as a means of providing a reservoir for the sealant material. When used, rout dimensions are commonly 3/4 inch wide by 3/4 inch deep, and the routing equipment must be designed so that it can easily follow meandering cracks without excessively damaging the surrounding crack. Several studies have documented enhanced performance associated with the use of routing (for example, Smith and Romine 1999; Caltrans 2008; MnDOT 2008; and Cuelho and Freeman 2004).
- <u>Crack cleaning</u>. Crack cleaning is performed by using compressed air to remove as much loose material, dust, dirt, and other debris as possible from the crack. The airflow should

have a minimum pressure of 100 psi and a maximum of 150 psi (Yildirim, Qatan, and Prozzi 2006). In addition, the compressed air equipment should use a filter so that oil is not sprayed into the crack. A cloth can be held over the compressed air flow to check the cleanliness of the discharge. To verify that the crack is clean (if it is wide enough), rub a finger or clean black cloth along the crack wall; if it does not collect dust it is ready for sealing.

- Crack drying. A hot-air lance is used to both clean out and dry cracks. This tool is especially useful where there is some moisture in the crack, but the pavement is not saturated. Furthermore, the hot-air lance warms the surface of the pavement, which helps contribute to a stronger bonding condition. Several studies have demonstrated the effectiveness of using a hot-air lance in improving the performance of crack seal installations (Smith and Romine 1999; MnDOT 2008).

  In essence, a hot-air lance produces a stream of hot compressed air that can be directed at the crack to remove debris, eliminate moisture, and warm the crack sidewalls to enhance the bond between the sidewalls and the sealant material. Typical requirements for hot-air lances are producing 1,800 ºF air at a velocity of about 3,000 feet per second (MnDOT 2008). The nozzle should be kept 2 to 4 inches away from the crack to prevent burning and scorching the HMA pavement.

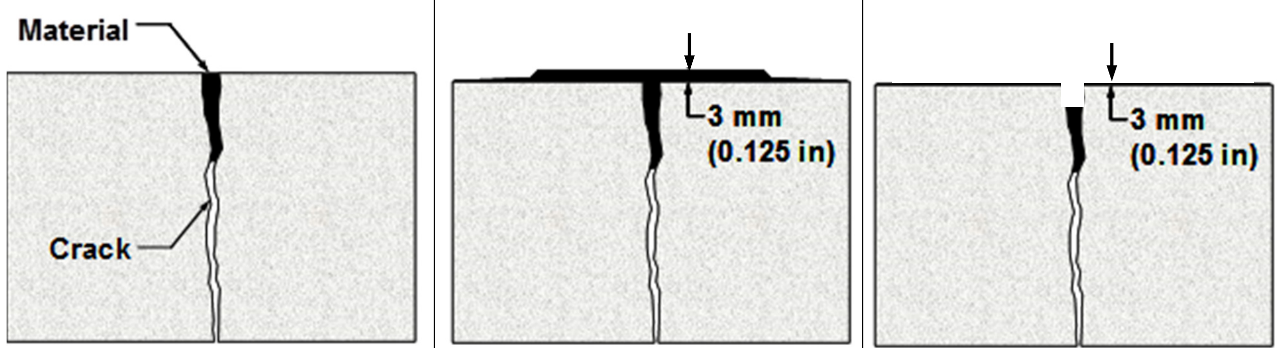
- Removing vegetation. Vegetation growing in a crack will inhibit the proper performance of the sealant. Where vegetation is present, an herbicide should be applied to the crack at least 2 weeks prior to the crack sealing operation.

- Placement configuration. Placement configuration refers to the way the sealant will be positioned in the crack, and will depend on whether the crack is routed and the purpose of the crack sealing operation. Primary configurations used by CDOT are shown in figure 20 and described below:

  - *Flush fill*. In the flush fill approach, the sealant is placed in the crack such that it level with the pavement surface. The flush fill can be used in conjunction with routing to produce a reservoir, but CDOT commonly does not rout cracks. It is not recommended that the flush fill configuration be used for pavements that will be overlaid.

– *Overband*. In the overband configuration, the sealant material is placed into and over an unrouted crack. The material over the crack can be left unshaped, or may be squeegeed to produce a thin band of material that extends several inches on either side of the crack. The overband configuration is not recommended for pavements that will be overlaid or where carbide-tipped plow blades are used for snow removal. In addition, pavements with an excessively high overband or with a high number of overbanded cracks may contribute to increased roughness levels.

– *Recessed*. The recessed configuration leaves the sealant beneath the pavement surface. This configuration should be used if the pavement is being overlaid shortly after sealant placement or if cracks are sealed when ambient temperatures are very low. The recessed configuration should be considered if excess sealant on the pavement surface is contributing to a rough ride.



a. Flush fill	b. Overband	c. Recessed

Figure 20. Commonly used CDOT crack sealing configurations.

- Material placement. The placement of the sealant material in the crack includes several critical aspects, as listed below (Smith and Romine 1999).

  – *Achieving sealant application temperature*. Thermoplastic sealing materials generally come prepackaged in blocks that are placed in a special melter/applicator for heating. These indirect-heat, agitator-type devices (meeting the requirements of Appendix X1.1 of ASTM D 6690) produce heat that is applied to a transfer oil that surrounds a double-jacketed melting vat containing the sealant material, thereby providing an indirect method of heating the material. The central agitator serves to ensure the uniformity of the temperature of the sealant. Throughout this process, it is important to follow the crack sealant manufacturer's recommendations with respect to safe heating temperatures, prolonged heating limitations, and recommended placement temperatures. A supplemental thermometer is highly recommended for verifying material temperatures shown on the melter temperature gauges. Sealant that is overheated or heated for an excessively long time will degrade.

- *Installing sealant*. Crack sealant should only be applied once the material has reached the recommended application temperature and several initial cracks have been cleaned and prepared. Most sealant applicators are pressure-wand systems commonly equipped with the sealant melter, and consist of a pump, hoses, and an applicator wand. During installation, the nozzle of the applicator should be placed such that the crack is filled from the bottom up (thus minimizing the entrapment of air) and to the proper level depending on the selected configuration. The operation should be done in a continuous motion along the length of the crack, with additional sealant re-applied in areas where the initial sealant application settled or was insufficient. Bubbling that occurs when applying the sealant indicates that moisture is still present in the crack and additional drying is needed. Note that different sealant configurations are created with different applicator wand tips.

- *Finishing*. The installation of the sealant is often followed by a squeegee to strike-off excess sealant or to shape the sealant material into an overband. The squeegee should closely follow the sealant application wand (within 2 to 3 feet). Excessively thick overbands (greater than about 1/8-inch) should be avoided to minimize joint plow damage.

- *Blotting*. After sealant application, a blotting material may be needed to reduce or minimize tracking of the sealant by vehicle tires. The need for this will depend on the type of sealant material, the ambient temperatures, and how quickly the road will be opened to traffic. Common blotting materials include toilet paper, talcum powder, limestone dust, sand, or proprietary, spray-applied detackifiers.

- *Clean up*. After the crack sealing activities are completed and before the roadway is opened to traffic, the work site should be cleaned to remove excess sealant or spills from the surface and any other debris. In addition, melters and other application equipment should be cleaned in preparation for their next use.

- Opening to traffic. Ideally, traffic should be kept off the crack sealant until it has fully cured; this will depend on the sealant material and the ambient temperatures, but is commonly about 30 minutes to 1 hours. If conditions require that traffic be allowed on the roadway before curing is complete, then a blotting material may need to be applied.

- Resealing a previously sealed crack. This may come up as a special consideration on a project that has been previously sealed. First, a determination should be made regarding the integrity of the existing sealant; if it is exhibiting significant failure (often taken as 50 percent or more of the length of the sealant is missing, degraded, debonded, or exhibiting some other form of distress that is preventing it from keeping moisture out), then the crack should be re-sealed. A critically important aspect of a resealing application is to ensure that all of the failed sealant is removed and the crack adequately cleaned so that the new sealant can properly bond. Once that is achieved, the same crack sealing procedures are followed.

Inspection and Acceptance

An effective crack sealing project requires that the appropriate pavement is being targeted and that all steps of the operation are performed properly. A summary of recommended inspection activities is listed below (after FHWA 2001):

- Pre-Application Inspection. Pre-application inspection refers to evaluations conducted on the job site prior to conducting the crack sealing operation.

  - *Placement Conditions*. Typical specifications for sealant operations require that the pavement and cracks be dry and that the surface temperature be in a range that will promote a good bond between the sealant to the pavement. To avoid adverse placement conditions, work should not be done during (or soon after) wet weather.

  - *Equipment Inspection*. All equipment should be inspected daily to ensure that it is in good mechanical condition. Any crack cutting and cleaning equipment should be inspected. Router/cutter configurations should be adjusted so that it will provide the desired reservoir. Cutting tool router bits or saw blades should be inspected for missing, chipped, rounded, or broken teeth. Air compressors, hot-air lances, and vacuum cleaning equipment (if used) should be checked for proper performance. For hot-applied sealants, this includes checking that the sealant melter is in good working order. Specifically, this involves checking that all heating, agitation, pumping systems, valves, thermostats, and other parts are functioning properly. Material squeegees or other shaping/forming tools should be inspected to ensure that they are clean, in good condition, and of appropriate configuration to produce desired sealant shape.

  - *Traffic Control*. The traffic control setup, including all signs, devices, flaggers, attenuator vehicles, and so on, should conform to the *Manual on Uniform Traffic Control Devices (MUTCD)* and CDOT standards and specifications.

- Project Inspection. Project inspection items revolve around specific installation activities, as are presented below. Note that not all of these procedures and equipment may be used on a given project.

  - *Reservoir Cutting*. If a reservoir is to be created in the crack, it is important to ensure that the proper reservoir dimensions (width and depth) are being maintained. The router or saw should be centered over the crack, and both sides of the crack should be cut back to sound pavement. Adjustments to the refacing process should be made if an excessive amount of spalling is observed during the cutting process. As part of this, all workers should be outfitted with the proper protective equipment, and the safety mechanisms and guards on equipment should be inspected to make sure they are functioning properly.

  - *Crack Cleaning*. All dirt or debris should be blown from refaced cracks prior to sealant application. A simple cleanliness inspection of the crack can be performed by running a finger along the crack sidewalls to verify that the crack is free from dirt, dust, and debris. The crack should also be free from moisture. As with the reservoir cutting process, all workers should be outfitted with the proper protective equipment, and the safety mechanisms and guards on equipment should be inspected to make sure they are functioning properly.

  - *Hot-Air Lance*. A hot-air lance may be used to dry out a crack, to minimize condensation formation, and to maintain warm pavement temperatures in preparation for the installation of a hot-applied sealant. During this operation, it is very important to avoid burning or scorching the existing pavement surface. Due to the high temperatures of the air from this device, all workers should be equipped with proper safety equipment.

- *Sealant Preparation*. Thermoplastic sealant materials require a certain level of preparation prior to their application in order to maximize their effectiveness. Care should be taken to assure that the material is heated to within the proper temperature range. If the temperature is too low, the material will not flow well, is less likely to penetrate a crack, and will not adhere to the crack sides. If the temperature is too high, the material will age-harden more rapidly, lose its ductility, and fracture more readily.
- *Sealant Application*. The sealant should be applied in a continuous motion with the nozzle in the crack, filling the crack from the bottom up. As needed, a finishing operation using a squeegee should closely follow the applicator wand. The finished sealant application should be inspected to locate areas where the sealant has settled or where too little material was applied. If such areas are observed, additional sealant should be reapplied to those areas to make the installation more uniform.

  Sealant should not be applied when the pavement is wet or when rain is expected during the sealing activity.
- *Blotting*. After sealant application, an appropriate blotting material should be used (as needed) to reduce the likelihood of sealant tracking by vehicle tires.
- *Clean-Up*. After the crack sealing activities are completed, the work site should be cleaned before opening the roadway to traffic.
- *Opening to Traffic*. Since all sealant materials used for HMA pavements are initially sticky and vulnerable to trafficking, the contractor should employ the necessary traffic control procedures to avoid use by both vehicles and pedestrians for the proper curing time.

• Acceptance. In addition to any of the above noted inspection activities, acceptance of the final work product includes checking for any missing sealant, excessive tracking or sealant pullout, or areas where the sealant has sagged too far into the crack.

CHAPTER 4. SUMMARY AND RECOMMENDATIONS

Summary

This report presents the results of a study of Colorado DOT's crack sealing practices and recommendations for a revised CDOT crack sealing policy. The study included a survey of other agency practices, a selected survey of CDOT practices, and a review of literature on crack sealing and filling. The results of this background study are reported in Chapter 2 of this report.

CDOT's current guidance on crack sealing is approximately 20 years old. Updated draft guidance was developed based on the current state of the practice in Colorado and elsewhere. This guidance is provided in chapter 3 of this report. It is envisioned that the final guidelines adopted by CDOT would be extracted from the guidance and disseminated as a stand-alone document.

Additional information on evaluating sealant on existing pavements is provided in Appendix D. The focus of this information is helping CDOT staff to identify when failed sealant is in need of replacement.

Recommendations

The guidance provided in chapter 3 differs in several respects from current CDOT practice. In order to improve the overall performance of crack sealing operations in Colorado, CDOT is encouraged to consider the following recommendations:

- Develop guidance on project selection to include identification of appropriate windows of opportunity to seal non-load related cracking.
- Where feasible, differentiate between crack sealing and crack filling operations. Transverse cracks that open and close with temperature changes present the greatest challenge for successful crack sealing and would benefit most from the use of high quality crack preparation procedures and sealant materials.
- Apply sealant in the spring and fall when cracks are opened a moderate amount and before deicing applications have started.

- Link sealant material selection to the temperature limits and performance requirements identified in ASTM D 6690.
- For enhanced sealant performance in working cracks, consider the creation of a uniform crack reservoir specially dimensioned for the sealant to be applied. The reservoir can most easily be created using a rotary impact router; however, if the cracks are quite straight, a diamond-blade crack saw may be used.
- Encourage the adoption of self-inspection procedures in which crack conditions are verified, and sealant is placed in clean and dry pavement.
- Use troubleshooting guidance to identify the cause and to resolve any premature failures.

REFERENCES

Al-Qadi, I., J. F. Masson, E. Fini, S. H. Yang, and K. K. McGhee. 2009. *Development of Performance-Based Guidelines for Selection of Bituminous-Based Hot-Poured Pavement Crack Sealant: An Executive Summary Report.* FHWA/VTRC 09-CR7. Virginia Department of Transportation, Richmond, VA.

California Department of Transportation (Caltrans). 2008. *Maintenance Technical Advisory Guide—Volume I Flexible Pavement Preservation*. Caltrans, Sacramento, CA.

Colorado Department of Highways. 1991. *Policy and Procedures for Crack Filling and Joint Resealing in Colorado*. Colorado Department of Highways memorandum from Doug Shaffer to District Engineers. Colorado Department of Highways, Denver, CO.

Colorado Department of Transportation (CDOT). 1994. *Guidelines for Pavement Surface Treatment*. Colorado Department of Transportation, Denver, CO.

Carter, S., K. Ksaibati, and G. Huntington. 2005. "Field and Laboratory Evaluations of Hot-Poured Thermoelastic Bituminous Crack Sealing of Asphalt Pavements." *Transportation Research Record 1933*. Transportation Research Board, Washington, DC.

Cuelho, E. and R. B. Freeman. 2004. *Cost-Effectiveness of Crack Sealing Materials and Techniques for Asphalt Pavements*. FHWA/MT-04-006/8127. Montana Department of Transportation, Helena, MT.

Federal Highway Administration (FHWA). 2001. *Crack Seal Application: Pavement Preservation Checklist Series*. FHWA-IF-02-005. Federal Highway Administration, Washington, DC.

Minnesota Department of Transportation (MnDOT). 2008. *Recommended Practices for Crack Sealing HMA Pavement*. Local Road Research Board (LRRB) Project 822. MnDOT Office of Materials, St. Paul, MN.

Peshkin, D., K. L. Smith, A. Wolters, J. Krstulovich, J. Moulthrop, and C. Alvarado. 2011. *Preservation Approaches for High-Traffic-Volume Roadways.* Strategic Highway Research Program (SHRP) 2 Report S2-R26-RR-1. SHRP, Washington, DC.

Shi, X., M. Akin, T. Pan, L. Fay, Y. Liu, and Z. Yang. 2009. "Deicer Impacts on Pavement Materials: Introduction and Recent Developments." *The Open Civil Engineering Journal*. Volume 3. http://www.benthamscience.com/open/tociej/articles/V003/16TOCIEJ.pdf (Accessed on 2/11/14).

Smith, K. L. and A. R. Romine. 1999. *LTPP Pavement Maintenance Materials: SHRP Crack Treatment Experiment*. FHWA-RD-99-143. Federal Highway Administration, Washington, DC.

Smith, K. L. and A. R. Romine. 2001. *Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements*. FHWA-RD-99-147. Federal Highway Administration, Washington, DC.

Shuler, S. 2010. *Evaluation of the Performance, Cost-Effectiveness, and Timing of Various Pavement Preservation Treatments*. CDOT-2010-3. Colorado Department of Transportation, Denver, CO.

Shuler, S. and J. Hessling. 2011. "Elevation, Deicer Impacts Crack Sealant Performance." *Pavement Preservation Journal*. Naylor, LLC. Gainesville, FL.

Yildirim, Y., M. Solaimanian, and T. Kennedy. 2004. *Comparison of Hot Rubber Crack Sealants to Emulsified Asphalt Crack Sealants (First Report of a Three-Year Study)*. Research Report 0-4061-1. Center for Transportation Research. University of Texas at Austin. Austin, TX.

Yildirim, Y., A. Qatan, and J. Prozzi. 2006. *Field Manual for Crack Sealing in Asphalt Pavements*. Texas Department of Transportation, Austin, TX.

APPENDIX A. ANNOTATED BIBLIOGRAPHY

Purdue University. 2012. ***Performance Evaluation of Crack Sealing and Filling Materials with Pavement Preservation Treatments.*** **Research in Progress. Purdue University and Indiana Department of Transportation, Indianapolis, IN.**

Revised (draft) specification and updated SPR-3114: Treatment Guidelines for Pavement Preservation.

Rajagopal, Arudi. 2011. ***Effectiveness of Crack Sealing on Pavement Serviceability and Life*****. FHWA/OH-2011/14. Infrastructure Management and Engineering, Inc., Columbus, OH. 81 p. http://www.dot.state.oh.us/Divisions/P...ans/Reports/2011/Pavements/134364_FR.pdf.**

This report presents the details of a study to evaluate effectiveness of Ohio Department of Transportation’s (ODOT's) prevailing crack sealing program. Evaluation was performed through field monitoring a large number of crack sealed and control sections. Field monitoring included collection of performance data over the five year period after crack sealing. The data collected were used to address the following specific issues: Do existing crack sealing practices within ODOT enhance pavement performance? What is the optimum timing of the treatment? Does crack sealing extend pavement life? Is crack sealing a cost effective treatment? The analysis revealed that crack sealed pavements, in general, performed better than the control sections on a 5-year cycle. Regardless of pavement type, aggregate type used in the surface layer, and the prior pavement condition, crack sealing always results in performance gain. Maximum performance gain can be achieved by treating pavements with Pavement Condition Rating (PCR) ranging from 66 to 80. The performance prediction models indicate crack sealing treatment can extend the service life of pavements by up to 3.6 years. The cost analysis using a common metric such as the Net Present Value illustrates that crack sealing, as a maintenance strategy, is economically viable for pavements in the prior PCR range of 66 to 70. From a practical point of view, it is hereby recommended that ODOT develops a policy to allow crack sealing as a strategy for pavement preventive maintenance for all pavements in the prior PCR range of 66 to 80.

Yardley, M. 2009. "Crack Sealing: A Waste of Time or Pavement Maintenance Budget Saviour." ***AAPA International Flexible Pavements Conference*****. Surfers Paradise, Queensland, Australia. 6 p.**

The sealing of cracks in asphalt pavements and joints in concrete pavements has been a maintenance and construction function for many years. Until recent years, the sealing approach was accepted as a menial maintenance task, with the value being seen as a short-term direction. Yet, others declaring no value in preserving their pavements with crack sealing deleted this task from their maintenance and construction programs altogether. Today's technology has improved with better performing types of sealing material and methods for sealing cracks/joints. At the same time, the demand for a cost effective preventative maintenance technique is required to extend the life of our roadway and pavement system. The current recognition that prompts corrective action to seal crack/joints before they begin to contribute to accelerated pavement deterioration will pay dividends. The investment that any State Road Authority, City or Shire has in pavement-in-place is far too great to even consider replacing at today's prices. The most cost effective form of pavement preservation is early intervention with best practice crack sealing.

Green, Roger. 2010. ***Crack Sealing: Database Analysis and Effects on Pavement Serviceability and Life*****. RIP. Ohio Department of Transportation, Columbus, OH.**

In March 2000, the Ohio Department of Transportation (ODOT) initiated a study to design a project to statistically verify the effectiveness of ODOT's current crack sealing program on pavement condition and life. The primary objective of that study was to determine if crack sealing was cost effective and, if so, to determine the optimal time, in terms of pavement condition rating or distress, to perform the sealing operation. From 2000 through 2002, the researchers worked with the Office of Pavement Engineering (OPE), the Districts, and Counties to initiate the field experiment, set up over 700 test sections (including control sections), conduct preliminary pavement condition evaluations, develop an interactive database, and establish guidelines for long term monitoring. ODOT has continued to collect data according to procedures recommended by the researchers after 2002. In early 2005, OPE asked the original PI to conduct a preliminary review of the data. The researcher critically reviewed the database and reported two important findings: 1) The database is incomplete with respect to certain fields, i.e., the crack seal date is missing; and 2) The pavement performance on certain test sections does not follow a logical trend, i.e. spikes in the pavement performance time plot. The objective of this project is to critically review, verify data integrity and completeness, and validate the crack seal database. Phase 1 is for verification of data integrity, completeness and validation of crack seal database. Phase 2 is for analysis of effectiveness of crack sealing on pavement serviceability and life.

Chehovits, J. 2005. "Proper Crack Sealing Provides Extended Life for Asphalt Pavements." ***HMAT*****. Vol. 10, No. 2. March/April 2005. National Asphalt Pavement Association, Lanham, MD.**

Proper crack sealing treatments extend the life of asphalt pavement by protecting it from further cracking and water damage. Treatments for "working cracks" (with more than 1/8 inch thermal movement) use routed widened reservoirs and highly extensible sealants to accommodate movement. Treatments for "non-working cracks" (with less than 1/8 inch movement) include cleaning and applications of flexible traffic resistant sealant. All crack sealing and or filling treatments must be able to function over the range of temperatures throughout the year, though different performance ranges are available. The manufacturer's installation and safety instructions and agency requirements must be followed for optimal performance.

Carter, Steve, Khaled Ksaibati, and George Huntington. 2005. "Field and Laboratory Evaluations of Hot-Poured Thermoelastic Bituminous Crack Sealing of Asphalt Pavements." ***Transportation Research Record 1933*****. Transportation Research Board, Washington, DC. pp. 113-120.**

This paper describes the results of field and laboratory tests evaluating four configurations and three materials used for crack surfacing. Crack surfacing, as defined in this paper, is the sealing of cracks over 1 in. (25 mm) wide in asphalt pavements. Laboratory testing using the thermal stress restrained specimen test (TSRST; AASHTO TP 10-93) determines the temperature at which a specimen with its ends restrained fails due to thermal contraction. Field studies evaluate the performance of two materials with the uniform overband configuration on three roads in Wyoming. All crack surfacing materials are commercially available hot-poured thermoelastic bituminous products. Overband configurations are found to be the preferred method for applying crack surfacing, based on the TSRST. Failure modes are evaluated and generally found to propagate from the interface between the surfacing material and the pavement to which it is bonded. Field studies indicate that traffic and snowplowing have a significant influence on the performance of crack surfacing. Cracks sealed with the same configuration and the same material performed substantially better on US-26 than on I-25 over the same time periods. The only obvious difference between the two is that I-25 has three to four times as much traffic and correspondingly greater snow control efforts. This study concludes that materials, configurations, and traffic or snowplowing frequency influence the performance of crack surfacing.

Cuelho, E. and R. B. Freeman. 2004. *Cost-Effectiveness of Crack Sealing Materials and Techniques for Asphalt Pavements.* FHWA/MT-04-006/8127. Western Transportation Institute, Montana State University, Montana Department of Transportation, and Federal Highway Administration, Washington, DC. 313 p.

Sealing or filling cracked asphalt pavements to prevent the intrusion of water into the pavement structure has long been an accepted practice of the Montana Department of Transportation. The goals of this research are to establish the most economical and effective method of sealing pavement cracks for Montana; and to better determine the role of crack sealing within Montana's pavement management system (PMS). This study has involved the construction of 4 experimental test sites within larger crack sealing projects. These test sites have included combinations of 11 sealant materials and 6 sealing techniques. Monitoring of the test sites includes visual inspections (for all of the sites) and nondestructive structural readings and surface distress identification under Montana's PMS (for one test location). An estimate of the useful life of each crack sealing method has been determined from these investigations. This report presents information on project history, the project methodology used for evaluating and analyzing the performance of sealed cracks, and the results of the cost-effectiveness analysis. Final results are presented for the 4 test sites: Conrad, Dutton, Tarkio, and Helena (Seiben). Results show that similar performance has been observed for all materials with ASTM D 5329 cone penetrations in excess of 90. In general, routing of transverse cracks improved the performance of the sealants. Routing does not appear necessary for centerline longitudinal cracks. Notably, router operators seem to prefer the shallow reservoir configuration as compared to square reservoirs. The test site established near Helena provided the most reliable and useful data. As such, a detailed review of the final performance from 4 1/2 years of service is summarized. In general, the highest failure rates occur during the coldest period of the year, and much of this distress exhibits a tendency to "heal" after exposure to the summer heat and traffic. An eclectic forecasting model has proven useful in predicting the life of crack sealing operations for those methods that did not show complete failure during the evaluation period. Structural evaluations using a Falling Weight Deflectometer did not prove an advantage for any particular sealing technique or sealing material nor did they prove the benefit of sealing cracks in asphalt pavements. Therefore, conducting a life-cycle cost analysis was impractical because no structural or ride benefit was proven at this site. However, a cost-effectiveness analysis was performed and the averaged results showed that, overall, Crafco 522 was the most cost-effective material and the Shallow and Flush was the most cost-effective fill technique. However, the crack sealing approach that has the highest cost-effectiveness as calculated herein (defined as the ratio of effectiveness to cost) may not offer the best value, if this effectiveness is in excess of that required to protect the pavement from premature damage. More research is necessary to substantiate the need for higher performance materials and techniques.

Fang, Chuanxin, Khaled A. Galal, David R. Ward, and John E. Haddock. 2003. *Initial Study for Cost-Effectiveness of Joint/Crack Sealing.* FHWA/IN/JTRP-2003/11. Purdue University, Indiana Department of Transportation, and Federal Highway Administration, Washington, DC. 259 p.

The sealing and resealing of joints and cracks in PCC, HMA, and composite pavements is assumed to be an important component of pavement maintenance. Recently this practice has been challenged by research indicating that sealing may not be cost-effective. The Indiana Department of Transportation currently spends approximately four million dollars annually to perform joint/crack sealing. The primary objective of the research presented in this report is to investigate the cost-effectiveness of joint/crack sealing in relation to pavement performance. The results of a mail survey showed that most states, including Indiana, do not have quantitative justification for sealing policies, nor do they know the cost-effectiveness of the operations. Based on the experimental design for this research, nineteen test sites were selected in Indiana, each site having one sealed section and one unsealed section. Collected data including falling weight deflectometer measurements, pavement roughness, visual condition surveys, and core samples were used to evaluate the pavement performance between sealed and unsealed sections. A three-dimensional finite element pavement model was developed to evaluate the test location effect on the load transfer measurements. The temperature effect was evaluated by statistical analyses and a temperature correction factor for deflections on asphalt pavement is provided. A statistical model was developed to compare the pavement performance between sealed and unsealed sections for three pavement types, PCC, HMA and composite. The results indicated that there appears to be no significant differences between the performance of sealed and unsealed sections regardless of pavement type, drainage condition and road classification.

Yildirim, Y., A. Qatan, and T. W. Kennedy. 2003. *Performance Evaluation of Hot and Cold Pour Crack Sealing Treatments on Asphalt Surfaced Pavements.* FHWA/TX-03-4061-2. University of Texas, Austin, Texas Department of Transportation, Federal Highway Administration, Washington, DC. 84 p.

This is the second report from the Center for Transportation Research on the Project 4061. It presents the results, findings, conclusions, and recommendations based on the field surveys of the test sections for the second year of a 3-year study. This study comes as an attempt to determine the feasibility of using both hot pour and cold pour sealants. This will be achieved by comparing the long-term performance of both hot and cold pour sealing materials. For the purpose of the study, seven sealing materials were selected; four hot pour sealants designated as H1, H2, H3, and H4 and three cold pour sealants designated as C1, C2, and C3. These materials were applied on eight pavement maintenance sections for testing purposes in five districts in Texas. The investigation on test sections was based on AASHTO P20-94, "Standard Practice for Evaluating the Performance of Crack Sealing Treatment on Asphalt Surfaced Pavements." Three investigation visits were conducted; the first one about three months after the construction (Summer 2001), the second one about one year after the construction (Winter 2002), and the third one which was completed approximately 18 months after the construction (Summer 2002). The visits indicated relatively excellent performance for the hot pour sealants in the majority of the test sections. On the other hand, cold pour sealants showed drastic decline in their performance with time.

Kuennen, T. 2004. "Crack-Filling Program Succeeds in Tough Times." ***Better Roads.*** **Vol. 74, No. 6. James Informational Media, Inc. Des Plaines, IL. pp. 18-21.**

After the capital improvements budget was cut in half, from $21 million, officials in Nassau County's Public Works Department set up an aggressive pavement crack-sealing program in partnership with an outside contractor. While crack sealing was already in place with outside contractors, the department decided to bring it in-house as a full-time seasonal program. After conducting feasibility studies, buying equipment and training crews, the department launched its first full season in fall 2003. The goal to achieve cost-effectiveness was to treat at least 5,000 lineal feet a day. The first season, crews repaired between 6,000 and 7,000 lineal feet a day. By bringing it in-house, the county is able to do repairs when it deems necessary, without having to wait for a contractor to be available. Routers are the key to productivity, so the county purchased two of them, which allows work to continue even if one of the machines breaks down. The county is using material to treat the sealant so that it doesn't stick to car tires. Sealants used and training methods are also described.

Shuler, Scott and Vittorio Ranieri. 2009. "A Study of the Performance of Six Crack Seal Installation Procedures." ***Sixth International Conference on Maintenance and Rehabilitation of Pavements and Technological Control (MAIREPAV6).*** **Politecnico di Torino, Turin Italy.**

This paper describes how the most common method of preventing moisture and debris infiltration into cracked pavement structures is by filling the cracks with asphalt sealers. Maintenance personnel responsible for this activity often have different opinions regarding the most effective method to use to seal these cracks and little objective evidence exists in the literature regarding the best techniques. Often, expedience and safety lead workers to fill the cracks as rapidly as possible without significant initial preparation. Mechanical routing of the crack to form a geometrically defined reservoir for the sealant requires more effort and time. This research was conducted to measure differences in performance between minimal crack preparation and significant preparation. Preparation techniques included routing cracks and air blowing to remove debris, blowing out debris while simultaneously heating the crack to remove any moisture, and simply blowing out debris with compressed air. After crack preparation each crack was filled using two techniques. These techniques included filling to the surface and overfilling and spreading the excess sealant over the edges of the crack. Three sealant suppliers provided five different products at three separate sites. Each combination of product and application technique was placed in six transverse cracks. This resulted in an experiment with a total of 420 filled cracks on approximately 16 km (10 miles) of pavement at three sites. Results after twelve months service indicate a significant difference in performance depending on the preparation method and filling technique. The best results were obtained when cracks were filled using the over-banding technique regardless of whether routed, hot air lanced or air blown. In addition, performance improved between the five month survey and the twelve month survey for some treatments indicating that some healing of the crack sealants may be occurring.

Shuler, Scott and Jason Hessling. 2011. "Elevation, Deicer Impacts Crack Sealant Performance." ***Progressive Railroading.*** **Vol. 5, No. 1. Trade Press Publishing Corporation. pp. 17, 35.**

This article will discuss how the authors measured the performance of two different crack sealants over a period of four years, and the authors found significant differences in performance after only one winter season. The authors also found that the application of magnesium chloride (MgCI) deicer to the pavements prior to crack sealing had a significant negative effect on performance of both crack sealants at the higher elevation test section, but not at the lower elevation test section. Crack sealants prevent moisture and debris intrusion into pavements and the length of time that crack sealants are effective is important to highway agencies. Many of these agencies utilize MgCI solutions to prevent snow and ice accumulation on roadway surfaces. Some maintenance engineers have reported that MgCI solution leaves a residue inside unfilled cracks in asphalt pavements and this affects the performance of crack sealants. If this is true, MgCI should not be applied prior to scheduled crack sealing operations. Unfortunately, snow and ice events can be very unpredictable. This makes planning sealing activities more complicated than they already are. Therefore, a full scale experiment was designed to measure the effect of MgCI on crack sealant performance in Colorado.

Yildirim, Yetkin, Yusuf Yurttas, and Ilker Boz. 2010. "Service Life of Crack Sealants." ***First International Conference on Pavement Preservation.*** **Paper No. 19. California Department of Transportation, Federal Highway Administration, Foundation for Pavement Preservation. Washington, DC. pp. 377-392.**

Crack sealing is vital for the preservation of a pavement and has long been regarded as a necessary annual procedure. However, with limited maintenance budgets and increasing labor and material costs, it is essential that pavement preservation agencies make the most efficient treatment decisions. Road agencies must consider the service life for the crack sealant material that is to be applied if the cost-saving potential of this treatment is to be fully realized. Evaluating the service life of potential crack sealant materials gives these local agencies the ability to choose the most cost-effective preservation treatment for their particular roadway. A study conducted by the Texas Pavement Preservation Center at the University of Texas at Austin measured the service life of hot pour and cold pour crack sealants which are the most commonly used ones by the Texas Department of Transportation (TxDOT). Over the course of three years, the study tested seven different types of sealants: three cold pour sealants and four hot pour sealants, on 33 test sections. The treatment effectiveness of these sealants was measured with regard to the percent failure of the sealed crack. If the treatment effectiveness fell below 80%, the sealant had "failed" and reached the end of its service life. The cold-poured crack sealants used in this study showed a service life of 10 – 16 months, while the hot-poured crack-sealants used in this study demonstrated a service life of 26 – 42 months based on an 80% effectiveness threshold.

Yang, Shih-Hsien et al. "Threshold Identification and Field Validation of Performance-Based Guidelines to Select Hot-Poured Crack Sealants." ***Transportation Research Record 2150.*** **10-0657. Transportation Research Board, Washington, DC. pp. 87-95.**

Hot-poured bituminous crack sealing has been widely accepted as a routine preventative maintenance practice. With proper installation, the sealing is expected to extend pavement service life by 3 to 5 years. However, current specifications for selection of crack sealants correlate poorly with field performance; hence, a set of new testing methods, based on sealant rheological and mechanical properties, was developed recently. Measurements of the mechanical properties of crack sealant at low temperatures are among the criteria introduced as part of the developed performance-based guidelines. The main purpose of this study was to identify and validate the low-temperature selection thresholds for the newly developed performance-based guidelines for selecting hot-poured bituminous crack sealants. In this study, selection criteria for crack sealant bending beam rheometer (CSBBR) and crack sealant direct tension tester (CSDTT) tests were identified. Two performance parameters for CSBBR test were used for the selection criteria: stiffness at 240 s and average creep rate (ACR). Both parameters were identified by comparing laboratory testing results with known sealant field performance, obtained from a long-term study in Canada. The selection criterion for the CSDTT test was extendibility, on the basis of field values reported in the literature. The recommended selection criteria were used to predict the field performance of 12 sealants evaluated by the National Transportation Product Evaluation Program (NTPEP). Results showed good correlation between the proposed selection thresholds and NTPEP field sealant performance.

Shuler, Scott. 2010. "An Apparent Healing Mechanism in Asphalt-Based Crack Sealants." *TRB 89th Annual Meeting Compendium of Papers.* 10-2525. Transportation Research Board, Washington, DC. 17 p.

Crack sealing may be one of the most cost effective and frequently used, methods of pavement preservation. Sealing cracks in asphalt pavements helps reduce moisture and debris infiltration into the pavement structure which should result in increased pavement life expectancy. However, the life expectancy of crack sealants is likely related to sealant type, installation method and pavement. And, it is logical to presume that sealant performance should be predictable. However, there have been indications that a certain amount of healing or resealing of asphalt-based crack sealants may occur during hot weather and through the kneading action of traffic. If this is true, performance prediction could become significantly more challenging. However, the implication could mean that sealing effectiveness has greater longevity than heretofore believed. To help answer this question an experiment was designed to evaluate performance of three crack sealants placed in three environments using three distinct installation procedures and two methods of crack filling. Supplies were instructed to bring materials, equipment and personnel necessary to successfully install each of the products in six cracks per each of the treatment combinations. The objective of the experiment was to determine short and long term performance characteristics of each combination of material, method and location. Performance was evaluated by measuring the amount and severity of cracking as a function of the original filled crack length. Results indicate that healing or resealing is occurring and does not seem to be related to supplier, installation method or location.

Al-Qadi, Imad L. et al. 2009. *Development of Performance-Based Guidelines for Selection of Bituminous-Based Hot-Poured Pavement Crack Sealant.* An Executive Summary Report. FHWA/VTRC 09-CR7. University of Illinois, Urbana-Champaign, Virginia Department of Transportation, Virginia Transportation Research Council, Federal Highway Administration, Washington, DC. 41 p.

This report summarizes research presented in separate technical reports, papers, and journal articles that collectively document the development of a systematic process to aid in the selection of appropriate bituminous hot-poured sealants for pavement cracks and joints. The following process elements are summarized herein: Apparent Viscosity Test for Hot-Poured Crack Sealants, Development of a Short-Term Aging Test and Low-Temperature Testing Bibliography, Sealant Flow and Deformation by Dynamic Shear Rheometry in Summer Temperatures, Characterization of Low Temperature Creep Properties of Crack Sealants Using Crack Sealant Bending Beam Rheometry, Characterization of Low Temperature Mechanical Properties of Crack Sealants Using Crack Sealant Direct Tension Test, and Development of Adhesion Tests for Crack Sealants at Low Temperature. This report brings the results of this cumulative research together to introduce a set of tests and performance parameters for sealant at installation and service temperatures; an aging procedure to simulate sealant weathering; and most important, a simplified chart with thresholds for all performance parameters for the straightforward selection of crack sealant.

Al-Qadi, Imad L. et al. 2009. "Performance-Based Specification Guidelines for the Selection of Bituminous-Based Hot-Poured Crack Sealants." *Journal of the Association of Asphalt Paving Technologists.* Vol. 78. Association of Asphalt Paving Technologists. pp. 491-534.

This paper describes how the long-term performance of pavements depends in good part on the quality and frequency of maintenance. Appropriate maintenance protects the pavement from deterioration, corrects deficiencies, and ensures safe and smooth riding. Crack sealing is practiced on a routine basis as preventive maintenance and as part of corrective maintenance prior to an overlay or a greater rehabilitation project. A timely and properly installed sealant adds several years of service life to the pavement at a relatively low cost. As a consequence, the selection of an appropriate sealant in a maintenance project becomes an important issue. Current sealant selection is based on ASTM standards that consist of quality control tests, not of performance indicators. These standards do not consider the changes in mechanical properties due to aging or the differences in local service temperatures. The main purpose of this study was to develop a systematic process to help users to select appropriate bituminous hot-poured sealants for pavement cracks and joints. The tests include in this paper covering a summary of four years research project including an accelerated aging test, a viscosity test performed at installation temperatures, a dynamic shear rheometer (DSR) tests to assess tracking resistance in summer temperature, a crack sealant bending beam rheometer (CSBBR) and a crack sealant direct tension test (CSDTT) for cohesive properties at sub-zero temperature, and a blister test for adhesive properties.

Shuler, Scott. 2009. "Short-Term Performance of Three Crack Sealants in Three Climates Using Several Installation Techniques." ***Transportation Research Board 88th Annual Meeting.*** **09-0689. Transportation Research Board. Washington, DC.**

One of the most effective methods of asphalt pavement preservation is crack sealing. Sealing cracks in asphalt pavements helps reduce moisture and debris infiltration into the pavement structure resulting in increased life expectancy of the pavement. However, there are many crack sealants and several methods of installation available. To help answer this question an experiment was designed to evaluate performance of three crack sealants placed in three environments using three distinct installation procedures and two methods of crack filling resulting in three factorials with eighteen treatments per location. Each supplier of crack sealant was instructed to bring the materials, equipment and personnel necessary to successfully install each of the products in six cracks per each of the treatment combinations for a total of 108 cracks per location. The objective of the experiment was to determine short and long term performance characteristics of each combination of material, method and location. Two methods were used to measure performance. These included evaluating the amount and severity of cracking as a function of the original filled crack length, and the Sealant Condition Number. Results indicate that performance suffers when the heat lance is used in preparation of crack filling at the temperatures utilized and that performance improves when the sealant is squeegeed over the crack after air blowing or routing. Routing the crack prior to sealing appears to improve performance. The surprisingly poor five month performance of some of the crack sealant methods indicates that some pavements may not be sealed as well as some believe.

Wilde, W James and Eddie N. Johnson. 2009. "Effect of Crack Sealant Material and Reservoir Geometry on Surface Roughness of Bituminous Overlays." ***Transportation Research Board 88th Annual Meeting.*** **09-2253. Transportation Research Board, Washington, DC. pp. 69-74.**

Many state, county, and municipal highway agencies have experienced the formation of bumps when placing single-lift overlays or the first lift of a multiple-lift overlay. These bumps are produced at the location of a previously existing crack, and even then almost exclusively when the crack has been sealed in advance of the overlay. When such bumps are not covered with a subsequent lift, what remains is often a rough ride on a newly overlaid roadway. The effects of crack sealant material type and geometry (shape) of the routed cracks in the existing surface on the formation of bumps in bituminous overlays are described. A matrix of four sealant type treatments and six geometries was designed and implemented in a test section in Jackson County, Minnesota. The overlay on the test section was constructed in September 2007. Results of this investigation indicate that cooler pavement surface temperatures, no overband, hot-poured crumb rubber, and hot-poured elastic sealants provide the best resistance to the formation of bumps in overlays.

Al-Qadi, Imad L. 2008. "Characterization of Low Temperature Mechanical Properties of Crack Sealants Utilizing Direct Tension Test." ***Civil Engineering Studies, Illinois Center for Transportation Series.*** **ICT-08-028. University of Illinois, Urbana-Champaign, Virginia Department of Transportation, Federal Highway Administration, Washington, DC. 71 p.**

Crack sealing has been widely used as a routine preventative maintenance practice. Given its proper installation, crack sealants can extend pavement service life by three to five years. However, current specifications for the selection of crack sealants correlate poorly with field performance. The purpose of this research was to develop performance guidelines for the selection of hot-poured bituminous crack sealants at low temperature. This was accomplished by measuring the mechanical properties of crack sealant at low temperature and then developing performance criteria for material selection. The modified direct tension test (DTT), crack sealant direct tension test (CSDTT), simulates the in-situ loading behavior of crack sealants in the laboratory. A modified dog-bone specimen geometry, which allows specimens to be stretched up to 95%, is recommended. This new specimen geometry also facilitates sample preparation. Tensile force is applied to the dog-bone specimen, with its effective gauge length of 20.3mm, and is pulled at a deformation rate of 1.2mm/min. Fifteen sealants were tested at various temperatures, and three performance parameters are suggested as indicators of sealant performance: extendibility, percent modulus reduction, and strain energy density. Extendibility, which is used to assess the degree of deformation undergone by a sealant at low temperature before it ruptures or internal damage is observed, is recommended as a measured parameter to be included in the performance-based guidelines for the selection of hot-poured crack sealants. Extendibility thresholds were defined as function of low service temperatures. The CSDT is conducted at +6oC above the lowest in service temperature because of the relatively high test loading rate compared to in-situ crack sealant movement rate.

Soliman, Haithem, Ahmed Shalaby, and Leonnie Kavanagh. 2008. "Performance Evaluation of Joint and Crack Sealants in Cold Climates Using DSR and BBR Tests." ***Journal of Materials in Civil Engineering*****. Vol. 20, No. 7. American Society of Civil Engineers, Reston, VA. pp. 470-477.**

Joint sealants are used widely in Canada to protect pavements from infiltration of water and incompressible materials. Sealants are typically selected based on field studies, which are commonly repeated on a 10-year cycle. This paper examines a laboratory evaluation method based on two laboratory tests that are commonly used for testing asphalt binders: dynamic shear rheometer (DSR) and bending beam rheometer (BBR). Creep stiffness, rate of change in creep stiffness, and rate of change in complex shear modulus with temperature were used to evaluate sealant performance in cold climates. A sealant ranking system was proposed based on the calculation of a sealant index, which combines the proposed evaluation criteria. This method can potentially provide a cost-effective and rapid alternative to field studies. Eight hot-pour sealants were evaluated using this method. Results were verified from an ongoing field study that started in 2004. A good correlation was found between the proposed simplified evaluation method and the existing method.

McGraw, James William and John Olson. 2007. "Evaluating Minnesota Crack Sealants by Modified Bending Beam Rheometer Procedure." ***TRB 86th Annual Meeting Compendium of Papers*****. 07-1812. Transportation Research Board, Washington, DC. 10 p.**

Due to poor performance of many of the crack sealing projects in Minnesota, research is being conducted to determine methods of improving Minnesota's crack sealing program. The current method for the selection of crack sealants is by specifying different types of sealants satisfying the ASTM D 6690 specification. Unfortunately the ASTM specification doesn't predict expected field performance for Minnesota's climate. Minnesota Department of Transportation (Mn/DOT) performed an evaluation of five hot-pour crack sealants that were developed for Minnesota's climate. The evaluation used the modified Bending Beam Rheometer (BBR) method developed by the U.S.- Canada Crack Sealant Consortium and determined that a state department of transportation (DOT) asphalt binder testing laboratory can successfully test crack sealants using the modified BBR. The Mn/DOT laboratory staff was able to use creep stiffness, creep m-value and steady-state creep rate tests to rank the sealants by expected field performance. The BBR tests showed differences between low modulus crack sealants (ASTM Type IV) and showed that some ASTM Type II sealants may perform as well as some low modulus products. The findings indicate that once the U.S.- Canada Crack Sealant Consortium have validated the sealant BBR performance criteria, the low temperature performance of crack sealants may be estimated better than with the current ASTM D 6690 tests. This procedure will be extremely valuable in grading sealants by low pavement temperature, improving the crack sealant selection process and can be used as an evaluation tool for new products.

Al-Qadi, Imad L. et al. 2007. "Low-Temperature Characterization of Hot-Poured Crack Sealant by Crack Sealant Direct Tensile Tester." ***Transportation Research Record 1991*****. Transportation Research Board, Washington, DC. pp. 109-118.**

The current specifications for selecting crack sealants correlate poorly with actual field performance. To address this issue and assist in predicting the low-temperature properties of hot-poured bituminous crack sealants, a modified direct tensile tester method has been developed. Sample geometry is modified to accommodate testing sealants. A sensitivity analysis considering various loading rates, sample lengths, and cross-section areas was conducted to define both optimized specimen geometry and testing protocol. Two types of sealants, having a wide range of rheological behaviors (one polymer-modified and one having crumb rubber), were tested at low temperature. Results showed that the rich polymer–modified sealant has a high resistance to failure compared with the sealant with crumb rubber–modified. Each sealant was tested at the lowest corresponding expected service temperature. A performance parameter, strain energy density, was proposed to differentiate crack sealant material in the laboratory.

Yildirim, Yetkin, Armagan Korkmaz, and Jorge Prozzi. 2006. ***Performance Comparison of Hot Rubber Crack Sealants to Emulsified Asphalt Crack Sealants.*** **FHWA/TX-06/0-4061-3. University of Texas, Austin, Texas Department of Transportation, Federal Highway Administration, Washington, DC. 64 p.**

This is the final report from the Center for Transportation Research on Project 4061. It presents the results, findings, conclusions, and recommendations based on the surveys, lab tests, and information collected on test sections for the 4-year study. Sealing and filling cracks has always been an important consideration in pavement maintenance. Hot rubber asphalt has been the most commonly used material for this purpose, providing good performance in most cases. Some Texas Department of Transportation (TxDOT) districts have been using cold pour asphalt emulsion crack sealants because of the ease of use. However, cold pour crack sealant requires longer setting and curing time, especially in areas of high humidity. The performance history of these cold sealants is not known or not well documented in comparison to the performance of hot pour crack sealants. Furthermore, the cost associated with the use of this material versus hot pour rubber asphalt is not well documented or determined. The intent of this research project is to compare the cost-effectiveness, performance, and life-cycle costs for hot pour rubber asphalt crack sealant and cold pour asphalt emulsion crack sealant. The comparison includes seven different crack and joint sealants: three cold pour and four hot pour. Eight different roads in five districts were selected for comparison of the sealants, for a total of thirty-three different test sections. The survey and field study results indicate that hot pour sealants performed better than cold pour sealants. In addition, hot pour sealants had lower average annual cost values than cold pour sealants. Modifications to the specifications for crack sealants currently used at TxDOT were suggested.

Masson, J-F. et al. 2005. "Variations in Composition and Rheology of Bituminous Crack Sealants for Pavement Maintenance." ***Transportation Research Record 1933*****. Transportation Research Board, Washington, DC. pp. 107-112.**

Bituminous crack sealants are used for the preventive maintenance of asphalt concrete pavements. The selection of a durable sealant can be difficult, however, mainly because of the lack of correlation between standard sealant specifications and field performance. Hence, an approved list of materials based on past performance is sometimes used to select sealants. However, sealant durability and performance vary over time. To investigate the effect of sealant lot variation on sealant properties, six lots of two sealants from different suppliers were analyzed for filler and polymer contents and rheological response. It was found that the difference in composition and rheology between lots can be similar to that between sealants produced by different manufacturers. Hence, sealant lot-to-lot variation can partly explain the variation in the field performance of sealants. Therefore, lists of approved products drawn from the field performance of past years are ineffective in the selection of sealants for future maintenance. The application of segregated sealants was also investigated, including assessing the effect of melter stirring on sealant homogeneity and measuring the segregation of sealant upon cooling. It was found that sealants do not segregate after their application and subsequent cooling and that a rapid circumferential stirring of 25 revolutions per minute in the heating kettle allowed for the remixing of a segregated sealant.

Ksaibati, Khaled and Steven D. Carter. 2006. *Evaluating the Effectiveness of Hot-Poured Crack Surfacing Material*. MPC Report No. 06-180. University of Wyoming, Laramie, Mountain-Plains Consortium, Fargo, ND. 121 p.

This research project evaluates the effectiveness of hot-poured crack surfacing material and its ability to seal asphaltic cracks. The term “crack surfacing” is used to describe the rigidity of the material and to distinguish it from crack sealants. The University of Wyoming, in cooperation with the Wyoming Department of Transportation (WYDOT), conducted field and laboratory evaluations to determine the in-situ performance, temperature and load characteristics, and rutting susceptibility of three selected manufacturer’s products: Deery American Corporation’s Level & Go and Recessed Repair Mastic, and Crafco Incorporated’s PolyPatch. The field evaluation was accomplished at selected test sections of Wyoming Route 93, US Route 26, and Interstate 25. These evaluations identified the modes of failure, superficial distresses, and percent effectiveness. The laboratory evaluation included performance of the Thermal Stress Restrained Specimen Test (TSRST) and the Georgia Loaded Wheel Tester (GLWT). The TSRST was used to evaluate the cold temperature bonding characteristics, in particular the fracture temperature, and the load capacity of the crack surfacing materials. To represent field conditions, the materials were configured as flush, uniform overband, tapered overband, and mill & fill. The GLWT was utilized to evaluate the rutting susceptibility of the materials in use. The findings of this research indicate that the Crafco PolyPatch and the tapered overband configuration were the best performers. Based on the results, it is recommended that the PolyPatch material be used with the tapered overband configuration for cold climate applications.

AASHTO. 2008. *Standard Practice for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements.* M324-08-UL. American Association of State Highway and Transportation Officials, Washington, DC.

No abstract available.

AASHTO. 2009. *Standard Practice for Determination of Low-Temperature Performance Grade (PG) of Asphalt Binders, Single User Digital Publication.* R049-09-UL. American Association of State Highway and Transportation Officials, Washington, DC.

This practice covers the determination of low-temperature properties of asphalt binders using data from the bending beam rheometer (T 313) and the direct tension tester (T 314). This practice can be used on data from unaged material or from material aged using T 240 (RTFOT), R 28 (PAV), or T 240 (RTFOT) and R 28 (PAV). This practice can be used on data generated within the temperature range from +6°C to -36°C.

This practice is only valid for data on materials that fall within the scope of suitability for both test methods T 313 and T 314.

This practice can be used to determine the following:

- PG Grade Determination of an Asphalt Binder—The determination of a low-temperature grade or grades that are satisfied by an asphalt binder. The determination of the temperature corresponds to the specification parameter, Tcr, the critical cracking temperature.
- Prequalification of an Asphalt Binder—The procedure required to qualify an asphalt binder for supply.
- Verification of an Asphalt Binder Grade—The testing required to certify that a binder complies with an existing prequalified binder.

While this practice determines the critical cracking temperature for typical hot-mix asphalt (HMA), the intent of this practice is grading of asphalt binder according to M 320, not performance prediction for asphalt pavement. This practice should not be used in lieu of T 322.

Note—The algorithms contained in this standard require implementation by a person trained in the subject of numerical methods and visco-elasticity. However, due to the complexity of the calculations they must, of necessity, be performed on a computer. Software to perform the calculations may be written or purchased as a spreadsheet or as a stand-alone program.

AASHTO. 2010. *Standard Practice for Quantifying Cracks in Asphalt Pavement Surface, Single User Digital Publication.* R055-10-UL. American Association of State Highway and Transportation Officials, Washington, DC.

This practice covers the procedures for quantifying cracking in asphalt pavement surfaces both in wheelpath and non-wheelpath areas. Detailed specifications are not included for equipment or instruments used to make the measurements. According to these specifications, any equipment that can quantify, with the accuracy stipulated herein, and which can be adequately validated, is considered acceptable.

Note—Standardization will produce consistent pavement condition estimates for network-level pavement management. As an option, the user may define and collect other data, such as edge cracking, centerline cracks, and transverse cracks. This standard is designed for use primarily with automated equipment. However, accommodations have been made for manual methods.

AASHTO NTPEP. *PCC Joint Sealant/HMA Crack Sealer Data Usage Guide*. AASHTO National Transportation Product Evaluation Program.

No abstract provided.

AASHTO NTPEP. 2007. *One Year Field and Laboratory Evaluation of Hot Mix Asphalt Crack Sealing Materials. 2005 Minnesota Test Deck.* 16002.1. AASHTO National Transportation Product Evaluation Program.

No abstract provided.

AASHTO NTPEP. 2009. *Two Year Report (Twenty nine months) of Field and Laboratory Evaluation of Hot-Mix Asphalt Crack Sealing Materials. 2005 Minnesota US 169 Test Deck.* 16002.2. Parts A and B. AASHTO National Transportation Product Evaluation Program.

The National Transportation Product Evaluation Program (NTPEP) was developed in order to evaluate a variety of traffic, construction and maintenance products. This report provides information concerning the installation and field evaluation of Hot-Mix Asphalt (HMA) Crack Sealing Materials submitted by manufacturers in 2005. Minnesota is the host state.

AASHTO NTPEP. 2009. *Final Report of Field and Laboratory Evaluation of Hot-Mix Crack Sealing Materials.* 16002.3. AASHTO National Transportation Product Evaluation Program.

No abstract provided.

MnDOT. 2008. *Local Road Research Board Project 822: Recommended Practices for Crack Sealing HMA Pavement.* MnDOT Office of Materials.
http://www.mrr.dot.state.mn.us/research/pdf/2008MRRDOC021.pdf.

No abstract provided.

WSDOT. 1992. *Crack Sealing: Effectiveness.* WA-RD 256.1. Washington State Department of Transportation, Olympia, WA.
http://www.wsdot.wa.gov/Research/Reports/200/256.1.htm.

A short, one year performance evaluation was made of four crack sealing products. The products: (1) CRF manufactured by the Golden Bear Division of Witco Chemical Corporation; (2) Flex-a-Fill manufactured by Deery Oil; (3) RoadSaver 221 manufactured by Crafco Incorporated; and (4) a sand slurry mixture designed by the Washington State Department of Transportation.

Hildreth, G. *Crack Sealing New York State*. Powerpoint Presentation. New York State Department of Transportation, Albany, NY.
http://www.clrp.cornell.edu/trainingevents/PDF-2006/Crack%20Sealing-Hildreth.pdf.

No abstract provided.

APPENDIX B. EXTERNAL SURVEY RESULTS

SUMMARY OF CRACK SEALING AND FILLING – HMA SURVEY

1. Respondent details:

	Response Percent	Response Count
Name:	100.0%	28
Title:	100.0%	28
Agency:	100.0%	28
Email Address:	100.0%	28
Phone Number:	100.0%	28
answered question		28
skipped question		0

1	Name:	Thomas
	Title:	Maintenance Liaison
	Agency:	Ga DOT
	Email Address:	tmims@dot.ga.gov
	Phone Number:	404-293-0048
2	Name:	Jeff Uhlmeyeer
	Title:	State Pavement Engineer
	Agency:	Washington State DOT
	Email Address:	uhlmeyj@wsdot.wa.gov
	Phone Number:	360-709-5485
3	Name:	Jim McGraw
	Title:	Chemical Lab Director
	Agency:	MnDOT
	Email Address:	jim.mcgraw@state.mn.us
	Phone Number:	jim.mcgraw@state.mn.us
4	Name:	Kent Ketterling
	Title:	State Maintenance Engineer
	Agency:	Wyoming DOT
	Email Address:	kent.ketterling@wyo.gov
	Phone Number:	(307)777-4051
5	Name:	Randy M. Cotter
	Title:	Maintenance Management Coordinator I
	Agency:	Nevada Department of Transportation
	Email Address:	rcotter@dot.state.nv.us
	Phone Number:	775-888-7050
6	Name:	Kent Ketterling
	Title:	State Maintenance Engineer
	Agency:	Wyoming DOT
	Email Address:	kent.ketterling@wyo.gov
	Phone Number:	(307)777-4051

7	Name:	Dennis Wofford
	Title:	Pavement Preservation Engineer
	Agency:	NCDOT
	Email Address:	dawofford@ncdot.gov
	Phone Number:	(919) 733-3725
8	Name:	Dennis J. Ortiz
	Title:	State Maintenance Engineer
	Agency:	NMDOT
	Email Address:	Dennis.Ortiz@state.nm.us
	Phone Number:	505-827-5498
9	Name:	Rukhsana Lindsey
	Title:	Deputy Maintenance Engineer
	Agency:	UDOT
	Email Address:	rlindsey@utah.gov
	Phone Number:	8019654196
10	Name:	Wheeler Nevels
	Title	Trans. Engr. Specialist
	Agency:	Ky. Dept. of Highways
	Email Address:	wheeler.nevels@ky.gov
	Phone Number:	(502) 564-4556
11	Name:	Jim McGraw
	Title:	Chem Lab Director
	Agency:	MnDOT
	Email Address:	jim.mcgraw@state.mn.us
	Phone Number:	651-366-5548
12	Name:	Justun Juelfs
	Title:	Lead Maintenance Reviewer
	Agency:	MT DOT
	Email Address:	jjuelfs@mt.gov
	Phone Number:	406-444-7604
13	Name:	Francis Todey
	Title:	Preservation Programs Engineer
	Agency:	Iowa Department of Transportation
	Email Address:	francis.todey@dot.iowa.gov
	Phone Number:	515-239-1398
14	Name:	John Fowler
	Title:	Pavement Management Engineer
	Agency:	Florida Department of Transportation
	Email Address:	john.fowler@dot.state.fl.us
	Phone Number:	(850) 414-4373
15	Name:	James Maxwell
	Title:	CE Manager 2
	Agency:	Tennessee DOT
	Email Address:	james.maxwell@tn.gov
	Phone Number:	615-253-0012
16	Name:	Anita Bush
	Title:	Chief M&AM Engineer
	Agency:	NDOT
	Email Address:	Abush@dot.state.nv.us
	Phone Number:	775 888-7856
17	Name:	Tony Sullivan
	Title:	State Maintenance Engineer
	Agency:	Ark. Hwy. and Transp. Dept.
	Email Address:	tony.sullivan@ahtd.ar.gov
	Phone Number:	501-569-2231

18	Name:	EDGARDO D BLOCK
	Title:	TRANS SUPV ENGINEER
	Agency:	CONNECTICUT DEPT OF TRANS
	Email Address:	edgardo.block@ct.gov
	Phone Number:	860-594-2495
19	Name:	Wheeler Nevels
	Title:	Trans. Engr Specialist
	Agency:	Ky Dept of Highways
	Email Address:	wheeler.nevels@ky.gov
	Phone Number:	(502) 564-4556
20	Name:	Steve Spoor
	Title:	Maintenance Services Manager
	Agency:	Idaho Transportation Department
	Email Address:	steve.spoor@itd.idaho.gov
	Phone Number:	(208) 334-8413
21	Name:	Andy Bennett
	Title:	CPM Scoping Specialist
	Agency:	Michigan DOT
	Email Address:	bennetta@michigan.gov
	Phone Number:	517-322-5043
22	Name:	Jim Feda
	Title:	Director of Maintenance
	Agency:	SCDOT
	Email Address:	fedajj@scdot.org
	Phone Number:	803 737-1290
23	Name:	Bill Tompkins
	Title:	Field Maintenance Engineer
	Agency:	Indiana Dept of Transportation
	Email Address:	btompkins@indot.in.gov
	Phone Number:	317-233-3345
24	Name:	Kim Martin
	Title:	Division Chief
	Agency:	PenDOT
	Email Address:	kimmartin@pa.gov
	Phone Number:	717-787-6899
25	Name:	Richard M. Shaw
	Title:	Asst. Commissioner for Operations
	Agency:	NJDOT
	Email Address:	RichardM.Shaw@dot.state.nj.us
	Phone Number:	609-530-2590
26	Name:	Gary Mayes
	Title:	Maintenance Services Engineer
	Agency:	MDOT
	Email Address:	mayesg@michigan.gov
	Phone Number:	517-322-3315
27	Name:	Greg Duncan
	Title:	Asst. Chief Engineer of Operations
	Agency:	Tennessee DOT
	Email Address:	Greg.Duncan@tn.gov
	Phone Number:	6157412342
28	Name:	Brad Darr
	Title:	State Maint Engineer
	Agency:	NDDOT
	Email Address:	bdarr@nd.gov
	Phone Number:	701-328-4443

2. Does your agency differentiate between crack sealing and crack filling?	Response Percent	Response Count
No	67.9%	19
Yes (please provide definitions for each or explain)	32.1%	9
answered question		28
skipped question		0

- Crack sealing is where the crack is enlarged by sawing the crack and cleaned. PM out then material added. Crack filling is the process of blowing out the crack and placing material.
- Filling on non-moving cracks. Sealing on moving cracks.
- Crack Sealing for active or moving cracks Crack filling for non-moving cracks.
- We define crack sealing as routing and sealing, whereas crack filling is just filling cracks at the existing pavement surface.
- Crack sealing and crack filling are differentiated based on two main factors:
  1) Type of material used - crack sealing uses AASTHO M324 TYPE II material and crack filling uses PG76-22 with 5% polyester fibers, delivered mixed at the plant (no field addition of polyester fiber)
  2) Type of crack treated - crack sealing is primarily used on working cracks (those with significant horizontal movement), predominantly transverse cracks and composite-pavement joint-reflection cracks; crack filling is used primarily on non-working cracks and joints (primarily block cracks and longitudinal paving joints).
- Crack sealing: Prepare a reservoir for type IV sealants by routing. Used mainly for single transverse working cracks that do not have much associated distress (raveling/secondary cracking). Crack filling: Blow out the crack with compressed air and fill with type I-III material.
- Crack sealing is performed on working crack typically caused by pavement movement horizontally and vertically (reflective cracking composite pavements). Crack filling is performed on non-working cracks typically caused by thermal changes.
- We are using the Federal Highway definitions which are:
  crack sealing- “The placement of specialized treatment materials (crumb rubber) above or into working cracks using unique configurations to prevent the intrusion of water and incompressibles into the crack”
  crack filling- “The placement of ordinary treatment materials (polymer modified emulsion) into non-working cracks to substantially reduce infiltration of water and to reinforce the adjacent pavement.”
- Sealed cracks are those that are sealed with a polymer or crumb rubber. Poured cracks are those that are poured with MC 3000 or another acceptable asphalt product.

3. Does your agency have policies for crack sealing or filling HMA pavements? Such policies would cover topics such as whether to seal or fill or what cracks to seal or fill by width or orientation, what materials to use, and so on. If applicable, please provide a copy of the most recent policy by posting it to the FTP or by providing a web address.

	Response Percent	Response Count
No	36.4%	8
Yes	63.6%	14
Provide URL or click here for ftp access. To review FTP instructions, use the "prev" button to return to the first page. Your answers so far will be saved.		10
answered question		22
skipped question		6

- WSDOT Std. Specification

  5-04.3(5)C Crack Sealing

  When the Proposal includes a pay item for crack sealing, all cracks and joints ¼ inch and greater in width shall be cleaned with a stiff-bristled broom and compressed air and then shall be filled completely with sand slurry.

  The sand slurry shall consist of approximately 20 percent CSS-1 emulsified asphalt, approximately 2 percent portland cement, water (if required), and the remainder clean No. 4-0 paving sand. The components shall be thoroughly mixed and then poured into the cracks and joints until full. The following day, any cracks or joints that are not completely filled shall be topped off with additional sand slurry. After the sand slurry is placed, the filler shall be struck off flush with the existing pavement surface and allowed to cure. The HMA overlay shall not be placed until the slurry has fully cured. The requirements of Section 1-06 will not apply to the portland cement and paving sand used in the sand slurry.

- "http://www.mrr.dot.state.mn.us/research/pdf/2008MRRDOC021.pdf

  4-page report on recommended practice. At end of document there are links to special provisions. Special Provision S-155 (2331) and S-156 (2331)."

- "Following are links to WYDOT's specification manual- section 403 covers crack seal, supplementary specification 400A, and contract administration manual section on crack sealing.

  http://www.dot.state.wy.us/files/content/sites/wydot/files/shared/Construction/2010%20Standard%20Specifications/2010%20Standard%20Specifications.pdf http://www.dot.state.wy.us/files/content/sites/wydot/files/shared/Construction/2010%20Supplemental%20Specifications/Division%20400/SS-400A_Amendments%20to%20Division%20400%20REV%2003-01-13.pdf

http://www.dot.state.wy.us/files/content/sites/wydot/files/shared/Construction/2009%20CM%20for%20EDS/Chapter%207/DIV%20400/Sect%20403%20Plant%20Mix%20Pavement%20Crack%20Sealing.pdf"

- See section 657 pg. 6-47 and section 1028 pg. 10-50

  https://connect.ncdot.gov/resources/Specifications/Pages/Specifications-and-Special-Provisions.aspx

- We have a standard for Crack Sealing but not a policy

- "These are draft ""guidelines"" for project selection as opposed to an official DOT policy.

  (crack_sealing_project_selection_guidelines.doc was uploaded to the Public folder on the FTP site provided above)."

- 117.00 - CRACK SEALING

  Crack sealing of flexible pavements is a routine maintenance activity that basically involves cleaning and filling cracks with a liquid sealant. Crack sealing can prolong the life of flexible pavements by preventing or reducing intrusion of water and incompressible materials from entering the pavement and base.

  To be cost-effective, crack sealing must be done at the proper time in a pavements life. Typically if a pavement has low to moderate density of cracks and the cracks show moderate to no deterioration at the edges, crack sealing is an appropriate maintenance procedure. However, if the cracks are very wide (greater then 1 inch) then an alternative maintenance strategy should be used, such as partial depth patching or spot patching.

  It is important to understand the difference between crack filling and crack sealing. Crack sealing is the placement of specialized materials either above or into working cracks to prevent the intrusion of water and incompressible materials into the crack. Crack filling is the placement of materials into nonworking cracks to substantially reduce infiltration of water and to preserve the pavement. Working cracks refers to horizontal and/or vertical crack movements greater than 1/8 inch throughout a year.

  Small to medium width cracks (¼ to 1 inch) are the best candidates for crack sealing. Cracks smaller then 1/4 inch may be better handled by some kind of surface treatment, such as a seal coat or slurry seal. Cracks larger then 1 inch and that are spalling may need to be repaired by patching.

  117.01 Procedure. If needed, rout out the crack to the sealant manufacturer's specifications for width to depth ratio. Clean the crack using high-pressure air, sandblasting, wire brushing or hot air blasting. This is a key step to crack sealing. If the crack is not thoroughly cleaned the sealant will not adhere to the sides. Hot air blasting is the preferred method because it helps dry the crack and if the sealing operation closely follows the hot air drying, the heated crack surface helps the sealant adhere to the crack. After cleaning the crack, sealant should be applied from bottom to within 1/8 inch of the top of the crack to prevent air bubbles from forming and creating a weak spot in the sealant. Fill the crack to no more than 1/8 inch of the top. Overbanding, or the application of sealers up to the top of cracks and out onto the pavement surface has been shown through research to be ineffective, wasteful and reduces the friction values of the roadway, and is therefore not to be done.

117.02 Materials. Refer to sealant manufacture's recommendations for the proper material to use based on climatic and temperature ranges in your area.

- www.crafco.com/PDF%20Files/News_Library/Reference%20Materials/...

- MEMORANDUM

To:	Darcy Rosendahl, Director of Operations
From:	Dave Levi, Maintenance and Engineering
Date:	February 10, 2006
Subject:	Crack Sealing Study

Recommendations to develop a crack sealing/pouring program were sent to the District on June 14, 2005. Comments regarding the crack sealing/pouring study were received from 5 of the 8 Districts. The initial recommendations were as follows:

Recommendations:

The terms sealed cracks and poured cracks in the following recommendations need to be defined to avoid any confusion.

Sealed cracks are those that are sealed with a polymer or crumb rubber.

Poured cracks are those that are poured with MC 3000 or another acceptable asphalt product.

1. Require all future HBP to use an anti-strip agent, unless testing shows that the new PG asphalts will not have a stripping problem.

2. On new or mine and blend projects the transverse cracks should be sealed early in the life of the pavement, suggest within 3 years after construction. These projects should also be monitored every other year after the initial cracks are sealed so all new cracks are sealed.

3. On thin lift overlay projects the reflective cracks should be poured every other year. If the cracks in the old existing pavement were sealed in the past, the reflective cracks in the new overlay should also be sealed rather than poured. The DE should have the option to seal the transverse cracks if an aggressive crack pouring program was used and cores have been taken to show we have filled the voids in the old existing pavement structure.

4. On existing pavements, where the transverse cracks have not been sealed in the past, the cracks should be poured. If cores indicate there is no stripping, the DE should have the option of sealing the crack or continue to pour the crack every other year.

Comments:

The following comments were received from the Districts regarding the recommendations made to the Departments crack sealing/pouring program.

Bob Walton:

I thought the document was well thought out and covered multiple considerations very well. I'll add a couple thoughts that you may wish to consider or discard.

In Fargo we have had success with routing or sawing asphalt for the first seal application. We also use a polymer when we rout or saw. I think Mn/DOT has specifications on routing, and is studying what size reservoir works best.

We have also found that if a crack is wider than 1", crack pouring is the best treatment. Crumb rubber won't work very well as it is usually applied when the crack is tighter, and then in the winter it opens so wide that the crumb rubber fails.

That is about all we had to add. Thanks for the opportunity.

Walt Peterson

The use of cutback oil from years back definitely degraded the cracks by striping from the bottom up. We have not milled any roadway that used crumb rubber or polymers. Milling gave us a view of the cracks from the side. Removing slabs would probably do the same.

If you have ever watched a train go over ties that were not on solid rock ballast, you can see how the ties pump fines. As the axle distributes load over the ties, the ties depress, water & fines splash out, the load passes over, the rail returns to proper elevation, until the next axle depresses the tie again. My point is that that same series of loading appears during spring thaw. That's when we see the moisture from the cracks and it's dirty dirt color.

I think if we start early in process, we get ahead of the early deterioration of the subgrade, and the cracks aren't as big. The joints that we sawed (& polymer sealed) on US 85, south of Watford City, were in good shape prior to our first seal, after about 4 years.

Larry Gangl

I have no comments.

Jerry Miller

Our District has sawed and sealed all new structural overlays and mine/blend projects since the early 1990's. We are sawing a ¾ x ¾ inch vessel and filling with polymer + over banding. This program has been quite successful when used on new pavements within 3 years after construction. There is always a follow up on all these projects within 2 years to saw and fill any new developed transverse cracks. Unless new guidelines are developed by MESD that require all districts to follow, our district intends to continue this method of crack maintenance.

It is our belief that the best method of maintaining thin lift overlays over old asphalt is either pouring with MC3000 or crumb rubber. Our district has a three year scheduled rotation for crack pouring on old asphalt surfaces throughout the district. We intend to experiment more with pouring transverse cracks using crumb rubber. This method will seal and fill depressed cracks.

Paul Regan

Use MC-3000 for all HBP crack maintenance.

Polymers and routing just provide a new crack next to the one that you seal with a polymer as it is stronger than the adjoining pavement.

Over banding with crumb rubber can cause striping of the asphalt beneath crumb rubber next to the asphalt joint as moisture moves up during the spring and fall due to capillary action.

We have had both situations happen with polymers and crumb rubber. We do not use either material for crack maintenance as they are more detrimental than helpful.

Lime is a wonderful product and has many uses. Injected into a new crack will probably cause the joint to raise rather than stay at the same elevation as it is expansive over time. This has happened to us on lime treated bases and resulted in costly joint repair contracts, milling projects and HBP overlays. It may be a good tool to consider for depressed joints.

Recommend that we use MC-3000 exclusively for HBP crack maintenance until a better method is found.

Revised recommendations based on comments received:

The terms sealed cracks and poured cracks in the following recommendations are defined as follows:

Sealed cracks are those that are sealed with a polymer or crumb rubber. Routing or sawing of the cracks may be used in conjunction with sealing at the discretion of the District Engineer.

Poured cracks are those that are poured with MC 3000.

1. Require all future HBP to use an anti-strip agent, unless testing shows that the PG graded asphalts used on the project will not have a stripping problem.

2. Seal/pour cracks in new hot bituminous pavement within the first three years after the pavement is placed. Cracks that are more than 3/4" wide shall be poured.

3. On new or mine and blend projects the transverse cracks should be sealed/poured early in the life of the pavement, suggest within 3 years after construction. These projects should also be monitored every other year after the initial cracks are sealed/poured so all new cracks are treated. Poured cracks should be retreated every other year.

4. On thin lift overlay projects where the existing transverse cracks were poured, the reflective cracks should be poured every other year. If the cracks in the old existing pavement were sealed in the past, the reflective cracks in the new overlay should also be sealed rather than poured. The District Engineer has the option to seal the transverse cracks if an aggressive crack pouring program was used and cores have been taken to show there is no stripping at the crack in the existing pavement structure.

5. On existing pavements, where the transverse cracks have not been sealed in the past, the cracks should be poured. If cores indicate there is no stripping, the DE should have the option of sealing the crack or continue to pour the crack every other year.

If you concur in the revised recommendations, please sign and return this memo. The Maintenance Operations Manual will be updated to reflect these procedures.

Darcy Rosendahl /s/ _ 02/15/06
Concur Date

Comments: MESD needs to work with Materials and Research and the industry on the use of anti-strip agents. MESD should also set up a CERT type team that would annually review this aspect along with all preventive maintenance strategies to document their performance.

4. Is crack sealing and/or filling done in-house, by contract, or both?			
	Crack Sealing	Crack Filling	Rating Count
In-house	77.8% (7)	**88.9% (8)**	9
Contract	**100.0% (7)**	85.7% (6)	7
Both	**100.0% (12)**	41.7% (5)	12
If done multiple ways, are the same material and installation specifications used for in-house and contract work?			11
		answered question	**24**
		skipped question	**4**

- Yes
- We do not require our in house maintenance forces to comply with all current specifications. They do follow the same general processes and operations.
- The same material is used. We do not specifically require our in house maintenance personnel to follow the full specification process. They do follow essentially the same procedures.
- Yes
- Yes
- Yes
- see attached SOG and special provision
- Not the same specification at this time. There is an ongoing effort to have a uniform specification for the crack filling materials.
- Installation specs are the same for both but different materials are used.
- Yes
- Yes

5. Do you have any performance or experience qualifications or pre-qualifications for crack sealing or filling contractors?

	Response Percent	Response Count
No	78.3%	18
Yes. (Are there any additional details you would like to provide?)	21.7%	5
answered question		23
skipped question		5

- If rout and seal warranty is used- less than 10% bond failure
- FDOT does not use crack filling or crack sealing as a standard practice. We recently completed construction of a research project to examine the benefits of crack filling/sealing on state highways. This research project required the contractor to have a minimum of 3 years of experience performing the same type of work.
- "PREQUALIFICATION OF BIDDERS:
  Each prospective bidder and subcontractor will be required to file a document entitled “Prequalification Questionnaire.” The foregoing shall be filed on a form provided by the Department. The form must be filled out completely, and the truth and accuracy of the information provided must be certified by a sworn affidavit signed by an officer, partner, owner or other authorized representative of the applicant who has authority to sign contracts or other legal documents on behalf of the applicant. A prospective bidder must be prequalified by and in good standing with the Department prior to being given authorization to bid. A prospective subcontractor must be prequalified by and in good standing with the Department prior to being approved as a subcontractor. Each prospective bidder or subcontractor shall notify the Department if there is any subsequent change in the name, organization or contact information provided. Prospective bidders’ “Prequalification Questionnaire” shall be filed with the Department at least fourteen (14) days prior to the date of opening bids on any letting in which the applicant intends to submit a bid to the Department, or at least fourteen (14) days prior to the date on which the applicant requests approval as a subcontractor under a contract awarded by the Department. Bidders intending to submit proposals consistently shall complete and submit the prequalification application annually; however, this document may be changed during such period upon submission of additional favorable reports or upon receipt by the Department of substantiated evidence of unsatisfactory performance. The Department reserves the right to request additional information and documentation to clarify and/or verify any information submitted in an applicant’s prequalification application. The prequalification form can be found at the web address http://www.tdot.state.tn.us/construction"
- Effective July 1, 2013 all contractors bidding on pavement preservation projects will have to have passed our Pavement Preservation Certification for the treatment they are bidding on.
- Must be pre-qualified in that category of work that paving contractors are in.

6. Does your agency have or require any training or certification programs for crack sealing or filling inspectors, applicators, or contractors?	Response Percent	Response Count
No	73.9%	17
Yes. (Are there any additional details you would like to provide?)	26.1%	6
answered question		23
skipped question		5

- Training is performed inhouse by veteran employees on the crews.
- Employees must be certified on crafco machine
- Training is informally provided to DOT inspectors of crack-sealing work. There are no OFFICIAL training or certification programs.
- Educational training is provided jointly by industry (Michigan Road Preservation Association) and DOT personnel. No certification program is in place at this time.
- See above.
- In house training on heating kettle specifics and personnel safety.

7. How does your agency determine which cracks are sealed or filled? Select all that apply.	Response Percent	Response Count
Crack width	82.6%	19
Crack depth	17.4%	4
Crack density or number of cracks	39.1%	9
Crack type or orientation	56.5%	13
Other (please explain)	30.4%	7
answered question		23
skipped question		5

- UDOT seals cracks flush with the pavement during September through April. The width of crack should be 1/4" to 1"
- Longitudinal and transverse cracks have different treatment specs.
  "Rout all existing cracks that are between 1/8 inch (3 mm) and 1 inch (25 mm) wide.

Rout all longitudinal cracks to produce straight 3/4-inch (19 mm) vertical walls and a 3/4 inch (19 mm) wide flat bottom reservoir.
Rout the transverse cracks to produce straight 1/2-inch (13 mm) vertical walls and a 1 1/2 inch (40 mm) wide flat bottom reservoir."

- This is based on the spec that is written, but as stated earlier, we really don't do crack filling and sealing as a matter of standard practice.
- "1. Sealing width range is 1/8 to 3/4 of an inch (deviations from this range are allowed if listed explicitly for each project in the Special Provision so that slight adjustments can be made based on a particular project); filling width range is 1/8 to 1.5 inches (same ""deviation"" caveat as for crack sealing).
  2. When both crack sealing and filling are undertaken in one project, the type of crack to be treated with sealing or filling is listed in the Special Provision(s). Each treatment is paid under a separate item under a separate Special Provision and there is a Notice to Contractor indicating the relative sequence of crack treatments (i.e. fill first, then seal).
  3. For stand-alone crack treatment projects, typically only one crack treatment is used - crack sealing, which can then be used on all cracks (this requires careful project selection to avoid conflicts in the field i.e. sealing a paving joint open more than 0.75 inches, which is outside where we would use crack sealing.
  4. For pre-overlay crack treatment, only crack filling is used - 0.5 to 1.25 inches uses PG76-22 with fiber in a recess-fill application, and cracks open more than 1.25 inches are filled with a small-aggregate size bituminous concrete (HMA) (say 0.25/0.375 NMAS HMA)"
- Pavement management uses a system that examines roads that are 3-5 years since being paved and evaluates extent of cracks. Crack sealing is viewed as preventive. Roads that show too high a percentage of cracking are put on the resurfacing list, rather than waste crack sealer on them.
- See SOG posted on ftp site--time to next resurfacing
- "MEMORANDUM
  To: Darcy Rosendahl, Director of Operations
  From: Dave Levi, Maintenance and Engineering
  Date: February 10, 2006
  Subject: Crack Sealing Study

  Recommendations to develop a crack sealing/pouring program were sent to the District on June 14, 2005. Comments regarding the crack sealing/pouring study were received from 5 of the 8 Districts. The initial recommendations were as follows:

  Recommendations:

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  1. Require all future HBP to use an anti-strip agent, unless testing shows that the new PG asphalts will not have a stripping problem.

2. On new or mine and blend projects the transverse cracks should be sealed early in the life of the pavement, suggest within 3 years after construction. These projects should also be monitored every other year after the initial cracks are sealed so all new cracks are sealed.

3. On thin lift overlay projects the reflective cracks should be poured every other year. If the cracks in the old existing pavement were sealed in the past, the reflective cracks in the new overlay should also be sealed rather than poured. The DE should have the option to seal the transverse cracks if an aggressive crack pouring program was used and cores have been taken to show we have filled the voids in the old existing pavement structure.

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Comments:

The following comments were received from the Districts regarding the recommendations made to the Departments crack sealing/pouring program.

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I thought the document was well thought out and covered multiple considerations very well. I'll add a couple thoughts that you may wish to consider or discard.

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We have had both situations happen with polymers and crumb rubber. We do not use either material for crack maintenance as they are more detrimental than helpful.

Lime is a wonderful product and has many uses. Injected into a new crack will probably cause the joint to raise rather than stay at the same elevation as it is expansive over time. This has happened to us on lime treated bases and resulted in costly joint repair contracts, milling projects and HBP overlays. It may be a good tool to consider for depressed joints.

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If you concur in the revised recommendations, please sign and return this memo. The Maintenance Operations Manual will be updated to reflect these procedures.

Darcy Rosendahl /s/ _ 02/15/06
Concur Date

Comments: MESD needs to work with Materials and Research and the industry on the use of anti-strip agents. MESD should also set up a CERT type team that would annually review this aspect along with all preventive maintenance strategies to document their performance."

8. Does your agency have a minimum crack width for sealing?

	Response Percent	Response Count
No	25.0%	6
Yes (please provide minimum size)	75.0%	18
	answered question	24
	skipped question	4

- >1/8"
- 1/4 inch
- 3/4"
- 1/8"
- 1/8"
- cracks that exceed 1/2" in width
- 1/4"
- 1/4"
- 1/8"
- 1/16"
- 3/16 inch
- 1/8"
- 1/8 inches (adjustable for special cases)
- 1/4 inch
- 1/8"
- 0.20"
- 1/4 inch
- 3/16"

9. Does your agency have a minimum crack width for filling?

		Response Percent	Response Count
No		43.5%	10
Yes (please provide minimum size)		56.5%	13
		answered question	23
		skipped question	5

- >1/8"
- 1/4 inch
- 1/8"
- 1/8"
- cracks that exceed 1/2" in width
- 1/4"
- 1/4"
- 1/8"
- 1/16"
- 1/8"
- 1/8 inches typical (adjustable for special cases) - 0.5 inches for filling prior to overlay
- 0.20"
- 3/16"

10. Does your agency have a maximum crack width for sealing?

		Response Percent	Response Count
No		75.0%	18
Yes (please provide maximum size)		25.0%	6
		answered question	24
		skipped question	4

- 1"
- 1"
- 0.75 inches (25% exceeding 0.75 allowed along crack length); this is adjustable for special cases (where we need to deviate).
- 1 inch
- 0.75"
- 1 inch

11. Does your agency have a maximum crack width for filling?

	Response Percent	Response Count
No	79.2%	19
Yes (please provide maximum size)	20.8%	5
answered question		24
skipped question		4

- 1"
- 1"
- 1 inch
- 1.5 inches (25% exceeding this width is allowed) - this is adjustable for special cases.
- up to 1.0"

12. Please provide any additional details on how crack width affects your crack sealing or filling policy.		
		Response Count
		13
	answered question	13
	skipped question	15

- N/A
- No response
- If cracks are wider than 3/4" we do not require routing. Require backer rod if joint width exceeds 3/8" see spec 403 for details
- If crack is greater than 3/4" it does not require routing.
- We fill cracks that exceed 1/2" in width, but normally we will fill the smaller cracks also
- We have a standard for the field personnel to use as a guide. It has information like, when to crack seal, How much Labor, Equipment, and Material type to use and the reporting unit is Gallons.
- 403.03.2 Routing
  Rout all existing cracks that are between 1/8 inch (3 mm) and 1 inch (25 mm) wide.
  Rout all longitudinal cracks to produce straight 3/4-inch (19 mm) vertical walls and a 3/4 inch (19 mm) wide flat bottom reservoir.
  Rout the transverse cracks to produce straight 1/2-inch (13 mm) vertical walls and a 1 1/2 inch (40 mm) wide flat bottom reservoir.
  Rout when the roadway is dry.
  Remove and dispose of the routed material from the roadway before opening the roadway to traffic.
- Different crack widths require different preparation methods. This information is detailed in the DOT Standard Specifications.
- Based on observations that occurred during recent construction of the research project, I am thinking that we should amend our spec to only require crack filling on cracks 1/8" or greater in width. Crack routing and sealing should probably be confined to cracks 1/4" or greater in width.
- Our policy is attached to Question 3.
- Guidelines are given in training on minimums and maximum widths related to the performance of the sealants.
- Do not fill alligator cracks, wide cracks. Al cracks must be clean and dry. Pavement temperature must be 40 degrees and rising.
- Longitudinal Cracks/joints that are too wide to fill/seal with one pass of the wand are not filled, but we come in a with a 12" milling head and mill that area, then replace with HMA.

13. When is crack sealing or filling typically performed? If crack sealing or filling is performed in multiple seasons, please indicate the most common season or choose "Other" and explain.

	Response Percent	Response Count
Spring	0.0%	0
Summer	8.7%	2
Fall	17.4%	4
Other (please explain)	73.9%	17
	answered question	23
	skipped question	5

- Our operation mainly consist of filling which is done year round.
- Fall and Summer
- Fall and Spring time frames during cooler weather.
- Fall and winter weather permitted, into early spring
- Fall, winter, and early spring
- September through April
- Crack sealing is performed spring, summer and fall.
- "Crack sealing may not be done after September 30. Crack filling may be done before May 15 or after September 30."
- The one project that we have had was constructed between March 4 and March 29, which I guess puts it on the borderline between winter and spring.
- November and December
- Preferred season is the fall, although we do consider spring projects
- Both Spring and Fall
- Contract work is done in three seasons when the air temperature is 45 degrees F and rising.
- "Crack sealing is performed in the Spring and Fall. Crack filling is performed in the winter months and early Spring usually ending in March or April"
- Spring and fall time frame. Typically the pavement temperature should be below 95 degrees.
- Spring and Fall. Program is federally funded and we begin in the Fall, completing the program in the Spring,
- "Crack filling -winter spring. Crack sealing- summer"

14. Is crack sealing or filling restricted by a minimum air temperature?

	Response Percent	Response Count
No	52.2%	12
Yes (please provide minimum temperature)	47.8%	11
answered question		23
skipped question		5

- Typically above freezing due to most machines not having heated hoses
- Manufacturers recommendations
- Air and pavement temp >50 ºF
- 40 degrees and rising
- 40 ºF
- 40 ºF
- When both the air and pavement temperatures are within the tolerances recommended by the manufacturer
- 40 ºF
- 45 ºF
- 40 ºF
- 40 ºF and rising

15. Is crack sealing or filling restricted by a maximum air temperature?

	Response Percent	Response Count
No	78.3%	18
Yes (please provide maximum temperature)	21.7%	5
answered question		23
skipped question		5

- Manufacturers recommendations
- When both the air and pavement temperatures are within the tolerances recommended by the manufacturer
- 70º
- 85 ºF
- We prefer temps between 40 to 65 ºF

16. Is crack sealing or filling restricted by a minimum pavement temperature?

	Response Percent	Response Count
No	52.2%	12
Yes (please provide minimum temperature)	47.8%	11
answered question		23
skipped question		5

- Manufacturers recommendations
- See 14
- 40º
- 32º
- 40º and rising
- 35 ºF
- When both the air and pavement temperatures are within the tolerances recommended by the manufacturer
- 32 ºF
- road temp not below freezing 32 ºF
- 40º
- 50 ºF

17. Is crack sealing or filling restricted by a maximum pavement temperature?

	Response Percent	Response Count
No	65.2%	15
Yes (please provide maximum temperature)	34.8%	8
answered question		23
skipped question		5

- Manufacturers recommendations
- 32º
- 35 ºF
- When both the air and pavement temperatures are within the tolerances recommended by the manufacturer
- 32 ºF
- 140 ºF
- 95º
- 100 ºF

18. Is crack sealing or filling restricted by recent rainfall?

	Response Percent	Response Count
No	56.5%	13
Yes (please provide the time duration since last rainfall)	43.5%	10
answered question		23
skipped question		5

- Pavement cannot be wet
- Restrict by rain or wet pavement
- Joints need to be clean and dry
- Surface has to be completely dry
- Pavement has to be hot and dry
- The only requirement is that the cracks must be dry
- Dry pavement
- Pavement must be dry, preferably 24 hours after rain.
- Specify dry cracks
- Judgment call

19. Is crack sealing or filling restricted by expected future rainfall?

	Response Percent	Response Count
No	82.6%	19
Yes (please provide minimum time until predicted rainfall)	17.4%	4
answered question		23
skipped question		5

- Unfavorable weather conditions
- Not specifically specified
- Imminent rain event
- Generally within 2 hours of work completion time

20. Is crack sealing or filling restricted by any other weather conditions?

	Response Percent	Response Count
No	56.5%	13
Yes (please provide details)	43.5%	10
answered question		23
skipped question		5

- Winter weather
- Snow covered roadways
- Windy conditions
- Snow and ice cannot be present. Hot and dry pavements can be sealed
- The reservoir and crack must be dry and free of dust, dirt and loose materials immediately before placing the backer rod, if applicable, and applying the sealant.
- The road must not be wet. So, it must not be currently raining, and if there is fog or mist that is causing the roadway to accept moisture, then that would restrict the placement of sealant.
- No frost, snow, ice or standing water may be present on the roadway surface or within the cracks.
- Although our policy does not reference pavement temperature or weather conditions, experience has shown better results under certain conditions.   Also, the products are used in conjunction with the manufactures recommendations in regards to pavement temperatures and weather conditions.
- Cracks must be clean and dry at the time of sealing or filling.
- Snow/ice

21. Are there different crack sealing or filling practices based on a roadway's functional classification, age, or other criteria?	
	Response Count
	19
answered question	19
skipped question	9

- Routes that have an annual pavement condition rating of 75-85 are crack filled
- No
- No.
- Sand the sealed cracks to eliminate tracking in aeras of stop and go traffic
- Cracks in high volume primary asphalt routes are sometimes routed.
- No
- no but by pavement type. Asphalt cracks are treated differently than concrete cracks
- No
- As pavements age after the initial crack sealing project, most of the follow up projects will be crack filling.
- No
- No
- No
- The only difference is that to seal transverse joint-reflection cracks in composite pavement, multiple reflection cracks are all sealed regardless of minimum width (i.e. hairline secondary cracks are struck off)
- There are separate requirements for crack filling prior to different preventive maintenance treatments.
- No
- Filling and/or routing and sealing cracks are not applicable to a pavement displaying structural problems such as extensive fatigue cracking, high severity rutting or any other extensive pavement deterioration.
- Yes, concrete uses a different material.
- Age of pavement and percenrtage of surface distress.
- MEMORANDUM
  To: Darcy Rosendahl, Director of Operations
  From: Dave Levi, Maintenance and Engineering
  Date: February 10, 2006
  Subject: Crack Sealing Study

  Recommendations to develop a crack sealing/pouring program were sent to the District on June 14, 2005. Comments regarding the crack sealing/pouring study were received from 5 of the 8 Districts. The initial recommendations were as follows:

  Recommendations:

The terms sealed cracks and poured cracks in the following recommendations need to be defined to avoid any confusion.

Sealed cracks are those that are sealed with a polymer or crumb rubber.
Poured cracks are those that are poured with MC 3000 or another acceptable asphalt product.

1. Require all future HBP to use an anti-strip agent, unless testing shows that the new PG asphalts will not have a stripping problem.

2. On new or mine and blend projects the transverse cracks should be sealed early in the life of the pavement, suggest within 3 years after construction. These projects should also be monitored every other year after the initial cracks are sealed so all new cracks are sealed.

3. On thin lift overlay projects the reflective cracks should be poured every other year. If the cracks in the old existing pavement were sealed in the past, the reflective cracks in the new overlay should also be sealed rather than poured. The DE should have the option to seal the transverse cracks if an aggressive crack pouring program was used and cores have been taken to show we have filled the voids in the old existing pavement structure.

4. On existing pavements, where the transverse cracks have not been sealed in the past, the cracks should be poured. If cores indicate there is no stripping, the DE should have the option of sealing the crack or continue to pour the crack every other year.

Comments:

The following comments were received from the Districts regarding the recommendations made to the Departments crack sealing/pouring program.

Bob Walton:

I thought the document was well thought out and covered multiple considerations very well. I'll add a couple thoughts that you may wish to consider or discard.

In Fargo we have had success with routing or sawing asphalt for the first seal application. We also use a polymer when we rout or saw. I think Mn/DOT has specifications on routing, and is studying what size reservoir works best.

We have also found that if a crack is wider than 1"", crack pouring is the best treatment. Crumb rubber won't work very well as it is usually applied when the crack is tighter, and then in the winter it opens so wide that the crumb rubber fails.

That is about all we had to add. Thanks for the opportunity.

Walt Peterson

The use of cutback oil from years back definitely degraded the cracks by striping from the bottom up. We have not milled any roadway that used crumb rubber or polymers.

Milling gave us a view of the cracks from the side. Removing slabs would probably do the same.

If you have ever watched a train go over ties that were not on solid rock ballast, you can see how the ties pump fines. As the axle distributes load over the ties, the ties depress, water & fines splash out, the load passes over, the rail returns to proper elevation, until the next axle depresses the tie again. My point is that that same series of loading appears during spring thaw. That's when we see the moisture from the cracks and it's dirty dirt color.

I think if we start early in process, we get ahead of the early deterioration of the subgrade, and the cracks aren't as big. The joints that we sawed (& polymer sealed) on US 85, south of Watford City, were in good shape prior to our first seal, after about 4 years.

Larry Gangl

I have no comments.

Jerry Miller

Our District has sawed and sealed all new structural overlays and mine/blend projects since the early 1990's. We are sawing a ¾ x ¾ inch vessel and filling with polymer + over banding. This program has been quite successful when used on new pavements within 3 years after construction. There is always a follow up on all these projects within 2 years to saw and fill any new developed transverse cracks. Unless new guidelines are developed by MESD that require all districts to follow, our district intends to continue this method of crack maintenance.

It is our belief that the best method of maintaining thin lift overlays over old asphalt is either pouring with MC3000 or crumb rubber. Our district has a three year scheduled rotation for crack pouring on old asphalt surfaces throughout the district. We intend to experiment more with pouring transverse cracks using crumb rubber. This method will seal and fill depressed cracks.

Paul Regan

Use MC-3000 for all HBP crack maintenance.

Polymers and routing just provide a new crack next to the one that you seal with a polymer as it is stronger than the adjoining pavement.

Over banding with crumb rubber can cause striping of the asphalt beneath crumb rubber next to the asphalt joint as moisture moves up during the spring and fall due to capillary action.

We have had both situations happen with polymers and crumb rubber. We do not use either material for crack maintenance as they are more detrimental than helpful.

Lime is a wonderful product and has many uses. Injected into a new crack will probably cause the joint to raise rather than stay at the same elevation as it is expansive over time. This has happened to us on lime treated bases and resulted in costly joint repair contracts, milling projects and HBP overlays. It may be a good tool to consider for depressed joints.

Recommend that we use MC-3000 exclusively for HBP crack maintenance until a better method is found.

Revised recommendations based on comments received:

The terms sealed cracks and poured cracks in the following recommendations are defined as follows:

Sealed cracks are those that are sealed with a polymer or crumb rubber. Routing or sawing of the cracks may be used in conjunction with sealing at the discretion of the District Engineer.

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1. Require all future HBP to use an anti-strip agent, unless testing shows that the PG graded asphalts used on the project will not have a stripping problem.
2. Seal/pour cracks in new hot bituminous pavement within the first three years after the pavement is placed. Cracks that are more than 3/4” wide shall be poured.
3. On new or mine and blend projects the transverse cracks should be sealed/poured early in the life of the pavement, suggest within 3 years after construction. These projects should also be monitored every other year after the initial cracks are sealed/poured so all new cracks are treated. Poured cracks should be retreated every other year.
4. On thin lift overlay projects where the existing transverse cracks were poured, the reflective cracks should be poured every other year. If the cracks in the old existing pavement were sealed in the past, the reflective cracks in the new overlay should also be sealed rather than poured. The District Engineer has the option to seal the transverse cracks if an aggressive crack pouring program was used and cores have been taken to show there is no stripping at the crack in the existing pavement structure.
5. On existing pavements, where the transverse cracks have not been sealed in the past, the cracks should be poured. If cores indicate there is no stripping, the DE should have the option of sealing the crack or continue to pour the crack every other year.

If you concur in the revised recommendations, please sign and return this memo. The Maintenance Operations Manual will be updated to reflect these procedures.

<u>Darcy Rosendahl</u> /s/ _ <u>02/15/06</u>
Concur Date

Comments: MESD needs to work with Materials and Research and the industry on the use of anti-strip agents. MESD should also set up a CERT type team that would annually review this aspect along with all preventive maintenance strategies to document their performance.

22. What procedures are used to determine qualified suppliers or products? Select all that apply.

	Response Percent	Response Count
Field test sections	17.4%	4
Field performance results	30.4%	7
National Transportation Product Evaluation Program tests	17.4%	4
Supplier certifications	**52.2%**	**12**
Independent lab tests	26.1%	6
Others (please specify)	43.5%	10
answered question		23
skipped question		5

- Our qualified product list (QPL) for certified products
- AASHTO T59 used for emulsions, AASHTO M324 used for hot pours
- Use NTPEP when a snow and ice state is host evaluation.
- Approved contractors
- 403.02 MATERIALS
  Crack Sealant. Use sealant meeting the ASTM D 5167 specifications in Table 403-1:
  TABLE 403-1. CRACK SEALANT SPECIFICATIONS
  PROPERTY REQUIREMENT
  Cone Penetration, 77 °F (25 °C), dmm (ASTM D5329) 100-150
  Cone Penetration, 0 °F (-18 °C), dmm (ASTM D5329 modified) 25 min.
  Flow, 140 °F (60 °C), 5h (ASTM D5329) 0.4 inch (10mm) max.
  Resilience, 77 °F (25 °C), (ASTM D5329) 30% to 60%
  Bond, -20 °F (-29 °C), 200% ext. (ASTM D5329) Pass 3 cycles
  Recommended Pour Temperature 380 °F (193 °C)
  Safe Heating Temperature 410 °F (210 °C)
  Asphalt Compatibility (ASTM D5329) Pass
- Testing is done in TDOT Materials and Tests lab before the product can be listed on Department's Qualified Products List. Certification is also required.
- Considering using NTPEP tests in the near future.
- In house testing for all lots of Type IV material. Qualified products list for contract crack filling materials.
- Hot poured rubber binder must conform with ASTM D 6690 Type I
- State experience

23. Is one material used under all conditions or are different materials used for different purposes? Possible differences could include crack filling versus sealing, prior to an overlay, type of crack, and so on.

	Response Percent	Response Count
One material for all conditions	34.8%	8
Different materials are used for different purposes (please provide details)	65.2%	15
answered question		23
skipped question		5

- Emulsions are used beneath HMA overlays, Hot pour is used for chip seal or pavement surfaces for maintenance applications.
- Type IV- transverse rout cracks and Type II-longitudinal and clean and seal.
- Review spec table 403.5.2-1
- Certain parts of our state may use a crack filler product for asphalt only and other parts of our state may use a crack filler product for asphalt and concrete surfaces
- Different material for crack filling vs. crack sealing
- One material for all of the Asphalt conditions weather it will get an overlay or not. There are other materials for concrete cracks along with backer rod to fill the cracks prior to sealing.
- The research project was constructed with an asphalt rubber product and a polymer modified product to gauge the difference between the two materials and their performance.
- Usually one material, Hot-Poured Elastic Type Joint Sealer, Type II, but others may be specified.
- Crack sealing ASTM 6690 Type II (AASTHO M324 TYpe II) is not allowed prior to an overlay; Pre-overlay crack filling 0.5-1.25 inches is with PG76-22 with polyester fiber, >1.25 inches with HMA.
- We have multiple products on our QPL.
- Type IV for crack sealing. Type I-III for crack filling.
- Crack Sealing- crumb rubber (Asphalt rubber sealant). Crack Filling- Emulsion
- One materials for bituminous pavement. For cracks in PC concrete pavement, other materials are used to either cut the bad section out and replace, or to inject a crack filler.
- Select from the Qualified Products list of TDOT
- MEMORANDUM

  To: Darcy Rosendahl, Director of Operations
  From: Dave Levi, Maintenance and Engineering
  Date: February 10, 2006
  Subject: Crack Sealing Study

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Concur Date

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24. What material acceptance tests do you use?

	Response Percent	Response Count
Penetration	90.9%	10
Softening	72.7%	8
Bond	81.8%	9
Resilience	63.6%	7
Aged resilience	9.1%	1
New performance-based tests	0.0%	0
Other (please specify)		13
answered question		11
skipped question		17

- Not sure due to our lab is the one that performs this
- AASHTO T59 used for emulsions, AASHTO M324 used for hot pours
- Will move to performance-based tests once lab and field validation projects are done.
- Flow and relative density. Review spec 807.2
- Manufacturer must meet NTPEP requirements, ASSHTO M 153, M 213, and D6690
- Tensile Strength Adhesion, 4 hour cure. Ductility, Force-Ductility, Flow, Asphalt Compatibility, Workability, Curing, Flexibility, 1/8inch x1inch x 6inches
- 403.02 MATERIALS
  Crack Sealant. Use sealant meeting the ASTM D 5167 specifications in Table 403-1:
  TABLE 403-1 CRACK SEALANT SPECIFICATIONS
  PROPERTY REQUIREMENT
  Cone Penetration, 77 °F (25 °C), dmm (ASTM D5329) 100-150
  Cone Penetration, 0 °F (-18 °C), dmm (ASTM D5329 modified) 25 min.
  Flow, 140 °F (60 °C), 5h (ASTM D5329) 0.4 inch (10mm) max.
  Resilience, 77 °F (25 °C), (ASTM D5329) 30% to 60%
  Bond, -20 °F (-29 °C), 200% ext. (ASTM D5329) Pass 3 cycles
  Recommended Pour Temperature 380 °F (193 °C)
  Safe Heating Temperature 410 °F (210 °C)
  Asphalt Compatibility (ASTM D5329) Pass
- Please see the spec (Dev305) that has been uploaded to your FTP site for the requirements.
- Flexibility, flow, viscosity, asphalt compatibility, bitumen content
- Currently part of a pooled fund research project looking at new test specifications.
- Material must conform to ASTM D 6690 Type I
- Unknown, this would be performed by our materials testing section. I don't believe they test crack sealer. Mainly go be national labs and mfgr certs.
- None

25. Does your agency have any additional material selection criteria not covered above?

	Response Count
	15
answered question	15
skipped question	13

- N/A
- No
- Adjusted cone penetration ranges and resilience for our climate. MnDOT Spec 3723 and 3725.
- No
- No
- A. Backer Rod – Refer to Section 03152.
- No
- Please see the spec (Dev305).
- No
- No
- No
- In house work done by maintenance forces bids material that is periodically sampled and tested to check for specification requirements.
- No
- ASTM
- No

26. Do you sample material in the field and test it to verify that it is the specified material?

	Response Percent	Response Count
No	63.6%	14
Yes	36.4%	8
answered question		22
skipped question		6

27. How do you evaluate material in the field to verify that the proper sealant was used?

	Response Percent	Response Count
Certifications	59.1%	13
On a Qualified Products List	59.1%	13
Sampling and testing	22.7%	5
Approving supplied material prior to use	13.6%	3
Sampling and testing during installation	4.5%	1
Other (please specify)	18.2%	4
answered question		22
skipped question		6

- Sampling
  1. Stockpile all sealant to be used on the project at least 20 working days before use. Keep the stockpile dry.
  2. Notify the Engineer when stockpile is established and ready to be sampled.
  3. Take at least one random sample of each batch or lot number with a minimum of 11 lb/sample.
  4. Do not place any material until the batch or lot material has been approved.
  5. No claim or extension of contract applies when the material fails to meet specification."
- "Crack filling material: The Contractor shall submit a Certified Test Report and bill of lading representing each delivery in accordance with AASHTO R-26(M). The Certified Test Report must also indicate the asphalt binder specific gravity at 77□F, rotational viscosity at 275□F and 329□F, and a mixing and compaction viscosity-temperature chart as if the asphalt binder were to be used as binder for the construction of hot-mix asphalt. The blending of PG asphalt binder from different Suppliers is strictly prohibited. Contractors who blend PG asphalt binders will be classified as a Supplier and will be required to certify the asphalt binder in accordance with AASHTO R-26(M)."" The Engineer may samples for testing but is not explicitly required to do so.
  Crack sealant:""During work progress, the contractor must submit to the Engineer the manufacturer's certificate of testing for compliance to AASHTO M-324 Type 2 requirements for each batch or lot of material utilized on the contract"" - the Engineer is not required to sample materials from the site explicitly, but can do so."
- None
- Since this is done in-house only, we rely on the supervisor to ensure quality.

28. Do you use any field acceptance tests, such as an adhesion test?

	Response Percent	Response Count
No	86.4%	19
Yes (please describe)	13.6%	3
answered question		22
skipped question		6

- AASHTO T59 used for emulsions, AASHTO M324 used for hot pours
- Visual inspection
- Visual determination for acceptance: "When work is complete on the project, or on a project location if multiple locations are included in the project, an inspection of the work shall be scheduled with the Engineer. The inspection is to take place before the subsequent surface treatment included in the project is applied. The Engineer will note all deficiencies including areas exhibiting adhesion failure, cohesion failure, tracking of sealant material, missed cracks or joints, and/or other factors that show the work is not acceptable. Work identified by the Engineer as not acceptable shall be re-done at the Contractor's expense. The Contractor shall notify the Engineer upon completion of required corrective work, or upon completion of work on the project location if corrective work is not required."

29. How is crack sealing or filling bid? Select all that apply.

	Response Percent	Response Count
Pounds applied	50.0%	10
Linear feet of cracking	15.0%	3
Unit area	5.0%	1
Lane mile	35.0%	7
Other (please provide more information regarding what your bid method is)	40.0%	8
answered question		20
skipped question		8

- Region preference
- Volume
- Gallons
- Gallons of emulsion for crack filling.

- This particular project was bid lump sum. The spec currently calls for it to be bid by linear feet of cracking, but I am leaning toward changing that to be bid by lane mile.
- Not applicable
- Performed in-house
- Not bid. We tried once to bid by the lane mile and received bids that were in excess of three times what it costs our crews.

30. If you selected more than one bid option, please explain when different options are used.

		Response Count
		6
	answered question	6
	skipped question	22

- Region preference
- See specification 403. Field engineers will normally recommend preferred method in their engineers recommendations.
- No specific selection method. It is at the prerogative of each Division.
- Crack Filling is bid by miles and pounds of sealer material. Crack Sealing is bid by miles and gallons of emulsion.
- Unit area (project square yards) when project limits are known (approaches lump-sum payment), for stand-alone projects. Lineal foot typical for pre-overlay crack filling (or for easily measured quantities such as a longitudinal paving joint). Pound when it is difficult to estimate the actual quantity needed, or for contracts (such as general commodity purchasing contracts) where the project locations cannot be pre-reviewed. The first option makes for easiest inspection (technique + missed cracks), and does not lend itself to over-application of material (sy). The second option dones not lend itself for over-application in any one crack (but it is difficult to identify ""phantom cracks"" sealed, were this to take place). The third option lends itself to over-application in any one crack, but it is simple for a contract with unknown projects (such as a commodity contract) - inspection needs to take care of measuring quantity used.
- For sealing concrete cracks a linear foot pay item is used.

31. Please describe the crack preparation procedures your agency uses and, if not always used, the conditions under which they are applicable. These might cover one or more of the following: Routing Air blasting Sand blasting Hot compressed air lance Wire brush		
		Response Count
		21
	answered question	21
	skipped question	7

- Compressed air from an air compressor is used to blow the cracks out prior to material being placed
- All the above depending on Region preference
- See special provisions for crack preparation
- See specification 403 and contract administration manual for details.
- Air blasting
- We route concrete and a few high volume aspahalt primary routes. All others we us hot compressed air lance.
- Routing and air blasting
- A. Apply sealant to designated joints as shown on the plans.
  B. Cleaning and Drying
  1. Asphalt joints – Clean 6 inches on both sides of the joint of foreign matter and loosened particles with a hot compressed air (HCA) heat lance immediately before sealing the joints. Adequate cleaning is determined by surface darkening at least 12 inches wide, centered on the joint.
  2. Concrete joints – Clean joints and surface in portland cement concrete by sand blasting before applying the sealant.
  C. Fill the joints following the Relief Joint Crack Sealing detail on the plans.
  D. Use an appropriate backer rod, compatible with the sealant and all components of the joint sealant system, in the joint opening where the depth and width of the joint opening are greater than 2 inches and ½ inch, respectively.
- Routing
- Crack Sealing 3/8 inch or less - Rout or saw to a minimum reservoir of 3/8 inch wide by 1/2 inch deep. Crack must be clean and dry before sealing. Larger than 3/8 inch - Clean cracks to necessary depth to accommodate the sealer and backer rod. Cracks must be clean and dry before sealing.
  Crack Filling 1/4 inch to 1 inch Cracks - Clear with air pressure or high-pressure water to remove foreign debris. Clean to a minimum of 1 inch and down to sound material. 1/4 inch or less - Clean sufficiently to remove sand and other foreign debris.
- 403.03.2 Routing
  Rout all existing cracks that are between 1/8 inch (3 mm) and 1 inch (25 mm) wide. Rout all longitudinal cracks to produce straight 3/4-inch (19 mm) vertical walls and a 3/4 inch (19 mm) wide flat bottom reservoir. Rout the transverse cracks to produce straight 1/2-inch (13 mm) vertical walls and a 1 1/2 inch (40 mm) wide flat bottom reservoir. Rout when the roadway is dry. Remove and dispose of the routed material from the roadway before opening the roadway to traffic.
  403.03.3 Cleaning

The reservoir and crack must be dry and free of dust, dirt and loose materials immediately before placing the backer rod, if applicable, and applying the sealant.

- Crack filling: air blasting. Crack sealing: routing, air blasting. A hot compressed air lance is used to dry cracks when they are moist."
- All cracks shall be thoroughly cleaned with high pressure, dry compressed air removing all vegetation, debris, moisture and foreign materials, as directed by the Engineer."
- Clean cracks using compressed air. Fill cracks. Surface may be sprinkled with a layer of fine sand to prevent tracking.
- Hot compressed air lance, wire brush are used (wire brush for cracks that are filled with dirt, vegetation, or debris within 1.5 inches of the surface) for both sealing and filling
- "Routing or sawing: 1:1 width to depth ratio, 7.5 cubic inches/foot minimum. Air blasting: 100 psi at continuous 150 cfm air flow, moisture and oil separators. Hot air lance: can be used to remove surface moisture, not used to dry wet pavement."
- 117.01 Procedure. If needed, rout out the crack to the sealant manufacturer's specifications for width to depth ratio. Clean the crack using high-pressure air, sandblasting, wire brushing or hot air blasting. This is a key step to crack sealing. If the crack is not thoroughly cleaned the sealant will not adhere to the sides. Hot air blasting is the preferred method because it helps dry the crack and if the sealing operation closely follows the hot air drying, the heated crack surface helps the sealant adhere to the crack. After cleaning the crack, sealant should be applied from bottom to within 1/8 inch of the top of the crack to prevent air bubbles from forming and creating a weak spot in the sealant. Fill the crack to no more than 1/8 inch of the top. Over banding, or the application of sealers up to the top of cracks and out onto the pavement surface has been shown through research to be ineffective, wasteful and reduces the friction values of the roadway, and is therefore not to be done.
- Cracks 1/4 inch or greater are blown out with a hot air lance and the sealant is then applied. We do not route our cracks at this time. We are in the beginning process of developing more detailed and refined crack sealing and filling specifications.
- "Crack sealing- routing, air blasting. Crack filling- air blasting"
- Air blasting, hot compressed air lance
- Routing, then air blast to clear water and particles, then fill. Crafco super shot melter is used.

32. In what (if any) situation do you use a recessed crack seal configuration, as shown above?	
	Response Count
	17
answered question	17
skipped question	11

- N/A
- N/A
- This is our standard configuration for the majority of projects
- None
- All
- None planned but it happens
- None
- None
- We have not used this configuration
- Not normally used
- None
- Portland-cement concrete joint resealing; pre-overlay crack filling (but no reservoir formation, just bottom-up filling existing configuration)
- All crack sealing specifies flush to 1/8" recess.
- We do not specify a recessed crack seal configuration.
- all crack sealing with routing
- N/A
- None

33. If used, what are the typical dimensions, as labeled in the figure?	
	Response Count
	7
answered question	7
skipped question	21

- N/A
- Recess by 1/4" see spec 403 for width and depth dimensions
- Rout dimensions inserted above depednding on orientation of crack.
- N/A
- 3/4" x 3/4" is typical.
- Reservoir width- 0.75" Reservoir depth - minimum 0.75" Recess depth- 0.25"
- N/A

34. Please describe the sealant placement procedures your agency uses with this configuration.		
		Response Count
		7
	answered question	7
	skipped question	21

- N/A
- See spec 403 and contract administration manual.
- 403.03.4 Sealing
  Install backer rod in cracks 1 1/2-inch (40 mm) wide and larger. Place sealant material within 72 hours of routing. Follow the sealant manufacturer's handling, mixing and application temperature requirements: Apply sealant filling the reservoir flush to the top using a pressure type applicator; Open the completed work to traffic once the sealant does not track; and Repair or replace all seal work damaged by traffic at Contractor expense. All cracks sealed require blotter material.
- N/A
- Fill bottom-up (have squeegee ready for any over-application strike-off)
- Road temperature not below freezing. No moisture in cracks. Usually transverse cracks. Cracks and joints shall be routed (50% of QA score). Reservoirs should be provided along the center of the crack width. Clean using high pressure air or hot air-blasting. Crack reservoir is filled from the bottom up to avoid air bubbles. Fill with sealant to within 1/4 inch of surface. Excess sealant on the pavement surface should be squeegeed to a smooth surface. Sealant is heated to a minimum of the manufacturer’s recommended pouring or application temperature, but temperature does not exceed the material’s safe heating temperature. Sealant temperature is checked periodically to assure proper temperatures. Sealant is continuously agitated to assure uniformity, except when adding additional material. Melting vat is kept at least one-third full to help maintain temperature uniformity. Use water/detergent mixture to minimize tracking. Allow sufficient time for sealant to cure before opening to traffic.
- N/A

35. In what (if any) situation do you use a flush fill crack seal configuration, as shown above?		
		Response Count
		17
	answered question	17
	skipped question	11

- All situations
- Std. Specifications requirement
- This configuration is rarely used, based on engineers recommendation.
- Mainly on high volume asphalt primary routes.
- None
- All situations
- This is the typical configuration
- All
- We have not used this configuration
- Flush fill is used in all situations unless another method is specified
- Cracks are filled flush with pavement surface.
- Most situations - also call for squeegee to strike excess sealant off
- Same as above, prefer flush to 1/8" recess.
- ALL
- We do not specify this method.
- In all situations.
- None

36. If used, what are the typical dimensions, as labeled in the routed version of the figure?	
	Response Count
	12
answered question	12
skipped question	16

- Varies depending on location and Region
- See spec 403
- 3/8" wide, 1/2" deep
- Use an appropriate backer rod, compatible with the sealant and all components of the joint sealant system, in the joint opening where the depth and width of the joint opening are greater than 2 inches and ½ inch, respectively.
- 3/8 inch width by 1/2 inch depth
- Inserted above
- N/A
- Not used
- No reservoir is created
- Same as above 3/4" x 3/4"
- We are not typically routing
- 1/4 inch to 1 inch in width

37. Please describe the sealant placement procedures your agency uses with this configuration.

	Response Count
	11
answered question	11
skipped question	17

- Blow out the crack, place rubberized sealant using a wand applied application
- Flush fill
- See spec 403 and contract administration manual for details.
- We use a wand with a disk on the application end to control volume placement to avoid over banding and then follow with a squeegee.
- Use an appropriate backer rod, compatible with the sealant and all components of the joint sealant system, in the joint opening where the depth and width of the joint opening are greater than 2 inches and ½ inch, respectively.
- Crack is slightly overfilled and followed by a narrow V-shaped squeegee. Sealant can spread on the roadway surface no more than 1/2 inch from the crack edge.
- Inserted above
- N/A
- The sealant shall be applied using the flush fill method. The crack shall be filled level with the asphalt surface. Immediately after placement of the sealant, a v-shaped rubber squeegee shall be use to level all excess material above the asphalt surface. Any sealant above the asphalt surface must be feathered out as directed by the Engineer
- Follow sealant application with squeegee to strike off all material.
- 1 inch depth

38. In what (if any) situation do you use an overband crack seal configuration, as shown above?		
		Response Count
		19
	answered question	19
	skipped question	9

- When applied as a surface treatment
- Rout and seal and clean and seal
- This configuration is not used in Wyoming
- We try to be recessed about 1/4", but we will also use a squeegee to level the material out
- On all secondary routes and most of primary routes.
- None
- Never planned but it happens.
- We use the routed configuration when the crack is 1/4" wide or wider.
- A small overband of no more than 1/2 inch on each side of a crack is allowed, but an overband is not required as part of the filling procedure.
- Overband non-routed is considered on cold in place recycle projects to limit breakout.
- We used the overband method exclusively in our research project.
- Not normally used
- Do not overband
- None
- All crack filling is non-routed with overband configuration.
- Not applicable
- This is our specified installation method
- In all situations
- All

39. If used, what are the typical dimensions, as labeled in the routed version of the figure?	
	Response Count
	9
answered question	9
skipped question	19

- 2 inch band width is typical
- 3/4 x 3/4 rout
- We do not route these cracks.
- 3/4" x 3/4" reservoir depth/width. 3" maximum overband width.
- NA
- Overband width: 3 in. Reservoir depth: 1/2 in. Reservoir width: 3/4 in.
- 2 inch overband, 1/8 inch depth of sealant, we do not require cracks to be routed.
- 3 inch maximum overband
- Less than 1/2 inch

40. Please describe the sealant placement procedures your agency uses with this configuration.

		Response Count
		11
	answered question	11
	skipped question	17

- Compressed air to clean and seal
- Over band- width 3" and thickness 1/16"
- Non-routed with the use of a squeegee
- We use a wand with a disk on the application end to control volume placement to avoid over banding and then follow with a squeegee.
- The crack/joint is routed, cleaned out and then the crack sealing material is applied.
- N/A
- Cold sealant is heated to around 400 degrees Fahrenheit in a large kettle, and then it is applied through a wand to the cracks.
- Apply material with a wand followed by a V or U shaped squeegee or a round application head with a concave underside. 4" wide and 1/8"- 3/16" thick over band.
- Apply the sealant in the prepared cracks at 370 to 420 degrees F. using a 2 inch pressure screed shoe to completely fill the crack. Following the sealant application with a "V-shaped" binder squeegee leaving a sealed 2-inch over band. After the crack is sealed, promptly remove any surplus sealant remaining on the pavement. Do not permit excessive over banding or wasting of sealant. Ensure that all cracks sealed have a minimum of 1/8 inch depth of sealant installed.
- Clean the crack(s) using 100 PSI compressed air, use a heating kettle to place the sealant material, squeegee to ensure material is placed into the crack.
- Rout, blast, fill

41. Please list all equipment typically used for crack sealant placement. Select all that apply.

	Response Percent	Response Count
Compressor	86.4%	19
Rotary saw	0.0%	0
Router	50.0%	11
Rotary impact router	0.0%	0
Applicator	**95.5%**	**21**
Squeegee	81.8%	18
Other (please specify)	31.8%	7
	answered question	22
	skipped question	6

- Apply sand when necessary
- Hot air lance
- Compressed air heat lance. see spec 403
- Compressor, Tar Kettle, Early Warner, Trucks
- High-pressure water for crack cleaning
- (1) Melter Applicator: The unit shall consist of a boiler kettle equipped with pressure pump, hose, and applicator wand; the boiler kettle may be a combination melter and pressurized applicator of a double-boiler type with space between the inner and outer shells filled with heat transfer oil. Heat transfer oil shall have a flash point of not less than 600°F. The kettle shall include a temperature control indicator and a mechanical agitator. The kettle shall be capable of maintaining the treatment material at the manufacturer's specified application temperature range. The kettle shall include an insulated applicator hose and application wand. The hose shall be equipped with a shutoff control. The kettle shall include a mechanical full sweep agitator to provide continuous blending. The unit shall be equipped with thermometers to monitor the material temperature and the heating oil temperature. The unit shall be equipped with thermostatic controls that allow the operator to regulate material temperature up to at least 425 °F.
  (2) Applicator wand
  (3) hot-air lance
  (4) squeegee (U configuration)
  (5) vertically mounted power driven wire brush"
- Crafco Super Shot melter that has the router, air lance and filler all in one unit.

42. Is the reservoir inspected prior to sealant placement?

	Response Percent	Response Count
No	38.1%	8
Yes (How?)	61.9%	13
answered question		21
skipped question		7

- Visual
- Visual and at time duct tape
- Visual inspection
- Yes, by inspecting tank
- Visual
- Routed dimensions are verified
- Visual inspection
- Reservoir gauge
- Visually
- Visual inspection
- visual inspection of existing crack (no manufactured reservoir)
- Varies from project to project
- Crew leader on job - visual

43. How do you determine if cracks are clean and dry enough for sealant installation?	
	Response Count
	22
answered question	22
skipped question	6

- Visual
- Cracks are sealed during dry conditions
- See 42
- Visual inspection
- Visual inspection
- Visually
- Visual
- Cleaning and Drying
    1. Asphalt joints – Clean 6 inches on both sides of the joint of foreign matter and loosened particles with a hot compressed air (HCA) heat lance immediately before sealing the joints. Adequate cleaning is determined by surface darkening at least 12 inches wide, centered on the joint.
    2. Concrete joints – Clean joints and surface in portland cement concrete by sand blasting before applying the sealant."
- Visually inspect to make sure cracks are free of dust/debris and have no moisture.
- Visual inspection
- Visual inspection
- Visual inspection
- Visual inspection
- Visual observation
- Pavement surface cracks, raveled longitudinal joints, and raveled transverse joints to be filled shall be treated with a hot-air lance prior to application of the crack seal material. Two passes, minimum, shall be made with the hot-air lance. The hot air lance operation shall proceed at a rate no greater than 120 feet per minute. There shall be no more than 10 minutes time lapse between the second hot-air lance treatment and the material application. Should this time be exceeded the Contractor shall make an additional pass(es) with the hot air lance. The use of the hot air lance is not intended to heat the crack. It is to be used to blow all debris from the crack to the depths specified below and to remove any latent moisture or dampness from inside the crack until the inside of the crack is completely dry in the opinion of the Engineer. "Moisture" does not include standing water. The hot air lance is not to be used to "boil off" or blow standing water from the bottom of a crack. If standing water is present in the bottom of any crack, the sealing operation shall be postponed until such time that the standing water evaporates naturally. The Contractor may be allowed to use compressed, oil-free, air (not heated) to blow standing water from a crack to help accelerate the natural evaporation of any standing water. If this is done, the crack must be allowed to dry naturally until all standing water is visibly gone. Then the hot air lance may be used. If a crack is already completely dry, in the opinion of the Engineer, the hot air lance should be operated at its lowest temperature possible.

- Visual inspection
- Operator experience
- Experience
- Visual inspection
- Visual
- The operator of the compressed air visually determines if warrants sealing
- Based on experience of crew

44. Are there any required equipment inspections? Please describe.	
	Response Count
	21
answered question	21
skipped question	7

- Yearly preventive maintenance inspection and the crews daily walk around
- No
- No
- Inspect contractors equipment to make sure it meet specifications.
- CDL inspection on all equipment prior to daily usage
- No
- FHWA guidance
- No
- No
- Pot size and compressor 185 cfm minimum.
- No
- The melter-applicator shall be an oil jacketed double boiler type, equipped with an agitator and separate thermometers for both the oil bath and the melting vat. All equipment necessary for the satisfactory performance of this operation shall be on the job and approved by the Engineer before work will be permitted to begin.
- No
- Not explicitly in the specification.
- Do not allow the material to exceed 400 F.
- Yes taught at our equipment academy
- No
- No
- No
- Yes, each piece of equipment is inspected at the beginning of the day.
- No, units are serviced at beginning of season and serviced as problems arise.

45. After the sealant is placed do you take any steps to protect the sealant from pull-out or tracking?

		Response Percent	Response Count
No		13.6%	3
Yes (please describe)		86.4%	19
		answered question	22
		skipped question	6

- Apply sand when necessary
- Use blotter material if needed.
- Apply sand if need be
- When traffic has to be allowed prematurely we use the manufacturers recommend liquid spray product to apply.
- Manufacturer recommendations
- We spread dry sand, if applicable, to allow traffic to cross
- If traffic will be on the material before it sets up, a detacking oil is applied to the material.
- Blotter material may be applied after the sealer surface has set sufficiently, to help limit tracking potential.
- Toilet paper blotter.
- We keep traffic off of the fresh product for approximately 15 minutes.
- May sprinkle sand mixture on surface to prevent tracking.
- Keep traffic off so that no tracking or pull-outs take place (wait until the material "sets"); re-treat any cracks where pull-outs have taken place. "detackifier" is allowed as an option (the detackifier has to be the sealant material's recommended type), but is not required.
- De-tackifying solution is used in areas such as intersections where the material does not have as much cure time.
- Glens oil
- Blot with sand
- Traffic is not permitted on sealant without approval of the resident construction engineer. RCE uses his/her judgement as to whether the sealant has cooled enough to carry traffic.
- Water/detergent mixture, toilet paper, sand for filling
- The foreman determines when traffic can be allow onto the roadway.
- Spray a de-tack agent on surface that expedites set up.

46. Are any procedures specified when crack sealant is placed prior to an overlay? These might include preparation method, material, configuration, time between sealing, and overlay construction.

		Response Percent	Response Count
No		60.0%	12
Yes		40.0%	8
		Please provide fruther details	10
		answered question	20
		skipped question	8

- Recessed joint sealing is specified.
- We recommend that the crack sealant be applied one year before HMA is placed or 30 days before WMA is placed.
- Internal department decisions and planning
- We try to apply the crack sealant at least three months prior to overlay.
- We may consider islation lift if the crack seal is recent and abundant.
- N/A
- Same as above
- Recessed-fill, only crack filler; cracks 0.5 or wider only (vs 1/8 inch)
- Crack sealing must be done at least 6 months prior to any asphalt overlay.
- We don't seal crack prior to overlays unless need is evident

47. Are any procedures specified when crack sealant is placed prior to a surface treatment?

		Response Percent	Response Count
No		84.2%	16
Yes		15.8%	3
		Please provide further details	5
		answered question	19
		skipped question	9

- Flush fill
- Recessed joint sealing is specified
- N/A
- Same as above
- See details below

48. Do crack sealing or filling procedures vary depending on the type of surface treatment (e.g., fog seal, slurry seal, chip seal, etc.) that will be placed over it?

	Response Percent	Response Count
No	71.4%	15
Yes	28.6%	6
Please provide further details		7
answered question		21
skipped question		7

- Emulsions are placed beneath HMA. Hot pours are used for surface treatments on chip seals and HMA, mostly for maintenance applications.
- See 47
- May fill just large cracks if we will be doing a scrub seal, slurry seal
- We don't rout the cracks when done as a preparation for a surface
- N/A
- Sealant is allowed for surface treatments less than 1" thick (i.e. microsurfacing, chip seal, ultra-thin bonded wearing course). Filler is used for 1" or more overlays. For pre-overlay crack filling, recessed-fill is used.
- Micro-surface and Ultra-thin overlay: Fill all visible cracks that are less than 1 1/4" wide. Chip seal: Fill cracks greater than 1/8" wide or 3 feet long. Paver placed surface seal (Nova-chip): Fill all cracks between 1/4" and 1 1/4" wide.

49. Are there any specific procedures applicable to the use of crack sealing as a stand-alone treatment?

	Response Percent	Response Count
No	81.0%	17
Yes (please provide details)	19.0%	4
answered question		21
skipped question		7

- See special provisions
- Please see all of my responses to every previous question in this survey. It has all been applicable to the use of crack sealing as a stand-alone treatment.
- Fill all visible cracks that are less than 1 1/4" wide.
- Follow the attached Quality Assurance form.

50. What is your field inspection and/or acceptance procedure with respect to the final, as-placed product?	
	Response Count
	17
answered question	17
skipped question	11

- N/A
- Visual
- See spec 403 including quality level analysis and pay factors.
- Visual inspection to verify bonding of material and to prevent over banding.
- Visual
- Making sure it is flush with the pavement and the cracks are sealed
- Visual
- Project inspector will spot review work to verify all cracks are properly filled and if any re-filling is necessary.
- Ensure rout is in spec. Clean and dry surface 35 f and rising. Flush fill with blotter"
- I make sure that all cracks meeting the minimum width have been routed and sealed or filled. I make sure that the cracks are completely filled.
- Visual inspection
- Visual inspection
- When work is complete on the project, or on a project location if multiple locations are included in the project, an inspection of the work shall be scheduled with the Engineer. The Engineer will note all deficiencies including areas exhibiting adhesion failure, cohesion failure, tracking of sealant material, missed cracks or joints, and/or other factors that show the work is not acceptable. Work identified by the Engineer as not acceptable shall be re-done at the Contractor's expense. The Contractor shall notify the Engineer upon completion of required corrective work, or upon completion of work on the project location if corrective work is not required.
- Some inspection during contract work.
- The number of lane miles for which asphalt pavement cracks have been satisfactorily sealed.
- Visual
- Not Applicable - there is no acceptance procedure for in-house work.

51. Do you have performance guarantees as part of your acceptance procedures?

	Response Percent	Response Count
No	80.0%	16
Yes (please describe the requirements and the associated guarantee or warranty period.)	20.0%	4
answered question		20
skipped question		8

- If warranty is used
- One year warranty
- Clause in contract - Performance. The Contractor shall repair/replace any crack sealant that fails to bond to the existing pavement within one year of initial placement. All costs to repair/replace the sealant shall be borne by the contractor.
- Warranty for various failure mechanisms for a two year period.

52. Do you have a typical maintenance schedule for the first crack seal application after constructing new pavement or placing an overlay?	
	Response Count
	21
answered question	21
skipped question	7

- Routes that rate between 75 - 85
- No
- No
- Based on performance of new pavement, no defined schedule set.
- After constructing an overlay we recommend that section of roadway be reviewed for crack sealing each year following two winters.
- No
- No schedule but we do maintenance inspection of our roads twice a year and determine crack sealing needs and resources.
- Five years
- No
- 3-4 years
- No
- No
- No
- Aim is for 4-6 years after bituminous-concrete placement for crack treatment (filler if only paving joints or non-working cracks, sealant if working cracks).
- Composite pavement usually have a contract crack treatment project 2 to 3 years after the overlay.
- See memo copied in other questions
- No. As needed or warranted.
- No
- 3 to 5 years
- No
- 3-5 years after pavement is placed, it is evaluated for the need for crack sealing

53. What is the typical or average time from when sealant is placed until it needs to be replaced? If known, please describe the conditions under which this varies.		
		Response Count
		19
	answered question	19
	skipped question	9

- This depends on ADT along a route, weather etc. Typically around 3 - 5 yrs"
- Unknown
- Maintenance plans reseal operations in 8 to 10 year time period. Still also based on roadway performance
- 5 years
- Approximately three years
- After new construction of asphalt pavement. It typically requires a crack sealant in three to four years depending on the traffic loads. The concrete pavements may go 10 to 15 years before needing to seal the cracks.
- Unknown.
- I don't have good data about that.
- Depends on surface and environment.
- Unknown
- Not known
- 1 to 2 years
- After a hiatus of 5 years, crack sealant was first placed in 2009 (four years ago). It still does not need to be replaced. Crack filler was also used in these projects and depending on the project there are minor areas where crack treatment is needed (mostly delamination OUTSIDE where the filler had been placed), but no areas requiring re-application of filler because of material failure.
- Composite of thin overlays vary depending on the condition of the pavement that is overlaid (1 to 4 years). Full depth HMA depending on thickness (5 to 8 years).
- Not none
- 3 to 5 years
- Crumb rubber - 3-5 years. Emulsion- 1-2 years
- 3 years
- Cracks are generally not re-sealed

54. How do you define sealant failure?		
		Response Count
		21
	answered question	21
	skipped question	7

- Not bonding, no elasticity
- Unknown
- Bond failure ,pull-outs
- Bond failure
- Debonding from one side of crack.
- Pull outs, loss of adhesion, extended cracking
- When the crack sealant material pulls out of the crack and not bonded or if the crack itself is not filled at all
- We have only been doing crack sealing for about six years. We haven't had any failures so far.
- When sealant no longer adheres to the sides of the crack.
- Pulling from edges. Pulling from the crack with traffic.
- I would define sealant failure as the point at which the sealant no longer provides a water proof seal to prevent water and debris from entering into the crack.
- Loss of sealant or bond failure
- Visual cracks
- Adhesion, cohesion failures, tracking (at the time of construction); adhesion and cohesion failures will be our failure criteria (25% or more of the length) (considering; not needed yet)
- Adhesion or cohesion failure are the main focus. Plow wear/abrasion and stone intrusion are other failures that are observed.
- No standard definition
- We don't
- When the sealant is pulled from the cracks by traffic or is torn by excessive crack movement.
- Cohesion or adhesion failure
- Pulling out, re-cracking
- Not defined.

55. How do you determine that crack sealant should be replaced?	
	Response Count
	19
answered question	19
skipped question	9

- N/A
- Unknown
- Visual inspections by maintenance during annual budgeting process. Roadways are reviewed and seal contracts recommended. There is also review by Materials program with path view analysis that can give recommendations.
- When the material is not adequately bonded to both sides of crack.
- District decision
- Visual failures during inspection of the roads
- I think the pavement would be overlaid prior to having to replace the cracksealant.
- If sealant is missing or no longer adheres to either side of the crack.
- Visually
- We don't
- Bond failure
- Visual observation
- 25% of the length not performing its function (considering; not needed yet)
- Visual determination that usually occurs when there is also new cracking that has not yet been treated in the pavement section.
- Operator experience
- There have not been any formal procedures developed
- Visual inspection
- Water getting into the roadway and causing more cracking or the sealant coming out
- Not done

56. Has your agency quantified the effect of sealant on pavement life?

	Response Percent	Response Count
No	86.4%	19
Yes (please provide this information and how it varies depending on different factors. If these studies have published results, please provide the applicable study: Click here for ftp access or provide URL. To review FTP instructions, use the "prev" button to return to the first page. Your answers so far will be saved.)	13.6%	3
	answered question	22
	skipped question	6

- This information would need to be acquired from our Materials program. Contact would be Greg Milburn, State Materials Engineer, 307-777-4476
- Current research AP Tech that has not been published yet.
- As part of our pavement management process and pavement deficiency ratings, performing crack sealing does extend the life of the pavemetn from an analysis perspective. I don't know by how much.

57. What factors affect the performance of sealant in your agency? These might include one or more of the following:

	Response Percent	Response Count
Pavement condition	81.8%	18
Placement or preparation procedures	77.3%	17
Placement conditions (environmental factors)	72.7%	16
Environment over time	59.1%	13
Traffic	63.6%	14
External forces such as snow plows	59.1%	13
Deicers	18.2%	4
Material quality	54.5%	12
Other (please specify)	13.6%	3
answered question		**22**
skipped question		**6**

- Freeze Thaw cycles are very high in Utah. We could have 3 to 4 freeze thaw cycle in one day.
- Unknown
- Pavement that is tending to ravel everywhere has caused us to overlay a section crack-filled - where the crack filling material was working as intended but the remainder of the pavement surface was raveling. This should be a filter for either (a) following the sealing/filling operation with a surface treatment/overlay project within a short period of time (1-2 years depending on condition) or (b) excluding the segment from crack sealing or filling.

58. What type and application method of deicer is typically used in your state? Do you feel that deicer application prior to sealing affects the crack sealant performance?	
	Response Count
	22
answered question	22
skipped question	6

- Brine, not if cracks are dry
- Unknown
- Spray brine, and rock salt- no sand. Salts will affect bond adhesion"
- Application of salt/sand with pre-wet. Do not feel this impacts sealant because of cleaning and widening specs prior to sealing. Grit material in recessed joints may have some impact after sealant is placed.
- Salt/sand, spread by sander trucks. brine and mag-chloride sprayed on road surface. have not noticed any effect as long as the cracks are aired out prior to applacation of material.
- Salt brine, No
- Salt spreader, No
- Yes but the cracks should be cleaned out prior to sealing
- Salt and calcium chloride. Application is from tailgate spreaders/v boxes from dump trucks.
- The Iowa DOT uses salt brine and rock salt as a deicer. I don't know that the deicer has an impact on sealant performance.
- Liquid and solid application. It could have an impact if applied after the rout.
- What is this deicer you speak of? Never heard of it.
- Brine and salt. Probably not, most sealant application is done in warm weather.
- Bulk salt, some salt brine, other chemical pre treatment.
- (Salt, magnesium chloride) - no information on deicer application prior to sealing is available for me to comment.
- Primarily rock salt or a brine/sand mixture. Some section pre-wet with calcium chloride or magnesium chloride. I do not concider deicer application a big factor in sealant performance.
- Salt/sand/Salt brine
- Various. No
- We have a relatively mild climate and may go years without a major snow or ice event. We use rock salt or salt brine as our primary deicer when we do have a winter storm event. We have not noticed any adverse effects on sealant performance due to the use of deicers.
- Brine, calcium chloride, magnesium chloride, beet juice. We have not noticed any affects to crack sealant.
- Calcium chloride, salt brine. Various spreaders, tank sprayers.
- Rock Salt treated with liquid calcium chloride. We do not feel that this affects crack sealer performance to any detectable degree

59. Please describe the typical problems that you have with crack sealing/filling projects.	
	Response Count
	19
answered question	19
skipped question	9

- Most common problem is with the equipment breaking down, personnel not know what temperature to heat material to
- Joints not being cleaned prior to placement. Bumps develop when hot poured material is used beneath HMA. Occasional tracking issues.
- Poor workmanship, lack of inspection
- Over-application of sealant by contractors, making sure cleaning and joint preparation is done properly, material quality issues.
- Too much over band on a dirty surface will come right up as traffic drives over it and can pull material from crack.
- Contracts apply to much sealant or fail to squeege properly
- Too soft, doesn't stay in the cracks, over filling, the Motorcycle association complains about crack seals causing them to have accidents, when cars drive over some cracks it pulls out the cracks with the tires. too brittle etc..
- If water is bleeding up through a joint, the material will not adhere to the pavement.
- The first problem we have is getting the projects let in a timely manner. Often districts wait too long to get the first crack sealing project let, so cracks deteriorate due to the delay. The second problem is being able to estimate the quantity of filler material needed on a project. The actual amount used can vary significantly from the engineers estimate, both high an low.
- Product running to low side. Contractor fails to flush fill. Traffic returned to road to quickly resulting in rubber pulling from crack. Toilet paper blotter bad PR sometimes"
- Having only had one project, it is hard to say what is typical. One major problem that we encountered during construction of our recent research project was when we were routing two cracks that intersected each other. One specific section of roadway had portions of the friction course "pop-out" as wedges in between the two routed cracks. Measurements indicated that the friction course thickness on that roadway was only 1/2 inches in thickness. Another issue that we had was in determining when the cracks were adequately cleaned. Not having much (any)experience with crack filling/sealing, we were counting on the contractor to use the proper equipment to adequately clean out the cracks. The material supplier who was on-site during construction was not happy with the cleanliness of the cracks, but I couldn't really hold up construction and demand that they get a bigger air compressor.
- The main point is insuring that the cracks are cleaned well before sealing. Most of the time this is not a problem but can be on occasion. In Tennessee, work on the Interstate system must be done at night and insuring that moisture in the crack is blown out may be an issue.
- Traffic control, tracking.
- 1. Pre-overlay crack filling paid by the pound, even though spec is clear on crack selection and application technique (massive over-application and bumps in the overlay,

even when no rubberized material was used). (Happened on one project due to over-application at properly selected cracks, on one more project due to improper crack filling selection (all cracks were filled regardless of width))- have discontinued this practice.
2. Minimum ambient temperature becomes a restriction quickly in the fall particularly on night filling/sealing projects.

- There have been several reasons for pre-mature failures that include project selection, workmanship quality, and material selection.
- Prior to changing to lane miles as the pay item we would have to much sealant applied because the contractor was being paid by the pound. The change in pay item and better project selection have reduced the typical problems encountered. We may have the occasional issue with sealant being pulled from the cracks but this is rare.
- Proper application procedures being followed. project selection
- Crews filling alligator cracks, too wide of bands, poor squeegee methods.
- We have not experienced any in the last 8-9 years.

60. Please provide copies of any other completed research studies, reports, specifications, or other information in support of your crack sealing and/or filling policies and procedures: Click here for ftp access or provide URL. To review FTP instructions, use the "prev" button to return to the first page. Your answers so far will be saved.

	Response Count
	5
answered question	5
skipped question	23

- None to provide
- TPF 5(255) Validation of performance based tests. LRRB Investigation 822. Canadian Infraguide
- This information would need to be provided by our Materials Program. Contact person was given previously.
- http://www.iowadot.gov/erl/current/GS/content/2541.pdf
  http://www.iowadot.gov/erl/current/GS/content/2544.pdf
  Crack sealing and filling specifications are available at above addresses."
- N/A

61. Would you like to be notified when a copy of these research results are available?

	Response Percent	Response Count
No	4.5%	1
Yes	95.5%	21
answered question		22
skipped question		6

APPENDIX C. CDOT SURVEY RESPONSES

Demographic Information				Preferred contact method if we need additional information:
Name:	Title:	Email:	Phone:	Response
D'Wayne Gaymon	LTC OPS II	dwayne.gaymon@state.co.us	970-384-3356	Email
TJ Blake	LTCOPS I	Todd.Blake@state.co.us	970-683-7592	Email
Greg Hayes	Deputy Maint. Supt.	gregory.hayes@state,co.us	303-365-7100	Email
Byron K Rogers	LTCOPs I	Byron.Rogers @state .co.us	970-522-9620	Phone
Phillip Anderle	Deputy Superintendent	phillip.anderle@state.co.us	970-350-2100	Email
Robert Madrid	Deputy Maintenance Superintendent	robert.madrid@state.co.us	719-546-5764	Email
Larry Dungan	LTC Ops 1	larry.dungan@state.co.us	303-941-3223	Phone

Demographic Informa	Which of the following do you use to select crack sealing projects? Select all that apply.					
Name:	Pavement age	Pre-determined schedule	Condition	Crack type or orientation	Crack width	Other crack sealing criteria, or additional details as needed to clarify selection methods:
D'Wayne Gaymon	x		x	x	x	
TJ Blake			x	x	x	
Greg Hayes	x	x	x			
Byron K Rogers	x	x	x	x	x	Ensure that there are no overlay projects upcoming withing 1 to 2 yrs depending on crack fill material on the road..Also depending on how much product is being applied. Chip seals may want to be done first or wait at least 1 year before chipping.
Phillip Anderle	x	x	x	x	x	
Robert Madrid	x	x	x	x	x	
Larry Dungan	x		x	x	x	Engineering projects and timelines for the road.

Demographic Informa	What is the narrowest crack width you typically seal? Please consider work that you would self-perform, not work that would be contracted out. (select one)		What is the widest crack width you typically seal? Please consider work that you would self-perform, not work that would be contracted out. (select one)	
Name:	Response	Other (please specify)	Response	Other (please specify)
D'Wayne Gaymon	1/4 inch		1 inch	If using Stone Mastic process would go wider.
TJ Blake	1/8 inch		1/2 inch	
Greg Hayes	1/16 inch		3/4 inch	
Byron K Rogers	1/4 inch	Depends on the type of product you are using and what type of crack and what you are wanting to accomplish		All the above. A crack filled is better than nothing.
Phillip Anderle	1/4 inch		1 ½ inch	We really need a Mastic material on our APL so we can better address our wide cracks.
Robert Madrid	1/4 inch		3/4 inch	
Larry Dungan	1/16 inch		1/2 inch	

Demographic Informa	During what season do you perform most of your crack sealing? (select one)	During what other season(s) do you perform crack sealing? Select all that apply.				
Name:	Response	Spring	Summer	Fall	Winter	Please provide additional clarifying details if necessary.
D'Wayne Gaymon	Fall	Spring			Winter	
TJ Blake	Fall				Winter	
Greg Hayes	Winter			Fall		Spring if the weather is still cool and dry.
Byron K Rogers	Fall			Fall	Winter	Schaffer memo is golden. As long as the cracks are dry you are making head way. Fall and early winter is the ideal time.
Phillip Anderle	Winter	Spring		Fall		
Robert Madrid	Winter			Fall		
Larry Dungan	Fall		Summer	Fall		Usually September the rain has washed most of the residue from the road and there is still expansion and contraction from the cool nights and hot days.

APPENDIX D. EVALUATING CRACK SEALING FAILURE IN HMA PAVEMENTS

The emphasis in this document is on the selection of good candidate pavements for crack sealing and on guidance to ensure the proper placement of sealant. Recognizing that sealants don't always perform as intended, this appendix provides information on how to identify sealant failures and how to address those failures.

Sealant performance problems can be categorized by when they occur. Problems that occur during construction are closely linked to crack preparation and material placement. Ideally these are identified and corrected during construction so that the overall job is successful. Other crack sealing-related problems may only develop over time. These may also be a result of construction problems, but problems that only become evident over time. While they could be said to contribute to premature failure, identifying "premature failure" requires an understanding of the expected performance of the sealant. Finally, sealants do eventually fail: recognizing what constitutes the normal failure of a sealant at the end of its life helps to determine when to reseal.

Construction Failure

Crack sealing construction failures are those problems that are identified during construction. These failures include tracking and adhesion failures. Bubbles in the sealant also indicate a construction problem, but are not necessarily indicative of a construction failure. Bubbles will occur when moisture trapped in the crack is vaporized by contact with the hot sealant. The resultant gas works its way to the surface of the sealant and appears as bubbles.

Premature Performance Failure

A sealant may appear to perform properly following construction, but then fail <u>after</u> construction but <u>before</u> the expected life of the sealant. Identification of premature failure includes both a consideration of what constitutes "premature" failure and the types of conditions that would constitute failure.

In general terms premature failure occurs when the sealant does not achieve its intended life. However, there is no fixed age that represents sealant life, as actual performance, even under ideal placement conditions, is affected by the environment, the condition of the surrounding pavement, traffic, and other external factors that are beyond the control of the material supplier or the crew placing the material. As such, expected lives are often expressed in terms of a range rather than a single value. This range could be 4 to 8 years, 5 to 10 years, or some other span reflecting the highly variable nature of sealant and pavement performance.

For the purposes of this document, the timing of premature failure is said to occur within 2 years of placement. While recognizing that a longer performance period is desirable, after 2 years it is difficult to separate failures caused by factors beyond the control of the materials supplier or construction crew from those factors that are within their control.

The other consideration is a definition of failure. A very simple approach is to define failure as occurring when the sealant no longer serves the purpose for which it was placed. Since the primary purpose of sealing cracks in HMA pavements is to keep moisture out of the pavement structure, a sealant has failed when water can get into pavement. This may be because the sealant is no longer present, because it is present but no longer bonded to the sides of the crack, or because it is present and bonded to the sides of the crack but no longer bonded to itself.

With this in mind, the following list summarizes premature crack sealant failures:

- Adhesive failure: the sealant has pulled away from the crack sides or is no longer bonded to the crack sides. The sealant may remain in the crack, may be partially or completely pulled out of the crack, or may have sagged to the bottom of the crack.
- Cohesive failure: the sealant remains bonded to the crack sides, but has internal cracks. This is often associated with a hardening of the sealant material so that it is no longer as resilient as desired.

Note that if snow plow blades are pulling out sealant that is either overbanded or extruded from a crack, this may signify a mechanical failure rather than a failure of the material or the placement procedure. Further investigation may be needed to identify whether there is underlying premature failure.

The presence of partial failure must also be considered. A partial failure occurs when only a portion of a sealed crack exhibits failure. While the determination of what percentage of partial failure constitutes overall failure of the sealant is arbitrary, a value of 25 percent is identified for this study.

End-of-Life Sealant Failure

Sealant materials, like the pavements they're placed in, age and eventually lose their effectiveness. The same failure criterion identified above is used to identify when a sealant has reached the end of its life: when it is no longer keeping moisture out of the pavement structure. Again, this can occur with the sealant missing or partially missing, or present but not effectively creating a barrier to water.

Table R lists some of the more common sealing problems that are associated with sealant failure, as well as underlying causes and recommended solutions. By recognizing these performance problems, material selection and placement processes can be refined over time to reduce or eliminate these problems from future projects.

Table R. Troubleshooting guidelines for HMA pavement crack sealing (after FHWA 2001).

	Problem	Typical Cause(s)	Typical Solution(s)
Construction Failures	Sealant not adhering to crack (adhesive failure)	▪ Crack not clean (including presence of deicer residue). ▪ Wet cracks. ▪ Sealant application temperature too low. ▪ Ambient temperature too low.	▪ Reclean crack. ▪ Allow crack to dry or use hot-air lance. ▪ Verify temperature gauges on melter; heat to correct temperature. ▪ Allow temperature to rise, or use hot-air lance.
	Sealant gelling in melter	▪ Overheated sealant. ▪ Sealant reheated too many times. ▪ Use of sealant with short pot life.	▪ Check melter temperature gauges. ▪ Use fresh sealant. ▪ Use sealant with longer pot life.
	Sealant pick-up when opened to traffic (tracking)	▪ Opened to traffic too soon. ▪ Crack not clean and/or dry. ▪ High ambient temperature. ▪ High sealant temperature. ▪ Excessive sealant application. ▪ Sealant too soft for climate. ▪ Absence of detackifier or blotter. ▪ Overheated or underheated sealant. ▪ Sealant contaminated with solvent or heat transfer oil from tank leak.	▪ Delay opening to traffic. ▪ Reclean or dry cracks. ▪ Seal in cooler temperatures. ▪ Apply sealant flush with or below pavement surface. ▪ Use stiffer sealant. ▪ Use an approved detackifier or blotter. ▪ Install at correct temperature; check temperature gauges on melter.
Premature and Performance Failures	Sealant hardening or cracking (cohesive failure)	▪ Sealant too stiff. ▪ Poor cleaning during installation. ▪ Sealant overheated during placement	▪ Use softer grade of sealant. ▪ Improve cleaning. ▪ Monitor melter temperature gauges
	Sealant losing bond to crack (adhesive failure)	▪ Crack faces not clean. ▪ Sealant too stiff. ▪ Pavement overheated by hot-air lance	▪ Improve cleaning. ▪ Select softer grade of sealant. ▪ Review use of hot-air lance to minimize burning pavement.
	Sealant removed by snow plows	▪ Sealant installed above pavement surface ▪ Bare pavement snow removal policy ▪ Loss of adhesion ▪ Carbide-edged plow blades ▪ Sealant installed during cooler temperatures	▪ Use a widened reservoir configuration. ▪ Apply sealant flush with surface or recessed. ▪ Use correct depth to width ratio. ▪ Apply sealant in moderate temperatures.
	Sealant-related bumps in HMA overlays	▪ Excessive sealant on surface. ▪ Overlay applied too soon after sealing. ▪ Adhesion of sealant to overlay.	▪ Use recessed or surface flushed sealant application. ▪ Seal at least one year prior to overlay. ▪ Apply detackifier or blotter to reduce sealant adhesion to overlay.