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Value Engineering Study of the Repair of Transverse Cracking in Asphalt Concrete Pavements

Research, Development, and Technology
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FOREWORD

This report is the 17th in a series of Federal Highway Administration (FHWA) studies to apply value engineering techniques to improve various pavement maintenance practices. It contains the results and recommendations of a team study on the repair of transverse cracks in asphalt pavements. The study was conducted by team members from the States of California, North Dakota, Iowa, Minnesota, Pennsylvania, and North Carolina. The report should be of interest to State and local highway engineers involved in planning and performing maintenance of asphalt concrete pavements.

Additional copies of this publication can be obtained from the National Technical Information Service (NTIS), 5280 Port Royal Road, Springfield, Virginia, 22161.

Stanley R. Byington, Director
Office of Implementation

NOTICE

Technical Report Documentation Page

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Study conducted by team members of California, North Dakota, Iowa, Minnesota, Pennsylvania and North Carolina

16. Abstract

This report summarizes the results of a cooperative value engineering study on the repair of transverse cracks in asphalt concrete pavements. The objective of the study was to optimize the expenditure of maintenance funding through an in-depth study of the present methods, materials, and equipments being used, and the development of better methods, materials, and equipment, and work crews, for optimum and safe repair of such cracks.

This report contains recommendations and guidelines on crack preparation, materials, equipment, and timing to effect cost-effective repairs to transverse cracks in asphalt pavements. All team members agree that timely, effective crack sealing extends pavement life and reduces future maintenance costs.

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Unclassified	Unclassified	50	

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

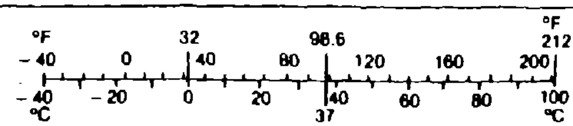
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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BACKGROUND

Pavement surface maintenance represents a significant portion of highway maintenance activities. Pavement cracking is one of the most troublesome aspects of surface pavement condition. Pavement cracking of asphalt surfaces is the predominant indicator of approaching pavement failure. In the view of many maintenance managers and highway engineers, cracking contributes to accelerated failure, effectively shortening the pavement's useful life.

The apparent need to repair cracks is beset with a number of troublesome problems. A wide discrepancy exists in the measurement of costs of crack sealing and filling operations among the States. Some measure cost by gallons of sealant used, others by lane miles, linear foot, or road mile. There is no correlation factor for these disparate methods of measuring cost.

In addition, agreement is lacking among highway maintenance managers, engineers, and researchers on approach, effectiveness or need to repair cracks. Some of the questions are:

- Does crack sealing prolong pavement life?
- Is crack sealing cost effective?
- Are there optimum methods and materials for performing the crack sealing operations?

PROJECT OBJECTIVES

Little research has been conducted in crack sealing and filling, and conclusions are not easily drawn from the sketchy results to date. This study recognizes the problems and the need for improvement. To that end, a methodology was developed which examines current practices used by different States. Methods, materials, equipment, and work crews presently being used were examined.

A value engineering (VE) approach was used to perform the study. The typical approach to VE follows a formal job plan. The Investigation Phase collects all relevant information and functionally analyzes the problem. It further selects those areas or aspects that appear most applicable for cost improvement. The Specualtion or Creative Phase develops numerous alternatives to the present methods for the selected areas. The Evaluation Phase analyzes the alternates developed in the previous phase and selects the optimum solutions. The

Development Phase prepares the optimum solutions as changes to the current approach. These solutions are then normally offered to management during the Presentation Phase.

In this study, information was gathered over a two-month period. To set the stage for the study, creative thinking was applied earlier than normal; and then reapplied when all information had been collected and analyzed. A random sample of 18 States, in addition to the 6 States participating in the study, was solicited for pertinent information.

The Presentation Phase could not be offered to the 50 State maintenance and engineering managers. This final report is intended to provide recommendations and guidelines to all concerned.

APPROACH

This value engineering study was performed in three sessions of about 4 days each, in three cities, over a 4-month period. This innovation (the normal VE study is usually accomplished in four to eight continuous working days) greatly enhanced the nation-wide scope of the information gathering functions of the 24 team members from six State highway departments.

The scene-setting, project explanation, and Information Phase were stressed at the meeting in San Francisco, California, from February 29 through March 3, 1988.

The Creative Phase was concentrated at the Des Moines, Iowa session, from April 5 to 8, along with the Evaluation Phase and part of the Development Phase. Also, in Iowa, the teams reported the answers to additional questions about maintenance practices in States other than the six States in attendance. These questions had been assigned at the end of the California meeting.

The Presentation Phase and draft final report presented in Washington, DC, during the June 6 through June 9 meeting carried the VE Job Plan to its customary conclusion with some extra emphasis on implementation.

This final report include the VE teams' findings, conclusions, recommendations, and an estimate of the benefits of the recommendations. It also spells out, in implementable detail, some guidelines to reap the benefits of the recommendations.

The States which sent representatives to all three meetings were North Carolina, Pennsylvania, Iowa, Minnesota, North Dakota, and California. The teams queried another 18 States to determine their repair practices for tranverse cracks in asphalt concrete pavements.

The VE team agreed that crack sealing and crack filling prolong pavement life by precluding the intrusion of water and other non-compressibles which lead to rapid deterioration of the pavement and eventual pavement failure. The team members reached this conclusion with no dissent.

DISCUSSION

GENERAL

The team members' Investigation Phase revealed the following aspects to be considered in their studies.

Pavement types. All paved roadways generally fall into three categories: (1) rigid pavement - portland cement concrete (PCC); (2) flexible pavement - asphalt concrete (AC); or (3) composite pavement, PCC with asphalt overlays. Approximately 94 percent of all lane miles of pavement in the nation are asphalt surfaced.

The following comments may apply to PCC but are written specifically for AC repairs.

Types of cracks. Team members agreed that the types of cracks in AC pavements which lend themselves to repair by sealing or filling fall into the following categories:

- Thermal cracks
- Reflective cracks (transmitted from below)
- Block cracking
- Map cracking

Figure 1 illustrates a typical transverse crack prior to sealing or filling.

Cracks are either well defined, with no spalls and no parallel cracking, or not well defined. Cracks can be said to be either "working" (horizontal and/or vertical movement), or "non-working."

Methods of repair. Cracks in asphalt pavements can be repaired by filling or sealing. In general, the objectives are similar, to preclude foreign material and prolong pavement life. Figure 2 illustrates severe damage in the lower portion of the pavement where a crack had not been repaired.

Figure 1. Typical Transverse Crack.

Figure 2. Pavement Deterioration Beneath the Surface Crack.

This study was restricted to consideration of cracks less than 1 1/2 in (37.5 mm) in width. Cracks of greater width that require special treatments are not covered in this study.

Figures 3 and 4 indicate delamination between the pavement layers in core samples taken adjacent to a crack in a pavement with no maintenance provided.

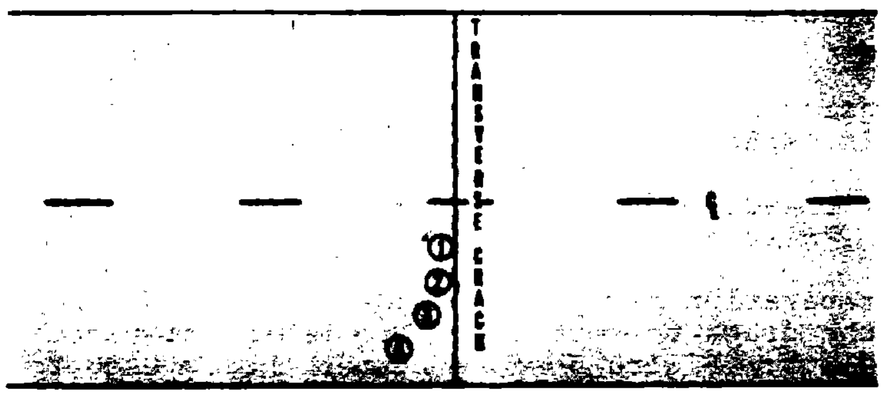

Figure 3. Core Sample Locations Adjacent to Transverse Crack.

Figure 4. Pavement Cores.

CRACK SEALING

Crack sealing is a method of repair for well defined cracks without secondary cracking deterioration. It is distinct from crack filling and was defined by the teams as a pavement preservation measure intended to prolong pavement life. Crack sealants are designed to preclude the intrusion of water into cracks for an extended period of time.

Normal crack sealing operations are conducted on cracks less than 1 1/2 in (37.5 mm) in width.

Sealing Preparation

Cracks in asphalt concrete pavements will require some preparation prior to placing the sealant. Three conditions and their effect on adhesion must be considered. They are cold temperatures, dirt and moisture.

Crack preparation may also include, as a first step, sawing or routing the crack to form a uniform vessel to receive and hold the sealant. Figure 5 shows routers being used to form a reservoir for crack sealing.

Figure 5. Routing of Transverse Cracks.

Whether or not sawing or routing is used, the crack needs to be cleaned. A number of alternatives exist for this purpose. Cleaning and drying with a hot air lance, compressed air only, sand cleaning, wire brushes and brooms are methods that can be used singly or in some combination.

Sealing Materials

The sealant material selected, and its application, is subject to a variety of factors for success:

o Temperature Range - The maximum and minimum temperatures which can be expected throughout the year in the particular geographic region.

o Performance - The material's ability to perform based on the vessel (crack) size, shape ratio, and extent of the joint movement.

o Adhesion - Condition of the adhesion surfaces and the environmental conditions present to preclude breaking of the seal upon movement of the crack.

Recent research has shown that the best performing sealants are the low-modulus, polymer modified, asphalt materials.[2,3] The properties of these materials are such that, in cold temperatures, the sealant will demonstrate resistance to stretching with crack movement, and resist tracking in hot temperatures.

The tests used to determine good cold temperature properties are the "cold bend," the "ductility," and "force ductility" tests. The resistance to tracking is reflected by the "flow" test and "softening point". (See Appendix B)

The State of Utah has been using several low-modulus materials for the last few years. The current Utah specifications are presented in Appendix B. These specifications may need modification for cold temperature compliance or hot temperature tracking resistance in climates that are significantly different than ambient low and high temperatures of 0 degrees F and 100 degrees F (-18 degrees C and 38 degrees C).

Material Placement

The 24 States studied are now using a variety of material placement techniques. States are currently conducting crack sealing at all times of the year: fall, winter, spring and summer. Arguments are made to support each choice of the time of year selected. Factors considered are:

o maximum opening of the crack (winter),
o minimum opening of the crack (summer),

- o average opening (late spring or early fall),
- o absence of ice and snow,
- o absence of rain, and
- o workforce availability.

Presently it seems that overbanding, flush squeegeeing, flush filling and underfilling are done throughout the year except during inclement weather. Figure 6 shows a typical squeegee used for joint and crack repair. Figure 7 indicates a tight squeegee immediately following a crack repair. The squeegee should follow within about one foot (1/3 meter) of the wand placing the material. Figure 8 shows a completed repair where a squeegee was not used.

Currently, the States that the teams studied begin their crack sealing operations at different times in the pavement's useful life. Some States seal cracks when they first appear, usually within the first three years after construction. Other States conduct crack sealing as a primary strategy to extend the pavement's useful life.

Failed pavements and areas of alligator or block cracking are generally not sealed by conventional crack sealing methods.

Some States utilize pavement maintenance management systems to track pavement condition and predict when crack sealing would be most beneficial.

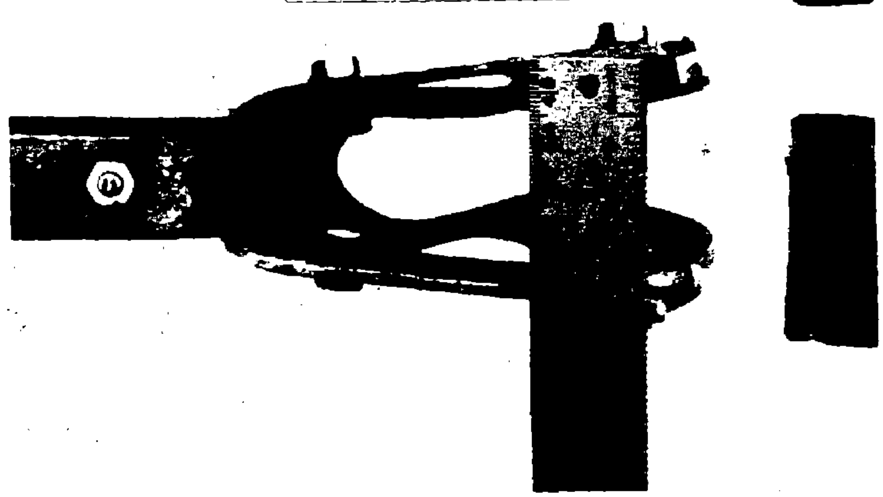

Figure 6. Typical Squeegee.

Figure 7. Squeegee in Use in Crack Repair.

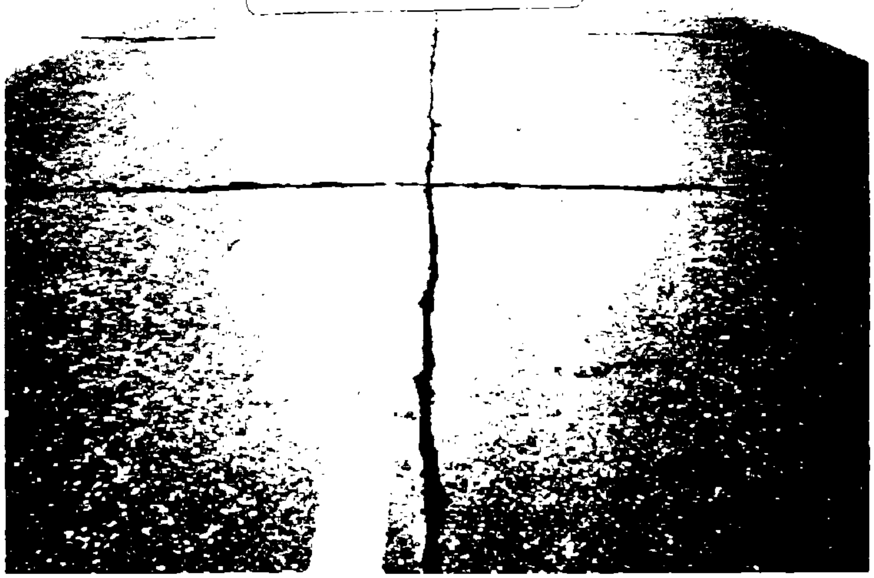

Figure 8. Repair Accomplished Without Squeegee.

Equipment

There are a variety of melting kettles used for hot-applied sealing compounds at the present time.

Study team members were concerned with features affecting productivity and safety issues, such as:

- o Melting time
- o Material loading features
- o Hose handling, storage, and clogging
- o Burners and the effect of wind
- o Temperature control and monitoring

Study team members were also concerned with equipment to be used for sawing and/or routing. The issues were:

- o Size and maneuverability of equipment
- o Secondary cracking
- o Spalling and tearing of joints
- o Vessel size and shape
- o Need to saw/rout and benefit

CRACK FILLING

Crack filling is a procedure to fill the pavement voids and/or reinforce the adjacent pavement. It is accomplished to prevent intrusion of water into the sub-base of the roadway and to strengthen the pavement section.

As discussed above, the filling of a crack implies different expectations of performance, as compared to sealing. The material used may, in fact, perform a short term seal. However, the sealing properties of the material are not critical.

Normal filling operations can be conducted on all cracks which, as defined in this study, are those of 1 1/2 in (37.5 mm) or less in width. Figures 9 and 10 show a crack filling operation with CRS-2 and use of a sand blotter to prevent tracking.

Preparation

Filling preparation may require the use of compressed air or a heat lance to clean the crack prior to filling, depending upon the material used. However, some States do not clean cracks prior to filling.

Material

Both hot and cold applied bituminous materials can be used for filling cracks. Cold applied materials are either cutback asphalts, i.e., RC-250 & MC-800, or emulsified asphalts, i.e., CRS-2. A number of additives can be used with the appropriate asphalt binders, such as rejuvenating agents, rubber, aggregates, fibers and polymers. Hot applied materials include asphalt cements such as paving grade asphalt and air refined asphalt. Figure 11 shows the use of two wands from one distributor, with squeegees being used. If squeegees are tightly applied, the roadway can be opened to traffic very quickly.

Figure 9. Longitudinal and Transverse Crack Filling.

Figure 10. Transverse Crack Repair with CRS-2 & Sand Blotter.

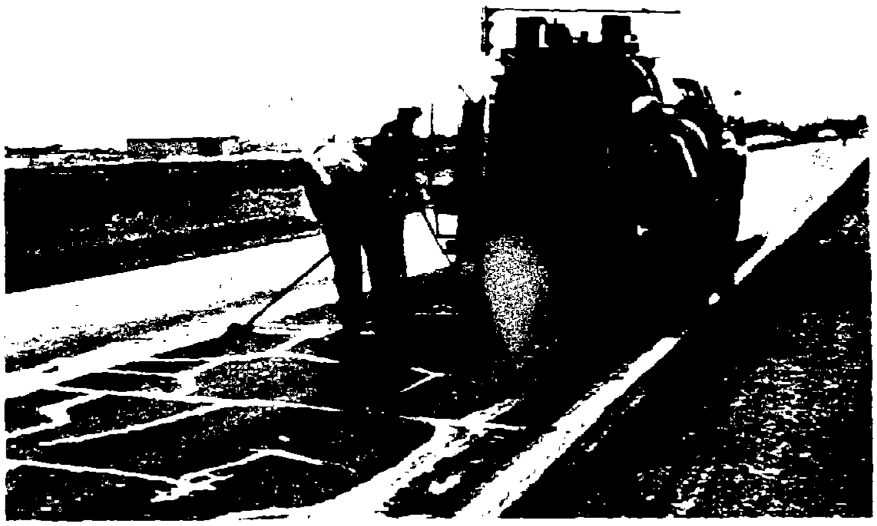

Figure 11. Two Wands Being Used With One Distributor.

Timing

With the exception that filling should not be conducted during periods of precipitation or extreme cold, conditions associated with weather and temperature are not critical for application.

Equipment

Specialized equipment is not necessarily required to apply the fill material. Ordinary asphalt distributors or direct heat kettles will meet the application requirements of some materials. Other materials will require the use of indirect heat equipment, if additives are used. Figure 12 shows the results of a filling operation. The pavement layers are held together and, thus, the pavement is more stable than one on which no maintenance has been done. (See also figure 4)

Figure 13 indicates tracking of filler material on a roadway where hot weather has forced filler material out of the crack.

Figure 12. Core Samples.

Figure 13. Tracking Caused By Thermal Expansion.

OBSERVATIONS

OVERVIEW

The majority of the States contacted indicate that they have a uniform statewide policy for crack sealing. Most state that they have a performance standard. This is indicative of the general importance associated with crack sealing operations.

A majority of the States also reported a general satisfaction with their programs, but felt an opportunity for improvement existed and that work needed to be done on materials and equipment, especially to reduce manpower requirements and improve safety.

Methods vary, but the majority of the states are using ASTM D-3405 and asphalt rubber as a sealant material. A number of States reported the practice of sawing or routing cracks prior to placing the sealant. The effectiveness of this practice is doubtful, however, because many States questioned its value or have discontinued sawing/routing except where underbody plows or graders will be used for snow removal.

The principal equipment used for cleaning cracks are the heat lance or compressed air.

Little or no information was made available on the cost of crack sealing by States other than the participating States. A wide discrepancy exists in the measure of unit costs. It appears that maintenance management systems are not being keyed to track costs of crack filling and sealing.

SIX STATES' PROFILES

Each of the six states which sent representatives was asked for a more detailed report of crack repairs in their juisdictions. The highlights of these reports follows:

California

California uses three different methods of repairing transverse cracks in AC pavement:

- Applying an emulsion and rejuvenating agent into the crack, followed by covering the area sealed with a damp sand to fill the crack and blot the surface of excess material.
- Applying a hot-pour petroleum based material or a blended compound into the crack.

- o Utilization of radiant heat asphalt repair equipment to heat the asphalt adjacent to the transverse crack, loosen the surface asphalt with a rake or similar tool, add sufficient reheated asphalt to fill the crack and repair any other deficiencies, level, apply a liquid rejuvenator to the surface, and roll.

Pennsylvania

Pennsylvania's methods and procedures manual states:

For rigid base roads -

Well-defined transverse crack

- o If routing, rout well-defined transverse reflective cracks to a depth of 1/2 to 3/4 in (12.5 to 19 mm) to a width of 1/2 in (12.5 mm). Transverse cracks wider than 3/8 in (9.5 mm) generally do not require routing. Routing is not required if using the overbanding process with applicator head.

- o Clean all cracks with compressed air to remove fines and dust. Cracks must be as clean as possible to insure good bonding.

- o A heat lance may be used to dry damp cracks.

- o Seal cracks with any of the following asphalt materials:

  AC and rubber
  AC and fibers
  Prepackaged AC & rubber
  Prepackaged AC & fiber

- o A squeegee should be used to level the sealant when using AC and rubber.

Multiple cracking

- o A reflective crack which has developed multiple secondary cracks that radiate approximately 6 to 12 in (150 to 300 mm) in each direction from, and parallel with it.

- o Clean area to be sealed using compressed air. In addition to using any of the materials used in the single cracking condition, RC-250 can be used to seal multiple cracks in the winter. This material should be covered with sand or aggregate before exposing to traffic.

For flexible base roads-

Well defined cracks - a single crack.

- o Clean crack using compressed air.

- o A heat lance may be used to dry damp cracks.

- o Seal cracks with any of the following asphalt materials:

  AC and rubber (preferred)
  AC and fibers
  Prepackaged AC and rubber or fibers

  RC-250 (winter only-acceptable)

Iowa

Iowa's DOT has three maintenance activities to repair transverse cracks in asphalt cement concrete surfaces:

- o joint and crack filling
- o joint and crack routing and sealing
- o slurry leveling

Pavements which have recently been paved or resurfaced with an asphalt cement concrete mix, and where crack repair is completed, are good candidates for routing and sealing.

All transverse cracks are filled, if sealing is not appropriate. If depressions have occurred in a crack area, slurry leveling is performed.

North Dakota

North Dakota for more than 40 years has coated (painted) the sides of visible cracks. This is usually done in the cold weather using a towed, single well distributor, and hand carts with built-on squeegees.

For the past 15 years, double-walled, melter applicators have been employed using modified asphalt (crumb-rubber, etc.) material. The State has a very limited number of these and only a minority of cracks are sealed using this method.

North Dakota has let contracts for the last four or five years to rout and seal cracks with polymer materials. In general, these have been demonstration projects to gain knowledge, and will be discontinued if it is found that contracting is inappropriate for this work.

The state intends to expand sealing with melter applicators and modified asphalt materials, depending on avaialable funds.

Minnesota

Minnesota's current crack repair program consists mainly of using an air refined asphalt cement (AC-3). There is also some use of asphalt emulsions and cutbacks.

The majority of the work is done in the winter and the spring when the work force is available.

During the past several years some test sections have been established to look at new methods and materials for crack sealing. This included examining various new routing and sawcutting configurations, heat lances, double jacketed kettles and various types of materials.

The experimental work also included some airport runways which had very severe transverse cracking.

The Operations Division of Minnesota DOT has established a peer review group to examine crack sealing. They are charged with reviewing current practices and recommending changes.

North Carolina

North Carolina has 121,950 miles (196,340 km) of State, county and some city streets maintained by the State forces. About 95 percent of these roads are asphalt surfaced pavements.

Routinely, the transverse cracks are sealed by cleaning with compressed air (15 percent of the time), and pouring them with RC-250 or CRS-2, using pour pots. The cracks are then blotted with sawdust or sand. The typical crew consists of twelve workers, not including traffic control. Generally, the cracks are sealed during the winter months when the cracks are more open. The results of this sealing method are unsatisfactory; usually the cracks reappear in one year or less. The State would like the sealant to last at least three to five years.

In 1984, the State began using asphalt rubber to seal transverse cracks, and better results were obtained. Currently there are several sealing projects which are using the asphalt rubber material.

STATES' SUMMARY

A total of 24 States were questioned about current practices of crack sealing and filling. Table 1 provides a detailed summary of current practies of the six States which sent team members to this VE study. Table 2 summarizes general practices of the other 18 States that were contacted by VE team members.

Table 1. Summary of Participant States.

GENERAL

	CA	IA	MN	NC	ND	PA
# Lane Miles Asphalt Surfaced	38,200	13,085	23,000	121,950	11,000	61,031
PMS	Y	Y	Y	N	Y	N
Uniform State-wide Policy	Y	Y	N	N	N	Y
Contract	Y	Y	N	Y	Y	Y
State Forces	Y	Y	Y	Y	Y	Y
Performance Standard	N	Y	Y	Y	Y	Y

METHODS

	CA	IA	MN	NC	ND	PA
Rout & Seal Individual Cracks	Y	Y	N	Y	Y	Y
Seal Only Individual Cracks	Y	Y	Y	Y	Y	Y
Full Width, Seal Chip/Slurry	Y	Y	Y	Secondary Roads	N	Y
Full Width, Fog Seal	N	N	Shoulders Only	Secondary Roads	Y	N
Full Width, Asphalt Overlay	Y	Y	Y	Y	Y	Y
Partial Width, Chip/Slurry	Y	Y	Low Vol. Roads	Y	N	Y
Partial Width, Fog Seal	N	N	N	Y	Y	N
Mill & Patch	Y	Y	Y	Some	Y	Y
Other	Heat plane Fabric	Slurry	N	N	N	RC-250 Winter
Do Nothing	N	N	N	N	N	N

CLEANING

	CA	IA	MN	NC	ND	PA
Compressed Air	Y	Y	Y	15%	Y	Y
Heat Lance	Y	N	N	Y	N	Optional
Wire Brush/Blower	N	N	N	N	N	Y
Saw & Rout	N	W/Backer Rope	N	N	Y	Y
Sandblast	N	N	N	N	Y	N
High Pressure Water	N	Y	N	N	N	N

Table 1. Summary of Participant States. (continued)

EQUIPMENT	CA	IA	MN	NC	ND	PA
Indirect Heat Melter Applicator	Y	Y	Y	Y	Y	Y
Original	Y	Y	Y	Y	Y	N
Modified	Y	N	N	N	N	Y
Distributor/Asphalt Kettle	Y	Y	Y	Y	N	Y
Wand (original)	Y	Y	N	N	Y	N
Wand (modified)	N	Y	Y	Y	Y	Special head
Squeegee	Y	Y	Y	Y	Y	Y
MATERIAL						
Asphalt Rubber	Y	N	Y	N	D 3405	AC+rubber
ASTM D 3405	Y	Y	N	Y	D 3405/78	AC+fiber
ASTM D 1190	Y	N	N	Y		D 3405
Emulsified Asphalt	CRS-2+ latex/recl.	CRS-2mod.	CRS-2	CRS-2	N	N
Cutback Asphalt	N	N	MC-80/250 RC-250	RC-250	MC-250	RC-250 winter
Blotting Material	Y	Y	Y	Y	Y	Y
TIMING/RESEARCH/COSTS						
When performed	Fall/40Fmin	40 F min	Winter/ spring	Winter/dry	Dry weather	Spring/ fall
Satisfactory Results	Y	moderate	moderate	N	moderate	moderate
Research Program	N	Y	Y	Y	Y	[illegible]
Innovations	Y	N	Y	N	N	[illegible]
Annual Budget $1000s	102,000	75,000	123,000	298,208	35,000	[illegible]
Annual Sealing Program $1000s	9,546	3,642		1,114	1,500	[illegible]
Unit Costs	$1,783/ lane mile	varies		$400/800 lane mile	$1700 $2000 road [illegible]	

Table 2. Asphalt Crack Sealing, Condensed Summary
(Other States Reporting).

	Uniform State-wide Policy	Performance Standard	Do Nothing	Rout & Seal	Seal Only	Asphalt & Rubber	Cutback Asphalt	Emulsified Asphalt	Satisfied w/Results	Innovative Equipment & Materials	Total Lane Miles	% Asphalt Surface
Arizona	Y	Y	N	N	Y	Y	N	N	N	Y	17,063	98
Arkansas	Y	Y	N	N	Y	Y	N	Y	N	Y	35,087	89
Florida	N	N	Y	N	N	N	N	N	Y	N	34,000	96
Georgia	na	na	N	N	Y	Y	Y	N	Y	Y	na	na
Illinois	Y	Y	N	Y	N	Y	N	N	Y	N	25,000	na
Louisiana	N	N	Y	N	N	N	Y	N	Y	N	na	na
Missouri	Y	Y	N	N	Y	N	Y	N	N	N	29,660	92
Nebraska	N	N	N	Y	N	Y	N	N	Y	N	13,085	53
New Hampshire	N	N	N	na	na	Y	N	N	Y	na	8,444	94
New Jersey	Y	Y	N	N	Y	Y	N	N	Y	na	6,842	73
New York	Y	Y	N	N	Y	Y	N	N	N	N	32,007	76
Ohio	Y	Y	N	Y	N	Y	Y	N	Y	na	35,887	95
Oklahoma	na	na	N	na	na	Y	Y	Y	Y	na	na	na
Texas	na	N	N	na	na	Y	N	N	Y	N	172,000	na
South Dakota	Y	Y	N	Y	Y	Y	Y	N	Y	na	na	na
Utah	Y	Y	N	Y	Y	Y	N	N	Y	Y	na	na
Wisconsin	Y	Y	N	Y	Y	Y	Y	Y	N	Y	na	na
Washington	Y	Y	N	Y	Y	Y	N	N	Y	Y	17,000	80

CONCLUSIONS

GENERAL

Sealing and filling of transverse cracks in asphalt pavements extends the service life of the pavement by precluding introduction of water and non-compressibles into the crack, protecting the sub-base and, in the case of filling, strengthening the adjacent pavement.

A review of cost allocation in several States indicated that labor costs amounted to approximately 66 percent of total cost; equipment costs were about 22 percent, and material costs about 12 percent of total cost for crack sealing and filling operations. Any method for reducing recurring labor costs by use of better materials would be very cost-effective.

VE TEAM RECOMMENDATIONS

The value engineering (VE) Team recommends elimination of routing/sawing of cracks in AC pavements prior to sealing, except in areas where underbody plows or graders will be used for snow removal. This will eliminate one person per sealing crew, which amounts to one-half person year per crew. The savings from this recommendation should conservatively amount to $33.5 million per year plus the cost of the router or saw, and its maintenance.

The team also recommended that the vehicle which tows the melter-applicator be configured to carry the air compressor for each sealing crew. This eliminates one truck and driver per sealing crew, which amounts to one-half person year per crew. The savings from this recommendation should conservatively amount to $33.5 million per year, plus the cost of one truck and its operating and maintenance cost.

The savings available from the above two recommendations amount to at least $67 million per year for the 48 contiguous States. A safety improvement also accrues since one less truck per crew will be on the road, one less dangerous piece of equipment per crew will be used (router/saw), and 2 less people on each sealing crew will be subject to traffic hazards during operations.

The third recommendation for which cost savings could be derived, based on the sketchy cost information available, nationwide, concerns the use of low modulus materials as the sealant of choice in all climatic conditions. This action should double or triple the life of the seal (3-6 years). A very conservative estimate of savings for this recommendation is $25 million per year in the 48 contiguous states. In addition, further savings will accrue from reduction in pothole patching and extended time between overlays or seal coats attendant with the longer life of the sealed cracks. Safety improvements are apparent when the sealing crews are exposed to traffic only 1/2 to 1/3 of their present exposure time.

Additional areas for value improvement are as follows:

- o Develop a piece of equipment that can distribute the materials and spread the materials in a one-pass operation. This will eliminate one person from each sealing crew ($33.5 million per year).

- o Consider research into sawing/routing new asphalt pavements and overlays, and filling with suitable materials, before opening to traffic, to relieve built-in stresses and prevent or defer "normal" cracking ($25+ million per year).

- o Consider establishing a national testing program for determining optimum materials and optimum preparation for repairing cracks in asphalt concrete pavements.

CONCLUSIONS - CRACK SEALING

Methods of Repair

Crack sealing is the appropriate method of repair for well defined cracks without secondary cracking.

Preparation

All cracks scheduled for sealing should be clean and dry prior to application. There is a benefit from heating the surrounding area prior to sealing.

Sawing and/or routing is a repair procedure used by some States for cracks. Four industry experts presented information to the teams on vessel size and configuration. Testimony conflicted on both equipment to use, and vessel configuration ratios. Arguments were made to support ratios of 1:1, 2:1, 1:2, and 1:4. No conclusive evidence was presented that sawing and/or routing produces any significant benefit. Moreover, some evidence was offered that showed that routing may produce secondary cracking. Therefore the VE teams concluded that sawing and/or routing should not be done on transverse or random cracks prior to placing the sealant. If later research should prove claims of longer life of repairs, and agreement can be reached on vessel size, the operation may provide enough benefit to justify the expense. It does not do so at this time.

In some instances consideration may be given to sawing and/or routing in areas where underbody plows or graders are used for snow removal.

Sawing and sealing new overlays on jointed concrete pavements, to control cracks, has been relatively successful in Pennsylvania and other States. The process involves refrencing, sawing and sealing the overlay to relieve built in stresses. Pennsylvania specifications require a reservoir to be created and sealed with ASTM D 3405 material.

This process has resulted in controlling cracks and has provided adequate sealing for up to six years.

Cleaning

The presence of dirt or moisture will interfere with sealant adhesion. Appropriate cleaning of the crack is necessary.

The VE teams concluded that the heat lance is the most effective preparation tool for the majority of conditions encountered. However, compressed air, sand blasting, wire brushes, etc. may also be used.

Material

The use of low modulus materials for crack sealing in all climate zones of the country is indicated. Polymer modified asphalts (low modulus materials) have yielded successful field performance in working cracks, which is the most severe condition. Different climatic zones may require more flexibility and ductility at low temperatures, and better anti-tracking properties at high temperatures.

Application

Most sealant materials are temperature sensitive. Following the manufacturer's recommendations will produce the required result both in melting the material for application, and a longer sealant life.

Adhesion is improved if the pavement surface and crack interfaces are warm. Application should closely follow cleaning with the heat lance. Correct use of the heat lance regulates the production rate. Heat lance operation requires softening of the surface asphalt which is indicated by a color change. Burning, which is indicated by smoke, must not occur.

Winter plowing activities may have a significant impact on sealant performance. An exposed band-aid is not recommended where underbody plows, or graders are used. However, the inverted band obtained by sawing and filling used by the Province of Ontario, Canada, has demonstrated adequate performance under these conditions.

Equipment

Application equipment should be capable of applying the sealant in accordance with the material manufacturers recommendations.

The VE team members expressed dissatisfaction with most melter applicators presently being used. Improvements need to be made in the following areas:

- o Melting time is too long for most melter applicators.
- o Material loading features are unsafe and most users need to retrofit equipment to protect workers.
- o Hose handling, storage and clogging problems need to be addressed. Cabinets or other means to retain heat within operating ranges need to be provided. The ability to backflush hoses is also desirable. Some manufacturers have produced new equipment which purports to solve these problems.
- o Burners on some models are easily affected by wind and cannot be used during adverse conditions, or while being towed to the job site.
- o Temperature control and monitoring on some models is poor. Users generally need to retrofit equipment to provide adequate controls to prevent overheating and to safeguard personnel.
- o The use of multiple fuels creates service problems.

Time of Year, Weather

The VE teams concluded that the extent of crack opening produced by thermal expansion or contraction is an important factor in crack sealing. Consequently, operations should be conducted during the appropriate time of year, when temperatures produce approximately average openings.

Actual operations should be conducted consistent with weather conditions. In particular, sealing may not be appropriate when the air temperature is below freezing, or when excessive moisture is present in the pavement. No sealing should be done during periods of precipitation.

The use of the heat lance effectively extends the conditions under which the crack sealing operations can take place.

CONCLUSIONS-CRACK FILLING

Pavements with cracks that exhibit depressions, parallel cracking or other failures, which would reduce the chance for sealant success, should be filled by the most cost effective method available. Figure 14 shows joint deterioration and settlement due to moisture. This failure lends itself to filling.

Figure 14. Joint Deterioration Due to Moisture.

Cleaning and Preparation

The presence of dirt or moisture will interfere with material adhesion. All cracks scheduled for filling should be relatively clean and dry.

Materials

A wide variety of materials can be used for crack filling, such as: asphalt cements, asphalt cements mixed with crumb rubber, polyfibers, or certain polymer modifiers, emulsions and cutbacks.

Application

Filling materials are applied over a wide range of temperatures. Most mixture temperatures are controlled by the additive. Asphalt cement, cutback and emulsion temperatures are controlled by material specifications.

Equipment

Because of the type of material used for filling, a wide variety of equipment is available. Materials with additives such as fibers or rubber must be applied with an indirect heating kettle with a pumping system capable of applying the material through a wand.

Figure 15 shows slurry material spread across the width of a crack, using a lute.

Figure 15. Using Lute to Spread Slurry.

Figure 16 shows a completed repair after slurry material has cured. When cured sufficiently, the lane can be opened to traffic.

Crack filling is not totally dependent upon the opening of the crack. Filling generally can be done in all seasons of the year. The critical factor is moisture. Filling should not be done during precipitation or while excessive moisture is present.

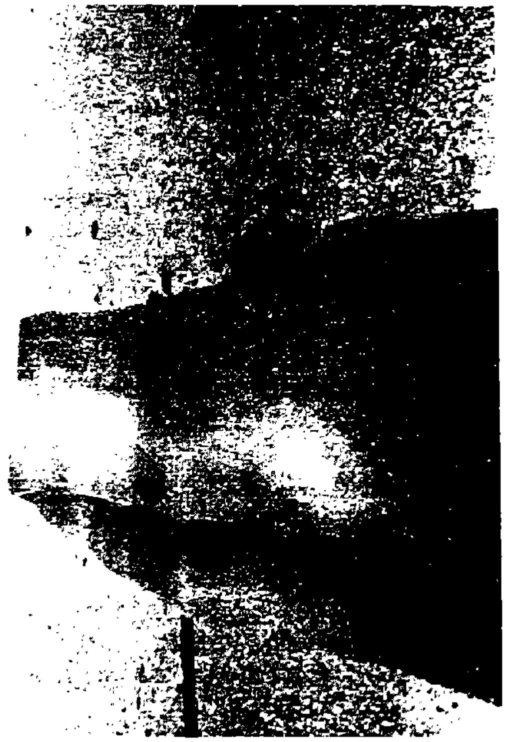

Figure 16. Repair Completed on the Now-leveled Joint.

RECOMMENDATIONS

GENERAL

All cracks in asphalt concrete pavements should be repaired as soon after initiation as possible.

All cracks should be sealed or filled to prevent pavement failure and to extend pavement life.

Material research should be done to provide longer-lived materials in order to reduce the high labor costs associated with asphalt pavement repair.

RECOMMENDATIONS - CRACK SEALING

Sawing and or routing of existing cracks is not recommended at this time except where underbody plows or graders are . for snow removal.

The heat lance is recommended as the preferred tool : cleaning cracks prior to sealant application. Heat lanced capable of producing approximately 3,000 degree F (1650 d. C) air with operating velocities of approximately 3,000 f (800 meter/second) at the nozzle orifice have produced good results, and are recommended.

The use of low-modulus materials is recommended for crack sealants. Research should continue to be done on sealant materials to identify superior performance characteristics. In addition, specifications and test procedures should be developed specifically for asphalt pavement crack sealants. The high labor cost in crack sealing operations (66% of total costs) could be greatly reduced by using customized, longer lasting materials.

Indirect heat transfer equipment should be used to melt and apply hot-pour sealant materials. Material manufacturers recommendations should be strictly observed.

Application equipment which can meet both the material manufacturer's specifications and the expected range of ambient conditions during application should be used.

The sealant material should be applied as soon as possible after cleaning with the heat lance. To assure satisfactory adhesion, the pavement should be warm and dry.

Users should develop equipment specifications which eliminate the problems delineated in the conclusions section of this report.

Crack sealing should be performed from early spring to late fall.

Use a vehicle capable of carrying or towing the combinations of required equipment (piggy-backing).

Repairs should be performed as a single-pass, moving, operation to reduce the number of set-ups for traffic control, and their attendant safety hazards.

Consideration should be given to the use of multiple crews to expedite the operation.

RECOMMENDATIONS-CRACK FILLING

Recommended procedures for crack filling operations, depending on conditions are:

- Assure that cracks to be filled are relatively clean and dry.
- Apply asphalt cements, emulsions, and cutbacks in the crack, followed by sand that acts as a filler and also a blotter to prevent pickup by traffic.
- Overband the cracks with a mixture of asphalt and six percent fiber or 25 percent rubber. The fiber

mixture is placed by means of a wand with an applicator head attached. The rubber mixture is placed with a wand and squeegee. Consideration should be given to applying all filling materials with an applicator head, or squeegee attached to the end of the wand.

- o Slurry patching should be done using a drag box, or screed, to feather the material.

- o In advanced stages of crack deterioration, additional activities may be appropriate. The failed area should milled/cut and removed. The area to be repaired can be heated with infrared heaters, patched with asphalt concrete and compacted. Infrared heaters are capable of heating the pavement from 1 to 3 in (25.4 to 76.2 mm) in depth.

GUIDELINES

Develop a uniform statewide crack repair policy. Performance standards outlining the procedures to be followed, the equipment and materials to be used should be implemented.

Each agency should develop training materials and training programs on the proper methods to repair cracks. Crews should be trained within a reasonable time prior to start-up of sealing activities.

Agencies should develop pavement maintenance management programs which include a pavement condition survey feature to indicate when crack repair would best be accomplished. Condition survey data should be in sufficient detail to rank locations requiring crack repair on a priority basis.

The low modulus crack sealant should be a homogeneous blend of materials with acceptable test properties of flexibility, ductility, force ductility and flow. See appendix B, under Crack Sealing Compound, paragraphs 2,4,5,6 and 8, for recommended specifications.

APPENDIX A - WORKSHOP ATTENDEES

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APPENDIX B
SPECIAL PROVISION - STATE OF UTAH

Asphalt Pavement Crack Sealing

Description: This work shall consist of cleaning, and sealing the cracks in the existing pavement.

Construction Requirements: Visible thermal cracking six (6) feet or more between cracks or as directed by the Engineer shall be cleaned and sealed. Immediately prior to sealing the crack and surface area for at least six (6) inches on both sides of the crack(s) shall be cleaned of foreign matter and loosened particles with a HCA (hot compressed air) heat lance. Adequate cleaning is determined by a darkening of the surface at least two inches in width, centered on the crack. Where dirt is still being retained on the unmelted (undarkened) surface the darkened width may be expanded to match the sealant configuration or as directed by the Engineer. The heat lance shall meet the following requirements: temperature of heated air at exit orifice minimum of 2,800°F. Velocity of exiting heated air minimum of 2,800 fps. Direct flame dryers shall not be used. The crack shall be overfilled and immediately squeegeed to form a band-aid; the squeegee shall be either attached to the wand or be kept within five (5) feet of the sealant applicator at all times. The band shall have the following configuration (see drawing Band-Aid Configuration). It shall have a band extending a minimum of one-half (1/2) inch to a maximum of one (1) inch on either side of the crack(s). The maximum width of the band shall be 3 inches. The band shall have a minimum thickness of 1/32 inch and a maximum thickness of 3/32 inch; at least ninety percent (90%) of the band placed shall have a thickness of 1/16 inch + 1/64 inch. A wipe zone, (anchor zone) flush with the pavement surface shall extend for a minimum of one-half (1/2) inch to a maximum of one (1) inch on either side of the band. The band shall be centered on the crack.

Where traffic or construction activities may cause tracking or pullout of the sealant material the contractor shall sand the sealant as it is placed or as directed by the Engineer.

Cracks in excess of 1" in width shall be filled with 1 2" minus plant mix or road mix or as directed by the Engineer.

Sealant material picked up or pulled out shall be replaced at contractor expense. Any damage to the traveling public resulting from sealant application or sealant pullout shall be paid for by the contractor.

Cleaning and sealing shall extend across the full width of the asphalt surfacing including the side slopes, or as directed by the Engineer.

Sealing shall be done only when the cracks are clean and dry and only upon inspection and approval by the Engineer.

Equipment: Sealant placement equipment shall use circulating hot oil heat transfer for heating the product (sealant machines). No direct heat transfer units (tar pots) shall be used. Maximum product tank capacity of sealant placement equipment shall not exceed 500 gallons. Alternate equipment shall be approved by the Engineer.

Temperature Control: Sealant manufacturer's instructions on application temperature shall be observed. The contractor's sealant unit shall have available at all times an operating ASTM 11-F thermometer with an intact mercury column or a certified, calibrated digital pyrometer, electronic thermometer, or equivalent direct reading temperature measurement device capable of reading within +/-50 degrees from 200 F to 600 F.

A log of product tank temperatures shall be recorded at one hour, +/-10 minute intervals, and kept available for inspection by the Engineer. Product tank temperatures shall be taken with one of the certified calibrated devices described. Temperature gauge readings are not acceptable.

Material that has been overheated in excess of 300 degrees above the manufacturer's recommended maximum temperature for one (1) hour or 60 degrees F. for 1/2 hour shall be wasted at the contractor's expense. Material shall not be placed if the temperature is below the manufacturer's recommended minimum application temperature.

The contractor's procedures for loading material into the product tank shall not depress the sealant temperature at the wand tip below the manufacturer's recommended application temperature.

Crack Sealing Compound: The crack sealant shall be a homogenous blend of materials combined in such a manner as to produce a material with the following properties:

1. Workability: The material shall pour readily over its specified application temperatures and penetrate a 1/4 inch crack for the entire ambient temperature range recommended by the manufacturer for application of this material.

2. Flexibility: A (1/8 in x 1 in x 6 in) specimen of the product conditioned to 0 degrees F shall be capable of being bent to a 90 degree angle over a 1.125 inch

mandrel conditioned to 0 degrees F in 2 seconds without cracking. (State of Utah Test).

3. Curing: The product shall cure sufficiently within 45 minutes of application, over the manufacturer's recommended ambient temperature range for application, to allow normal traffic without tracking.

4. Ductility: A standard specimen shall be capable of being pulled a minimum of 30 cm at 1 cm/min at 39.2 degrees F (State of Utah Test).

5. Force-Ductility: The standard specimen (See ductility) shall not exceed a force of 4 lb. during the specified elongatlon: 30 cm at 1 cm/min at 39.2 degree F (State of Utah Test).

6. Flow: Material shall comply to ASTM D-3405, Section 4.3 Flow.

7. Tensile Strength Adhesion: Material shall comply with ASTM D-3406, Section 4.7 Tensile Adhesion; except that sealant specimens shall be cured 4 hours (not 7 days).

8. Asphalt Compatibility: There shall be no failure in adhesion, or formation of an oily ooze at the interface between the sealant and the asphalt concrete or softening or other harmful effects on the asphalt concrete when tested at 140 degrees F.

9. Packaging and Marking: Sealant material shall be supplied preblended, prereacted and prepackaged. If supplied in solid form the blocks of completed material shall be cast in a plastic or other disolvable liner having the capability of becoming part of the crack sealing liquid. The sealant shall be delivered in the manufacturer's original sealed container. Each container shall be legibly marked with the manufacturer's name, the trade name of the sealer, the manufacturer's batch or lot number, the application temperature range, the recommended application temperature and the safe heating temperature.

10. Sampling: All sealant to be used on the project will be stockpiled at the site at least ten (10) working days prior to use, or at least twenty (20) working days prior to use if stockpiled at the vendor's place of business. Subsequent deliveries shall be placed in separate stockpiles. Stockpiles shall be waterproofed. The Engineer shall be notified when each stockpile has been established and ready to be sampled. Not less then one random sampre of each

or batch number (minimum of 10 lbs/sample) will be taken. No material shall be placed until the Engineer has approved the material for placement.

11. Compliance: Failure to meet specification shall not be cause for claim or extension of contract. The contractor shall be held liable for all costs incurred in procuring and testing of materials that are found to be out of specification.

12. Field Performance Tests: Sealant shall have performed satisfactorily for at least one (1) year at a U.D.O.T. approved test site before the manufacturer shall be permitted to bid.

13. Dissimilar Materials: Mixing of different manufacturer's brands or different types of sealant shall be prohibited.

The type of materials used shall be at the discretion of the supplier to produce the desired finished product. Applicable Vendor Certificates as required by the Utah Department of Transportation shall accompany all shipments supplied to the Department.

Method of Measurement: Crack sealing shall be measured by the ton of material used. The measured quantity shall include the blended mixture and dissolvable liner. The Engineer may require the weighing of equipment for determination of actual quantities of material used.

Basis of Payment: The completed and accepted quantities of this item shall be paid for at the contract unit bid price per ton of "Crack Sealing". The price per ton shall include all specialized equipment, specialized materials, labor, tools, and other incidentals necessary to complete the work, including brooming, and sanding.

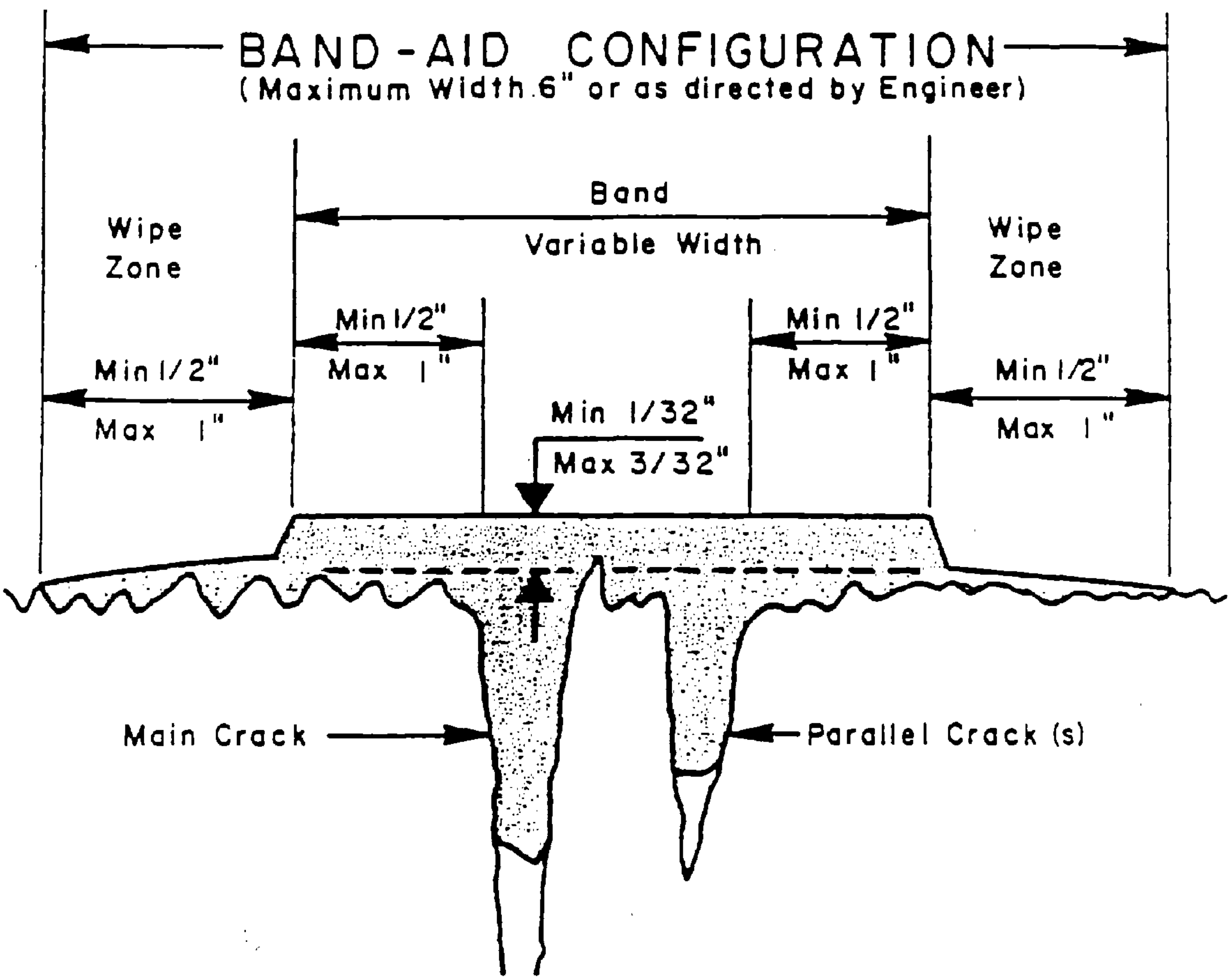

Figure 17. Crack repair cross section.

APPENDIX C - GLOSSARY

Anchor zone: A predesigned width of diminishing thickness (feathered width extending outward from the band.

Band: A layer of sealant or filler of variable thickness and width placed above a crack and extending over the pavement on either side of the crack.

Band-aid: A band of low modulus polymer modified sealant of controlled thickness and width with anchor zones extending on either side of the band.

Crack (non-working): A crack may exhibit some relatively small temperature related movement.

Crack (not well defined): Pavement surrounding the primary crack is deteriorating; spalling, radial and/or parallel cracks, individually or together, will be present.

Crack (well defined): Pavement surrounding the primary crack is intact and does not exhibit significant surface deterioration (spalling), or secondary cracking (parallel or radial) cracking.

Crack (working): Crack expands and contracts due to temperature change. Pavement on either side of the crack may exhibit vertical movement.

Crack filling: A pavement preservation method intended to prolong pavement life by precluding the intrusion of water into the crack for an extended period of time. Normal crack sealing operations are conducted on cracks less than 1 1/2 in (37.5 mm) wide.

Drag box: A box for slurry used to contain and place slurry mix.

Function: The specific work that an item or service must do.

Heat lance: A tool producing a high temperature, high velocity air blast fueled by propane.

Low modulus polymer modified sealant: A material meeting or exceeding ASTM standard D-1190, or D-3405 specifications.

Lute (hand lute): A hand-held screed similar to a squeegee used for leveling and feathering a narrow slurry placement.

Overband: See Band.

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