CRREL REPORT 92-18

State-of-the-Art Survey of Flexible Pavement Crack Sealing Procedures in the United States

Robert A. Eaton and Jane Ashcraft

September 1992

Abstract

A survey of all 50 United States was conducted in September of 1990 to determine the state of the art of crack sealing procedures on flexible asphalt concrete pavements. The results were tabulated and a summary report prepared. A meeting was held at the U.S. Army Cold Regions Research and Engineering Laboratory to discuss the draft report; the comments and suggestions received were incorporated into this report. At the meeting the group identified the need for a trade organization to develop uniform specifications and terminology and to promote proper equipment, methodology, materials, training and education in the pavement crack sealing industry.

Cover: Using a hot compressed air lance to prepare pavement crack for sealing.

For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380, *Metric Practice Guide*, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

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U.S. Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

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Robert A. Eaton and Jane Ashcraft

September 1992

Prepared for
ENGINEERING AND HOUSING SUPPORT AGENCY
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PREFACE

This report was prepared by Robert A. Eaton, Research Civil Engineer, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, and Jane Ashcraft, Consultant, Algonquin Resources Corporation, Lebanon, New Hampshire.

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The authors also thank all the attendees at the November 1990 meeting held to discuss the draft report for their input. In addition to the authors, attendees were:

D. Aker	ARTCO Equipment Sales
J. Davis	Davis & Swanson
A. Flynn	Koch Materials
C. Gardner	Northeast Pavement Maintenance
S. Gerard	Science and Technology Corporation
S. Gray	State of New Hampshire DOT
B. Hosley	Federal Highway Administration—Region 1
R. Joubert	Asphalt Institute
S. Ketcham	CRREL
J. LeBrun	State of New Hampshire DOT
T. Marlar	Video Consultant
S. McKinley	State of New Hampshire DOT
M. Nicholson	NICOM
J.L. Slatten	CRAFCO, Inc.

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INTRODUCTION

This report presents the results of a September 1990 national survey of crack sealing practices for flexible asphalt concrete pavements. It is a summary of the current methods and materials used by contractors and state departments of transportation and a comprehensive literature search. In this survey all 50 departments of transportation were contacted to ensure national coverage.

Few state departments of transportation are able to specify equipment, materials or procedures for the entire state. Most states are divided into districts, divisions or counties that are essentially autonomous. Each district is governed by its unique budget, geography, climate and past practices; therefore, differences exist within individual states. As with any survey, the responses are subjective judgments of the individuals contacted. Not all states do crack sealing, but all states indicated that cracks in their asphalt pavements were a problem. States with numerous freeze-thaw cycles cite crack sealing as a major procedure that must be addressed yearly.

When cracks appear in the asphalt there are four alternatives: 1) sealing the entire surface, 2) overlaying 3) doing nothing, or 4) sealing the cracks. To seal the entire surface or overlay is far more expensive than crack sealing. To do nothing will cause further deterioration of the road. Crack sealing is the logical alternative. Of the 40 states that use crack sealing as a maintenance procedure, over 70% reported extending the pavement life by at least three years. If the decision is to seal the cracks it must be done correctly. This report presents the current national practices and the authors' recommendations.

CRACK SEALING

Crack sealing is a maintenance procedure for either flexible asphalt concrete pavements, portland cement concrete (PCC) pavements, or PCC pavements with asphalt overlays. *This report will deal only with crack sealing of flexible asphalt pavements.* It is not intended to address maintenance procedures in either PCC pavements or asphalt with a rigid base.

Crack sealing is designed to extend the life of existing pavements by eliminating or reducing the entrance of water into the pavement structure through the upper surface. By stopping the entrance of water, the rate of deterioration of the road is significantly slowed. This allows the need for overlaying to be deferred for a substantial number of years and thus reduces maintenance costs. For most regions this is the bottom line: spend some time and money now, or spend much more later.

All 50 states were contacted in September 1990, and it was found that 45 of them sealed cracks. Kentucky, Hawaii and Florida seal the entire surface of the roads instead of crack sealing. Louisiana and Rhode Island neither crack seal nor surface seal their roads. A huge amount of time and money is spent to maintain the vast network of roads throughout the country and, for most states, crack sealing is one of the most efficient ways to prolong pavement life.

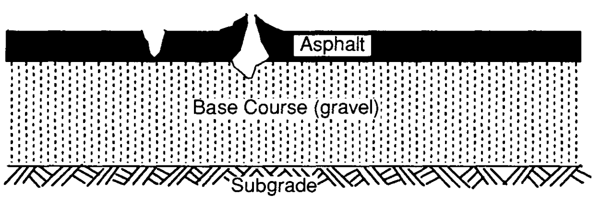
THE ECONOMICS OF CRACK SEALING

Ten percent of the asphalt roads in the United States have structures that will be unaffected by cracks because the base course and subgrade materials allow rapid water drainage. Ninety percent will have significant problems because the water will deteriorate the pavement, the base course and the subgrade material.

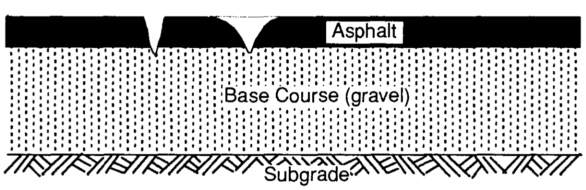
If the pavement is *not* sealed, water will enter the pavement, especially at cracks that are over 1/8 to 1/4 in. wide. Hairline cracks and cracks up to 1/4 in. wide admit water through the pumping action of traffic. Water lying on the roadway is pushed down into the cracks when vehicles pass over the cracks.

Cracks over 1/4 in. wide are open sufficiently to allow water to flow easily by gravity into the pavement surface and then into the base course. Once water enters, it quickly deteriorates the pavement where it causes extensive and expensive damage. The pavement will cup or lip, which will allow even more water to enter. Cupping is a formation where the sides of the crack angle down and in and produce a reservoir that holds water. With lipping, the sides of the crack angle upward and are easily broken by traffic (see Fig. 1).

Not all deterioration will be visible. According to a study by Ontario's Ministry of Transportation, on heavy traffic highways, half or more of the original asphalt layers may disintegrate from the bottom up (Chong and Phang 1987). The combination of water and heavy traffic accelerates the deterioration because the traffic forces more water into the cracks than would occur naturally. The continuous pumping action eats away the underside



a. Lipping.



b. Cupping.

Figure 1. Lipping and cupping caused by water entering pavement surface.

of the asphalt and support for the upper layer of pavement is eliminated.

In areas with extensive freeze-thaw cycles, the pavement and subbase will deteriorate much more rapidly than in more moderate climates due to thermal expansion and contraction. Continuous movement of the cracks is produced with freeze-thaw cycles and this movement accelerates the deterioration.

Products used to melt the ice and snow in the winter also contribute to the problem. The brine solution, created when snow combines with salt, accentuates the freeze-thaw problem by slightly melting the base course. This produces even more thermal movement within the crack, and the structure, weakened by a saturated base, will experience localized failures when subjected to traffic.

All cracked pavements will experience disintegration or spalling. These problems are accentuated in roadways where there is either high volume or heavily loaded traffic. Once a roadway starts to disintegrate, potholes quickly develop. During freezing, a frost-susceptible base course can be pushed upward by the expansion of the water in the base. When the base course thaws, it is saturated and has reduced load-carrying capacity. As traffic passes over this saturated material, the pavement repeatedly flexes and cracks and creates a pothole.

To avoid the above situation, the following choices are available: 1) seal the entire surface or a portion of it with an overlay, slurry seal (asphalt mixed with sand) or chip seal (asphalt sprayed on road surface with crushed stone placed on top), or 2) fill and seal only the cracks. Using the data supplied by the states, a surface seal will cost between 3 and 14 times as much as sealing the cracks. An overlay will cost 8 to 26 times as much as crack sealing. Although surface sealing or overlaying improves the road's appearance, the problems have been solved only temporarily because the cracks will reappear within a 1- to 2-year span. If the cracks have not been sealed before the surface seal or overlay is applied, the water will enter the new surface and continue through the older surface to the base course.

On the other hand, if the cracks are properly sealed, the states indicated an average gain of three years of extra service. One state reported as much as eight years of extra life. By eliminating the entrance of water one also eliminates the disintegration of the subsurface materials. The surveys indicated that crack sealing slowed the reappearance of reflective cracks in the new surface. Reflective cracks are caused by problems within the base course and cannot be eliminated without addressing the initial cause of the problem. However, they still must be sealed to prevent further damage to the base course.

While not all states were able to quote a cost per linear foot, samples are included here to give a rough estimate of the costs. These are figures for work done by local maintenance crews. Contractors' work is governed by the lowest bid for a proposed job.

The following figures provided by the states are based on price per gallon or pound, which was provided by the states. The price per gal. or lb was converted to a cost *per linear foot* based on a crack 1/2 in. wide and 1/2 in. deep.

State	*Cost per linear foot*	*Comments*
New York	$0.20	ASTM 03405 or D1190 Includes labor
Nevada	$0.50	ASTM 03405 Includes labor and equipment
New Mexico	$0.30	ASTM D 3405 Includes labor
Pennsylvania	$0.30	AC 20 (with fiber or powdered vulcanized rubber) Includes labor and equipment
Colorado	$0.30	Light grade asphalt Includes labor and equipment
Georgia	$0.31	AC 10 or 20 with crumb rubber Includes labor and equipment
South Dakota	$0.18	AC with 20% ground rubber Includes labor and equipment
Idaho	$0.35	Rubberized asphalt Includes labor and equipment
Maryland	$0.60	ASTM D3405 Includes labor

The following costs *per linear foot* were provided by the states.

Nebraska	$0.30–0.35	Asphalt emulsion with 22% rubber Includes labor and equipment
Texas	$0.157	ASTM D3405 Includes labor.
California	$0.48	ASTM D3405 Includes labor
Minnesota	$0.40–0.60	ASTM D3405 Includes labor, depending on traffic control

The New York State Department of Transportation (Hahn and Kirkpatrick 1983) has been able to decrease the amount of sealant they purchase within the last five years because of the effectiveness of their crack sealing program. Only 13 states were able to provide any costs. A pavement management program with accurate documentation would enable all states, districts or divisions to make accurate cost assessments of their maintenance programs.

CHIP SEAL, SLURRY SEAL AND OVERLAY COSTS

Costs to provided by the states chip seal, slurry seal, or overlay are based on 1 mile of 24-ft-wide road with 5,000 linear ft of 1/2-in.-wide by 1/2-in.-deep cracks per mile and are shown in the following table:

State	*Cost per mile*	*Comments*
Colorado	$5,100. $17,000.	Seal coat with sand Overlay (includes equipment, labor and materials)
Nevada	$8,600.	Chip seal (includes equipment, labor and materials) All overlay work is contracted out
South Dakota	$2600. $6,700.	Chip seal Overlay (includes equipment, labor, and materials)
New Mexico	$8,000. $14,000. $20,000.	Chip seal (maintenance crews) Chip seal (contractors) Overlay (contractors) Includes equipment, labor and materials
Pennsylvania	$7,000. $24,000. $40,000.	Oil and chip seal Slurry seal Overlay (done by contractors) Includes equipment, labor and materials
Georgia	$20,838. $10,278. $8,997. $31,690.	3 layer chip seal (asphalt layers alternated with progressively finer stone layers) 2 layer chip seal Slurry seal Overlay (includes equipment, labor and materials)

These costs reflect a ratio range of a low of 3 to 1 to a high of 26.7 to 1 when comparing slurry seal, chip seal or overlay costs to crack sealing costs for the same state.

In order to get the maximum life from either a new pavement or a newly overlaid pavement, one must check the pavement for cracks within 1 to 3 years. Particular attention should be paid to utility cuts, catch basins, manhole covers and other fixed structures within the pavement. Because of differences from the materials used in the original construction, these are points of weakness where cracks will first appear. It is not economical to do only crack sealing if the pavement is seriously deteriorated. At this stage the cracks should be properly sealed or filled and then overlaid at a later date. Proper methods of sealing cracks before placement of an overlay will be discussed later in the report.

TYPES OF CRACKS

The November 1990 meeting reviewed crack types and definitions identified by the Federal Highway Administration (FHWA), Canadians and others. Due to conflicting definitions and the large number of types identified, it was agreed that there were only five basic crack types: transverse, longitudinal, block, reflective and alligator.

The following definitions were established at the meeting:

1. *Transverse cracks* cross the pavement either from shoulder to shoulder or from shoulder to center line. They are usually temperature related and are typically the first cracks to appear. They are caused by the inability of the asphalt layer to redistribute the stresses that occur along the pavements' width and length as the temperature decreases. As the pavement becomes older and stiffer, it loses even more ability to adjust. The cracks then develop at closer and closer spacing.
2. *Longitudinal cracks* run the length of the pavement roughly parallel to the center line. Like the transverse crack, they also occur because of the pavement's inability to redistribute stress and become worse as the road ages. They usually appear later than transverse cracks.
3. *Block cracks* are those that appear to be in a block or square pattern and are usually spaced between 4 and 12 ft. This is a fatigue crack or a crack that appears because of traffic load and volume, or due to failures in either the base or subgrade materials. This type of crack usually appears as the road reaches the end of its life. It can, however, occur earlier if the base course is not thick enough, is improperly compacted or lacks proper drainage.
4. *Reflective cracks* are those of any configuration that appear when the surface material cannot adjust or change with the movements in the subsurface materials. To eliminate this type of crack, you need to address the source of problems in the subsurface materials.
5. *Alligator* or *map cracking* (Fig. 2) is an overall cracking pattern that resembles alligator skin or a road map. The cracks are extensive, close together and go in all directions. This indicates

Figure 2. Alligator (or map) cracking.

a seriously deteriorated road. The life of a road in this condition cannot be saved by crack sealing.

*Crack sealing can and should be applied to transverse, longitudinal, block and reflective cracks. It **cannot** save a pavement with alligator cracking.* A surface with alligator cracking has failed and needs to be reconstructed. Until permanent repairs can be made, it can be covered with a geotextile fabric and then overlaid. The fabric will provide a water barrier and possible additional load bearing capacity. Fabrics can be laid in strips that cover only a portion of the road or large sheets across the entire roadway.

Reflective cracking will reappear in later overlays, but sealing these cracks will extend the pavement life significantly by keeping water out. Maintenance personnel can then defer the extremely expensive job of totally rebuilding a road for at least three to five years.

CRACK SEALING PROCEDURES

There are several crack sealing alternatives and each individual state or municipality must decide which is the most cost effective and efficient method for their specific situation.

Local contractors can handle the entire process from cleaning to sealing. If one advocates routing, the type and size of crack to be routed must be specified along with the routing profile to be used. The contract should also delineate the method of crack cleaning and the equipment to be used. It is important to specify the sealant either by brand or an ASTM, AASHTO or Federal specification. A decision to overband or fill must be made and application procedures compatible with that decision must be delineated. Then put it out for bids. A number of public works agencies use this method and find it efficient and effective.

Local maintenance crews can perform the same tasks. However, training and education are necessary if they are unaccustomed to either the procedures, equipment or materials. Newer sealants require accurate melting temperatures and can be incompatible or dangerous when heated in older equipment. It may be necessary to purchase new kettles to obtain the accuracy necessary for proper application. Crew safety is a major concern. Routers, air lances and the hot compressed air lance (HCL) are all inherently dangerous pieces of equipment that can cause serious injuries if used incorrectly or without proper protection. The most important component is the ability and willingness of the crew to use the equipment properly and adhere to the manufacturer's recommendations. An uncomfortable or unwilling crew will not perform the job properly and poor results will be obtained. Manufacturers are very willing to demonstrate their equipment and materials and can provide instruction manuals.

No matter which method is used, it is strongly advised that either material tests be performed or your state department of transportation be contacted for its advice before committing to equipment, a single product or specification. Included in this report are maps of the United States showing design freezing indices (Fig. 3), state routing practices (Fig. 4)

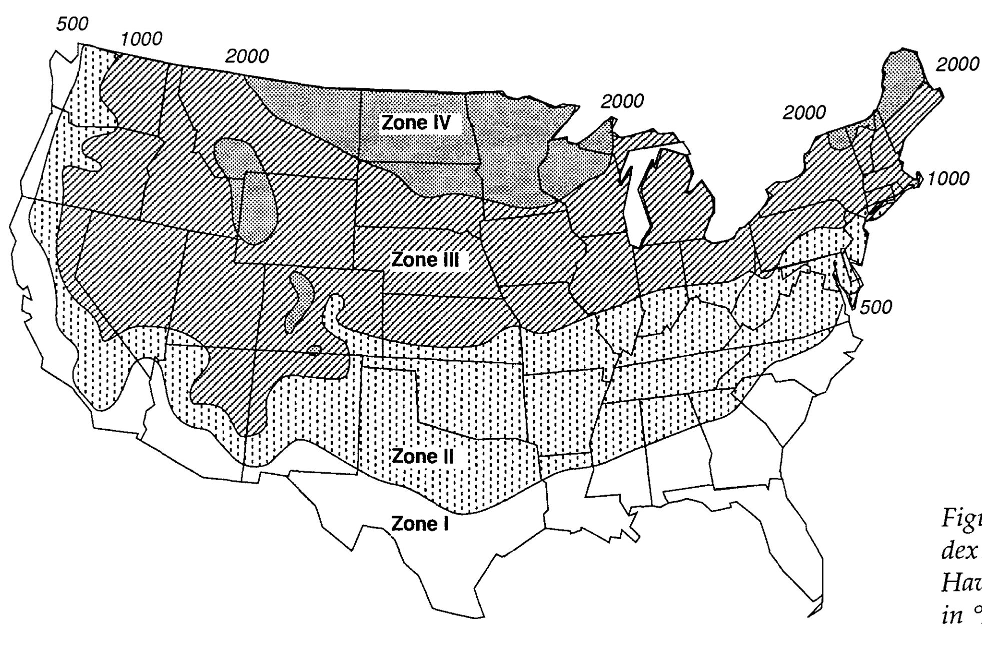


Figure 3. Design freezing index zones (Alaska—Zone IV, Hawaii—Zone I). Units are in °F-days.

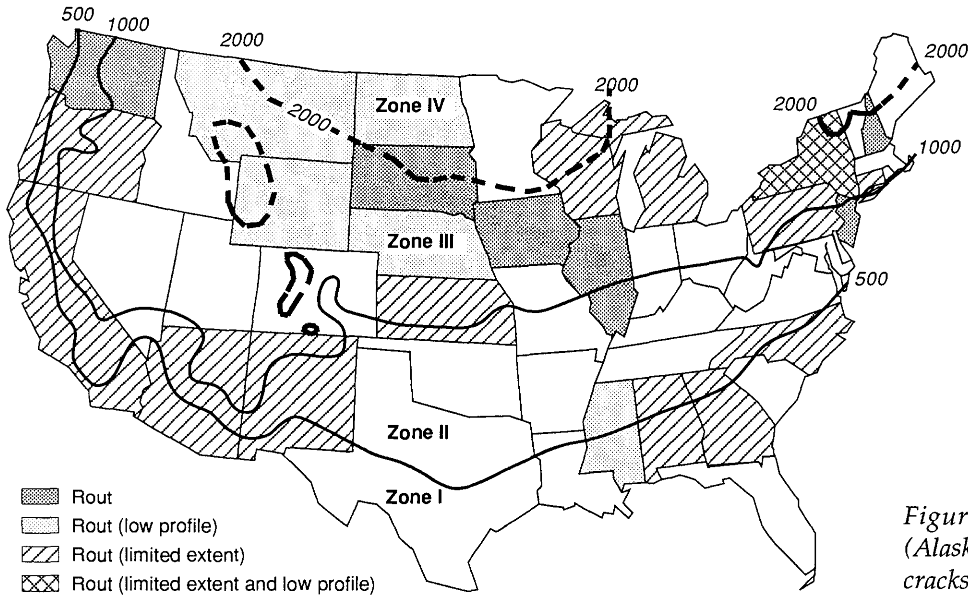


Figure 4. Routing practices (Alaska and Hawaii do not rout cracks). Units are in °F-days.

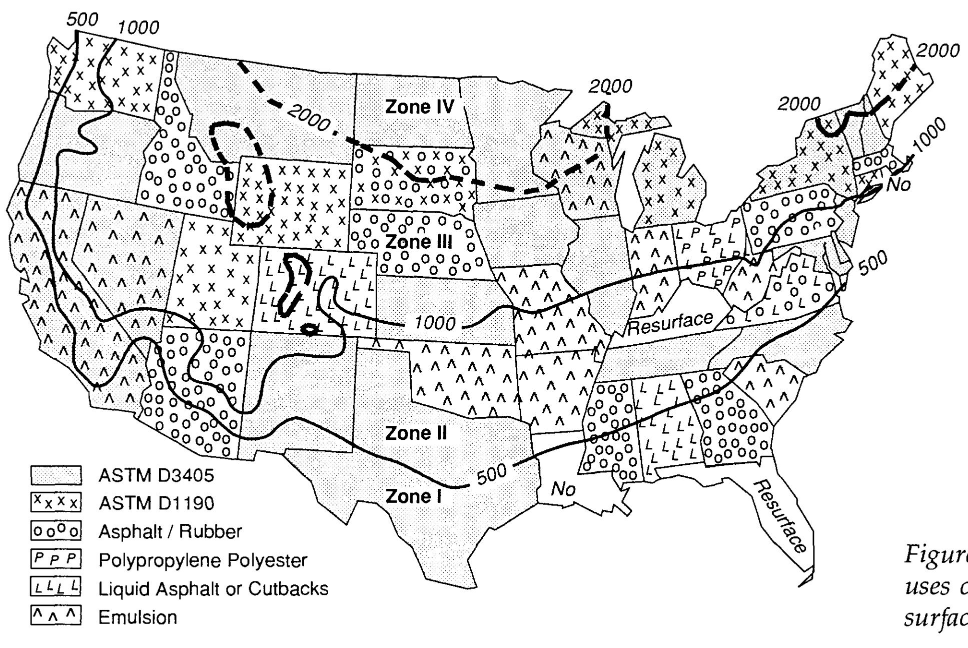


Figure 5. Sealant usage (Alaska uses cutbacks; Hawaii only resurfaces). Units are in °F-days.

and sealant usage (Fig. 5), as well as a table with specifications of types of equipment, materials, and methods of application for crack sealing (Table A1). Figure 6 shows the states that have experienced difficulty with crack sealants. Most lie along the 1,000°F-day freezing index line, which denotes a region with a very high number of freeze-thaw cycles.

Maintenance personnel within a particular state may differ as to preferences. Few states mandate a certain product or procedure for the entire state. Most districts are guided by past practices and the good experiences by their crews having used the procedures. There is also continuing research in this area, and new, or improved products continue to become available.

There are five critical factors affecting a successful crack sealing program: 1) crack preparation, 2) crack cleaning, 3) selection of sealant, 4) application of sealant, and 5) ambient temperature. The following sections describe each factor.

Figure 6. States experiencing problems with sealants. Units are in °F-days.

CRACK PREPARATION

It is essential that the crack be clean, dry and free of all materials before you attempt to either fill or seal the cracks.

The three predominant choices of the 50 states interviewed for this report will be described with their relative advantages and disadvantages.

Routing

This method consists of mechanically cutting the pavement along the crack lines (Fig. 7). The primary purposes of routing are 1) to provide a reservoir for the sealant in smaller cracks and 2) to provide an intact side wall for sealant adhesion in badly deteriorated cracks. The two most common types of routing machines are the spindle and star wheel routers. The spindle resembles a wood routing machine with the cutters revolving around a vertical shaft. A star wheel router uses different configurations of cutters arranged around a wheel with each blade free to rotate as it strikes the pavement. Star wheel routers may be offset to control the width of the cut. A rout can be done either on a 1 × 1 profile, cutting as wide as deep,

Figure 7. Routing a pavement crack prior to sealing.

or a 2 × 1 or 4 × 1 profile, cutting 2 or 4 times as wide as deep (also known as low profile routing). Routing profiles of 2 × 1 or 4 × 1 can follow meandering cracks better and are far easier on cutting blades. However, routing of any configuration is detrimental to pavements above six years old or less than 2 in. thick. It can cause surrounding pavement to crack even more. It is extremely labor intensive and, therefore, expensive. Because it is a slow procedure it exposes crews to dangerous traffic conditions for a longer period of time than either the HCL or compressed air. There is considerable debate over whether the benefits of routing outweigh the disadvantages.

Twenty-six states are either now using this method or have tried it in the past (see Fig. 4). However, of those 26, 15 use it only on certain cracks, to a limited extent, by contract only, or are no longer routing. For specifics please refer to the Table A1.

Advantages

1. Routing opens small cracks and allows for greater penetration of the sealant.
2. It produces uniform edges on the cracks and, some feel, better adhesion of the sealant.
3. It allows the cracks to be filled with sealant to roadway level or just below and, therefore, keeps it below traffic and snowplow level.

Disadvantages

1. It is extremely labor intensive and, therefore, very expensive.
2. It is difficult to follow meandering cracks with a machine and some portions of the crack may be missed.
3. In older pavements, greater than six to seven years old, it may destroy the adjoining asphalt and, therefore, do more damage than good since it will create numerous small cracks radiating from the original crack.
4. Because routing is a slow process, maintenance crews are exposed to the dangerous situation of working on heavily traveled roads for a much longer period.
5. Routing equipment is heavy and difficult to control and maintenance personnel must be relieved frequently.
6. This is step one of a two-step process. All routed cracks must be blown clean with compressed air before they can be sealed or filled.

Routing summary

Although the disadvantages appear to outweigh the advantages, a number of states strongly favor routing as being the best way to address smaller cracks and cracks in new pavements. Some states use it only in these instances. One state has its crews routing at night in heavy traffic areas so that the problem of exposing the crews to a dangerous situation is minimized. Several states rout and then come back at a later date to clean and seal the cracks. Most states that rout contract out the complete job because they find it cost efficient.

The Ontario Ministry of Transportation, which has done extensive studies of routing techniques (Chong and Phang 1987, Chong 1989), advocates a 4 × 1 rout because it induces far less strain on the sealant, allows greater bonding, enables the router to follow sharp directional changes better, and produces less stress on the equipment and bits.

Compressed air

The compressed air crack cleaning method (Fig. 8) consists of using just high pressure compressed air to blow out foreign materials from the crack and, to a limited extent, dry the crack. It is imperative that proper line filters be used to remove water and oil from the pressurized air. Otherwise, these contami-

Figure 8. Crack cleaning with compressed air.

nants will prevent the sealant from adhering to the pavement. A small backpack blower carried by a crew member does not generate the pressure required to remove larger pieces of material. Therefore, a standard air compressor should be used.

Thirty-six states reported using compressed air. Some use it alone while others use it in conjunction with other methods.

Advantages

1. It is fast and, therefore, cost-efficient.
2. Crews are exposed to the dangers of heavy traffic for a shorter amount of time than with routing
3. Most foreign matter and pieces of asphalt can be removed by this method.
4. The crack cleaning operation can immediately precede the sealing operation.
5. It can be used to easily follow a meandering crack.

Disadvantages

1. It does not widen small cracks to allow for greater sealant penetration.
2. It does not thoroughly dry cracks that have water or ice in them.
3. On small cracks air alone will not remove vegetation.

Compressed air summary

Almost all states that report doing crack sealing or filling use compressed air alone or in conjunction with routing. To have a good seal it is absolutely essential to remove foreign material, dust and water from the cracks; in-line filters must be used to prevent equipment contamination from entering the crack. Cleaning with compressed air is the minimum that can be performed. However, it is questionable that this alone is enough, especially in smaller cracks or in less than optimum weather conditions.

Hot compressed air lance

The hot compressed air lance (Fig. 9) is a propane-fired wand that combines compressed air to blow out the crack with heat to burn out vegetation and to dry the crack and surrounding pavement. A crewman using the HCL can be placed in front of the truck which dispenses the sealant and, thus, ensure a clean and dry crack. It is a relatively new method (introduced in the United States in 1982) and has already been improved. Nineteen states are now either using it exclusively, are experimenting with it, or are using it on a limited basis. It is preferable to using just compressed air because it can dry or warm the crack during less than optimum operating times.

Advantages

1. The HCL is fast and, therefore, cost efficient.
2. Crews are exposed to the dangers of heavy traffic for a shorter amount of time than with routing.
3. The hot lance dries the crack and allows for a better seal.

Figure 9. Hot compressed air lance.

4. The heat slightly melts the old asphalt in the crack and allows for better adhesion.
5. It removes oxidized materials.
6. It burns and kills vegetation or seeds that are growing or germinating in cracks.
7. A hot lance can be used to easily follow a meandering crack.
8. It does not weaken old pavements as routing does.

Disadvantages

1. It is a more dangerous piece of equipment than the router or compressed air wand because high heat (up to 2200°F) is generated.
2. If used improperly, the HCL can burn the existing asphalt and weaken it.
3. Because the HCL is a new piece of equipment, it lacks the extensive field experience of the other two methods.
4. It does not widen smaller cracks to allow greater penetration of the sealant.

HCL summary

Several state DOTs are now using the HCL method exclusively and feel that it is extremely effective. Others tried early models and felt that they burned the asphalt and were too dangerous. Several states report that they require only their contractors to use the hot lance. Others report that they are leaving it to the discretion of their contractors or maintenance crews as to whether they use the hot lance or just compressed air. Of the states not using it, some cite the expense of buying new equipment (approximately $2,500 plus two propane tanks for each wand) or their impression that moisture is not a problem. These feel that simply working on dry days is sufficient. However, if a standard air compressor is already available, the cost for propane is approximately 1/2 cent per foot and one tank will do 8,000–9,000 feet of cracks. All who use the hot lance feel that on older roads (above 6–7 years) it does not weaken existing pavements as routing does.

CRACK SEALANTS

The type of sealant you choose is extremely important. *No matter how expensive your sealant is, it is the least expensive part of the job.* Your labor and equipment costs are the far bigger items in your formula. To skimp on the sealant would be penny wise and pound foolish; it will cost you more in the long run. A cheap sealant that does not last or is not effective will cost more than an expensive one that will do the job for a longer period. If you have to put the crews back on the job next year or even next spring to reseal the same cracks, or if you have water entering through failed seals, your ultimate cost will be much greater.

Of the 45 states that did crack sealing (Fig. 5), all but six reported using some sort of rubberized product. Of the six states that use only asphalt emulsions, the five reporting good results were all southern states where freeze-thaw cycles are not considered a major problem. The states specified the type of product they wanted by using either the ASTM or AASHTO or Federal specifications. Most reported that their sealant must meet ASTM D3405, D3405 modified to individual requirements, or D1190 specifications. ASTM D3405 is equivalent to AASHTO M301 or Federal specification SS-S-1401 C. ASTM D1190 is equivalent to AASHTO M173 or Federal specification SS-S-164. States reporting that they used crumb rubber in an asphalt emulsion reported good results if the rubber was 22% by weight (± 1–2%) in the emulsion.

Using prepackaged sealant eliminates mistakes in mixing and assures a uniform product. It also ensures a more efficient operation if crews are not waiting for asphalt delivery. Most new products are prepackaged.

Some states have experimented with using different products based on differences of geography and climate within their state. Not all products are suitable for every climate. States with extensive freeze-thaw cycles need sealants with more ductility, whereas warmer areas need sealants with less flow in hot weather.

All states reported some failures of the sealants they used. Most felt that failures were caused by improper cleaning of the joint before sealing. With *all* the products, it is extremely important that the cracks be clean and dry before applying sealant.

The only other significant factor causing failure was overheating the sealant or reheating it too often. The newer products are heat sensitive and under heating or over heating will destroy their effectiveness. Simply adhering to the manufacturers' instructions should ensure good results.

The sealant specifications noted above are suitable only for roadways and are *not recommended* for application in areas where pedestrians, slow moving traffic, or parked cars are a factor. In those instances you need a sealant that is stiffer (has a lower viscosity) and, therefore, will not be picked up by either tires or shoes. Use a sealant that meets ASTM 1401 or 1401C (most recent update) specifications, and stay away from sealants with fibers since they are picked up by slow moving or parked cars.

Additionally, none of the products listed are jet fuel resistant and, therefore, *should not* be used on runways. Jet fuel resistant sealants *can only be used on PCC*. To make asphalt runways jet fuel resistant, use a regular ASTM D3405 sealant and then seal coat with a coal tar emulsion.

The required properties for acceptable performance of sealant material ASTM D3405 are explained in Chehovits and Manning (1984), which states that these general requirements may be separated into nine specific characteristics that are important in roadway sealants:

1. Ability to be easily and properly placed in a crack through application equipment.
2. Adequate adhesion to remain bonded to the asphalt concrete crack faces.
3. Adequate resistance to softening and flow at high in-service pavement temperatures so that the sealant will not flow from the crack and therefore prevent tracking.
4. Adequate flexibility and extensibility to remain bonded to crack faces when extended at low in-service temperatures.
5. Sufficient elasticity to restrict the entrance of noncompressible materials into the crack.
6. Sufficient pot life at application temperatures for application of the total amount of prepared material.
7. Resistance to degradation from weather to ensure long in-service life of the sealant.
8. Compatibility with asphalt concrete.
9. Low cure time to permit opening to traffic as soon as possible after application (Belangie and Anderson 1981).

Sealant selection summary

Based on comparisons of the design freezing index map (Fig. 3), the sealants currently used and the sealant ratings, as reported by the individual state, the following recommendations can be made:

1. States in *Zone 1*, below 500°F-days will have good results using emulsions, asphalt with rubber, or ASTM D3405 or their equivalent.
2. States in *Zones II and III*, between 500°- days and 2000°F days, will have good results using ASTM D3405, ASTM D1190, or asphalt with rubber (22% ± 2%) or their equivalent.
3. States in *Zone IV*, above 2,000°F-days. will have good results using ASTM D3405 or ASTM D1190 or their equivalent.

Application of sealant

The methods of application of the sealant varied greatly from state to state and even within a single state (Table A1). Perhaps deciding which method is best for you was summed up by one engineer who felt strongly that no matter how good your product was, how state-of-the-art your equipment was, if your crews were not comfortable using it, they would do a poor job.

For safety reasons, if you are using the newer sealants that require high heat, the kettles being used should be double jacketed and oil fired. The heat level required to melt the sealant makes it inherently dangerous. They should also have accurate temperature gauges so that you do not destroy the sealant's effectiveness through improper heating.

It is extremely important that the sealant be applied as soon after crack cleaning as possible. Therefore, the wand (Fig. 10) or pour pot (Fig. 11) should follow the cleaning operation by no more than about 25 ft. If you must seal in weather below 40°F (not recommended), insulate the hose so that the sealant does not cool before installation.

There is also considerable debate about whether to overband the sealant (apply sealant on the pavement surface on each side of the crack), or simply fill the crack to just below surface level. Ontario's Ministry of Transport has done testing of both methods and advocates overfilling to just cover both edges of the crack and allow for shrinkage during cooling (Chong 1990). This prevents the sealant from being sheared off by snow plows, and abraded by traffic. However, they rout all their cracks, and this method may not be advantageous if you simply blow out or hot lance the cracks. Perhaps the best answer is to place sufficient sealant to fill the cracks and squeegee the excess so that the sealant is not forming a ridge that would interfere with plows or cause rough pavements. Keep the overbanding to a minimum since it is simply a waste of sealant and causes problems if it is too extensive. A thin 1- to 1-1/2-in. overband on each side of the crack (Fig. 12) is plenty.

Do not overband in parking lots, on city streets where cars park, or on sidewalks. The heat generated by car tires or the summer sun will melt the sealant and either pedestrians' shoes or car tires will pick it up.

The survey also indicated that only one state used backer rods in normal crack sealing operations. These are preformed, flexible rods inserted into the crack to keep the sealant from penetrating deeper. While they can cut down the amount of

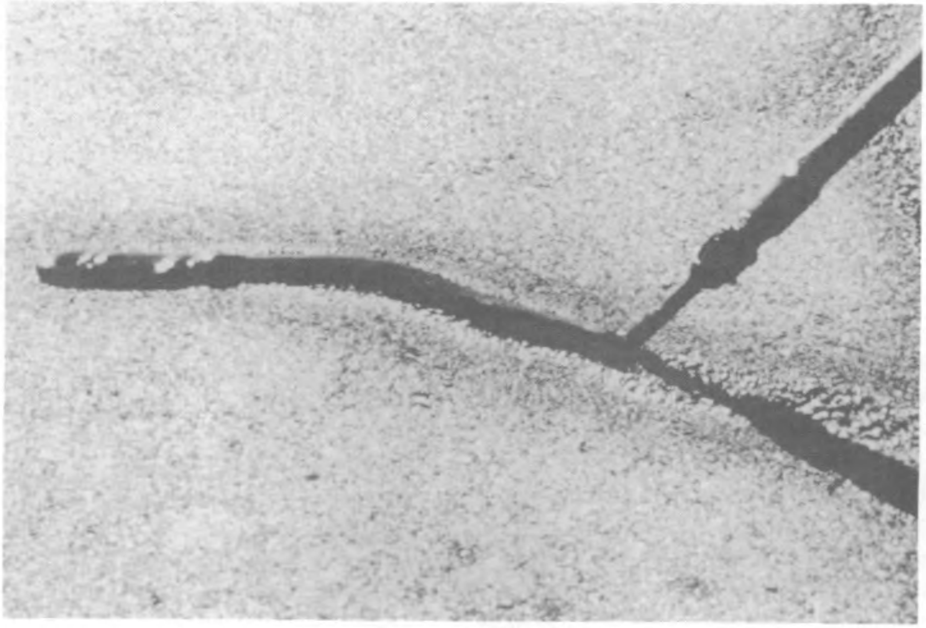


Figure 10. Wand for sealant application.

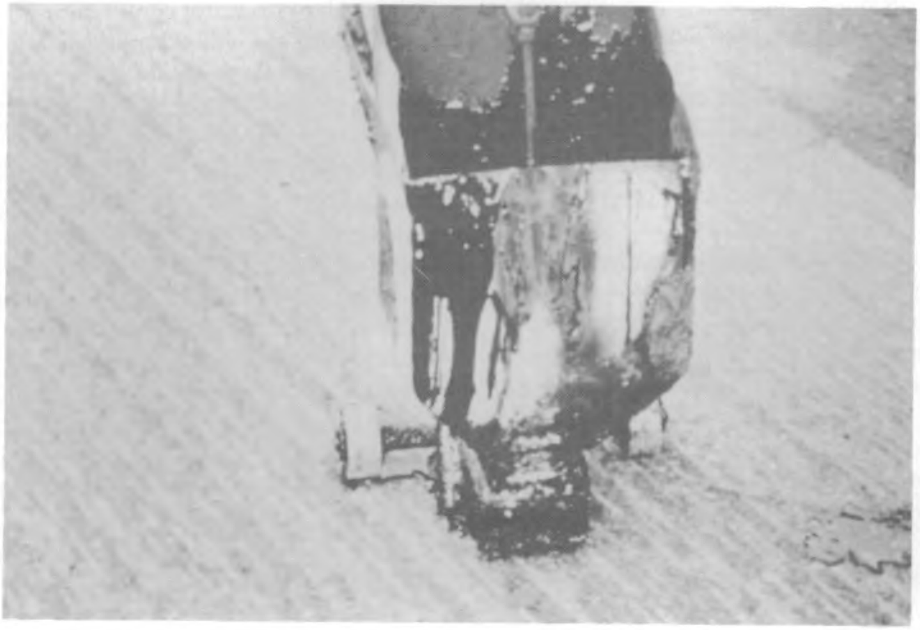


Figure 11. Pour pot with sealant.

sealant needed to fill a large crack, they are expensive and labor intensive to install. Most states reported using an asphalt patch in large cracks (over 3/4 in. or 1 in. wide). Several states also found during experimentation with backer rods that they tore easily or were melted by hot sealant. One state found cheap nonplastic rope an inexpensive alternative. Cracks greater than 2 in. should be filled with a proper asphalt concrete material and then sealed.

In summary, use the best sealant available for your area or job, apply it only to clean, dry cracks, keep the heat within the temperature range recommended by the manufacturer, and do not overfill or overband the crack excessively.

Figure 12. Sealed cracks with overbands.

Ambient temperature requirements

There are three variables to be considered here.

1. When cracks are at their greatest width.
2. Time of year when crews are available.
3. Most effective temperature range for sealant application.

While the first two are important factors, the third is the determining one. If time and money are spent to seal cracks, do it at the best time. Do not waste the material, the manpower, and the equipment if there will be a high failure rate due to the temperature at which the sealant was applied.

Cracks are open widest in the winter. The low temperatures allow pavements to contract to their greatest degree. This is also the time when highway crews are often most available. However, this is not necessarily the best time to seal in colder climates. Moisture or ice will be in the cracks, and the temperature is often below that recommended by the manufacturer. Late fall and early spring will give the best results. The cracks will have opened due to cooler temperatures, the crews will not have the summer overload of work to contend with, and the temperature will be within the range specified by the manufacturer. A safe rule of thumb is to seal when the temperature is between 40° and 70°F. During colder months or if winter sealing is imperative, the cracks must be dry and warm.

Sealing before an overlay

Many states have experienced problems with the sealant ridging or bleeding through the overlay if the sealant was applied too heavily and/or immediately before overlaying.

Seal the cracks at least three months, but preferably, one year before a road or section of road is overlaid. Deferring an overlay allows the sealant time to adjust to pavement stresses. Do not overfill the cracks; fill to about 1/8 in. below surface level, and apply an overlay that is at least 3/4 in. thick. Using this method will prevent water from entering the pavement and deteriorating the pavement and subsurface materials the year before overlaying. It will also extend the life of the new overlay.

CONCLUSIONS AND SUGGESTED CRACK SEALING PROCEDURES

Based on personal discussions with state department of transportation personnel, and the meeting at CRREL, we recommend the following crack sealing procedures for the most cost-effective performance.

General

1. Check pavements one year after placement of a new pavement or overlay for cracks.

2. Seal only transverse, longitudinal, block or reflective cracks. *Do not seal alligator cracked areas. These indicate base failure.*
3. Allow one year before overlaying.

Crack preparation

1. We recommend the hot compressed air lance (HCL) for crack preparation on all pavements. The HCL *should* be used on all cracks and all pavements greater than six years old to prevent fracturing.
2. Clean and dry all cracks with the HCL immediately before sealing.
3. If routing:
   a. Rout pavements less than six years old.
   b. On cracks less than 1/2 in. wide use a 4 × 1 profile to a maximum routed width of 2 in. .
   c. On cracks greater than 1/2 in. wide rout only if crack wall is deteriorated to a point that it must be cut back to provide undamaged asphalt for sealant adhesion.

Sealant

1. Use the best sealants specified for your area (see Table A1).

Sealant application

1. Apply the sealant within the recommended temperature range of 40° to 70°F.
2. Only overband cracks 1/4 in. or less wide.

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APPENDIX A: SUMMARY OF STATE QUESTIONNAIRES

The individual state survey questionnaires may be found in CRREL Internal Report 1104 dated March 1992, by Robert A. Eaton.

Table A1. Summary of September 1990 state crack sealing practices survey.

State	*Zone*	*Crack size*	*Rout*	*Cleaning method*	*Sealant*	*Method*	*Performance (yrs effective)*
AL	I,II	See it Seal it	Generally no	Compressed air	Liquid asphalt with sand cover	Pour pot	Very good to good (3–5)
AK	IV	>1/4"	No	Compressed air	RC 800 MC 250	Pour pot	Very good to poor (1)
AZ	I,II, III	See it Seal it	Very limited	Compressed air	Rub. asph. (20%)	Fill, no overband	Good to fair (3)
AR	II	1/8" up	No	Compressed air	CRS 2 Emulsion or AC	Fill	Good to excellent (5+)
CA	I,II, III	1/4" up	Contract only	Compressed air HCL	ASTM D3405 CRS 2 W/Latex CRS 2 W/Reclamite	Fill	D3405—Very good (3+) CRS 2 W/L—Good (3) CRS 2 W/R—Good to (3+) Fair
CO	II,III IV	>1/4"	Possible	Do not clean use emulsified oil	Light grade asphalt	Fill	Good to poor (<3)
CT	II,III	1/4" up	Contract	HCL	AASHTO M173	Overband	Good to fair (3–5)
DE	II	1/8"–1"	No	Compressed air	Rub. asph. (18%)	Overband	Excellent to good (3)
FL	I				Resurfaces		
GA	I,II	1/8"–1"	Very little	Compressed air	AC 10; AC 20	Overband	Very good to good (2)
HI	I				Resurfaces		
ID	III, IV	>1/4"	Tried	Compressed air tried HCL	Rub. asph. (22%)	Fill	Very good to good*
IL	II,III	1/8" up	Yes 1X1	Compressed air Wire brush	ASTM D 3405	Overband	Excellent to good (6–8)
IN	II,III	1/8" up	No	Compressed air	Emulsion	Bucket	Very poor (<1 [30 days])
IA	III	See it Seal it	Yes 1X1	HCL (started)	CRS 2 poly latex mod. on older ASTM D 3405	Overband	Very good to pretty good (2–5)
KS	II,III	1/8" up	Depends on width of crack	Compressed air HCL experimenting	Switching to ASTM D 3405	Overband	— (3–5)
KY	II				Resurfaces		
LA	I,II				Does not seal cracks		
ME	III,IV	1/8"–3/4"	No	No cleaning	SS-S-164	Fill	No rating
MD	II	1/8 to 1-3/4"	No HCL	HCL	ASTM D 3405		Very good to good (3+)

* Do with overlay

Table A1 (cont'd). Summary of September 1990 state crack sealing practices survey.

State	*Zone*	*Crack size*	*Rout*	*Cleaning method*	*Sealant*	*Method*	*Performance (yrs effective)*
MA	III	1/4–1"	No	Compressed air	Rub. asph. Asph. w/polyester	Overband	Very good (4–5)**
MI	III,IV	Hairline up	Yes Reflective cracks	Compressed air on older pavements and HCL	ASTM D 1190 ASTM D 3405 AC 20 + Fiber	Overband older; fill	Satisfactory (8) (8) (2–4)
MN	IV	Age determined	Yes	Compressed air HCL	ASTM D 3405	Slight overband	Good to excellent (6)
MS	I,II	1/4–1"	Yes 4X1	Compressed air	Rub. asph. emulsions	Overband	Very good (3–5†)
MO	II,III	1/8" up	No	Will use HCL	Hot emulsion	Overband	Poor to good (1)
MT	III,IV	See it Seal it	Yes 4X1	Compressed air HCL	ASTM D 3405	Overband	Very good to fair (2–3)
NE	III	1/4–1"	<1/4" 2X1	Compressed air trying HCL	Rub. asph. (22%)	Fill	Good (6+)
NV	II,III	1/8-3/4"	No	Compressed air	ASTM D 3405	Overband	ASTM D3405—Good to fair (3–5)
NH	III,IV	1/4" up	Yes	Compressed air HCL	ASTM D 3405	Pour pots	Excellent to good (2)
NJ	II,III	See it Seal it	Yes	Compressed air	AASHTO M301 ASTM D 3405	Fill	M301 Good to fair (2–3) D3405 Very good to fair (2–3)
NM	I,II, III	See it Seal it	<1/2"	Compressed air on >1/2"	ASTM D 3405 ASTM D 3406	Fill if rout; Overband	Good (2–3)
NY	III,IV	See it Seal it	Minor extent low profile	Compressed air HCL	ASTM D 3405 ASTM D 1190 Rub. Asph.	———	Good (5)
NC	I,II	See it Seal it	No	HCL	ASTM D 3405	———	— (1–2)
ND	IV	———	Yes 1X1 and 4X1 good pavements	Compressed air HCL	ASTM D 3405	———	— (1–2)
OH	III	1/8–3/4"	No	Compressed air occasionally	Cutback with crumb rubber polypropylene polyester	Fill and overband	Cutback—Good to fair (1–2) Polypropylene—Very good to good (3–5) Polyester—Very good to good (3–5)
OK	II	1/8–1/2"	No	Compressed air	AC 2 emulsion CRS 2 emulsion	Pour pots and overband	Good to poor (3–5)
OR	I,II, III	1/8–1"	1 Area only	Compressed air	ASTM D 3405	Fill	Very good to good (8)
PA	II,III	1/4"Up	Occasionally	Compressed air HCL wet/temp.	AC 20 with rubber or fiber—polypropylene or polyester	Overband	Very good (5)

** Then overlay

† Resurface at 5 years

Table A1 (cont'd).

State	*Zone*	*Crack size*	*Rout*	*Cleaning method*	*Sealant*	*Method*	*Performance (yrs effective)*
RI	II,III				Does not seal cracks		
SC	I,II	1/8–1/4"	No	Do not clean	CRS 2 emulsion	Overband	— (<2)
SD	III,IV	Age not size	Yes	Compressed air	Hot pour elastic and AC w/ground rubber (20%)	Overband	Hot pour—Excellent (7–8) to very good; AC—Excellent to fair (<1)
TN	II	3/16–3/4"	No	Compressed air	ASTM D 3405	Trying fill	Very good (3+)
TX	I,II	<1/8"	No	No	ASTM D 3405	Overband	Good to fair*
UT	II,III	1/4–1"	No longer	Compressed air	ASTM D 1190 Mod.	———	Good (4)
VT	III,IV	1/4" Up	No longer	HCL	ASTM D 1401	Try not to overband	Excellent to fair (3)
VA	II	Varies	Some	Compressed air HCL	Rub. asph. polymer Polypropylene asphalt Cut back asphalt	———	———
WA	I,II III	1/4–3/4"	Yes	Compressed air	AASHTO M173 sand slurry for hairline	Try fill	Good (12)
WV	II,III	1/4" or less	No	Compressed air	Emulsion and sand	———	Fair to poor (1–2)
WI	III,IV	Fill >3/4" Seal >1/4"	When sealing	Wire brush Compressed air	RC 800 ASTM D 3405	Fill and overband	RC—Very good to poor (2) ASTM—Very good to fair (3–5)
WY	III,IV	1/8–1"	Yes 2X1	Compressed air HCL	ASTM D 1190 with ground tires	Fill	Excellent (5–10)

* Do with overlay

APPENDIX B: SAMPLE QUESTIONNAIRE

1. Is your state highway department sealing cracks in flexible asphalt concrete pavements as a form of maintenance?
    a. For how many years have you been doing this?

2. What method of cleaning the cracks before sealing is used?
    a. wire brush
    b. routing
    c. compressed air
    d. hot compressed air lance
    e. pressurized water
    f. sawing
    g. other (please specify)

3. What type of sealant is now being used?
    a. brand name if available
    b. reason(s) for choice
    c. cost per linear foot including labor

4. What type and size crack do you seal with the method used?

5. Do you use backer rods?

7. What type equipment do you use to apply sealant?
    a. do you use squeege?

8. How would you rate the sealant in the following areas:

    0—very poor; 1—poor; 2—fair; 3—good; 4—very good; 5—excellent

    a. resistance to being forced out by traffic
    b. resistance to oxidation
    c. resistance to becoming brittle
    d. resistance to particles entering crack
    e. resistance to flushing or bleeding
    f. ability to bond to pavement
    g. abrasion resistance
    h. ability to rebond

9. How would you rate its effectiveness in cold weather?

10. How long is it effective in sealing cracks?

11. Do cracks appear again after asphalt overlay is applied?

12. Does sealant bleed through overlay surface?
    a. do you get ridging?

13. How many miles of roads do you crack seal in a year?

14. How many men in crew ?

15. Months in which you seal cracks.

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A survey of all 50 United States was conducted in September of 1990 to determine the state of the art of crack sealing procedures on flexible asphalt concrete pavements. The results were tabulated and a summary report prepared. A meeting was held at the U.S. Army Cold Regions Research and Engineering Laboratory to discuss the draft report; the comments and suggestions received were incorporated into this report. At the meeting the group identified the need for a trade organization to develop uniform specifications and terminology and to promote proper equipment, methodology, materials, training and education in the pavement crack sealing industry.

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