LTPP Pavement Maintenance Materials: SHRP Crack Treatment Experiment, Final Report

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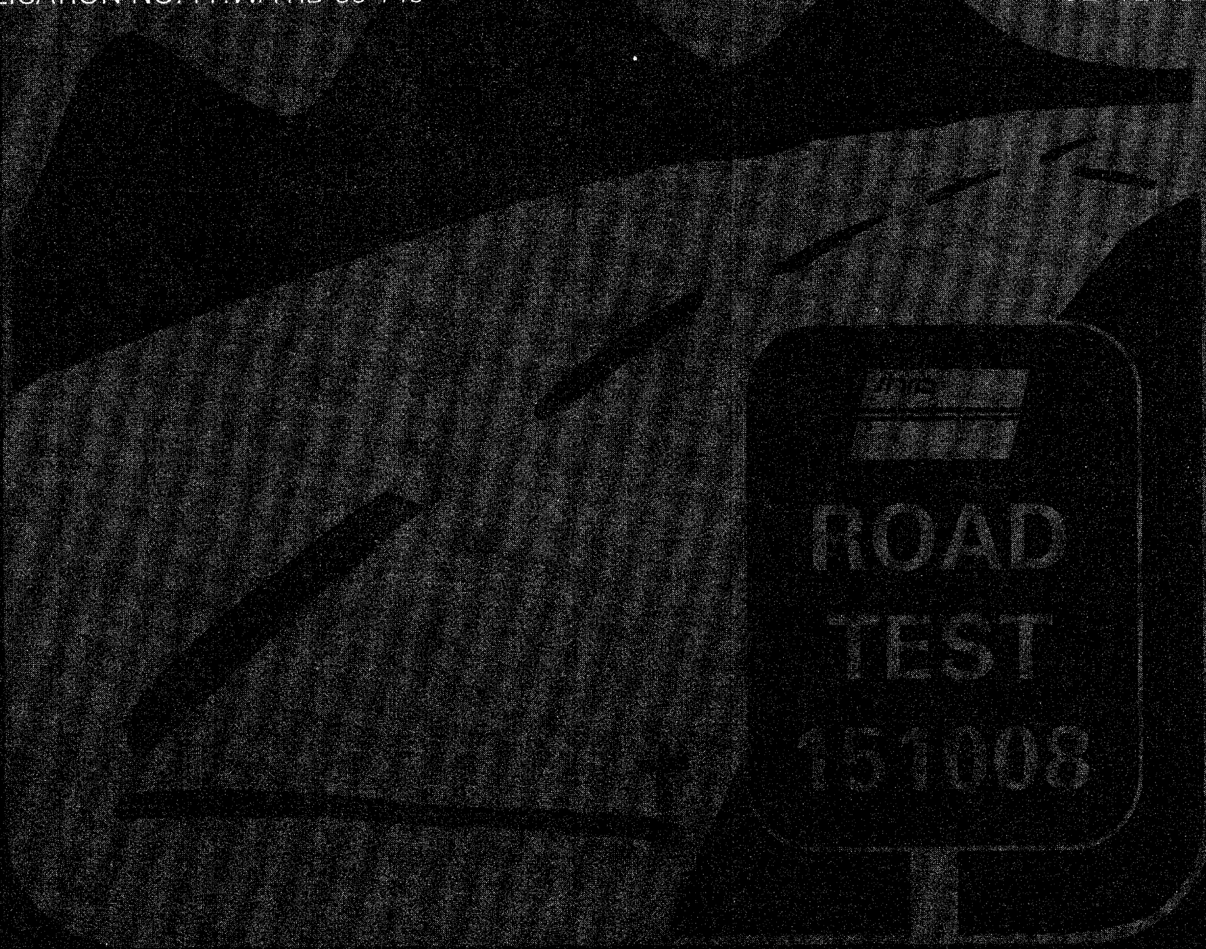

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
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LTPP

FOREWORD

Crack sealing and filling on asphalt concrete pavements is a commonly performed highway maintenance operation. The Strategic Highway Research Program's (SHRP) H-106 crack treatment study was part of the most extensive pavement maintenance experiment ever conducted. The information derived from this study will contribute greatly toward advancing the state of the practice of crack treatments on asphalt-surfaced pavements.

This report provides information to pavement engineers and maintenance personnel on the results of the H-106 crack treatment experiment. It presents the performance and cost-effectiveness of various crack sealing and filling materials and procedures for repairing cracks on asphalt-surfaced pavements.

This report will be of interest to anyone concerned with the maintenance and rehabilitation of asphalt-surfaced pavements.

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Director
Office of Infrastructure
Research and Development

NOTICE

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16. Abstract

The Strategic Highway Research Program (SHRP) H-106 maintenance experiment and the Federal Highway Administration (FHWA) Long-Term Monitoring (LTM) of Pavement Maintenance Materials Test Sites project studied two distinct asphalt concrete (AC) crack treatments: transverse crack sealing and longitudinal crack filling. Both activities are performed frequently in order to extend pavement life by preventing or substantially reducing the infiltration of water into the pavement structure.

Highway agencies use different materials and methods to treat cracks in AC pavements, and some of these treatments are inherently better than others; however, the relative effectiveness of a treatment often depends on the situations or conditions under which they are used. The primary objective of the H-106/LTM crack treatment experiment, then, was to determine the most effective and economical materials and methods for conducting crack sealing and crack filling operations. Secondary objectives included the identification of both performance-related material tests and quicker, safer installation practices.

This report documents the entire AC crack treatment study, including the installation of 31 unique crack treatments (i.e., combinations of sealant/filler materials and installation method) at 5 different test sites, the laboratory testing of experimental sealant/filler materials, and the 7-year performance monitoring of the various crack treatments. It also discusses the results of comprehensive statistical analyses conducted on material performance and laboratory testing data. The results of a detailed cost-effectiveness analysis are also presented.

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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	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

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

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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CHAPTER 1. INTRODUCTION

Objectives

Under the Strategic Highway Research Program (SHRP) H-106 maintenance experiment and the Federal Highway Administration (FHWA) Long-Term Monitoring (LTM) of Pavement Maintenance Materials Test Sites project, two distinct asphalt concrete (AC) crack treatment activities were studied: transverse crack sealing and longitudinal crack filling. Both activities are frequently performed by highway agencies in order to extend pavement life via preventing or substantially reducing the infiltration of water into the pavement structure.

Several different materials and methods are used in crack treatment operations, some of which are inherently better than others. In many cases, however, the relative effectiveness of materials and methods depends on the situations or conditions in which they are used. Several studies have been conducted in the past to assess the effectiveness of these items. Although these individual studies have gradually advanced the state of the technology, a more comprehensive investigation, such as that conducted in SHRP project H-106, has been long overdue.

The primary objective of the H-106 crack treatment experiment was to determine the most effective and economical materials and methods for conducting crack sealing and crack filling operations. Secondary objectives included the identification of both performance-related material tests and quicker, safer installation practices. Toward these ends, a total of four transverse crack-seal test sites and one longitudinal crack-fill test site were constructed throughout the United States and Canada between March and August 1991. The general locations of these test sites are shown in figure 1.

Scope

This report covers all aspects of the crack treatment portion of the H-106 maintenance study. The various aspects of planning, installing, and evaluating the experimental crack treatment sites constructed in the project are discussed in chapters 2, 3, and 4. An in-depth performance analysis, conducted for the purpose of establishing useful trends or relationships among installation, laboratory testing, and field performance, is presented in chapter 5. Chapter 6 summarizes the preliminary findings and recommendations.

Project Overview

As stated previously, this project focused on both transverse crack sealing and longitudinal crack filling operations. By definition, crack sealing is the placement of specialized materials into and/or above "working" cracks in order to prevent the intrusion of water and incompressibles into the cracks ("working" cracks refer to cracks that undergo significant amounts of movement, generally $\geq$ 2.5 mm). Crack filling, on the other hand, is the placement of materials into "non-working" cracks to substantially reduce water infiltration and reinforce adjacent cracks.

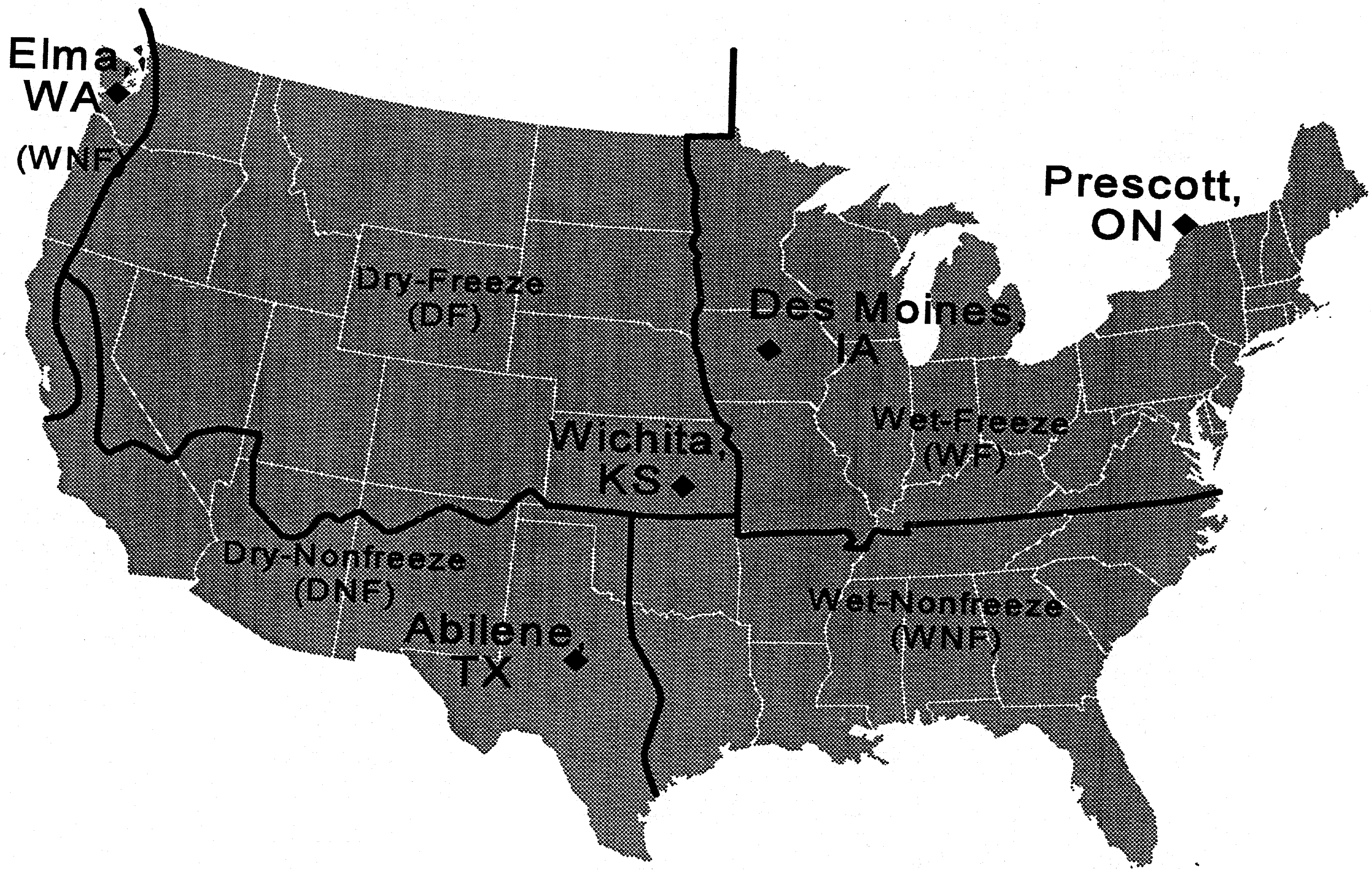


Figure 1. AC crack treatment test site locations.

Because of the predominant interest in, and need for, longer lasting crack sealants, the emphasis in this study was placed on crack sealing.

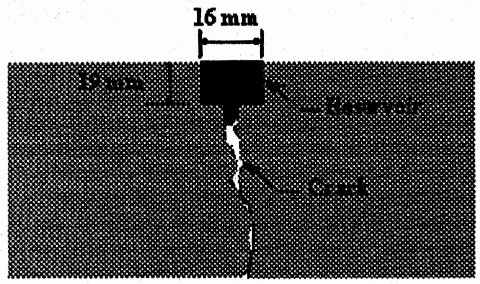
In the experiment, several different treatments were applied and evaluated for performance over several years. The test sites containing the treatments were located on two- and four-lane highways of moderate traffic volume, representing four fundamental climatic regions, as shown in figure 1: dry-nonfreeze, dry-freeze, wet-nonfreeze, and wet-freeze. In order to examine the effects of ambient weather conditions during sealing operations, the site at Wichita, Kansas consisted of an ideal-conditions test lane and an adverse-conditions test lane. These two lanes were located adjacent to one another.

The basic character of each test site was formulated in the SHRP H-105 project and finalized just prior to the SHRP H-106 installations. In all, 10 material products were placed in the transverse crack-seal sites and 6 material products were placed in the longitudinal crack-fill site. Table 1 presents the entire list of materials, both primary and state-added, that were installed in the experiment.

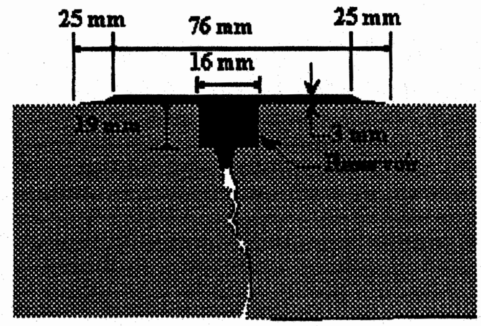
The installation methodology for a particular material involved: (1) the configuration in which the material was placed and (2) the method of crack preparation. Figure 2 shows the eight

Table 1. List of material products installed in H-106 crack treatment experiment.

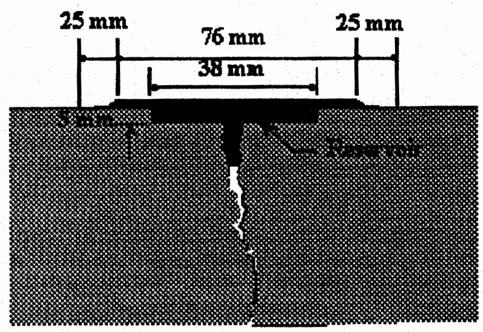
Product	Material Type	Test Site Locations
	Primary Crack-Sealant Products	
Meadows Hi-Spec®	Rubberized Asphalt	Abilene, TX; Elma, WA; Wichita, KS; Des Moines, IA
Crafco RoadSaver® (RS) 515	Rubberized Asphalt	"
Koch 9030	Low-Modulus Rubberized Asphalt	"
Meadows XLM	Low-Modulus Rubberized Asphalt	"
Kapejo BoniFibers® + AC (AC-20)	Fiberized Asphalt	"
Dow Corning® 890-SL	Self-Leveling Silicone	"
	Primary Crack-Filler Products	
85-100 Penetration-Graded AC	Asphalt Cement	Prescott, ON
Witco CRF®	Emulsion	"
Crafco AR2	Asphalt Rubber	"
Hercules Fiber Pave® + AC (85-100 Pen. Graded)	Fiberized Asphalt	"
	Additional (State-Added) Products	
Crafco RS 211	Rubberized Asphalt	Elma, WA; Prescott, ON
Crafco AR+	Rubberized Asphalt	Wichita, KS
Koch 9000-S	Asphalt Rubber	"
Elf CRS-2P	Emulsion	Des Moines, IA
Hy-Grade Kold Flo	Rubberized Emulsion	Prescott, ON



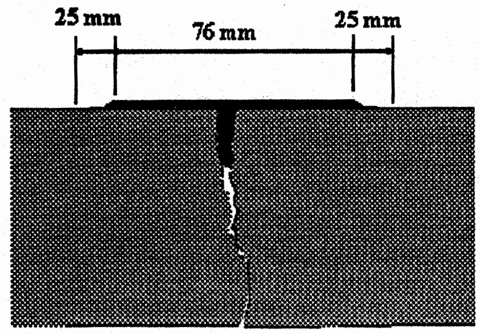
Configuration A
Standard Reservoir-and-Flush



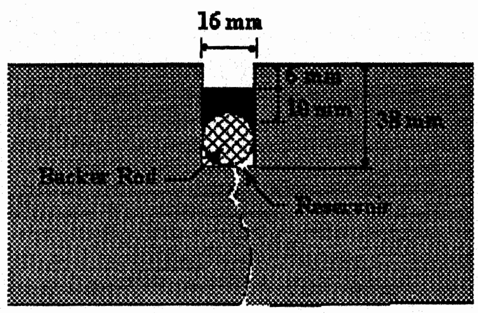
Configuration B
Standard Recessed Band-Aid



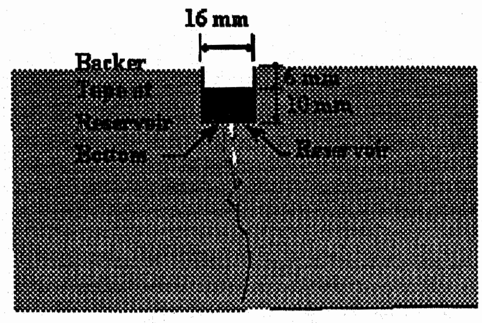
Configuration C
Shallow Recessed Band-Aid



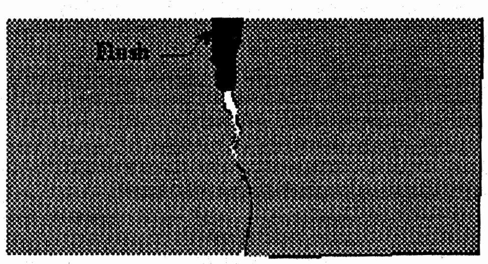
Configuration D
Simple Band-Aid



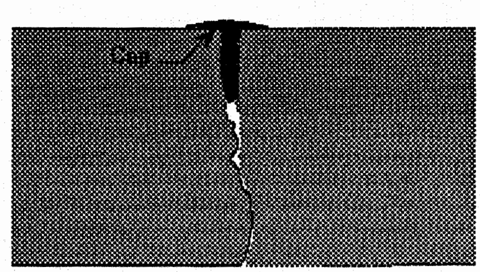
Configuration E
Deep Reservoir-and-Recess



Configuration F
Standard Reservoir-and-Recess



Configuration G
Simple Flush-Fill



Configuration H
Capped

Figure 2. Material placement configurations for AC crack treatments.

placement configurations employed (designated A through H), while table 2 lists the seven crack preparation procedures used (designated 1 through 7). Altogether, 13 unique installation methods were implemented. These methods are, herein, presented as A-3, D-4, E-6, etc.

Table 3 provides a complete matrix of the treatments applied at each site. As can be seen, some materials were placed using only one method, while others were placed using several methods. A total of 31 distinct treatments were applied in the experiment, several at multiple locations.

Test Site Characteristics

I-20, Abilene, Texas

This crack-seal test site, representing the dry-nonfreeze climate, was located between mileposts 278 and 282 in the westbound driving lane of Interstate 20 near Abilene, Texas (see figure 3). The pavement section was originally constructed in the mid-1960s using 76 mm of AC, 203 mm of crushed limestone base, and 406 mm of crushed caliche subbase placed on a 152-mm lime-stabilized subgrade. A 64-mm AC overlay with a geofabric interlayer was placed in 1989.

Pavement condition at the time of installation was fairly good. Transverse cracks were the only significant form of distress present. These cracks were typically about 3 mm wide and were spaced fairly regularly—between 15 and 18 m. Very little spalling and secondary cracking was observed along the transverse cracks.

Table 2. Crack preparation procedures included in H-106 crack treatment experiment.

Designation	Crack Preparation Procedure
1	None—no cleaning and no accessory materials (e.g., backer materials)
2	Wirebrushing—crack channels cleaned with mechanical wire brush followed by high-pressure air compressor
3	Hot airblasting—crack channels cleaned, dried, and heated with hot compressed-air (HCA) lance connected to high-pressure air compressor
4	High-pressure airblasting—crack channels cleaned with high-pressure compressed air
5	High-pressure airblasting and backer rod—crack channels cleaned with high-pressure compressed air; backer rod placed at bottom of crack reservoir
6	Sandblasting and backer rod—crack channels cleaned with light application of sandblasting followed by high-pressure airblasting; backer rod placed at bottom of crack reservoir
7	Sandblasting and backer tape—crack channels cleaned with light application of sandblasting followed by high-pressure airblasting; backer tape placed at bottom of crack reservoir

Table 3. Summary of crack-seal and crack-fill installations.

Treatment Material	Installation Method (configuration-preparation procedure)	State/Province Installed				
		Texas	Kansas	Washington	Iowa	Ontario
Meadows Hi-Spec	A-2				✓	
	A-3	✓	✓	✓	✓	
	B-3	✓	✓	✓	✓	
	C-3		✓		✓	
	D-3	✓	✓	✓	✓	
	D-4	✓	✓	✓	✓	
Crafco RS 515	B-3	✓		✓	✓	
	C-3		✓		✓	
	D-3	✓	✓	✓	✓	
Koch 9030	B-3	✓		✓	✓	
	C-3		✓		✓	
	D-3	✓	✓	✓	✓	
Meadows XLM	B-3	✓		✓	✓	
	C-3		✓		✓	
	D-3	✓	✓	✓	✓	
Kapejo BoniFiber + AC	D-3	✓	✓	✓	✓	
Dow 890-SL	E-5	✓	✓	✓	✓	
	E-6		✓			
	F-7		✓			
Crafco AR+	B-3		✓			
Koch 9000-S	B-3		✓			
Elf CRS-2P	G-4				✓	
Crafco RS 211	B-3			✓		
	H-4					✓
AC	G-1					✓
	G-4					✓
Crafco AR2	D-4					✓
	G-4					✓
Hercules Fiber Pave + AC	D-4					✓
Witco CRF	G-4					✓
Hy-Grade Kold Flo	G-4					✓

Configuration
A. Standard Reservoir-and-Flush
B. Standard Recessed Band-Aid
C. Shallow Recessed Band-Aid
D. Simple Band-Aid
E. Deep Reservoir-and-Recess
F. Standard Reservoir-and-Recess
G. Simple Flush-Fill
H. Capped

Preparation Procedure
1. None
2. Wire Brush and Compressed Air
3. Hot Compressed-Air Lance
4. Compressed Air
5. Light Sandblast, Compressed Air, and Backer Rod
6. Compressed Air and Backer Rod
7. Light Sandblast, Compressed Air, and Backer Tape

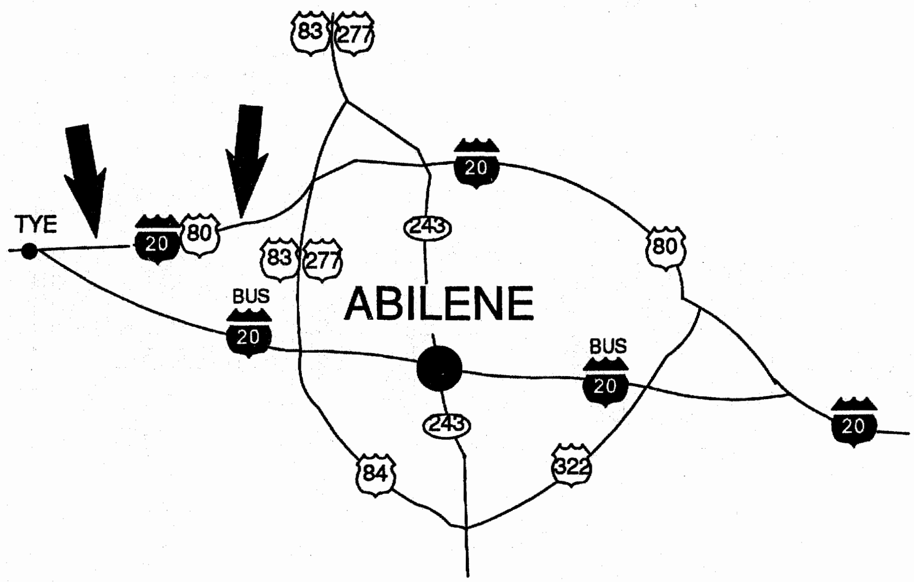


Figure 3. Abilene, Texas transverse crack-seal test site.

Two-way traffic on this four-lane interstate facility, as recorded in 1988, was approximately 19,900 vehicles per day (vpd). Data on the percentage of trucks were not available, but it was estimated to be fairly high—in the vicinity of 15 to 20 percent. Assuming a directional distribution of 50 percent and a lane distribution of 60 percent, the amount of traffic traversing the test site (i.e., the westbound driving lane) was estimated to be nearly 6,000 vpd.

The mean annual precipitation at the Abilene site is about 600 mm (U.S. Dept. of Commerce, 1983). Mean annual monthly temperatures range from 7°C to 29°C, and the mean number of days with minimum temperatures below 0°C is about 45 (U.S. Dept. of Commerce, 1983).

WA 8, Elma, Washington

This wet-nonfreeze crack-seal test site was located between mileposts 0 and 7.25 in the eastbound passing lane of Washington State Route 8 near Elma, Washingon (see figure 4). The pavement section was originally constructed in 1964 as a full-depth AC pavement. An AC overlay in the mid-1980s brought the total depth of AC to 229 mm.

When this road was selected as a crack-seal site, overall pavement condition was fairly good. Transverse cracks were present, typically at 23 to 31 m. The cracks, ranging between 3 and 6 mm wide, were accompanied by very few spalls and secondary cracks. Some rutting was evident in the wheelpaths, but usually to depths no greater than 6 mm.

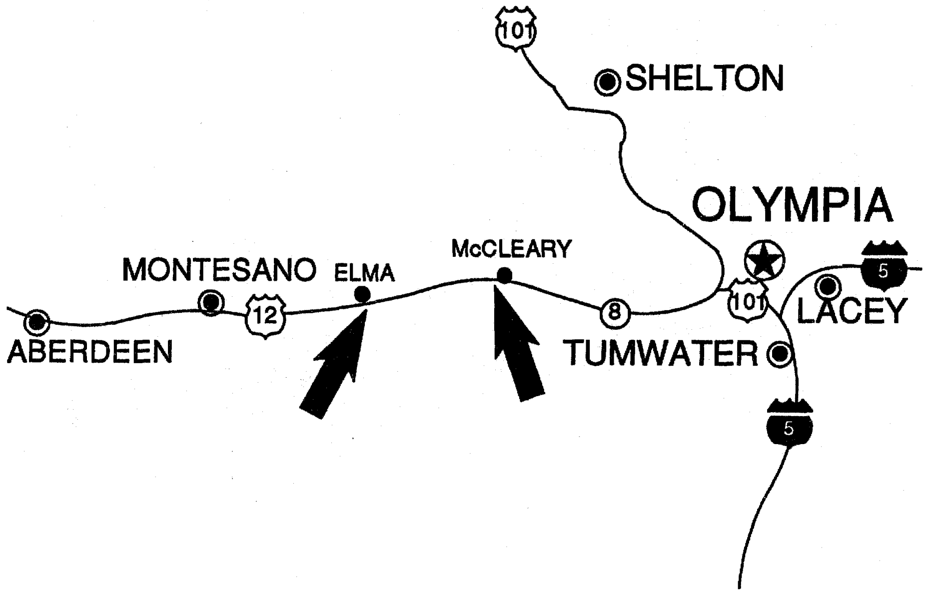


Figure 4. Elma, Washington transverse crack-seal test site.

During the winter and early spring of 1991, the surface course in the driving lane of this four-lane divided highway experienced some severe delamination due to heavy freeze-thaw cycles. The deterioration was sufficient to warrant full-depth repairs and the placement of a chip seal in this lane over much of the section. Hence, the original idea of sealing both lanes to investigate the effects of traffic on sealant performance had to be abandoned and only the cracks in the passing lane were sealed.

Two-way traffic on this facility in 1990 was approximately 14,000 vpd, 9 percent of which was truck traffic. No lane-traffic distributions were obtained; however, estimates from the field indicated that no more than 40 percent of the traffic occupied the passing lane, which is where the experimental seals were located. Assuming a directional distribution of 50 percent, the maximum amount of traffic passing over the test site was estimated to be 2,800 vpd, easily making it the lowest trafficked site.

The mean annual precipitation at the Elma site is about 2,450 mm (U.S. Dept. of Commerce, 1983). Mean annual monthly temperatures typically range between 5°C and 21°C, and the mean number of days with minimum temperatures below 0°C is about 90 (U.S. Dept. of Commerce, 1983).

<u>KS 254, Wichita, Kansas</u>

This crack-seal site, representing the dry-freeze climatic zone, was located between mileposts 4.5 and 10.2 of Kansas State Route 254 near Wichita, Kansas (see figure 5). The eastbound lane of this two-lane highway represented the ideal-conditions lane, while the westbound lane represented the adverse-conditions lane. The date of original construction for this pavement

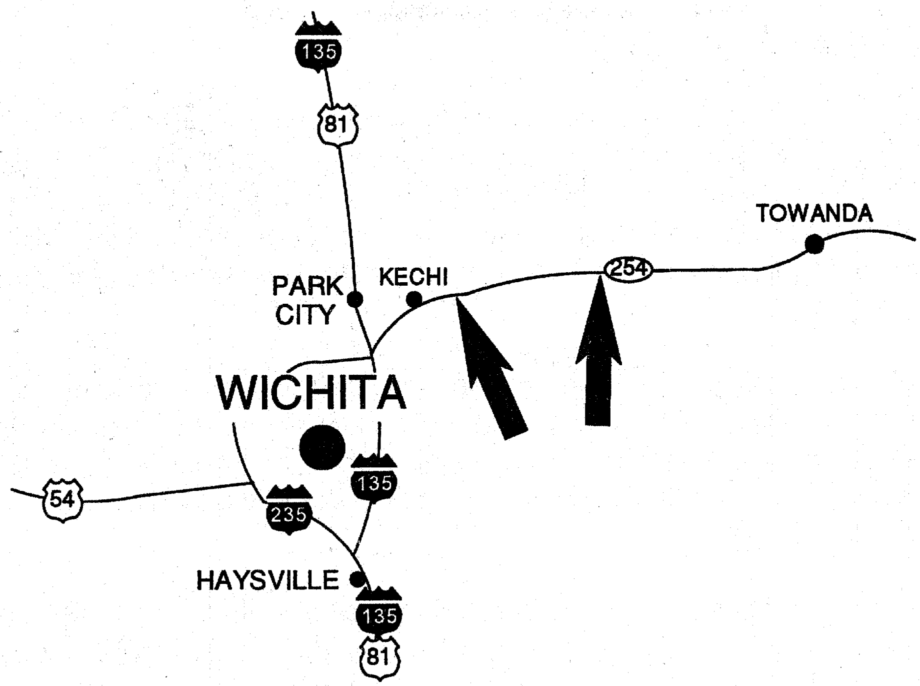


Figure 5. Wichita, Kansas transverse crack-seal test site.

section was not available; however, it was constructed as a full-depth AC pavement. In the summer of 1989, rehabilitation was performed by milling off 38 mm of the AC surface and placing a blend of recycled and new AC to a depth of 76 mm. Hence, the final cross section was composed of 305 mm of AC.

As with the Abilene site, pavement condition at the time of installation was fairly good. Transverse cracks, between 3 and 5 mm wide, were typically spaced between 18 and 25 m apart. Some of the transverse cracks exhibited a considerable degree of secondary cracking. To the extent possible, these cracks were excluded from the experiment.

Two-way traffic on this undivided highway was estimated in 1988 to be 7,000 vpd, with 13 percent trucks. However, judging from observations made during the installation and 10 subsequent field inspections, this figure was believed to be considerably higher. Based on the 7,000-vpd estimate and assuming a directional distribution of 50 percent, the amount of traffic traversing each test site was at least 3,500 vpd.

The approximate mean annual precipitation at the Wichita site is 810 mm (U.S. Dept. of Commerce, 1983). Mean annual monthly temperatures range from 1°C to 27°C, and the mean number of days below 0°C is about 112 (U.S. Dept. of Commerce, 1983).

I-35, Des Moines, Iowa

The location of this wet-freeze crack-seal site was between mileposts 93 and 102 in the northbound driving lane of Interstate 35 near Des Moines, Iowa (see figure 6). The pavement section was originally constructed in 1965 with 254 mm of jointed reinforced concrete (JRC) pavement placed on a 102-mm granular subbase. The joints were doweled and spaced 23 m apart. In 1988, some partial- and full-depth patching was done, followed by the placement of a 102-mm AC overlay.

By the time this experimental site was installed, most of the transverse joints had reflected up through the overlay. Several of the reflective cracks had been treated in 1989 with an emulsion material, of which only traces remained. On average, transverse cracks were 2 to 4 mm wide and were accompanied by some spalls and secondary cracks. Some longitudinal cracks were present along the lane–shoulder joint.

Two-way traffic on this four-lane facility was estimated in 1990 to be 20,700 vpd, with approximately 20.5 percent trucks. Based on a 50 percent directional distribution and a 60 percent lane distribution, more than 6,200 vpd crossed over the test site (i.e., the northbound driving lane).

Mean annual precipitation at the Des Moines site is about 840 mm (U.S. Dept. of Commerce, 1983). Mean annual monthly temperatures range from -6°C to 24°C, and the mean number of days below 0°C is about 140 (U.S. Dept. of Commerce, 1983).

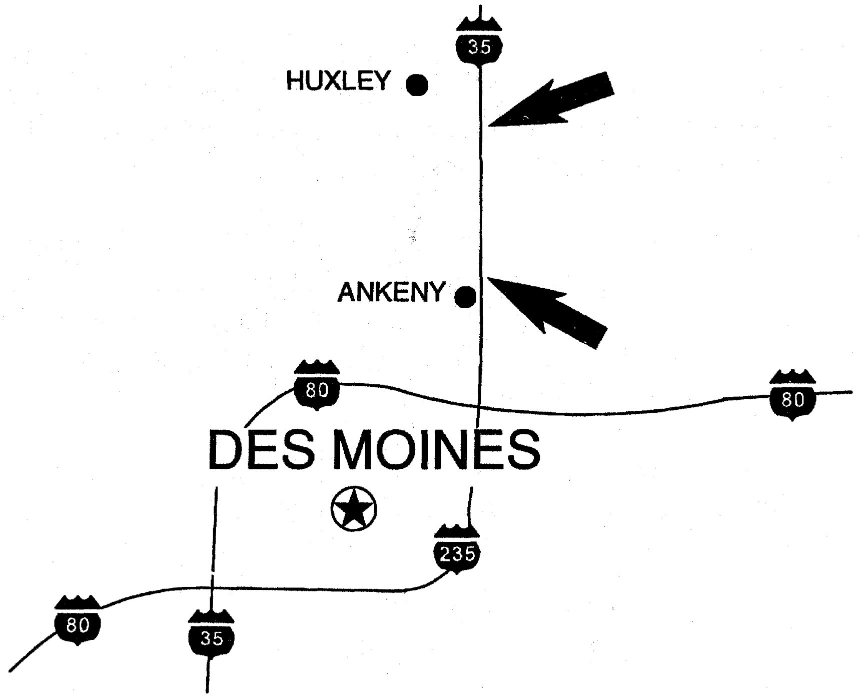


Figure 6. Des Moines, Iowa transverse crack-seal test site.

Highway 401, Prescott, Ontario

The longitudinal crack-fill test site, constructed in the wet-freeze climate, was located between kilometerposts 716 and 718 in the eastbound lane of Highway 401 near Prescott, Ontario (see figure 7). The date of original construction for this pavement section was not available; however, the section was constructed as a 230-mm jointed plain concrete (JPC) pavement placed on 305 mm of granular subbase. In 1979, a 127-mm AC overlay was placed on the existing concrete surface.

Transverse reflective cracks had developed in both lanes in the mid-1980s, at which time they were sealed with a hot-applied rubberized asphalt. A fair percentage of these seals were observed to have failed at the time the crack-fill experiment was installed. The longitudinal centerline crack sealed in this experiment typically ranged from 3 to 5 mm wide. Some segments of the crack were spalled or potholed, and tight alligator cracks ran along much of the crack length.

The two-way traffic for this four-lane divided highway was estimated in 1991 to be 12,000 vpd. The percentage of trucks was not available; however, it was believed to be at least 12 percent. Because of the location of the longitudinal crack, very little traffic crossed the crack-fill treatments.

Mean annual precipitation at the Prescott site is about 850 mm (U.S. Dept. of Commerce, 1983). Mean annual monthly temperatures range from -7°C to 21°C, and the mean number of days below 0°C is about 140 (U.S. Dept. of Commerce, 1983).

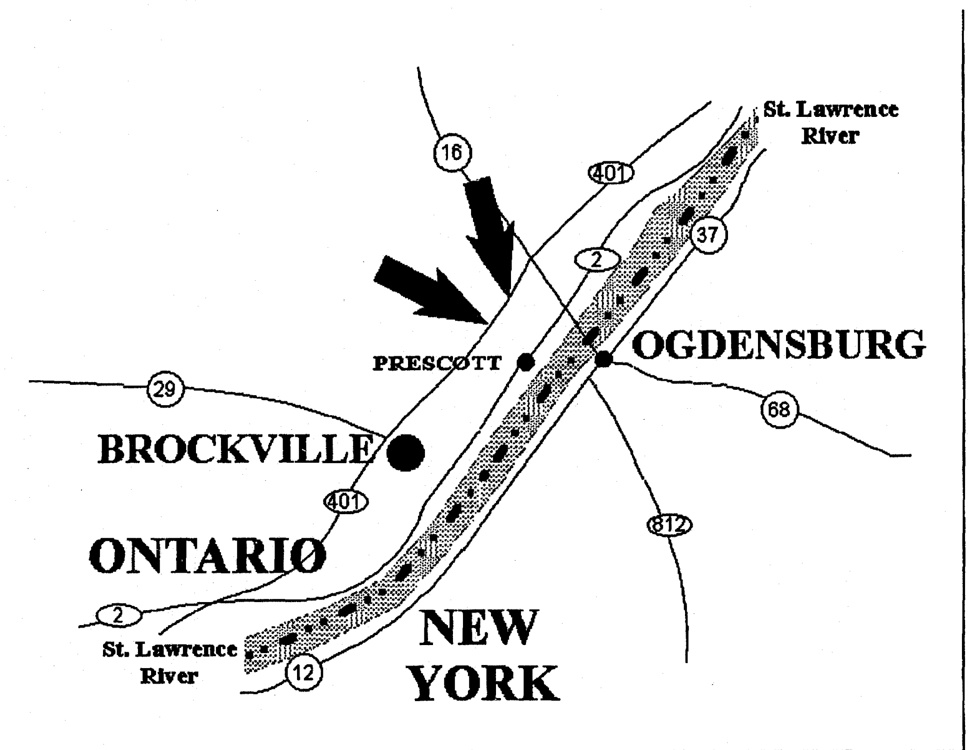


Figure 7. Prescott, Ontario longitudinal crack-fill test site.

CHAPTER 2. TEST SITE INSTALLATIONS

After an extensive 4-month search in which 38 potential test sites were field-reviewed, primary and backup test sites were selected in February 1991 (except for the crack-fill site, which was selected in June 1991). These sites were selected based upon an overall rating of numerous characteristics, including the quantity and appropriateness of distress, the uniformity and future availability of the pavement section, and the ability and willingness of the local maintenance force to participate in the study.

The field installation process began in March 1991 with the Abilene test site and concluded in August 1991 with the Prescott test site. Upon completion, roughly 6,710 m of cracks were treated with the experimental materials.

Table 4 summarizes basic information regarding the layout and construction of each test site. As can be seen, each test site typically took between 1 and 2 weeks to lay out and construct. The actual time required at each site depended on the weather conditions encountered, the length of the test site, the number of materials that were to be placed, and the available resources of the participating agencies. For instance, at the 1.6-km Prescott test site, five materials—two of which were cold-applied emulsions—were placed in 2 working days. In contrast, the two subsites at Wichita, each greater than 8 km long, took nearly 14 working days to construct. Eight materials were placed at each of these subsites, and a few days of inclement weather were experienced.

For the most part, the installations followed the procedures and criteria described in the SHRP H-106 *Experimental Design and Research Plan (EDRP)* (Evans et al., 1991). However, a few changes were made prior to and during the H-106 field installations. These included:

- Reduction in reservoir width for configurations A, B, and E (from 19 mm to 16 mm).
- Incorporation of two "no seal" test sections at Des Moines.

Table 4. Test site construction information.

Test Site Location	Facility Type	Participating Agency	Activity	Test Site Duration (Layout and Construction)	Total Number of Layout and Construction Days
I-20, Abilene, TX	4-lane interstate	Texas State Dept. of Highways and Public Trans.	Transverse crack sealing	3/20/91 - 3/27/91	5
KS 254, Wichita, KS	2-lane highway	Kansas DOT	Transverse crack sealing	4/10/91 - 5/2/91	10
WA 8, Elma, WA	4-lane highway	Washington State DOT	Transverse crack sealing	4/22/91 - 4/27/91	3
I-35, Des Moines, IA	4-lane interstate	Iowa DOT	Transverse crack sealing	5/30/91 - 6/7/91	5
Hwy 401, Prescott, ON	4-lane highway	Ontario Ministry of Transportation	Longitudinal crack filling	8/28/91 - 8/29/91	2

- Modification of installation methods for two Dow Corning 890-SL sections at Wichita adverse-conditions subsite (methods E-6 and F-7 were used instead of method E-5).
- Incorporation of six supplemental (State-added) material products for performance evaluation (see table 1).
- Incorporation of six additional test sections at Des Moines for investigating the performance of RS 515, 9030, and XLM sealants placed in configuration B.

Nearly every experimental treatment was replicated twice in the field to increase the statistical validity of performance analyses. The exceptions to this were the two Dow Corning 890-SL sections located in the Wichita adverse-conditions subsite. Here, methods E-6 and F-7 were used in one section each, replacing the two sections allotted for method E-5.

Test Site Arrangements

Once each site was selected and approved for use, efforts were made to determine the resources needed for complete installation of the various test sites. This entailed the estimation of material requirements and a knowledge of the manpower and equipment available at each participating agency. For instance, one agency did not have access to a hot compressed-air lance; therefore, arrangements had to be made with an equipment manufacturer to lease one.

Initial material estimates were made based on the number of sections testing each material and the application rates associated with the various material configurations. A 25 percent wastage factor was then applied to each material estimate. After conversations with manufacturers and expert consultants, the hot-applied material estimates were again increased to ensure proper functioning of the asphalt kettle units and to reduce the likelihood of material overheating. A sufficient amount of material in the kettle vat helps safeguard against heating and application problems.

To further inform participating agencies about what to expect during the installations, layout and construction plans were prepared and sent to the project supervisors at each agency. These plans presented the scope and objectives of the project and outlined the responsibilities of the participating agency and the SHRP contractor. Conceptual maps illustrating the proposed layout of test sections for treatments also were included in this document. Several copies of these maps were later made and distributed to field maintenance supervisors to assist them in coordinating the installations.

Installation Process

The sequence of activities during each test site installation was rather straightforward. Each experimental installation consisted of three primary phases:

1. Test site layout.
2. Initial crack preparation (i.e., crack cutting).
3. Final crack preparation (i.e., crack cleaning) and material placement.

Before any cracks could be prepared or material installed, the experimental test sections had to be laid out. Furthermore, since detailed inspection and documentation of cut cracks was required, the crack-cutting phase was conducted separately from the crack-cleaning and material-placement phase.

Test Site Layout

The location of the experimental test sections at each site depended on the highway facility type and the constraints associated with the pavement section. As seen in table 4, all of the sites except Wichita were four-lane facilities. Additionally, with the exception of Elma, the experimental test sections at each site were established in the outside lane (i.e., the driving lane). At Elma, the inside lane (i.e., the passing lane) had to be used because of surface delaminations that occurred in the driving lane shortly before the scheduled installation.

The first phase in each experimental installation involved conducting a pavement survey and laying out the site. A cursory inspection of the cracks was made first to determine which were suitable for inclusion in the experiment. The criteria differed for transverse and longitudinal cracks. Suitable transverse cracks had to be full-lane-width cracks, accompanied by minimal edge deterioration (i.e., spalls, secondary cracks). Suitable longitudinal cracks, on the other hand, could be accompanied by a greater amount of edge deterioration. When suitable cracks were identified in the field, they were marked and numbered with spray paint.

Crack-seal treatments assigned to each test site were implemented in test sections consisting of 10 suitable transverse cracks. The test sections were arranged in random order to form a test replicate (see appendix A for the sequence of sections at each test site). This replicate of test sections was repeated so that two sets of each treatment were applied, as shown in figure 8. This design was also used at the crack-fill site, except that the test sections consisted of twelve 7.6-m divisions of continuous longitudinal centerline cracks. Crack-seal test sites ranged from 5.6 to 14.5 km long, depending primarily on the crack spacing and the number of sections proposed for each test site. The longitudinal crack-fill test site was approximately 1.6 km long.

Often, partial lane-width cracks and considerably deteriorated cracks were encountered in the crack-seal test sites. These cracks were either sealed with the experimental materials during installation or were sealed after installation using whatever material was available. However, treatments for these cracks were not evaluated.

Permanent marking tape was used on the shoulders to mark the test section boundaries. A three-digit code designating the treatment type used in the adjacent section was then spray-painted next to the strips of marking tape.

After each test site was laid out, the test sections, experimental cracks, and important permanent fixtures (i.e., milepost markers, bridges) were stationed. The stationing served as a mapping reference in the event that remarking became necessary as a result of the paint fading over time.

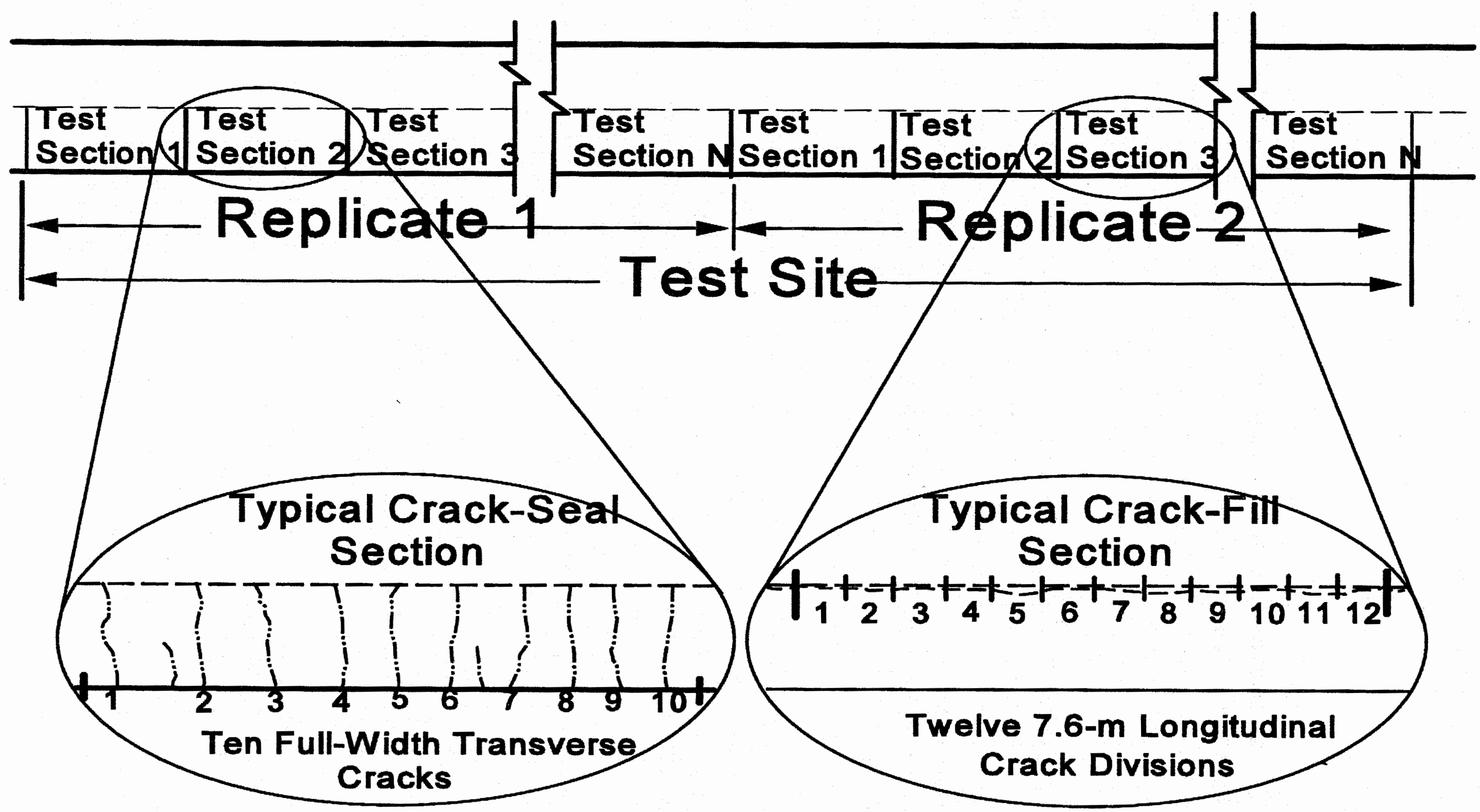


Figure 8. Conceptual layout of test sections at each test site.

At the crack-seal sites, a detailed inspection of experimental cracks 3 through 10 in each test section was performed. This inspection involved sketching the general pattern of each crack and recording the location(s) of deteriorated segments as a function of lane position (see figure 9). A similar, less-intensive inspection was done on experimental cracks 5 through 12 in each section at the crack-fill site. Since the longitudinal cracks were much straighter and more deteriorated, only the excessively wide or potholed crack segments were identified and recorded.

The next step in the layout phase involved the placement of Parker-Kalon® (P-K) nails to monitor horizontal crack movement throughout the year. The nails were driven flush into the pavement on each side of, and perpendicular to, experimental cracks. The nail heads were dimpled so that accurate measurements with a caliper could be taken during the installation and during each subsequent evaluation.

At the crack-seal sites, the nails were installed near the center of the experimental lane, roughly 138 mm on each side of the last eight experimental cracks in each test section. At the crack-fill site, only two sets of nails were installed in each section. This was because little movement was anticipated and the variation in movement along the entire crack was expected to be small. With the exception of the Prescott site, this proved to be the most time-consuming step in the layout phase, occasionally taking more than a full day to complete.

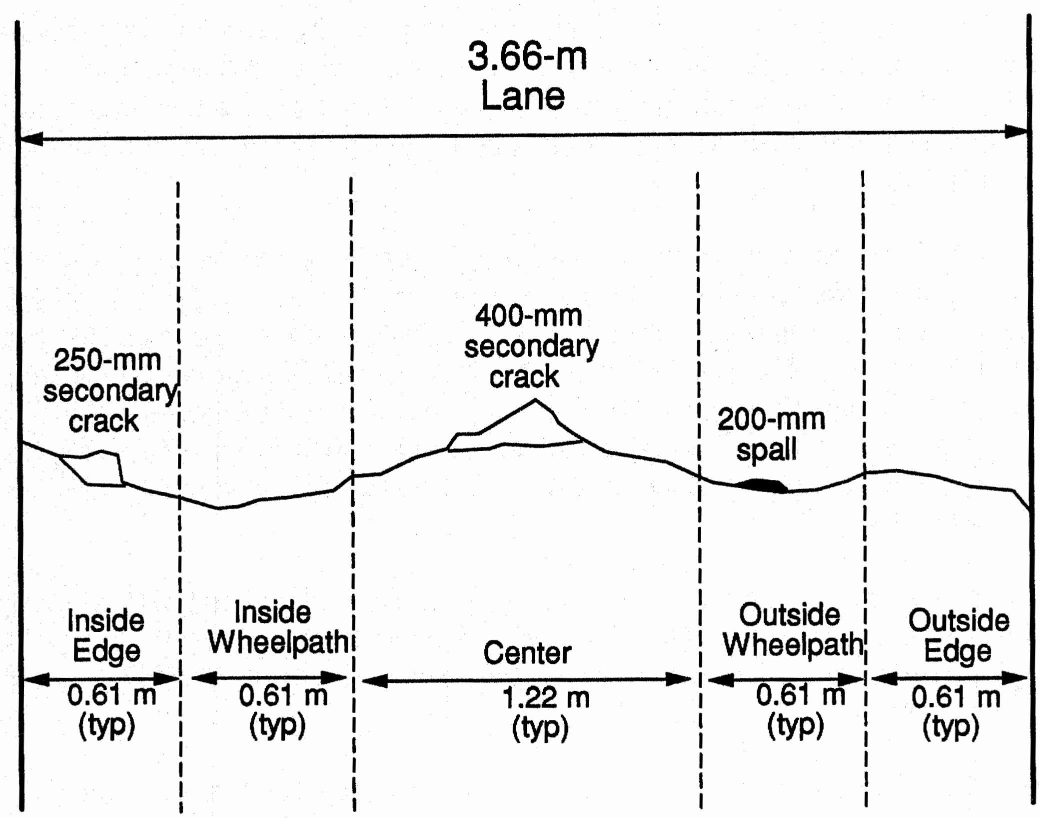


Figure 9. Initial inspection sketch of transverse crack.

Although efforts were made during each layout to achieve uniformity among test sections, a final cursory survey was performed at each site to identify and record any global distresses (e.g., rutting, raveling) or localized features (e.g., drainage structures, superelevation) that could bias performance results.

Initial Crack Preparation

The next step was initial crack preparation or crack cutting. This phase, although labor-intensive, was rather simple and straightforward. Two two-person crews were usually deployed—one to cut the cracks and one to blow debris off of the roadway. In some cases, the machine operators were switched periodically for physical relief or training purposes. In the latter case, only productivity was sacrificed.

Project staff regularly checked work quality to the extent possible by measuring reservoir dimensions and inspecting the operator's ability to follow cracks with the router or saw.

Between 1 and 2 days of crack cutting was typical at each site. Lane closures were established for the cutting operations at Abilene, Elma, and Des Moines. At Wichita, temporary construction zones were set up using signs and flagmen.

Final Crack Preparation and Material Placement

In the final phase, maintenance crews cleaned cracks and installed the experimental materials. The crack-cleaning operation generally preceded the material installation operation by 3 to 5 minutes or 15 to 30 m. This gave the project staff time to monitor the crack-cleaning activity. In most cases, the crack-cleaning crew had to be restrained from getting too far ahead of the installation operation.

At crack-seal sites, one of four methods were used for final crack preparation, depending on the sealant material that was installed. Sections where hot materials were applied were generally airblasted either with hot compressed air or conventional compressed air (preparation procedures 3 and 4, respectively). Two Hi-Spec sections at Des Moines used a combination of wirebrushing and compressed air (preparation procedure 2). Silicone sections involved more detailed preparation; crack reservoirs were lightly sandblasted and cleaned with compressed air, and then backer rod was installed. Crack preparation at the crack-fill test site consisted primarily of conventional airblasting.

At the Wichita adverse-conditions subsite, the weather conditions often had to be artificially produced. This meant that water had to be poured into and over experimental cracks and then allowed to permeate the crack for a short time (approximately 5 to 10 minutes) prior to the cleaning/drying operation.

The manner in which experimental products were installed depended upon the type of material. Hot-applied materials were applied to cracks using the applicator system affixed to kettle units. This system consists primarily of a pump, hose, and wand. Cold-applied asphalt materials were placed using hand-held pour pots, and self-leveling silicone was dispensed from 0.9-L cartridges using either manual or air-powered caulking guns.

Once applied into or over the crack channels, asphalt materials were molded into desired configurations using the appropriate squeegees. The squeegees were generally run between 0.6 and 3.0 m behind the material applicator, depending on the material viscosity at placement. No finishing was required for the self-leveling silicone product.

In order to minimize tracking, traffic control had to be maintained long enough for the treatments to solidify or form a protective skin. On a couple of occasions, maintenance vehicles (e.g., trucks pulling arrow boards, crash attenuator trucks) followed too closely behind the installation operation, causing some of the materials to be tracked.

Cleanup

After completing the installation of one hot-applied material, the asphalt kettle used in the installation had to be cleaned for preparation and application of the next hot-applied material. This meant first pumping as much of the old material out of the unit as possible. A few blocks (34 to 45 kg) of the next material to be installed were then loaded into the kettle vat and heated to application temperature. This material, mixed with remnants from the previous material, was then pumped from the vat and properly disposed. As a result, contamination by the previous material was all but eliminated and the kettle was prepared for formal loading and heating of the next material.

The cleanup associated with the fiberized asphalt materials was arduous and time-consuming. Therefore, these materials either were placed last (in cases where only one kettle was available), or were placed using a separate kettle.

Materials

Rubberized Asphalt

The hot-applied, rubberized asphalt product Meadows Hi-Spec served as the control sealant material for the transverse crack-seal experiment. Nearly one-third of the treatments at each site involved the use of Hi-Spec, as seen in table 3 of chapter 1.

Hi-Spec came packaged in 22.6-kg boxes, each containing two 11.3-kg blocks of sealant. These blocks were loaded into the kettles and heated to temperatures between 200°C and 210°C. Although the manufacturer advised avoidance of prolonged heating or overheating to prevent decomposition, Hi-Spec was reported to be a little less sensitive to temperature than other hot-pour materials. Nevertheless, no heating problems were observed during the installations.

Even though Hi-Spec was placed in four different formats (configurations A, B, C, and D), the procedures used were similar. For cut cracks, the sealant was placed from the bottom up, overfilling the reservoir to the extent necessary for either flush or band-aid squeegeeing. For uncut cracks, enough sealant was applied to the crack to form the desired band dimensions with the band-aid squeegee. Figures 10 and 11, respectively, illustrate the Hi-Spec reservoir-and-flush and band-aid configurations employed.

Hi-Spec treatments were not without construction problems. Unanticipated down time at the Abilene site created a situation in which Hi-Spec had to be reheated for application the next day. Most of its original quality, however, was believed to have been retained by loading additional blocks of material during the reheating process.

Several Hi-Spec treatments at Wichita and Elma were subjected to considerable amounts of bubbling. This bubbling occurred in both airblasted and hot-airblasted test sections and was believed to have been the result of capillary moisture emanating from saturated base layers. It was observed more in the uncut crack sections where the cleaning/drying operation was less effective because of the small crack channels. In order to minimize the bubbling, airblasting operators were instructed to be more meticulous in drying the cracks. Roughly 15 to 20 minutes of curing time typically was needed for the Hi-Spec.

Modified Rubberized Asphalt

The three modified rubberized asphalt products (Crafco RS 515, Koch 9030, and Meadows XLM) were placed at each site using identical configurations and crack preparation procedures. Final crack preparation was accomplished using the heat lance, and configurations B, C, and D were employed, although not at every site.

Sealants RS 515 and 9030 came packaged in boxes, each containing two 11.3-kg blocks. Meadows XLM, on the other hand, came packaged in pails containing one 19.1-kg block, which made loading more difficult. Recommended heating temperatures for these products ranged from 177°C to 188°C for XLM and 193°C to 204°C for RS 515. While these heating temperatures were similar to these required for Hi-Spec, the softer asphalt bases necessitated closer temperature monitoring.

Heating problems for these products generally were avoided. The only severe overheating that occurred in the experiment took place at Abilene, where XLM was inadvertently heated to temperatures exceeding 204°C. Unfortunately, additional material was not available to replace the overheated batch. Although some gelling was noted, it was not significant. Most noticeable was the appearance of microbubbles in this sealant during placement.

As with Hi-Spec, some of these sealants experienced substantial bubbling during installation. At Elma, XLM and 9030 sustained considerable bubbling, and at Wichita, RS 515 bubbled. In each case, the exposed crack channels were dry; however, base layers were at least partially saturated, which is a condition conducive to capillary action.

Overall, application and finishing of these materials were quite similar. Occasionally, the viscosity of the products and the size of the crack reservoirs necessitated immediate reapplications. In these instances, sealant from the original application sank deep into the crack and left insufficient material at the surface to form the desired configuration.

Figure 10. Hi-Spec reservoir-and-flush configuration (configuration A).

Figure 11. Hi-Spec simple band-aid configuration (configuration D).

Although traffic control was normally maintained for at least 30 to 60 minutes after each test section installation, these sealants usually cured 15 to 20 minutes after placement.

Fiberized Asphalt

Two types of fiber materials were installed in this experiment: Kapejo polyester fibers (BoniFibers) and Hercules polypropylene fibers (Fiber Pave 3010). Both were mixed with asphalt cement obtained from a local distributor. The blend of polyester fibers and AC-20 was placed at the five transverse crack-seal sites, while the blend of polypropylene fibers and 85-100 penetration-graded AC was placed at the longitudinal crack-fill site.

Polyester fiber came packaged in 9.1-kg bags, three per box. The fiber was pre-weighed (5 percent by weight of asphalt) at the maintenance yards and added on site to the asphalt cement, which was kept heated in the kettles (see figure 12). The entire process of adding the fibers, thoroughly mixing the components, and heating to the application temperature usually took between 1 and 2 hours, depending on the melter unit agitation system. Units with full-sweep agitation capabilities greatly expedited preparation.

The placement of BoniFiberized asphalt was standard at each test site. Final crack preparation was accomplished using the heat lance and the product was placed in the simple band-aid configuration. Application from some kettle units was occasionally difficult. For example, the unit used at Elma had poor pumping capabilities, and when the material temperature was not properly maintained, the hose clogged. This occurred twice; both times a torch was required to unclog the hose.

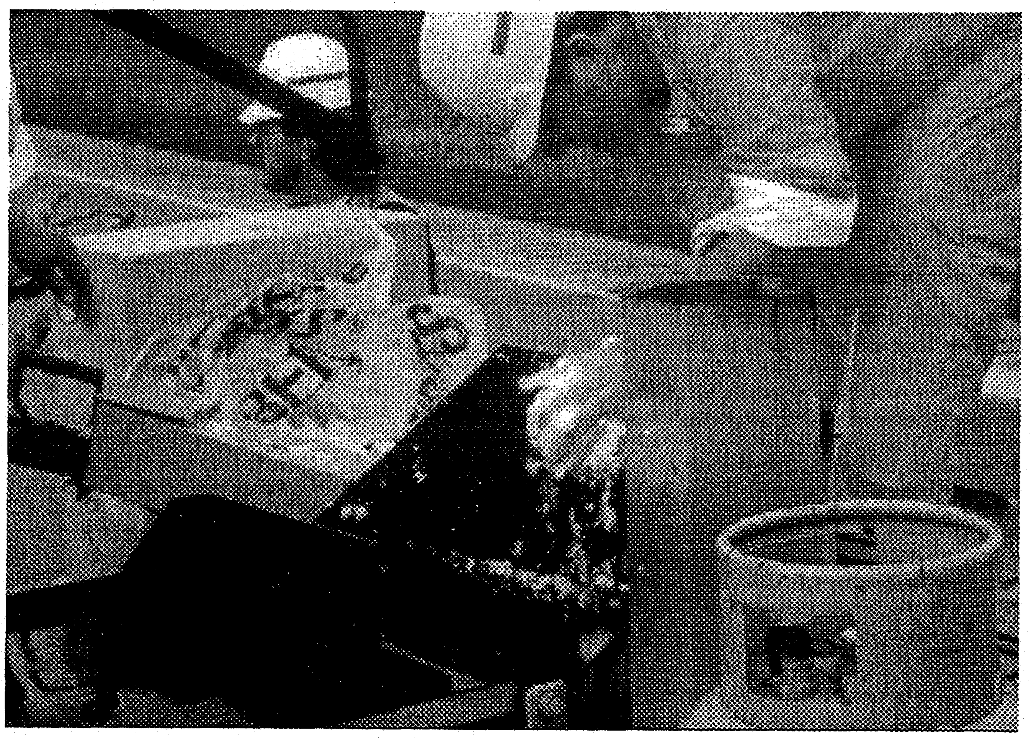


Figure 12. Addition of BoniFiber polyester fibers to asphalt cement.

Curing time, with respect to all the other experimental materials, was perhaps lowest with this product because of the lower application temperature. Although traffic control was generally maintained for at least 30 to 60 minutes after placement, only 10 to 15 minutes were actually necessary.

As for construction deficiencies associated with this product, considerable bubbling did occur at the Elma and Wichita test sites. Again, water in the pavement system was believed to have caused most, if not all, of the bubbling.

Fiber Pave came packaged in 16.3-kg bags. As before, the fiber was pre-weighed (7 percent by weight of asphalt) at the maintenance yard and then added to the asphalt cement on site. Although AC-20 was originally planned, a softer asphalt (85-100 penetration-graded asphalt cement) was used because of the climate.

Two replicate sections of Fiber Pave asphalt were constructed at the Prescott site. In both sections, cracks were blown clean using compressed air, and the fiberized asphalt was placed in the simple band-aid configuration.

The sensitivity of the Fiber Pave polypropylene fibers created some interesting problems during preparation. Since this particular type of fiber melts at temperatures above 150°C, the asphalt cement had to be kept below this temperature throughout preparation and application. This was a difficult task, given that the kettle used did not have a full-sweep agitation system or adequate pumping capabilities. In fact, in the first attempt to mix the fibers with the asphalt, the asphalt was heated above 150°C to foster the mixing process. This, of course, melted the fibers and the batch had to be discarded.

Preparation of the second batch was controlled more carefully. While it took significantly longer to mix (2 to 3 hours), a satisfactory product was obtained. The subsequent application also was successful, despite the strain placed on the kettle unit's pump.

Self-Leveling Silicone

Dow Corning 890-SL self-leveling silicone was placed in two replicate test sections at each transverse crack-seal site. Once the experimental cracks were cut, the standard installation sequence consisted of:

1. Light sandblasting of the crack reservoirs.
2. Airblasting with compressed air.
3. Placement of backer rod at a nominal depth of 16 mm.
4. Installation of sealant, recessed 6 mm below the pavement surface.

The backer rod used in the experiment was 22-mm-diameter closed-cell Sof® Rod. A roller-type insertion tool was used to install the backer rod below the pavement surface. Figure 13 shows backer rod installation.

Figure 13. Backer rod installation.

Because of the small amount of material required for the experiment, 857-mL cartridges of 890-SL were purchased instead of the 151-L drums typically used in sealing projects. Both manual and air-powered caulking guns were used to dispense the silicone into the cracks. Figure 14 shows the in-place, recessed silicone.

Because of the unfamiliarity associated with installing 890-SL, a few construction mistakes occurred at the initial installation at Abilene. First, a few segments of sealant were placed too high (≤ 3-mm recess), which often enabled vehicle tires to pull the material out during the curing process. A 6-mm recess was used at the remaining test sites.

Second, several seals became contaminated with sand particles because the sand from the sandblasting operation had not been blown completely off the roadway and shoulder. Measures were taken at the other sites to prevent this from happening.

As mentioned previously, the standard 890-SL installation method (E-5) was replaced at the Wichita adverse-conditions subsite by two different methods (E-6 and F-7). In one section, method E-6 was used. This involved the elimination of light sandblasting, leaving only conventional airblasting for crack cleaning. This time-saving method was included to evaluate its cost-effectiveness. In the second section, method F-7 was employed. Here, a more shallow cut (13 mm deep) was made and the reservoir was sandblasted and airblasted. Backer tape was then placed at the reservoir bottom instead of using backer rod. Because of the irregularity of the crack reservoir, it was more difficult to place the tape than to use backer rod.

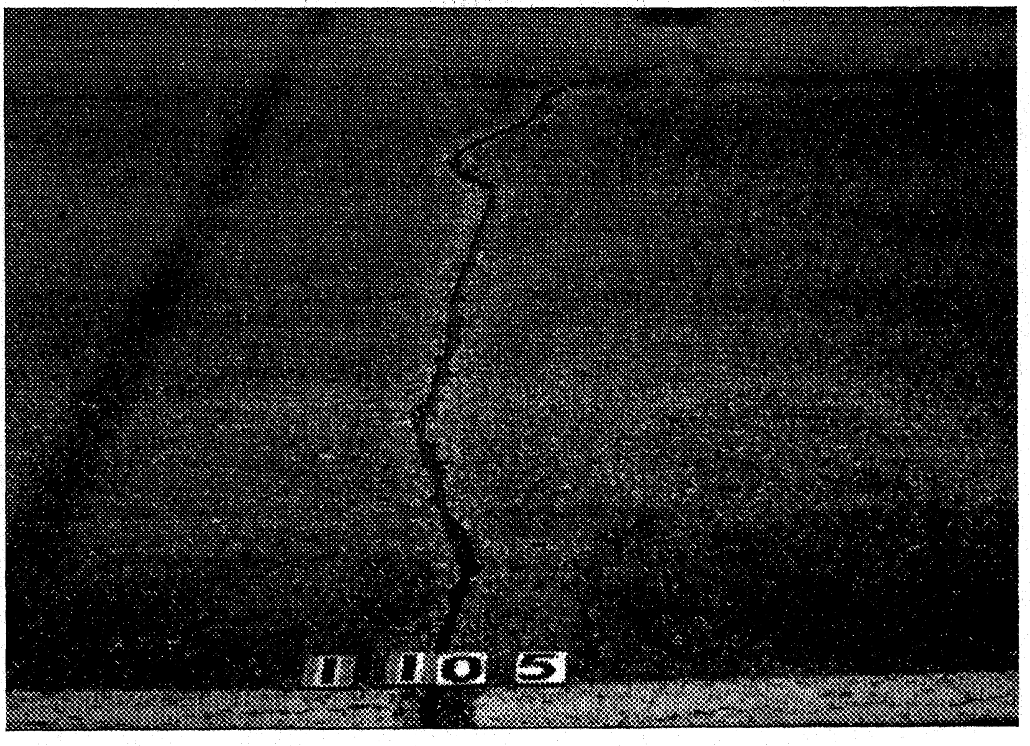


Figure 14. 890-SL deep reservoir-and-recess configuration (configuration E).

Asphalt Rubber

The asphalt rubber product Crafco AR2 was placed as a filler material at the Prescott test site. Consisting of a selected blend of asphalt cement and vulcanized, granulated crumb rubber, this product came packaged in boxes containing two 11.3-kg blocks of material. The recommended heating temperatures range from 177°C to 200°C.

The installation of AR2 took place without any construction problems. Crack preparation in all four AR2 sections was accomplished by conventional airblasting. The product was placed in the flush-fill configuration in two sections and in the simple band-aid format in the other two sections. Since most segments of the longitudinal crack were fairly wide (> 6 mm), the crack usually was filled from the bottom up, overfilled, and then struck off with the appropriate squeegee. The high rubber content associated with AR2 resulted in a viscosity that resembled fiberized asphalt more than rubberized asphalt. However, it was easier to squeegee this material than fiberized asphalt.

Emulsion

Witco CRF was another filler material installed at Prescott. This proprietary (modified) emulsion was supplied in 208-L drums and required no heating. The drum was loaded on the tailgate of a pickup truck, and was rolled and rotated end-over-end a few times to disperse asphalt particles that might have settled to the bottom during storage.

Two replicate sections of CRF were installed in the experiment. In these sections, crack cleaning was accomplished by conventional airblasting, hand-held pour pots were used to place the emulsion into the cracks, and a flush squeegee was used to strike off excess material. Figure 15 shows the placement of CRF in the flush-fill configuration.

Two basic problems were experienced with the installation of CRF. First, throughout the test sections, a few short segments of deep, wide cracks permitted the highly liquid emulsion to run down into the pavement base, necessitating repeated applications to successfully fill the segments. Although the manufacturer's recommendations suggested the placement of sand at the bottom of deep, wide cracks to serve as a barrier, such action was not taken in this case because of the small number of sizable cracks.

Second, although lane closures were maintained for a few hours after placement, CRF tracked heavily when exposed to traffic. The emulsion typically "broke" within 30 minutes after application, and had formed a skin prior to the lane opening. Obviously, however, traffic was able to dislodge a good portion of the material from the crack. In this case, sand should have been used as a blotter to prevent tracking.

Equipment

Equipment played a crucial role in the experimental installations. Most participating agencies either possessed or could readily obtain the equipment necessary for getting the job done. However, a few special arrangements for equipment had to be made by the project staff prior to the installations. These arrangements included the following:

Figure 15. Placement of CRF in flush-fill configuration (configuration G).

- Crafco Model 200 rotary-impact router (and operator) for use in Abilene.
- L.A. Manufacturing Model "C" hot compressed-air lance for primary use in Abilene and backup use in Wichita and Des Moines.
- Cimline Model 200 melter-applicator specially adjusted for use with fiberized asphalt application at Wichita and Des Moines.

With the exception of configurations A and B at the two Wichita subsites, rotary-impact routers manufactured by Crafco were used to create reservoirs for the hot-applied materials at each crack-seal site. Pressed with a considerable amount of crack cutting and only one available router, it was decided at Wichita that two Cimline random crack saws, equipped with 203-mm diamond blades, would be used to facilitate the cutting operations. These saws were not quite as productive as the routers, but they provided smoother reservoir sidewalls, the effect of which will be assessed in future analyses. Figures 16 and 17 show the rotary-impact router and diamond blade dry saw used at the two Wichita subsites.

Although dry sawing was originally proposed for crack cutting in all the Dow Corning 890-SL sections, rotary-impact routers ultimately had to be used at Abilene and Elma. Maintenance crews at both of these sites made initial attempts to saw the cracks using 356-mm-diameter saws. However, the saws could not follow the cracks effectively and consequently caused significant damage. Because of this, the remaining cracks were cut with routers.

Various air compressors, made by Ingersoll Rand, Joy, Sullair, and Worthington, were used in the experiment. All of the air compressors used in the crack-seal installations were capable of providing 689 kPa of airblast. However, some of the units were not equipped with oil- and moisture-filtering systems. While oil contamination was not detected in these units, moisture was observed occasionally and confirmed by holding a white cloth over the wand during operation. Such moisture was a cause for concern when airblasting was used to clean cracks immediately prior to installation.

Heat lances from three different manufacturers were used for final crack preparation: the L.A. Manufacturing model C, the Cimline Hot Rod, and the Seal-All Torch. Although each brand was very effective at removing debris and drying moisture, two general observations were noted. First, the push-button ignition switches furnished on some units often did not work and alternative lighting sources had to be used. Second, the units having high blast and heat capabilities (915 m/s and 1650°C) were noticeably more efficient, but required extra caution to avoid burning the AC. Figure 18 shows one of the heat lances used at Abilene.

Most sandblasting operations were conducted using Clemco blast machines connected to portable air compressors. Typically, one pass was made with the sandblaster along each side of a crack reservoir. A short time later, the reservoir and adjacent roadway were cleaned by airblasting. Sandblasting wands were held approximately 100 to 200 mm from the reservoir. At Wichita, a wooden rod was attached to the wand to help direct the blast against the crack sidewalls (figure 19).

Figure 16. Carbide-tipped rotary-impact router.

Figure 17. Random crack saw with 200-mm diamond blade.

Figure 18. Hot airblasting using hot compressed-air (HCA) lance (crack preparation procedure 3).

Figure 19. Light sandblasting using wand with attached wooden guide (crack preparation procedure 5).

For the wirebrush-airblast cleaning procedure specified at Des Moines, a commercial power-driven brush was not available. As a substitute, a random crack saw, specially equipped with a 200-mm wirebrush, was used. The wirebrush was somewhat stiff and had an occasional tendency to spall the crack-reservoir edges.

Many different kettle units, manufactured by Crafco, Cimline, Aeroil, and Marathon, were used for preparation and installation of hot-applied material. The kettles ranged widely in age, vat size, and heating and application features. In most instances, the materials took between 1.5 and 3 hours to heat to application temperatures. Heating time depended primarily on the kettle size and the amount of material loaded into the vat. The 757-L melters usually required 1.5 to 2 hours, whereas the 1515- and 1890-L melters needed up to 3 hours.

Two additional factors that influenced heating time were the size of the material blocks and the type of agitation system on the kettle unit. Smaller blocks and full-sweep agitators provided greater exposure to heat, decreasing the amount of time needed for heating.

Two types of squeegees were fabricated by the project staff for the experiment: flush squeegees and band-aid squeegees. Both were prepared by forming 360-mm straight industrial squeegees into a "U" configuration. The rubber inserts were removed beforehand and then reattached. A special cut (65 to 75 mm wide by 3 to 4 mm deep) was made in the rubber insert of the band-aid squeegee while the rubber insert of the flush squeegee was left flat.

Documentation

In addition to laying out the test site and coordinating the installations, project staff were charged with collecting as much pertinent information about the test site installations as possible. To simplify this task, eight different documentation forms were developed prior to the installations as part of the *EDRP* (Evans et al., 1991). Many items were documented in these forms during the field installations, including:

- Climatic conditions.
- P-K nail measurements.
- Periodic hot-applied material temperatures.
- Crack conditions at placement.
- In-place sealant dimensions.
- Equipment brands and features.
- Production rates.
- Labor requirements.

Appendix B includes a detailed discussion of the types of installation data collected and shows completed samples of the eight documentation forms used.

Photographic prints and slides were another form of documentation. Pictures of representative cracks in each test section were taken to help illustrate the condition of the cracks before, during, and after the installation process.

Cost and Productivity Data

Material Cost Data

The quantities of each primary material needed for the experiment were estimated prior to purchase. Estimates for each material were developed by summing the individual volumes associated with each proposed configuration and multiplying that sum by a wastage factor (usually 10 percent) and the material's unit weight. In every case, more than enough material was ordered.

Treatment application cost is an important factor in assessing overall cost-effectiveness. It is determined by multiplying the application rate (kilograms per linear meter of crack) by the total material cost (i.e., purchasing and shipping costs) on a per kilogram basis. Since the actual application rates for each treatment during installation were unobtainable, tables 5 and 6 have been prepared as a resource for estimation of application rates and costs.

In table 5, the volume (per linear meter of crack) associated with each configuration has been computed, based on the nominal crack channel and overband dimensions listed. In table 6, the typical purchasing cost (January/February 1991) and typical unit weight for each material are provided. (Material shipping costs are not included because of the unavailability of some cost data and wide variations in the data obtained.) Application rates and application costs for each primary treatment were calculated based on the configuration volumes in table 5 and the material unit weights and costs in table 6.

Table 5. Estimated volumes for primary material configurations.

Configuration	Channel Dimensions, mm[a]	Overband Dimensions, mm[b]	Total Cross-Sectional Area, mm^2	Volume (per linear meter of crack), m^3/lin m	Volume, with 10 percent wastage, m^3/lin m
A	16 x 19	-	304	3.04×10^{-4}	3.34×10^{-4}
B	16 x 19	76 x 3.2	547	5.47×10^{-4}	6.02×10^{-4}
C	38 x 5	76 x 3.2	433	4.33×10^{-4}	4.76×10^{-4}
D	3 x 25	76 x 3.2	318	3.18×10^{-4}	3.50×10^{-4}
D[c]	4.5 x 38	76 x 3.2	414	4.14×10^{-4}	4.55×10^{-4}
E & F	16 x 9.5	-	152	1.52×10^{-4}	1.67×10^{-4}
G[c]	4.5 x 38	-	171	1.71×10^{-4}	1.88×10^{-4}

[a] Channel dimensions - nominal dimensions of material placed below pavement surface.
[b] Overband dimensions - nominal dimensions of material placed above pavement surface.
[c] Crack-fill configurations.

Table 6. Primary material costs and estimated application rates and costs.

Material	Material Cost, $/kg	Material Unit Weight, kg/m³	Estimated Application Rates for Primary Configurations, kg/lin m of crack						Estimated Application Costs for Primary Configurations, $/lin m of crack					
			A	B	C	D	E & F	G	A	B	C	D	E & F	G
Meadows Hi-Spec	0.64	1,110.4	0.371	0.668	0.529	0.389			0.24	0.43	0.34	0.25		
Crafco RS 515	0.90	1,155.2		0.695	0.550	0.404				0.63	0.50	0.36		
Koch 9030	0.77	1,099.2		0.662	0.523	0.385				0.51	0.40	0.30		
Meadows XLM	1.32	971.2		0.585	0.462	0.340				0.77	0.61	0.45		
Kapejo BoniFibers + AC	≈0.44[a] (≈2.75)[b]	1,054.4				0.369						0.16		
Dow Corning 890-SL	≈6.61	1,297.6					0.217						1.43 + 0.25	
AET Sof Rod (22 mm)	$0.245/lin m	—												
Asphalt Cement	≈0.26	1,003.2						0.189						0.05
Witco CRF	0.44[c]	988.8						0.186						0.08
Crafco AR2	0.62	1,057.6				0.481		0.199				0.30		0.12
Hercules Fiber Pave + AC	≈0.53[a] (≈3.39)[b]	1,073.6				0.488						0.26		

[a] Cost of fibers and AC combined.
[b] Cost of fibers only.
[c] Estimated cost.
NA=Not available.

Productivity

While the various operational procedures have been described throughout this section, two key aspects of these procedures have yet to be discussed. Productivity and labor requirements associated with sealing and filling operations are perhaps the most important factors because they influence treatment performance and account for roughly 80 percent of the cost, depending on the size of the project. Table 7 shows a summary of the typical labor, equipment, and time requirements for the various operations performed in the crack treatment experiment.

Crack cutting typically was a one- or two-person operation, depending on the type of equipment used. For sawing operations, a spotter often was needed to help the saw operator maneuver the machine in difficult situations. Between 1 and 3 minutes per 3.66-m crack was typical for routing operations, whereas 2 to 5 minutes was the normal range for sawing operations. Obviously, crack spacing had an effect on production rate, but other factors did too; reservoir dimensions, pavement temperature, the type of aggregate in the AC, and the level of wear on the cutting blades all seemed to affect the speed of the operations. Crack cutting was the limiting operation in the initial crack preparation phase.

Table 7 shows that sandblasting was the most labor-intensive and time-consuming crack-cleaning operation. Three, or sometimes four, persons were necessary for performing this task; airblasting and hot airblasting operations required two persons.

The installation of cold-applied materials generally required more labor and time than the installation of hot-applied materials. This was especially true of the installation of emulsions, where two pour pots were needed to expedite the operation. Silicone installation would have gone much more quickly had 151-L drums and appropriate pumps been used. The 857-mL silicone cartridges had to be replaced continually, as two cartridges would seal only about three cracks.

In most instances, material application was the constraining operation in the final crack preparation and material installation phases. Cleaning operations often were held back to allow for optimum material placement, while squeegeeing often was held up by material application.

Comments

To help ensure the proper installation of the sealant and filler products, material manufacturers were asked to provide a representative at the installations. However, the initial contacts were not made in time to permit the presence of representatives at the first installation at Abilene. Their guidance would have been beneficial at this site. Representatives usually were present at the other sites. However, in some cases, the manufacturers could not find or afford to send representatives to observe the installations.

Table 7. Typical requirements for various installation procedures.

Procedure	Required Labor (Number of Persons)	Required Equipment	Estimated Time for Ten 3.66-m Transverse Cracks, min[a]		Estimated Time for 91-m Stretch of Longitudinal Cracks, min[a]
			15-m Spacing	30-m Spacing	
Crack Cutting					
Routing	1	Carbide-tipped rotary-impact router	20 to 25	20 to 30	—
Sawing	2	Diamond blade dry saw	30 to 40	50 to 60	—
Crack Cleaning					
Airblasting	2	Air compressor, truck	12 to 18	15 to 20	10 to 15
Hot Airblasting	2	Hot compressed-air lance, air compressor, propane tank, truck	20 to 25	20 to 30	—
Sandblasting	2 to 3	Sandblaster, air compressor, truck	30 to 35	45 to 55	—
Wire Brushing	1	Wire brush unit or equivalent	NA	30 to 40	—
Hot-Applied Sealant Installation					
Material Application	2	Approved melter/applicator, truck	15 to 20[b]	25 to 30[b]	10 to 15[b]
Material Finishing	1	Squeegee	15 to 20	25 to 35	10 to 15
Silicone Sealant Installation					
Backer Rod Placement	1 to 2	Properly adjusted roller tool	12 to 18	20 to 25	—
Silicone Placement	2	Manual or air-powered caulking gun	35 to 45[b]	50 to 65	—
Emulsion Installation					
Emulsion Placement	2 to 3	Cornucopia pot(s), truck	—	—	20 to 30[b]
Material Finishing	1	Squeegee	—	—	20 to 30

[a] Times do not include operational delays.
[b] Constraining operation.
NA=Not available.

The *EDRP* specified the use of rotary-impact routers for crack-cutting in hot-applied material sections (Evans et al., 1991). Diamond-blade dry saws were required for crack-cutting in the silicone sections. However, as discussed previously, rotary-impact routers were used in the silicone sections at Abilene and Elma, and diamond-blade dry saws frequently were used in place of routers at Wichita. The stipulations in the *EDRP* were intended to allow for stronger performance correlations between test sites.

Because the effects of sealing conditions on performance were intended to be among the factors studied in this project, the ideal- and adverse-condition subsites were included at Wichita. However, some of the test sections at Elma and the ideal subsite at Wichita could have been classified as adverse condition, because the pavement systems were partially saturated during placement as a result of particularly wet weather at these locations (Elma receives roughly 2,160 mm of rain per year). Consequently, the presence of moisture in cracks was checked often and recorded prior to installation. Similarly, the formation of bubbles in hot-applied materials after placement was frequently monitored and documented.

CHAPTER 3. MATERIAL TESTING

Laboratory Tests Performed

Two sets of laboratory tests were conducted on the primary experimental materials: initial tests and supplemental performance tests. Initial tests ensured that the materials used in the experiment met the specifications maintained by the manufacturer. Supplemental performance tests were intended to strengthen correlations between laboratory-determined engineering properties and actual field performance.

In all, 9 of the 10 primary material products used in the experiment underwent laboratory testing. Each of the six primary sealant products distributed to the various sites for installation originated from one production batch. For instance, the Hi-Spec material placed at Abilene came from the same batch as the Hi-Spec placed at Elma, Wichita, and Des Moines. Samples of the six primary sealant materials and three primary filler materials were taken during installation from the Abilene and Prescott sites, respectively, and shipped to the laboratories for testing.

Several of the initial tests, particularly those run on the silicone and rubber-modified asphalt materials, were performance tests. These included ASTM D 3407 bond, resilience, penetration, and flow tests, as well as ASTM D 412 tensile stress and elongation tests. The remaining initial tests were general property-indicator tests. These included such tests as specific gravity, tack-free time (silicone), viscosity (CRF emulsion), and denier (fiber). The test procedures followed for each material product are listed in table 8.

The battery of supplemental performance tests was assembled to investigate major performance properties such as flexibility, adhesiveness, cohesiveness, resilience, and durability. At least one innovative or standard test was selected to correspond with each of these important properties. Most of the tests originally identified were performed successfully with few or no modifications. There were, however, a couple of tests that could not be conducted because of procedural or equipment problems. Table 9 lists the original battery of tests, the properties sought, and general comments about the conduct of each test.

Test Results

In all, 38 tests were attempted, of which 36 were completed successfully. Generally, two or three replicates of each test were performed to provide more reliable results. The averages of these replicates were used in the analyses. With one exception, all nine material products tested passed the various initial test requirements. The one material that did not pass, Meadows XLM, failed only to meet the resilience specification of 35 percent recovery, as shown in table 10.

Looking at the initial test results for the four rubber-modified sealants, it is interesting to note the differences in softness (cone penetration test at 25°C) and resilience. By far the softest material, XLM exhibited poor resilience (16 percent recovery), seemingly making it susceptible

Table 8. Designated initial test procedures.

Material Type	Test Procedures
Rubberized Asphalt	ASTM D 3407 and D 70
Modified Rubberized Asphalt	Modified ASTM D 3407 and D 70
Silicone	ASTM C 603, C 679, D 412, D 1475, and D 2240
Asphalt Rubber	ASTM D 5078 and D 70
Fiber	ASTM D 1577, D 3937, D 2256, and D 882
Emulsion	ASTM D 244

Table 9. Target properties and modifications of supplemental performance tests.

Test	Derived Procedure	Pertinent Property(s)	General Comments
Cone Penetration @ -18°C	ASTM D 3407	Low-temperature flexibility	Conducted @ -18°C
Softening Point	ASTM D 36	High-temperature tracking potential	None
Cold Bend	Utah Test	Cohesion	Conducted @ -18°C
Force Ductility	ASTM D 113 & Utah Test	Flexibility	Ductility test run @ 4°C
Tensile Adhesion @ 24°C 1. PCC blocks 2. AC blocks 3. AC blocks, H_2O-immersed	ASTM D 3583	Adhesion/cohesion	Standard test run using PCC blocks. Alternative tests run using AC blocks (water-soaked and unsoaked)
Modulus @ 1. 24°C 2. 4°C 3. -18°C	ASTM D 412	Flexibility	Conducted at separation rate of 51 mm/min instead of 508 mm/min. Tests initially set up for -18°C, 24°C, and 60°C. Latter temperature changed to 4°C due to extreme material softness at 60°C.
Modulus after 504 hours artificial weathering	ASTM G 23 & ASTM D 412	Durability/flexibility	Performed @ 24°C only on silicone; rubber-modified asphalt sealant samples ran during hot cycles of weathering phase.
Track Abrasion	ASTM D 3910	Durability	Test discontinued due to shearing and pull-up problems.
Modified Bond Tests 1. Reservoir configuration 2. Recessed band-aid configuration 3. Simple band-aid configuration	ASTM D 3407	Adhesion/cohesion	PCC blocks and sealant material formed to required configuration. Samples subjected to 10 cycles of 100% extension @ -29°C and recompression to original width at room temperature.

Table 10. Initial test results for rubberized asphalt products and corresponding requirements.

Test	D 3405 Criteria	Hi-Spec	Modified ASTM D 3405 Criteria	RS 515	9030	XLM
Cone Penetration, dmm (25°C)	≤ 90	62.5	60 to 180	75.5	114.5	148.0
Flow, mm (25°C)	≤ 3	0.0	≤ 5	1.0	0.0	2.5
Bond, 50% extension (-29°C)	3 cycles	Pass				
Bond, 100% extension (-29°C)			3 cycles	Pass	Pass	Pass
Resilience, % recovery (25°C)	≥ 60	63.7	≥ 35	38.3	83.7	16.0
Asphalt Compatibility	No failure	Pass	No failure	Pass	Pass	Pass

to stone intrusion. The second-softest sealant, 9030, showed the best resilience with 84 percent recovery. Hi-Spec and RS 515 showed similar degrees of softness, but RS 515 was much lower in resilience than Hi-Spec (38 and 64 percent recovery, respectively).

Table 11 presents mean results for some of the more meaningful test parameters in the supplemental performance test program. Considered to be a good cold weather performance indicator, cone penetration at -18°C was performed on all of the primary materials except silicone and asphalt cement. In comparing penetration at 25°C with penetration at -18°C for the four rubber-modified sealants, 9030 exhibited the smallest percentage of drop (47 percent), followed by XLM (60 percent), RS 515 (64 percent), and Hi-Spec (76 percent). Both fiberized asphalt materials completely resisted penetration at -18°C, indicating highly inflexible materials at low temperatures.

As expected, softening points for the rubber-modified materials were sufficiently high (>71°C) to prevent tracking problems in the summer. CRF and the two fiberized asphalt materials, however, exhibited low softening points (<52°C). This is an important observation, especially for the fiberized asphalt materials that were placed in the simple band-aid configuration.

In the cold-bend test, 3-mm x 25-mm x 25-mm material samples were bent to a 90° angle over a 29-mm mandrel in a period of 2 seconds. The samples and mandrel were conditioned to -18°C. None of the four rubberized asphalt sealants developed cracks, thereby passing the test.

The force-ductility test, a modified version of the ASTM D 113 ductility test, was conducted at 4°C. In the test, briquette material specimens were pulled apart at a rate of 10 mm/min until ultimate rupture. Load-deformation plots were generated from each run. Results from the test showed XLM incurred the lowest buildup of force through 150 percent elongation, followed by RS 515, 9030, AR2, Hi-Spec, and the two fiberized materials (see figure 20).

Table 11. Supplemental test matrix for primary treatment materials.

Test Procedure	Test Description	Meadows Hi-Spec	Crafco RS 515	Koch 9030	Meadows XLM	Kapejo Fiberized Asphalt	Dow Corning 890-SL	Witco CRF	Crafco AR2	Hercules Fiberized Asphalt
D 3407	Cone Penetration (-18°C), dmm	15	27	60	60	0		23	4	0
D 36	Softening Point, °C	86	99	93	89	50		26	72	51
Utah	Cold Bend (-18°C)	Pass	Pass	Pass	Pass					
D 113/Utah	Force Ductility (4°C) Max Elongation, mm	439	439	305	274	51			310	1,397
	Stress, kPa	14.5	7.6	9.6	2.1	120.6			13.1	51.0
D 3583	Tensile Adhesion (Std, 24°C) Max Elongation, %	704	515	441	547		606			
	Type of Failure	Adh	Adh	Adh	Adh		Adh/Coh			
	Tensile Adhesion (Modified #1, 24°C) Max Elongation, %	690	760	303	607		627			
	Type of Failure	Adh	Adh	Adh	Adh		Adh/Coh			
	Tensile Adhesion (Modified #2, 24°C) Max Elongation, %	683	680	336	539		486			
	Type of Failure	Adh	Adh	Adh	Adh		Adh			
D 412	Modulus Test (-18°C) Tensile Strength, kPa	421.0	456.1	113.0	102.7		310.7			
	Ultimate Elongation, %	425	868	1093	1035		4566			
	Stress @ 150% Elongation, kPa	318.3	261.1	50.3	29.6		64.8			
	Modulus Test (4°C) Tensile Strength, kPa	227.4	182.6	53.1	72.3					
	Ultimate Elongation, %	960	1255	620	960					
	Stress @ 150% Elongation, kPa	130.2	93.7	32.4	19.3					
	Modulus Test (24°C) Tensile Strength, kPa	73.0	53.1	59.3	33.1		301.8			
	Ultimate Elongation, %	863	910	832	915		2096			
	Stress @ 150% Elongation, kPa	48.9	26.2	31.7	13.8		75.8			
D 3407 Modified	Modified Bond #1 (25°C) % Debonding	1.2	0.2	0.0	0.0		0.0			
	Modified Bond #2 (25°C) % Debonding	0.5	5.2	6.3	0.0					
	Modified Bond #3 (25°C) % Debonding	0.7	2.9	0.7	0.0					

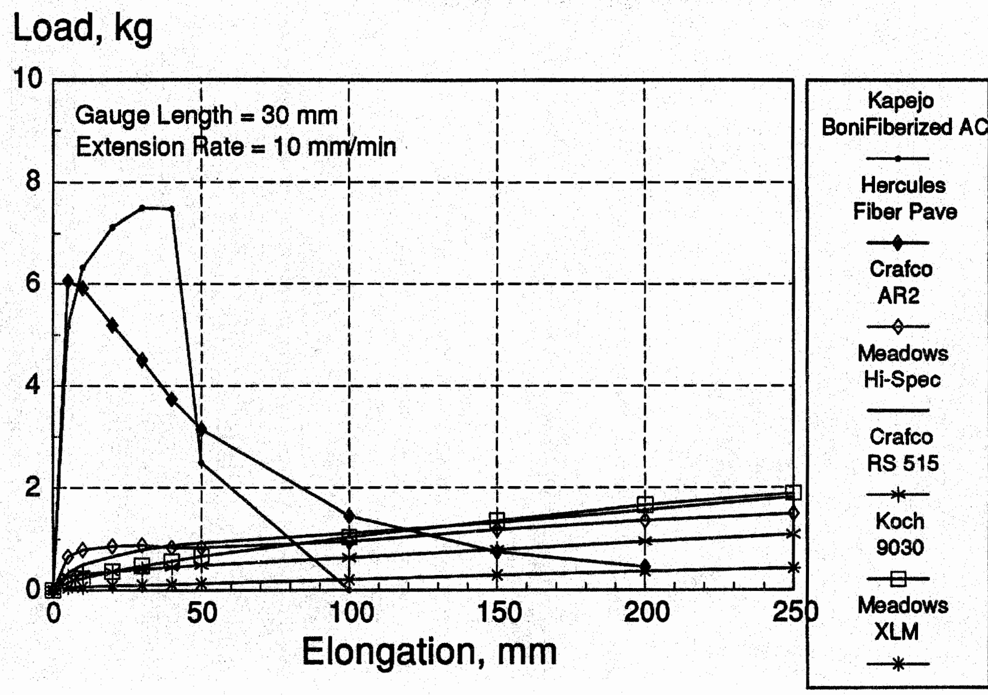


Figure 20. Force-ductility load-elongation curves for various primary materials.

In a similar test—the ASTM D 412 modulus test—dumbbell-shaped material samples were pulled apart at a rate of 51 mm/min until rupture (see figure 21). Results showed that XLM and 890-SL consistently developed the lowest forces at various temperatures, as illustrated in figures 22 through 24. At 23°C and 50 percent elongation, Hi-Spec exhibited forces four times those of XLM and 890-SL. For RS 515 and 9030, the factor was approximately two. At the more critical temperature of -18°C, the factors of force over 890-SL at 50 percent elongation were 14.8 for Hi-Spec, 12.6 for RS 515, 2.8 for 9030, and 1.6 for XLM.

Further examination of the force-elongation plots shows 890-SL was least affected by temperature. In going from 25°C to -18°C, 50 percent more force was required. This compares with 167 percent for XLM, 115 percent for 9030, 950 percent for RS 515, and 517 percent for Hi-Spec.

The tensile adhesion test, illustrated in figure 25, was conducted to provide an indication of a material's ability to extend without experiencing cohesion loss or adhesion loss. Three variations of the test were performed on each of the four rubberized asphalt sealants and the silicone sealant. The first variation used portland cement concrete blocks, and the second variation used asphalt concrete blocks. A third variation, also using asphalt concrete blocks, included a phase during which the sealant-block system was soaked in water prior to testing. In each variation, 13-mm x 51-mm x 51-mm material specimens were tested at 25°C using constant separation rates of 13 mm/min.

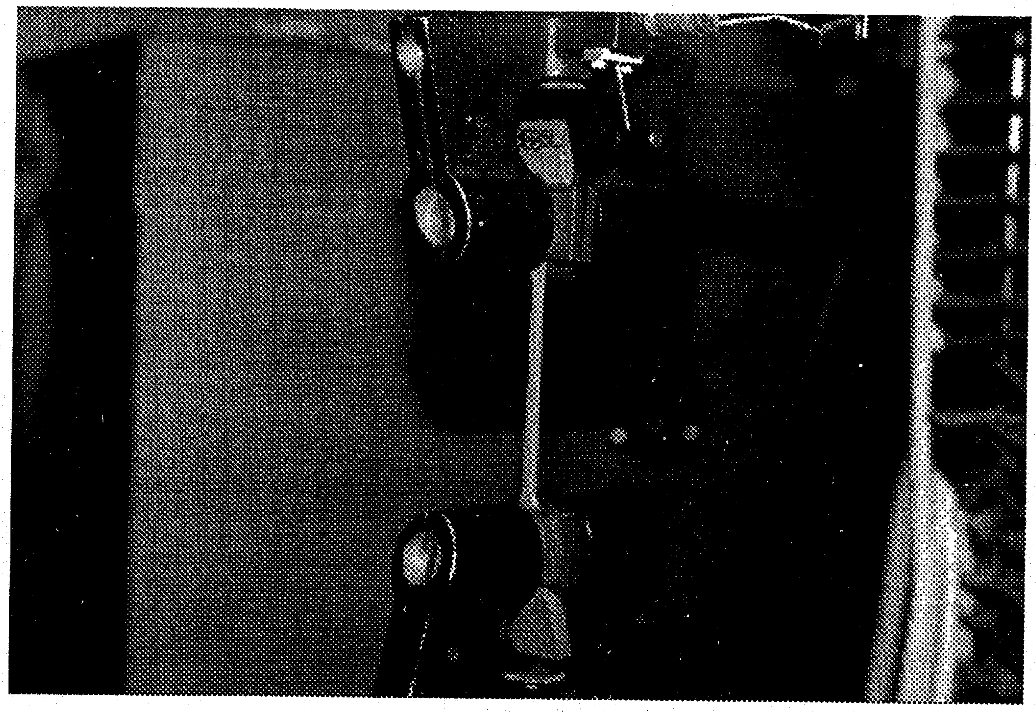


Figure 21. ASTM D 412 modulus testing.

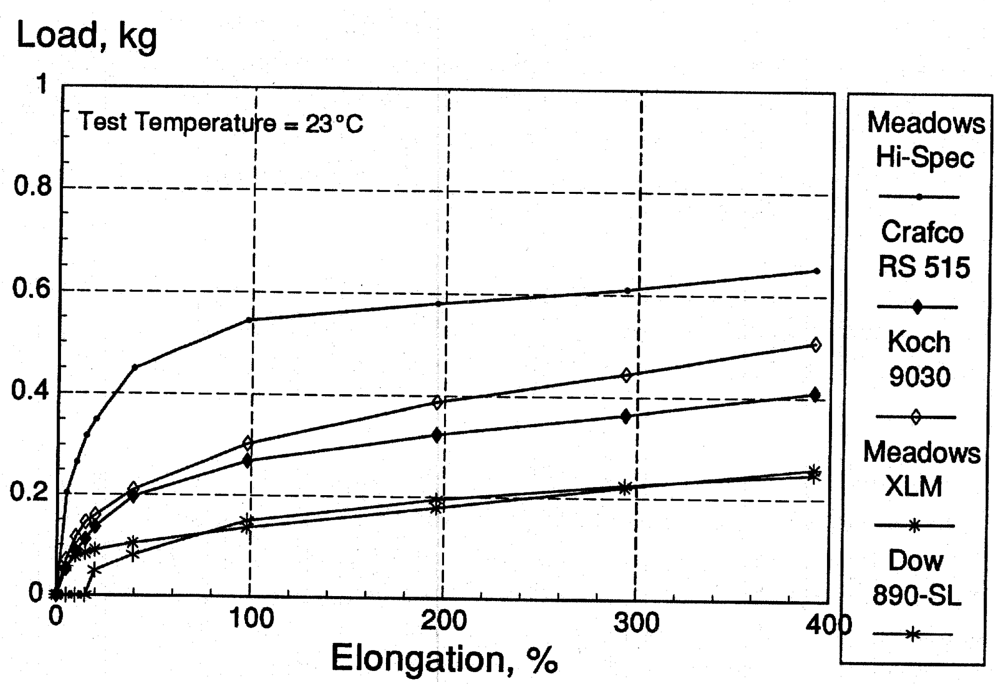


Figure 22. Load-elongation curves for modulus test conducted at 23°C.

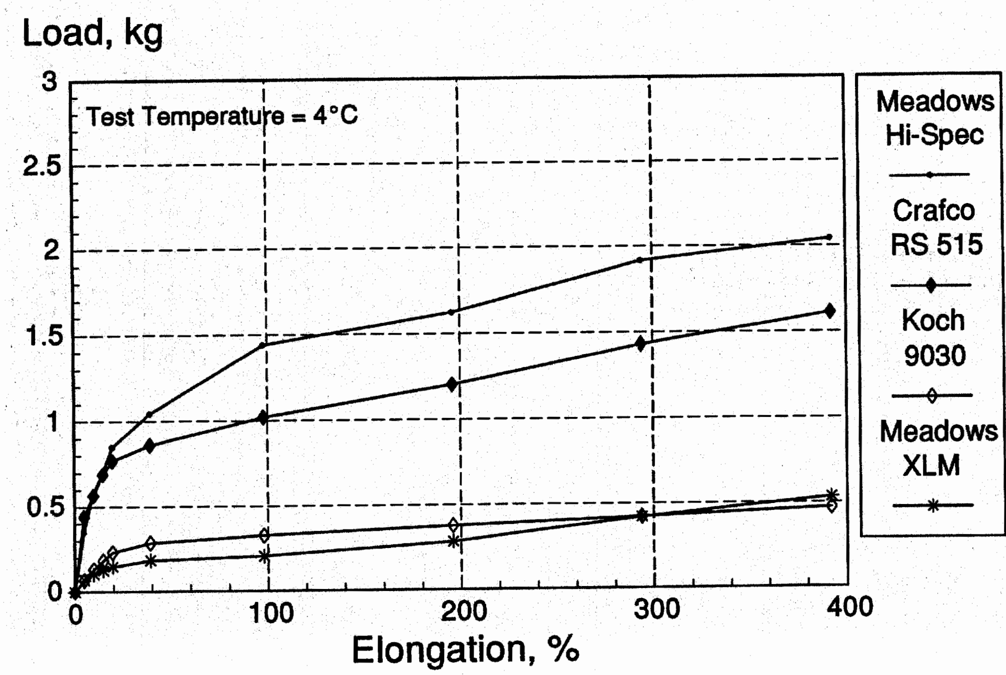


Figure 23. Load-elongation curves for modulus test conducted at 4°C.

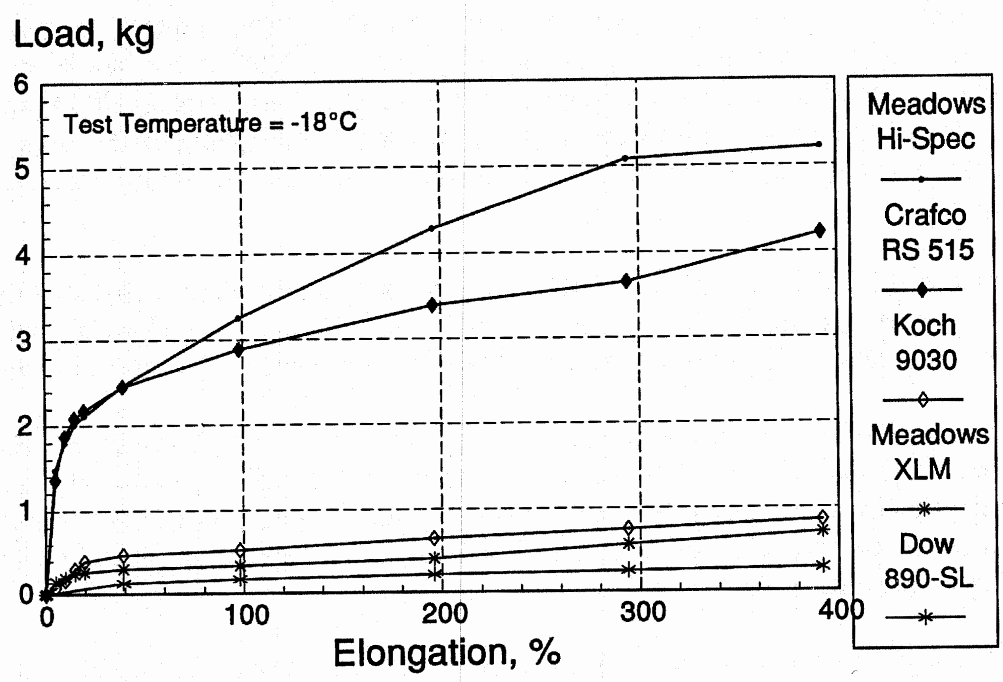


Figure 24. Load-elongation curves for modulus test conducted at -18°C.

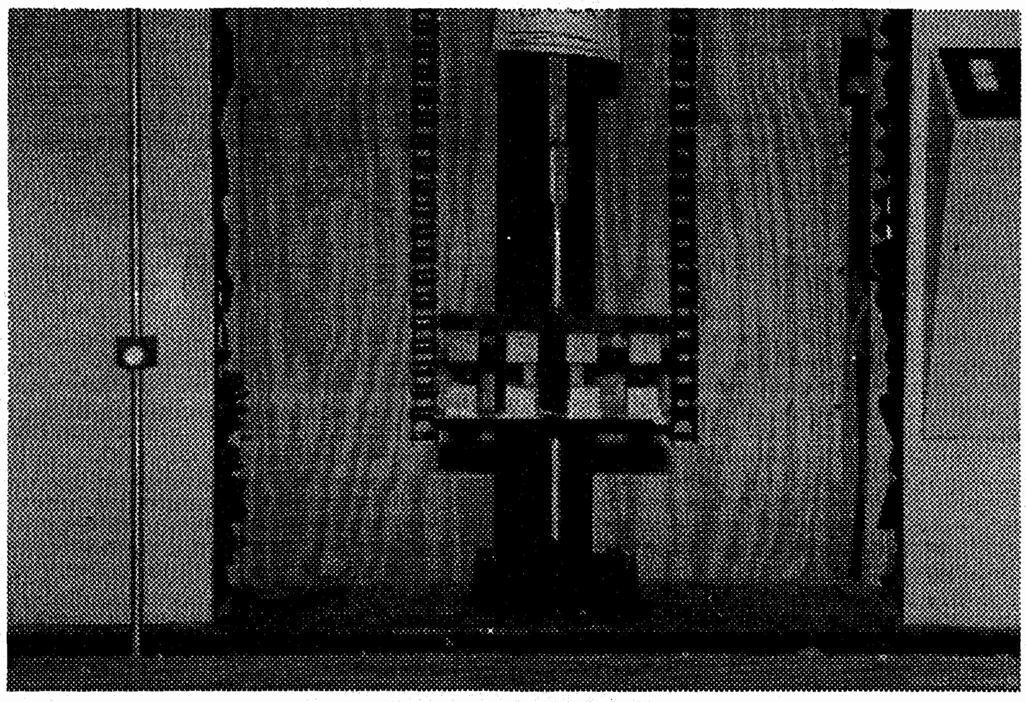


Figure 25. ASTM D 3583 tensile adhesion testing.

The tensile adhesion test results yielded a few interesting observations. First, the small material shape factor (width/depth = 0.25) associated with this test produced much higher extension loads than in other load-deformation tests. This effect was most apparent with 890-SL silicone. Second, water-immersed specimens normally incurred greater stresses during extension than non-immersed specimens. Likewise, specimens bonded to AC blocks normally incurred greater stresses than specimens bonded to PCC blocks. Finally, Koch 9030 exhibited adhesion failure at significantly lower deformations. Maximum elongations for Hi-Spec, RS 515, XLM, and 890-SL were between 57 and 92 percent greater than the maximum elongation exhibited by 9030.

Three modified bond tests (ASTM D 3407) were devised to test sealants placed in shapes representative of configurations B, D, and E used in the field. In each test, materials were subjected to 10 cycles of 100 percent extension at -29°C and recompression at room temperature.

XLM showed excellent performance in all three test formats, experiencing no adhesion or cohesion loss. Both 890-SL and 9030 also showed no losses when placed in the recessed format. With the exception of XLM, sealants placed in the recessed band-aid configuration became fully debonded at the bottom of the crack reservoir. The 9030 sealant exhibited the highest percentage of debonding in this format (6.3 percent).

A complete summary of initial and supplemental performance test results are provided in table C-3 of appendix C. In addition, figures C-1 through C-10 illustrate the various D 412 and D 3583 load-deformation curves for different sealants.

CHAPTER 4. FIELD PERFORMANCE

Introduction

As discussed in chapter 2, the experimental crack seal and crack fill materials were installed at five test sites throughout the United States and Canada in the spring and summer of 1991. With the exception of those installed at Elma, Washington and Prescott, Ontario, the treatments at each site were evaluated for field performance 10 times between the time of installation and February 1998. The Washington site was overlaid after approximately 4 years, thereby allowing only eight evaluations of that site and the Ontario site was resurfaced after approximately 5 years, thereby permitting 9 of the 10 scheduled inspections. Table 12 provides a complete listing of the test site inspections (by week) and the corresponding treatment ages.

The first evaluation was conducted with the intention of recording any construction-related failures or distresses. With the notable exceptions of 890-SL and XLM at Abilene, such observations were limited. As expected after installation, 890-SL had experienced some pull-out problems because of an inadequate recess, as well as considerable sand intrusion during the curing process. XLM, on the other hand, showed significant early overband wear as a result of overheating prior to placement.

The third evaluation at each site was conducted in January and February 1992 in order to determine the extent to which cracks were opening during the coldest time of the year. The ages of the crack fillers and sealants at that time were approximately 6 and 9 months, respectively. As a result of the combined action of crack movement and overband wear, significant increases in treatment failure were recorded during these evaluations.

Table 12. Summary of test site inspections and corresponding treatment ages.

Inspection No.	Planned Nominal Age, months	Abilene, TX		Elma, WA		Wichita, KS		Des Moines, IA		Prescott, ON	
		Week of Inspection	Age, months	Week of Inspection	Age, months	Week of Inspection	Age, months	Week of Inspection	Age, months	Week of Inspection	Age, months
Installation		3/20/91 - 3/27/91		4/22/91 - 4/27/91		4/10/91 - 5/2/91		5/30/91- 6/7/91		8/28/91 - 8/29/91	
1	1	5/5/91	2	5/19/91	1	6/9/91	2	6/30/91	1	10/6/91	1
2	3	6/23/91	3	7/21/91	3	7/21/91	3	9/8/91	3	12/8/91	3
3	9	1/5/92	10	1/26/92	9	2/9/92	10	2/9/92	8	2/23/92	6
4	12	3/8/92	12	5/17/92	13	4/26/92	12	5/10/92	11	6/21/92	10
5	18	9/27/92	18	10/4/92	18	10/18/92	18	10/25/92	17	11/8/92	15
6	30	12/5/93	33	11/28/93	31	11/14/93	31	10/31/93	29	10/24/93	26
7	42	10/30/94	44	12/4/94	44	10/9/94	42	10/9/94	40	10/23/94	38
8	54	12/11/95	57	4/3/95	48	11/28/95	55	11/30/95	53	10/25/95	50
9	66	12/8/96	69	—	—	12/8/96	68	2/20/97	69	11/17/96	63
10	78	2/11/98	82	—	—	10/27/97	79	10/13/97	77	—	—

The fifth round of evaluations, performed in the fall of 1992, represented the final evaluation under the SHRP H-106 contract. Since the overall performance of treatments at that time remained very good, continued yearly monitoring of the treatments was deemed necessary to obtain clearer distinctions in treatment performance. For this reason, a 5-year follow-up study sponsored by the FHWA was conducted following the termination of SHRP in the spring of 1993. Under the follow-up study, the experimental crack treatments were annually evaluated between the months of October and February, beginning in 1993.

Prior to each evaluation, the project staff was responsible for contacting the participating State maintenance agency and selecting the day(s) to do the evaluation. Normally, the smaller test sites, such as Abilene, Elma, and Prescott, were evaluated in 1 day. The two Wichita subsites and the Des Moines site, however, normally took 2 days to evaluate. For each evaluation, an additional day was allotted in case of rain or the need for test section remarking.

At the outset of most site inspections, the experimental cracks and test sections were remarked with semi-permanent paint to ensure proper demarcation for the next field inspection. Traffic control for the evaluations at Abilene, Elma, and Des Moines normally were conducted as moving operations, using two or three trucks equipped with arrow boards and crash attenuators. At Prescott, the passing lane was coned off, whereas flagpersons were used at Wichita.

Performance Data Collection

Several types of performance data were routinely collected in the crack-treatment field evaluations, per the SHRP H-106 *Evaluation and Analysis Plan* (*EAP*) (Evans et al., 1992). Although test sections consisted of either 10 transverse cracks (each crack was 3.66 m long) or 12 longitudinal crack divisions (each crack division was 7.63 m long), only the last 8 treated cracks or crack divisions (i.e., transverse cracks 3 through 10, longitudinal crack divisions 5 through 12) in each section were inspected. In this way, the effects of problems that may have occurred at the start of each test section during the material installation process were minimized.

As with the initial inspection of the cracks treated in the experiment, the treatments were examined over 0.61-m edge and wheelpath segments and 1.22-m center segments at the crack-seal sites and over 1.53-m segments at the crack-fill site. Along each segment, the treatments were examined for the presence, amount (i.e., length), and severity of the following distress types:

Distress Type	Severity Levels
Weathering	low- and high-severity
Pull-outs	partial- and full-depth
Overband wear	low-, high-, and extreme-severity
Tracking	low- and high-severity
Extrusion	low- and high-severity
Stone intrusion	low- and high-severity
Adhesion loss	partial- and full-depth
Cohesion loss due to tensile/shear forces	partial- and full-depth

Distress Type	Severity Levels
Cohesion loss due to bubbling	partial- and full-depth
Edge deterioration	low- and high-severity

The amount and severity of each identified distress within a given segment was manually recorded on a four-page performance evaluation form (see appendix D for the complete form). A partial illustration of the four-page form (the first two pages, covering cracks 3 through 6 of a specified test section) used in the last five inspection rounds of the transverse crack-seal sites is provided in figure 26. In this figure, key distress types are listed along the top and the crack-seal segments are given along the left margin. Example data are handwritten on the form, indicating the amount (in inches) of a particular distress type and severity level observed within a given crack segment during a given performance inspection.

Once all of the distress data for a particular test site and field inspection round were collected, the data were manually entered into Microsoft Excel©, which served as the database manager for the project. The entered data were carefully checked for accuracy and corrections were made as necessary.

Most of the distresses represented a reduction in a treatment's ability to perform its function (i.e., to keep water and incompressibles out of the crack channel). Examples of these distresses include partial-depth adhesion and cohesion loss, and overband wear. On the other hand, some distresses, such as full-depth pull-outs and full-depth adhesion and cohesion loss, signified a treatment's failure to perform its function. These distresses were termed "failure distresses." The total amount of failure distress observed in a treatment formed the basis for performance comparison.

In the majority of the cases, only one failure distress was observed over a particular portion of a crack. Sometimes, however, two types of failure distress were observed over the same portion of a crack. To avoid over-assessing the actual amount of treatment failure, the overall amount of failure for each evaluation segment was recorded during the evaluations. Thus, if 102 mm of full-depth adhesion loss and 102 mm of high-severity secondary cracking were found to exist over the same portion of the crack, then 102 mm of overall failure was recorded.

In the first evaluation, the presence of five construction-related distresses were considered. These included construction bubbles, material sagging, sand intrusion, overband wear, and tracking. As mentioned previously, the most notable construction-related distresses were observed at Abilene, where 890-SL experienced sand intrusion and pull-outs during curing and XLM exhibited high levels of overband wear.

In each of the first five inspection rounds, distance measurements between P-K nail sets were taken across each experimental crack using a 305-mm digital caliper. These measurements were taken to determine how much each crack moves during a year. Climatic data, such as air temperature and cloud cover, were also recorded after each test section was evaluated.

Rep-Sect	Material	Config	Prep	Crack	Segment	Pull-outs (in) Eval 5 Ptl Dpth	Pull-outs (in) Eval 5 Full Dpth	Pull-outs (in) Eval 6 Ptl Dpth	Pull-outs (in) Eval 6 Full Dpth	Pull-outs (in) Eval 7 Ptl Dpth	Pull-outs (in) Eval 7 Full Dpth	Pull-outs (in) Eval 8 Ptl Dpth	Pull-outs (in) Eval 8 Full Dpth	Pull-outs (in) Eval 9 Ptl Dpth	Pull-outs (in) Eval 9 Full Dpth	Pull-outs (in) Eval 10 Ptl Dpth	Pull-outs (in) Eval 10 Full Dpth	Edge Deterioration (in) Eval 5 Low Severity	Edge Deterioration (in) Eval 5 High Severity	Edge Deterioration (in) Eval 6 Low Severity	Edge Deterioration (in) Eval 6 High Severity	Edge Deterioration (in) Eval 7 Low Severity	Edge Deterioration (in) Eval 7 High Severity	Edge Deterioration (in) Eval 8 Low Severity	Edge Deterioration (in) Eval 8 High Severity	Edge Deterioration (in) Eval 9 Low Severity	Edge Deterioration (in) Eval 9 High Severity	Edge Deterioration (in) Eval 10 Low Severity	Edge Deterioration (in) Eval 10 High Severity	Overband Wear (N, L, H, E) Eval 5	Overband Wear (N, L, H, E) Eval 6	Overband Wear (N, L, H, E) Eval 7	Overband Wear (N, L, H, E) Eval 8	Overband Wear (N, L, H, E) Eval 9	Overband Wear (N, L, H, E) Eval 10
1-1	4	D	3	3	ISE		2		2		2		4		4		4													L	L	L	L	H	H
	4	D	3	3	IWP																									H	H	H	H	E	E
	4	D	3	3	JCN	1		1					1		1		1													L	L	L	H	H	H
	4	D	3	3	OWP														3		3		3		3		5		5	H	H	H	E	E	E
	4	D	3	3	POE																									L	L	L	L	H	H
	4	D	3	4	ISE													1		1		1		1		1		1		L	L	L	L	H	H
	4	D	3	4	IWP																									H	H	E	E	E	E
	4	D	3	4	JCN																									H	H	H	E	E	E
	4	D	3	4	OWP																									H	H	E	E	E	E
	4	D	3	4	POE																				4		4		4	L	L	L	L	H	H
	4	D	3	5	ISE																									L	L	L	L	H	H
	4	D	3	5	IWP																									H	H	H	H	E	E
	4	D	3	5	JCN						3		3		3		3													L	L	H	H	H	E
	4	D	3	5	OWP																									H	H	H	H	E	E
	4	D	3	5	POE																									L	L	L	L	H	H
	4	D	3	6	ISE																									L	L	L	L	H	H
	4	D	3	6	IWP																									H	H	H	E	E	E
	4	D	3	6	JCN																									L	L	H	H	H	E
	4	D	3	6	OWP																									H	H	E	E	E	E
	4	D	3	6	POE																									L	L	L	L	H	H

Figure 26. Crack-seal performance evaluation form.

Rep-Sect	Material	Config	Prep	Crack	Segment	Adhesion Loss (in) Eval 5 Ptl Dpth	Eval 5 Full Dpth	Eval 6 Ptl Dpth	Eval 6 Full Dpth	Eval 7 Ptl Dpth	Eval 7 Full Dpth	Eval 8 Ptl Dpth	Eval 8 Full Dpth	Eval 9 Ptl Dpth	Eval 9 Full Dpth	Eval 10 Ptl Dpth	Eval 10 Full Dpth
1-1	4	D	3	3	ISE												
	4	D	3	3	IWP												
	4	D	3	3	JCN												
	4	D	3	3	OWP												
	4	D	3	3	POE												
	4	D	3	4	ISE												
	4	D	3	4	IWP												
	4	D	3	4	JCN												
	4	D	3	4	OWP												
	4	D	3	4	POE												
	4	D	3	5	ISE												
	4	D	3	5	IWP												
	4	D	3	5	JCN												
	4	D	3	5	OWP												
	4	D	3	5	POE												
	4	D	3	6	ISE												
	4	D	3	6	IWP												
	4	D	3	6	JCN												
	4	D	3	6	OWP												
	4	D	3	6	POE												

Crack	Segment	Cohesion Loss (in) Eval 5 Ptl Dpth-Tens	Eval 5 Full Dpth-Tens	Eval 5 Ptl Dpth-Bub	Eval 5 Full Dpth-Bub	Eval 6 Ptl Dpth-Tens	Eval 6 Full Dpth-Tens	Eval 6 Ptl Dpth-Bub	Eval 6 Full Dpth-Bub	Eval 7 Ptl Dpth-Tens	Eval 7 Full Dpth-Tens	Eval 7 Ptl Dpth-Bub	Eval 7 Full Dpth-Bub	Eval 8 Ptl Dpth-Tens	Eval 8 Full Dpth-Tens	Eval 8 Ptl Dpth-Bub	Eval 8 Full Dpth-Bub	Eval 9 Ptl Dpth-Tens	Eval 9 Full Dpth-Tens	Eval 9 Ptl Dpth-Bub	Eval 9 Full Dpth-Bub	Eval 10 Ptl Dpth-Tens	Eval 10 Full Dpth-Tens	Eval 10 Ptl Dpth-Bub	Eval 10 Full Dpth-Bub
3	ISE		2				2				2				2				4				4		
3	IWP	2	1			1	8			1	8			1	8			4	13			6	16		
3	JCN				1				1	3			1	3			1	2	9		1	4	10		1
3	OWP		4			3	4			3	4			4	4			2	20				24		
3	POE																		1				1		
4	ISE																								
4	IWP		1				1				5				5				8				10		
4	JCN																	1	4			1	4		
4	OWP	3				1	3			1	3			2	3				6				6		
4	POE																								
5	ISE																		6				7		
5	IWP		2				3				3			1	3			3	12				21		
5	JCN										1				1			3	10			3	13		
5	OWP																	6	7			5	13		
5	POE																		1				1		
6	ISE																								
6	IWP	4				4				4				2	7			5	10			5	10		
6	JCN																								
6	OWP						2				2				2			4	12			2	15		
6	POE																								

Crack	Segment	Overall Failure (in) Eval 5	Eval 6	Eval 7	Eval 8	Eval 9	Eval 10
3	ISE	4	4	4	6	8	8
3	IWP	7	8	8	8	13	16
3	JCN	1	1	1	2	11	12
3	OWP	7	7	7	7	24	24
3	POE					1	1
4	ISE						
4	IWP	1	1	5	5	9	10
4	JCN					4	4
4	OWP		3	3	3	6	6
4	POE				4	4	4
5	ISE					6	7
5	IWP	2	3	3	3	12	21
5	JCN			4	4	13	16
5	OWP					7	13
5	POE					1	1
6	ISE						
6	IWP				7	10	10
6	JCN						
6	OWP		2	2	2	12	15
6	POE						

Figure 26. Crack-seal performance evaluation form (continued).

Finally, in addition to the evaluation and P-K distance measurements, two different in-place tests were occasionally performed on the treatment materials. One test, the nondestructive coin test, was done regularly on the elastic-type seals during moderate- and warm-weather evaluations (i.e., temperature > 10°C) to give a rough indication of the material's resilience. The test procedure consists of inserting a quarter half-way into the sealant/filler and measuring the amount it is ejected after a 1-minute period. Full ejection of the quarter indicates a very resilient material, one capable of keeping incompressibles from penetrating the crack reservoir. The second test, the destructive pull-out test, was usually conducted during cold-weather evaluations to indicate material flexibility and low-temperature adhesiveness. In this test, a 50-mm segment of sealant/filler is cut along the crack reservoir sidewalls and at one end. The segment is then grabbed at 25 mm and pulled straight up at a constant, gradual rate. If the sealant/filler continues to pull out of the reservoir with limited stretching, then the bond is inadequate. If it doesn't pull out of the reservoir, the amount that it stretches before rupture is measured to determine how extensible or flexible the material is.

Summary of Treatment Performance

Though not each test site was evaluated the planned 10 times, the overall performance trend for each site can be seen in figure 27. Each test site performance trend is represented by the time-series effectiveness values of primary treatments placed at the site. As can be seen, small to moderate drops in treatment performance were experienced in the first three winters at Wichita, Abilene, Des Moines, and Prescott, followed by major reductions in performance in the fourth, fifth, and sixth winters.

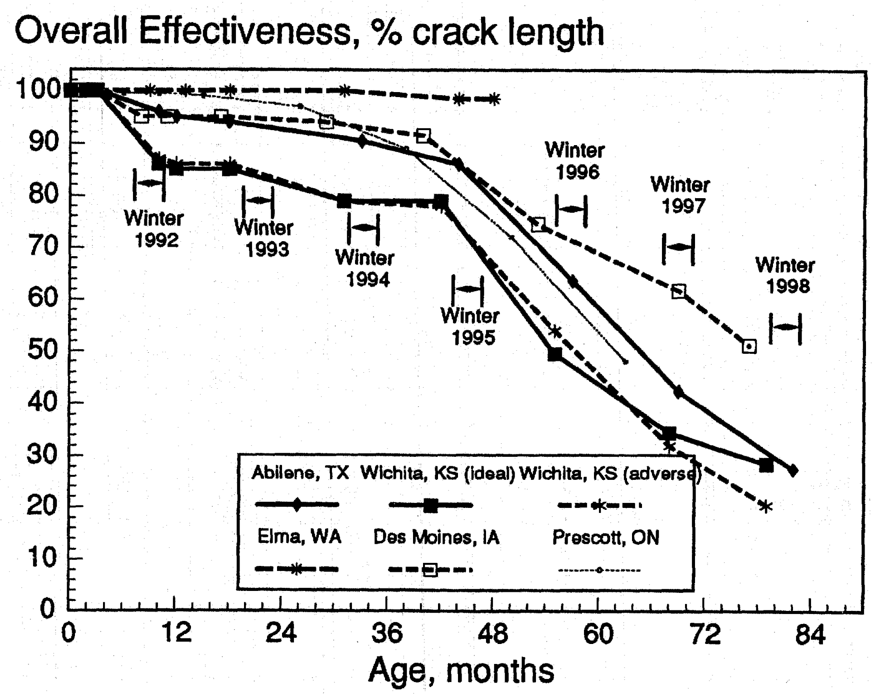


Figure 27. Overall performance trends of primary experimental treatments by site.

At the Elma site, where temperatures are fairly moderate year-round and the traffic level is low, only slight decreases in performance were experienced throughout the entire 4 years of service. Crack fillers at the Prescott site held up fairly well the first two winters, but began incurring substantial failures after the third winter.

Crack-Seal Experiment

The performance ratings listed below were applied to the various experimental treatments for general discussion purposes. The ratings, established by Mike Belangie, were originally based on the level of overall failure observed in a particular treatment (Belangie and Anderson, 1985). The effectiveness level is simply the failure level subtracted from 100 percent (e.g., 10 percent overall failure equals 90 percent overall effectiveness).

Rating	Effectiveness Level, %
Very good	90 to 100
Good	80 to 89
Fair	65 to 79
Poor	50 to 64
Very poor (failed)	< 50

Figures 28 through 32 show the time-series effectiveness trends of the crack-seal treatments placed at Abilene, Elma, Wichita, and Des Moines. Excluding the treatments at Elma, only 9 of the 61 treatments exhibited greater than 80 percent overall effectiveness after the final round of evaluations. Moreover, 32 of the 61 treatments reached "failed" status (<50% effectiveness).

The primary modes of crack-seal failure did not change significantly over time. Each treatment type typically exhibited one predominant mode of failure and one or two secondary modes of failure. As seen in table 13, the predominant mode of failure was usually adhesion loss or cohesion loss. Figures 33 and 34 provide conceptual illustrations of these types of failures. For configurations A, B, and C of the rubberized asphalt seals (Hi-Spec and RS 515), adhesion loss accounted for between 77 and 91 percent of the overall failure. The remaining failure was mostly comprised of edge deterioration.

For configurations B and C of the low-modulus rubberized asphalt seals (9030 and XLM), adhesion loss accounted for between 73 and 79 percent of the overall failure. These percentages are considerably lower than the corresponding percentages for the rubberized asphalt seals, primarily because the XLM C-3 treatment at the Wichita adverse-conditions site experienced several pull-outs shortly after construction and because the XLM B-3 treatment at Abilene exhibited significant edge deterioration.

For configuration D of the rubberized asphalt seals, between 95 and 98 percent of the failures were the result of full-depth cohesion loss. In this type of failure, the overband is worn away by traffic and the remaining sealant thickness is insufficient to withstand the internal stress brought by crack-opening movement. This mode of failure was almost as predominant in the fiberized asphalt and low-modulus rubberized asphalt seals.

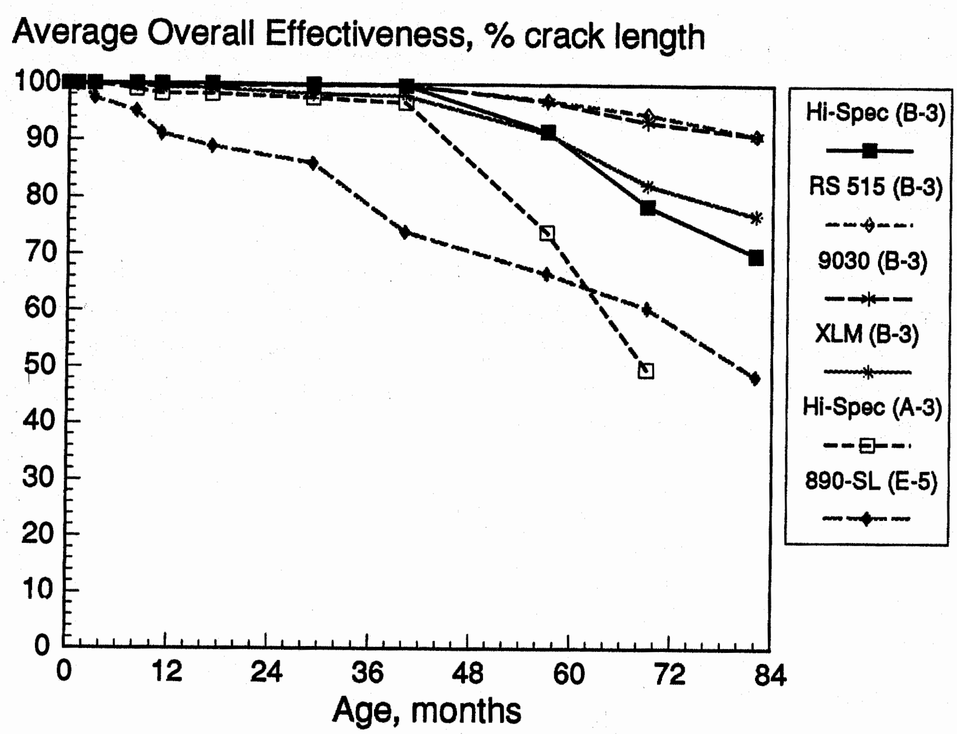


Figure 28. Time-series effectiveness trends of Abilene, TX crack-seal treatments.

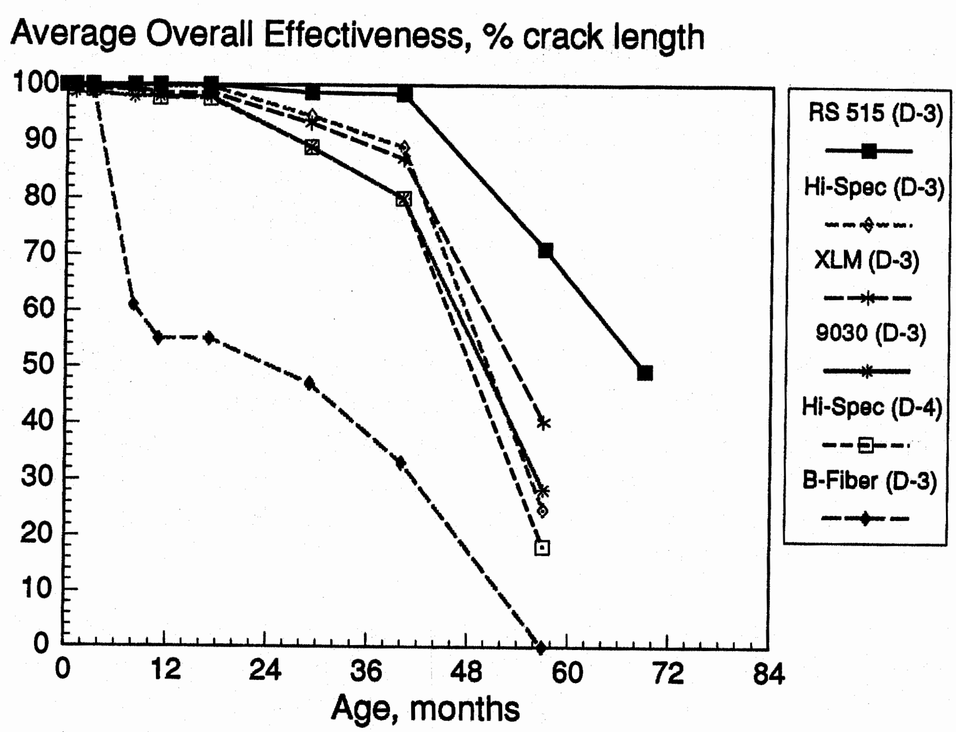


Figure 28. Time-series effectiveness trends of Abilene, TX crack-seal treatments (continued).

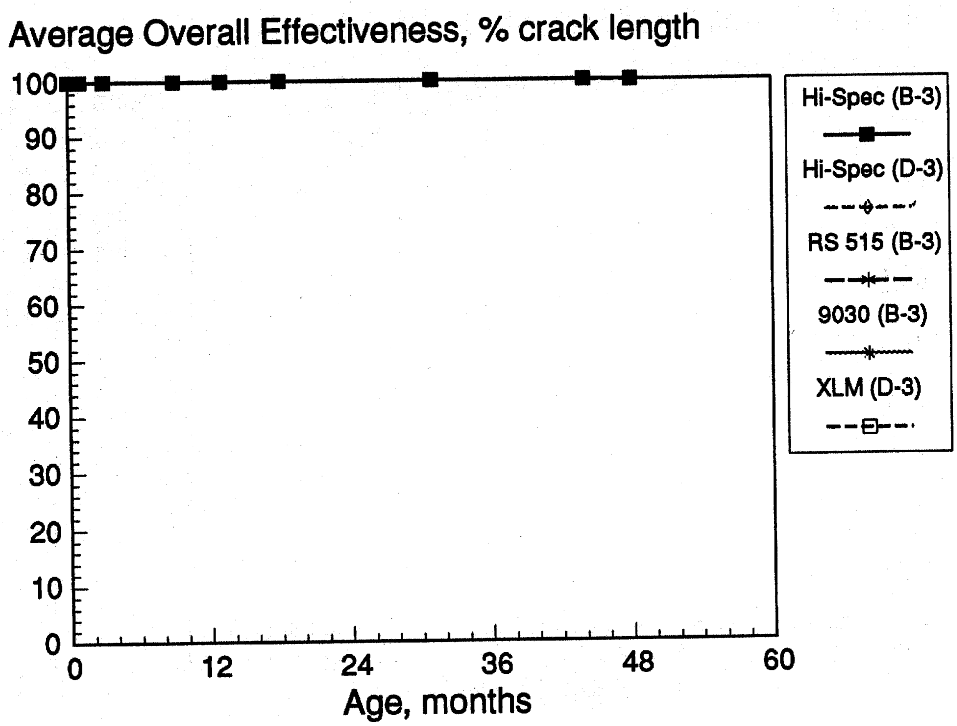


Figure 29. Time-series effectiveness trends of Elma, WA crack-seal treatments.

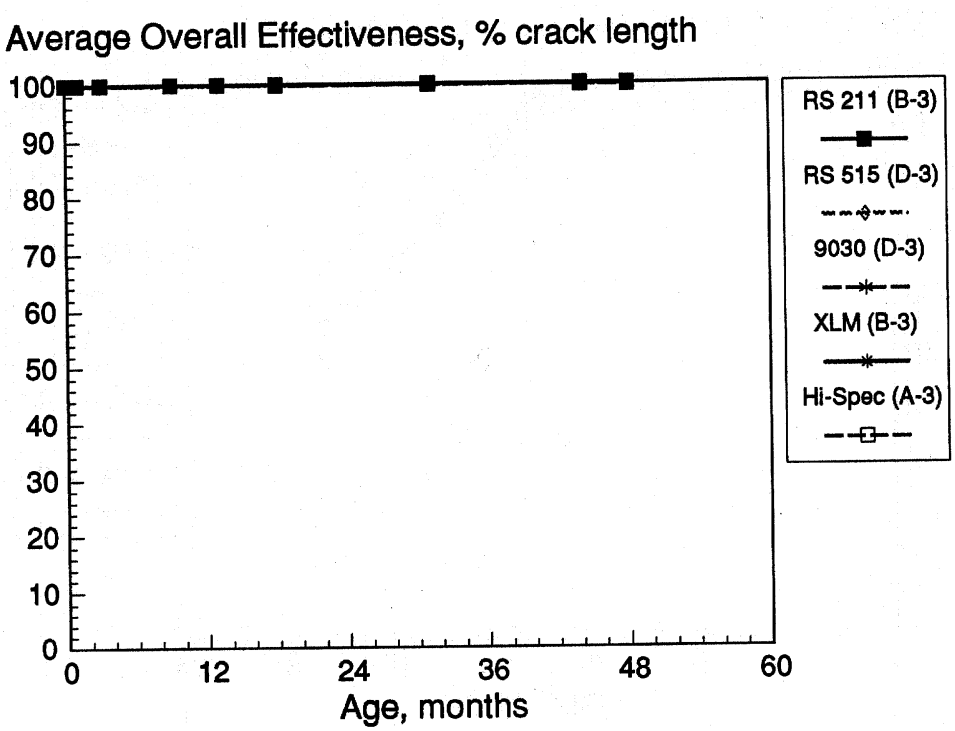


Figure 29. Time-series effectiveness trends of Elma, WA crack-seal treatments (continued).

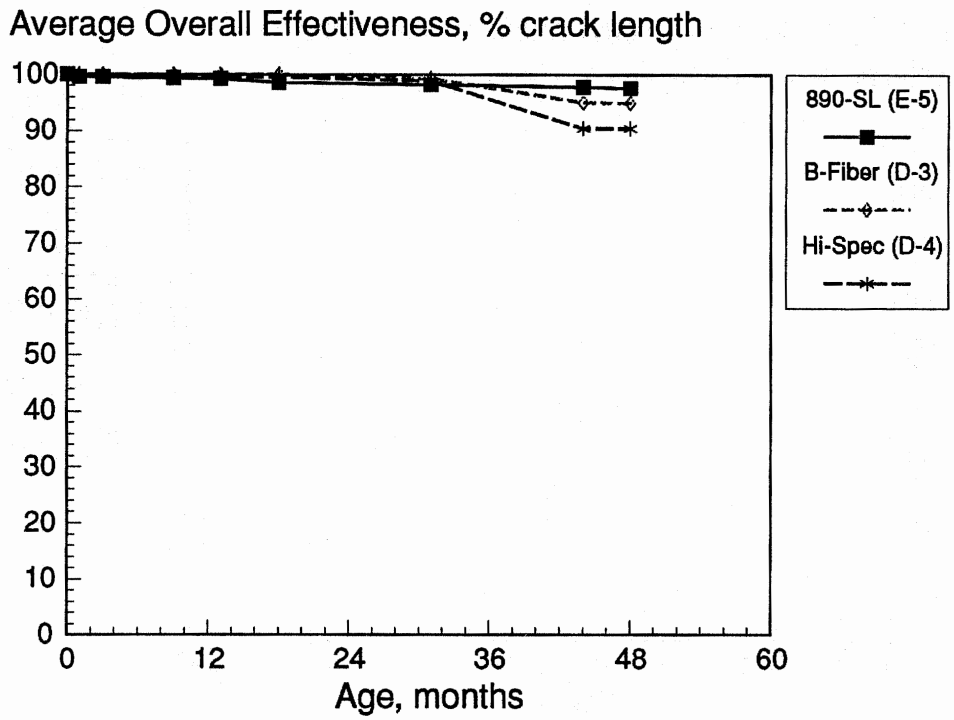


Figure 29. Time-series effectiveness trends of Elma, WA crack-seal treatments (continued).

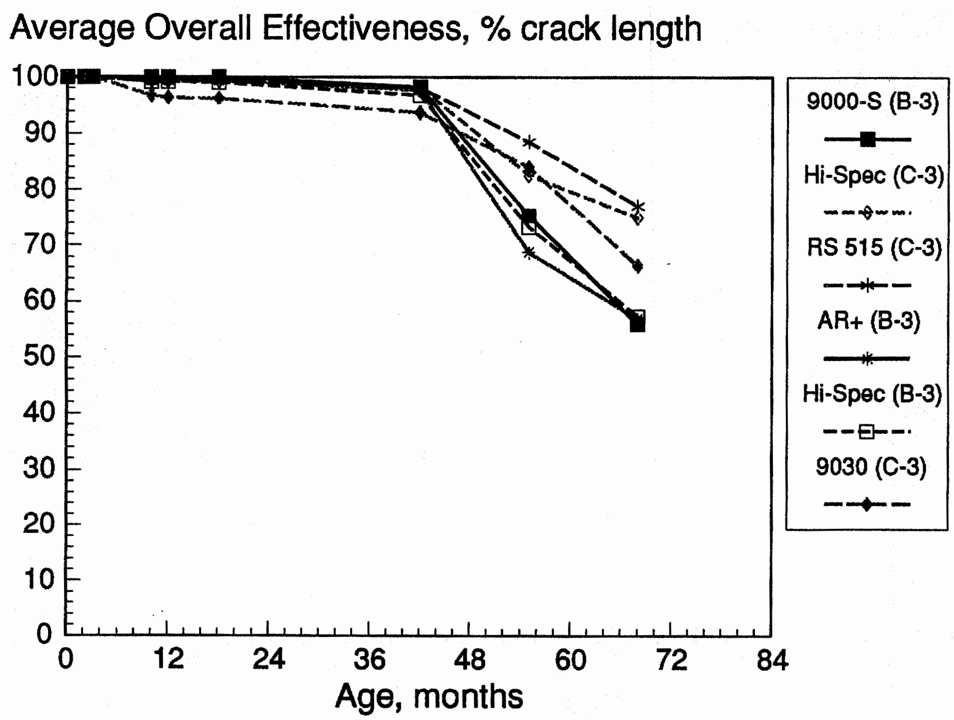


Figure 30. Time-series effectiveness trends of Wichita, KS adverse-conditions crack-seal treatments.

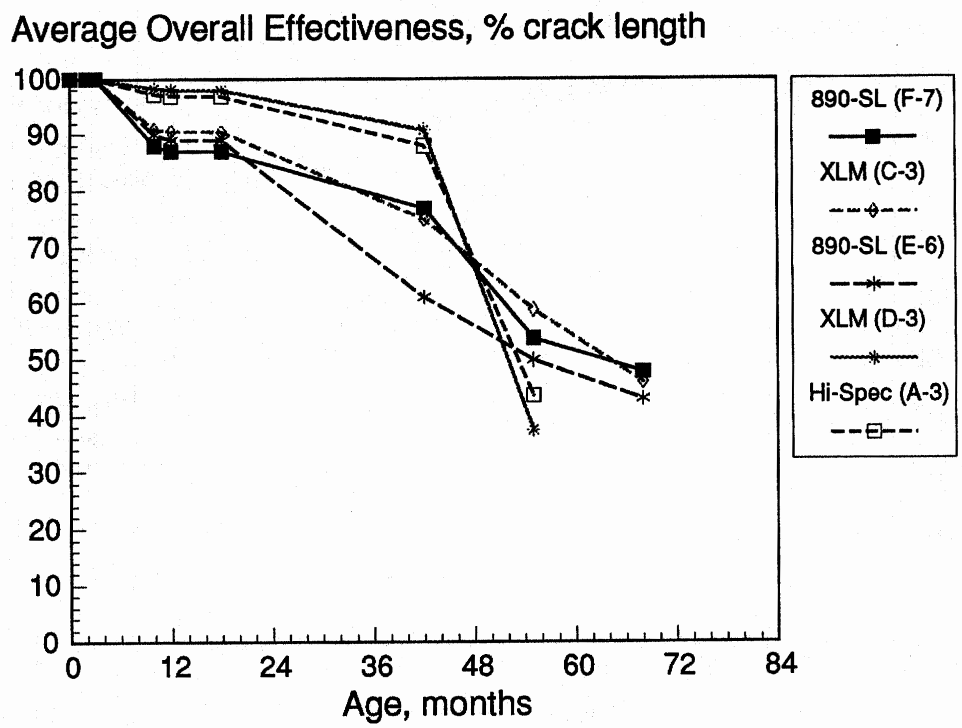


Figure 30. Time-series effectiveness trends of Wichita, KS adverse-conditions crack-seal treatments (continued).

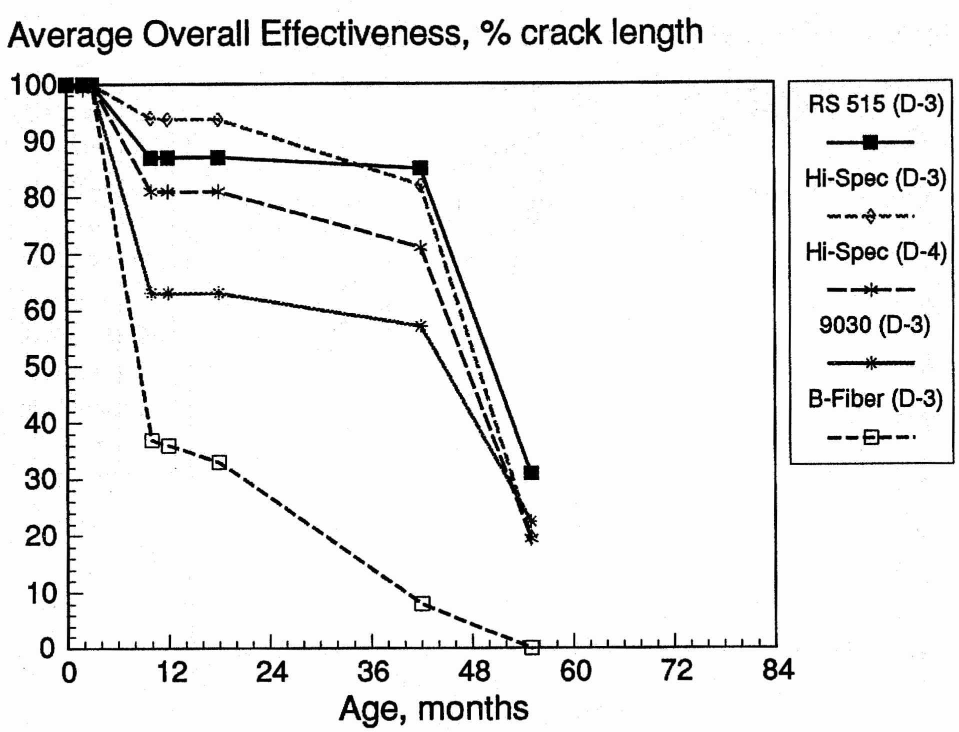


Figure 30. Time-series effectiveness trends of Wichita, KS adverse-conditions crack-seal treatments (continued).

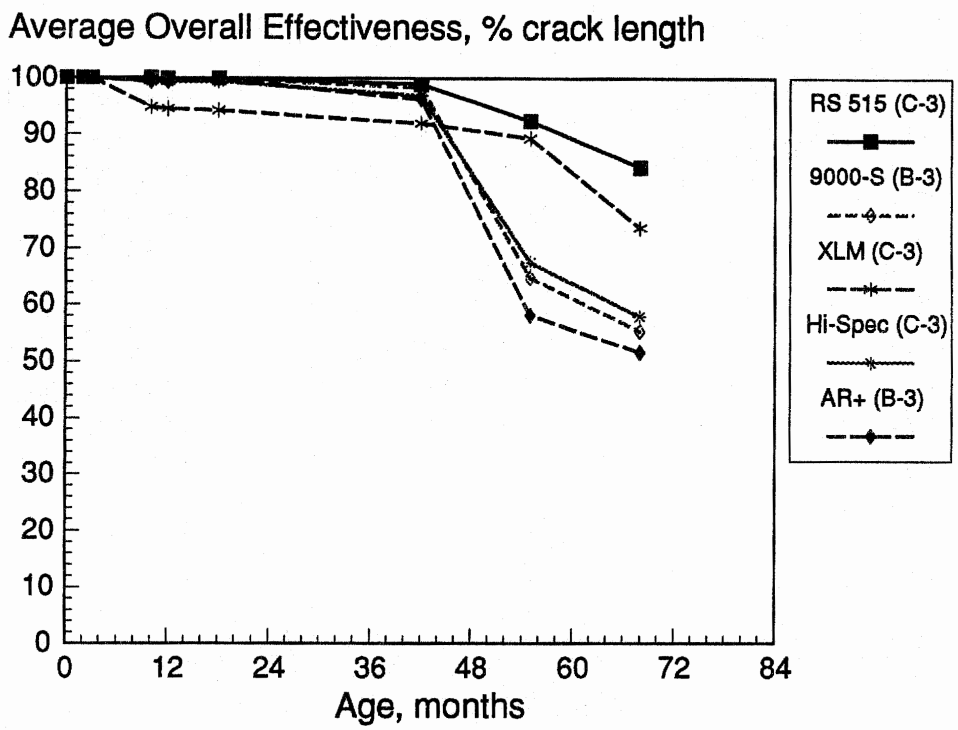


Figure 31. Time-series effectiveness trends of Wichita, KS ideal-conditions crack-seal treatments.

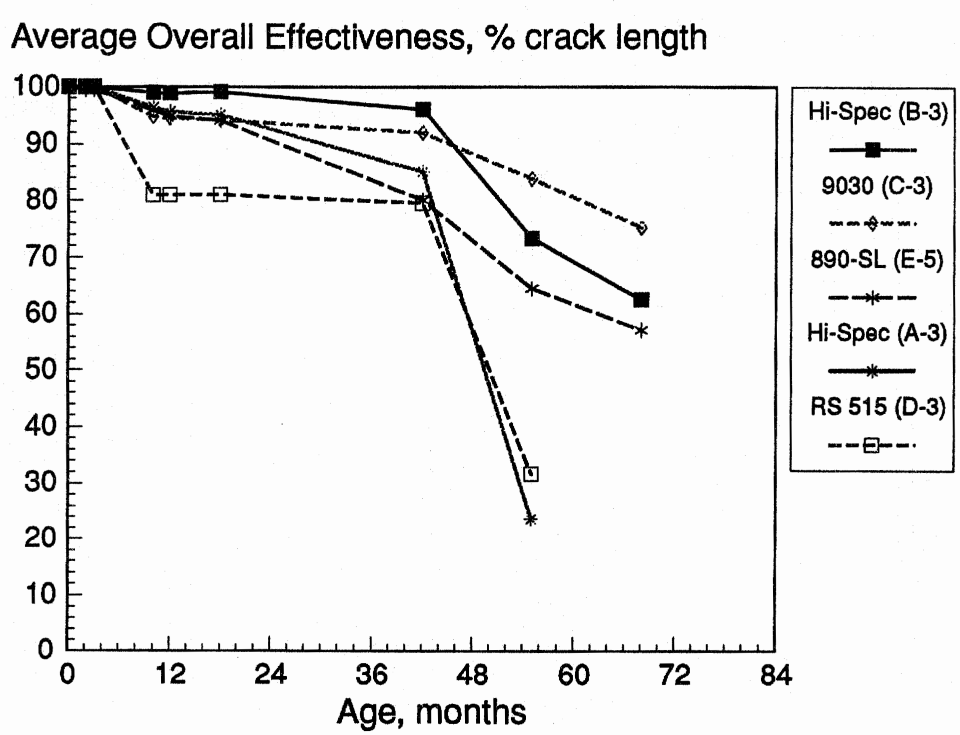


Figure 31. Time-series effectiveness trends of Wichita, KS ideal-conditions crack-seal treatments (continued).

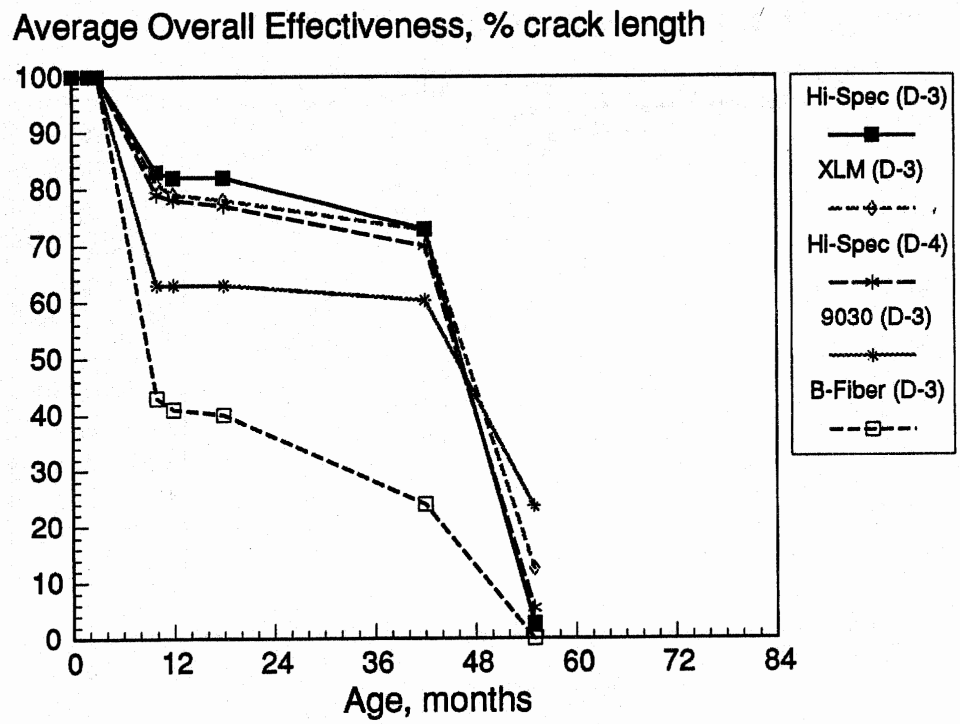


Figure 31. Time-series effectiveness trends of Wichita, KS ideal-conditions crack-seal treatments (continued).

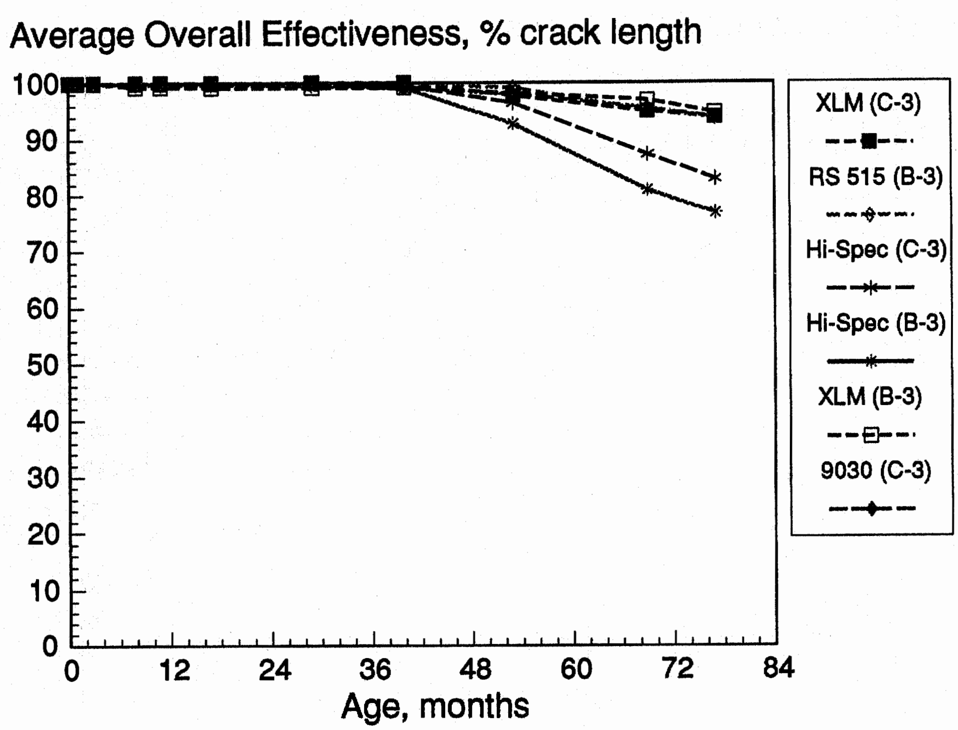


Figure 32. Time-series effectiveness trends of Des Moines, IA crack-seal treatments.

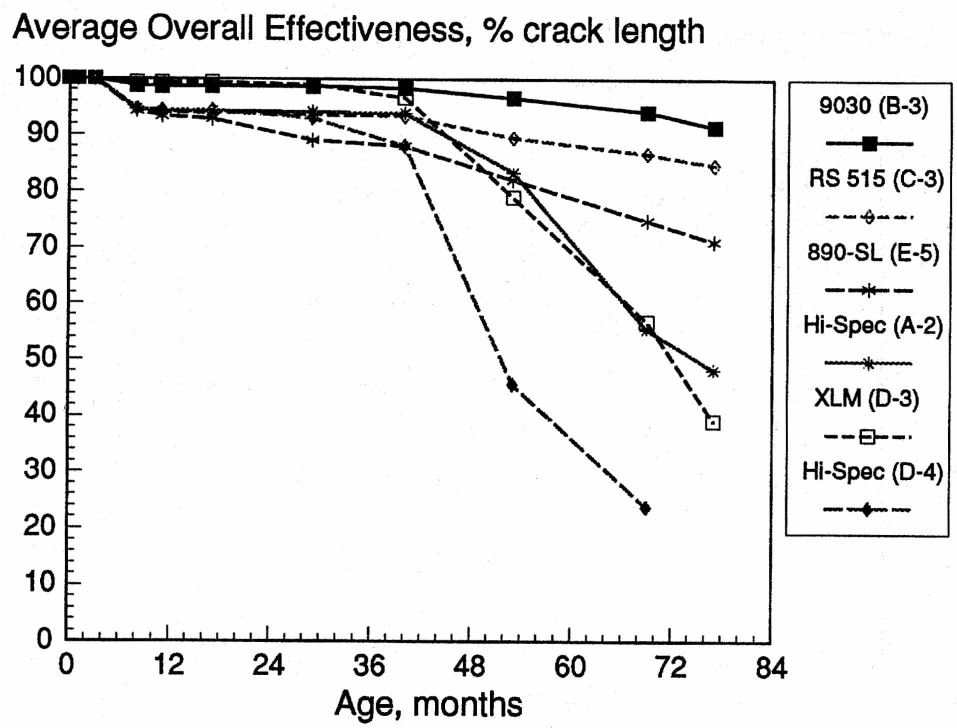


Figure 32. Time-series effectiveness trends of Des Moines, IA crack-seal treatments (continued).

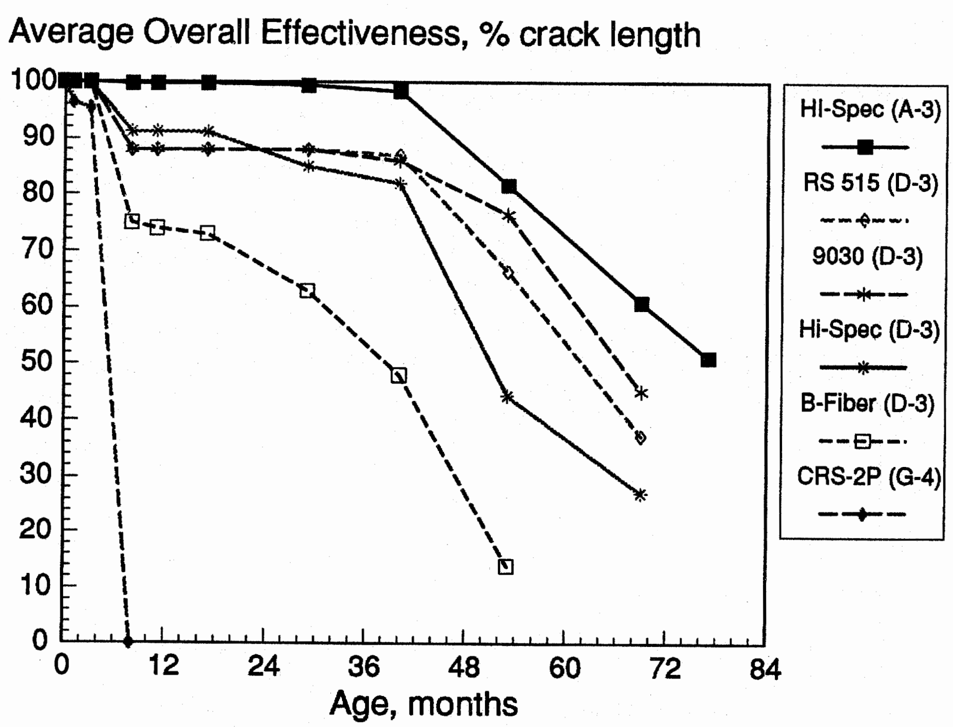


Figure 32. Time-series effectiveness trends of Des Moines, IA crack-seal treatments (continued).

Table 13. Breakdown of failure modes for experimental crack seals.

Material type	Installation method (configuration-preparation)	Percentage of overall failure			
		Full-depth adhesion loss	Full-depth cohesion loss	Full-depth pull-outs	High-severity edge deterioration
Rubberized asphalt	A-2	83	0	0	17
	A-3	77	0	0	23
	B-3	88	0	1	11
	C-3	91	0	2	7
	D-3	0	98	1	1
	D-4	0	95	1	4
Low-modulus rubberized asphalt	B-3	79	0	1	20
	C-3	73	0	16	11
	D-3	0	90	6	4
Fiberized asphalt	D-3	0	92	1	7
Self-leveling silicone	E-5	32	0	10	58

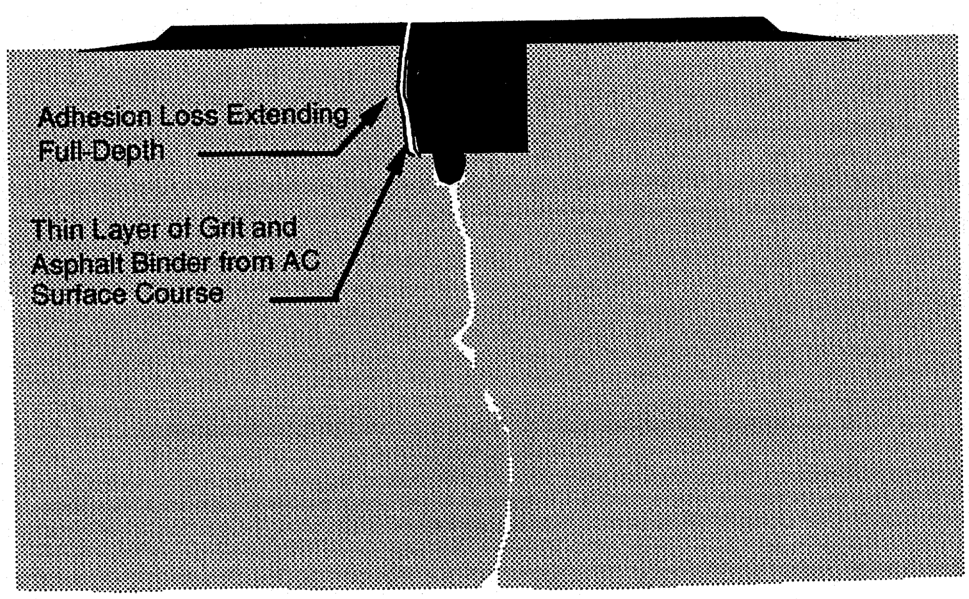


Figure 33. Illustration of full-depth adhesion loss in recessed band-aid.

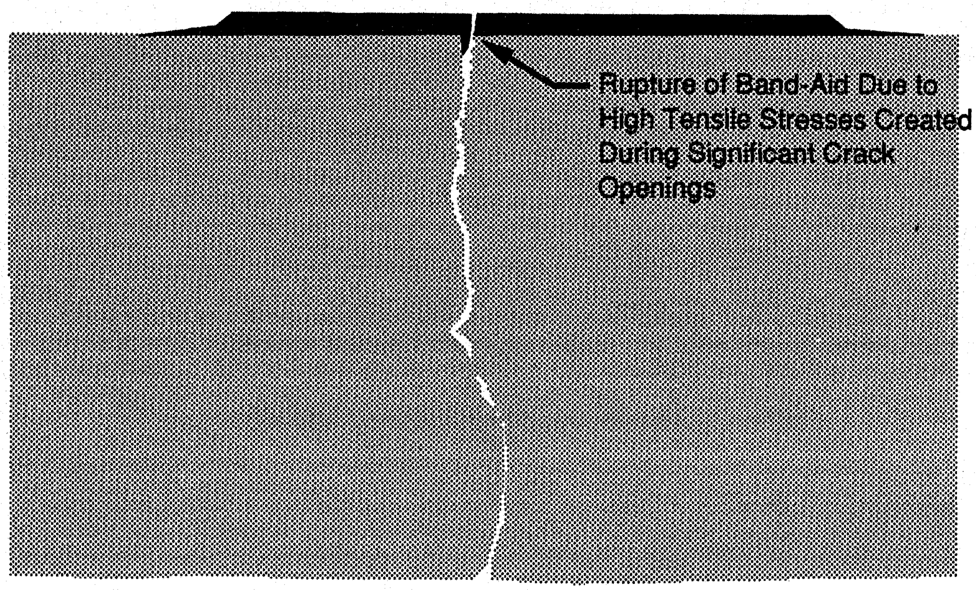


Figure 34. Illustration of full-depth cohesion loss in simple band-aid.

Finally, for the silicone seals, the primary mode of failure was edge deterioration. Over half of the failure in this treatment was the result of high-severity edge deterioration, largely stemming from low-severity spalls and secondary cracks created by saw-cutting operations during installation. Figure 35 shows a typical spall and secondary crack associated with an 890-SL silicone seal placed at Abilene.

Crack-Fill Experiment

As seen in figure 36, half of the longitudinal crack-fill treatments at Prescott performed favorably, whereas the other half failed. The primary modes of failure in these treatments were cohesion loss for asphalt cement, CRF, and Fiber Pave, and adhesion loss for RS 211 and Kold Flo. For the AR2 material, adhesion loss was the predominant mode of failure in the simple flush-fill configuration (G-4), and pull-out failure was the main failure constituent in the simple band-aid configuration (D-4).

Figure 35. Typical spall and secondary crack adjacent to 890-SL silicone seal.

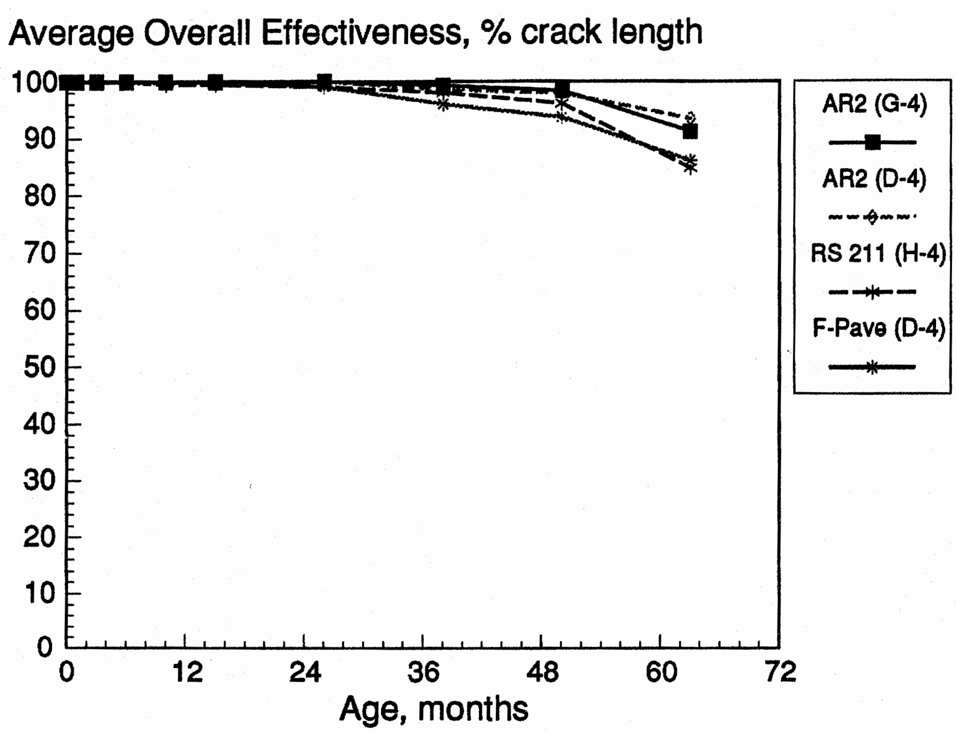


Figure 36. Time-series effectiveness trends of Prescott, ON crack-fill treatments.

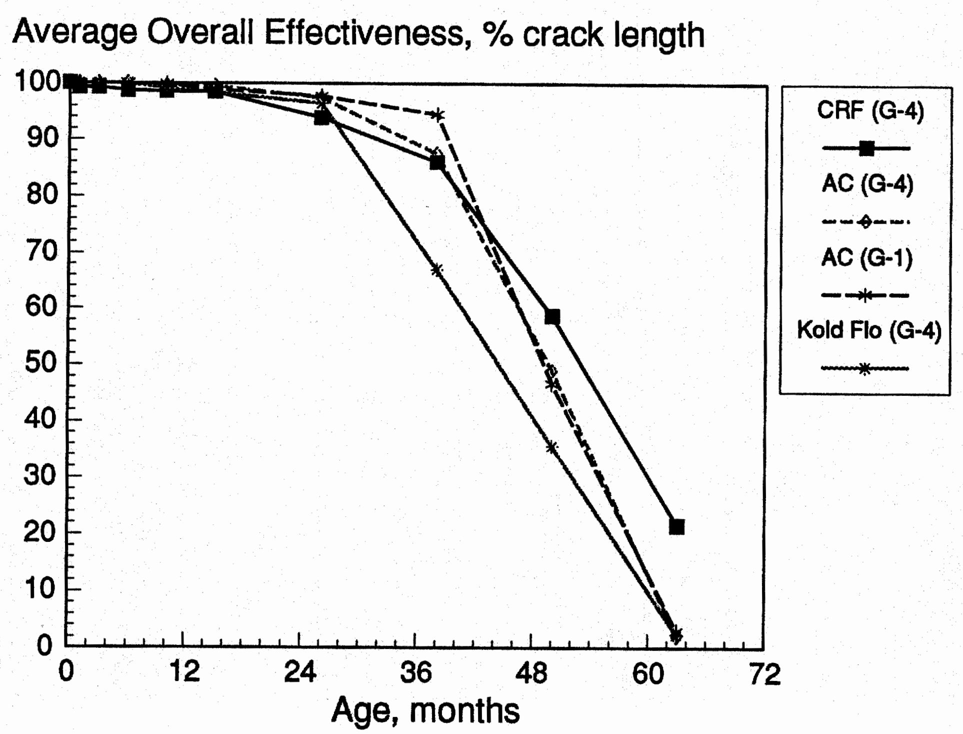


Figure 36. Time-series effectiveness trends of Prescott, ON crack-fill treatments (continued).

CHAPTER 5. DATA ANALYSIS

As stated in chapter 1, the primary objective of this experimental project was to determine the most effective and economical materials and methods for conducting crack-sealing and crack-filling operations. To accomplish this objective, a statistical analysis was conducted on the field performance data to determine differences in performance among the various treatments. This was followed by a detailed cost-effectiveness analysis, whereby the total cost of applying a given treatment was weighed against how long the treatment performs.

A secondary objective included finding correlations between field performance and laboratory testing data. It was envisioned that new information in this area would lead to improved performance-based sealant specifications.

This chapter describes the statistical methods used to analyze the various types of installation, field performance, and laboratory testing data, and presents the results of the analyses performed. Listed below are the various types of analyses that were conducted in order to interpret the data.

- Comparative analysis—Comparison of performance between test sites, materials, and methods using descriptive statistics (i.e., mean, standard deviation).
- Analysis of variance (ANOVA)—Statistical analysis to identify significant differences in long-term performance between treatments.
- Cost-effectiveness analysis—Life-cycle cost analysis and comparison using long-term performance trends.
- Laboratory testing–field performance correlation analysis—Statistical analysis of laboratory testing and field performance data to identify performance-indicative laboratory tests.

Statistical Methodology

The statistical analysis of data was performed using Microsoft Excel© and SAS® version 6.12 statistical software. With the project data stored in Excel© spreadsheets and with Excel© software providing the capability of organizing data and performing general statistics, this program was used for the comparative and cost-effectiveness analyses, and was used to create American Standard Code for Information Interchange (ASCII) data files for SAS® statistical analyses.

In the comparative analyses, the statistical means of treatment performance were computed and then comparisons were made among materials, methods, configurations, and test sites. In the cost-effectiveness analysis, those statistical means were entered into a general cost-effectiveness formula to generate average annual life-cycle costs that could then be compared.

The SAS® statistical analyses consisted of analysis of variance (ANOVA) and correlation analysis. For both of these analyses, command files were created in SAS® that instructed the program how to read the ASCII data, what types of statistical analysis to perform, and what form of output to produce.

For the analysis of long-term treatment performance, the SAS® General Linear Model (GLM) procedure with the multi-variate analysis of variance (MANOVA) option was used. This test procedure uses the mean and variation in treatment performance to determine if the performance of one or more of the treatments is statistically different. The procedure was run in conjunction with the Tukey studentized range grouping method, which groups treatments of similar performance and ranks both the groups and the treatments within each group. A confidence level of 95 percent (i.e., $1-\alpha = 95$ percent) was used in the analysis.

Correlation analyses between laboratory test results and field performance were made using the SAS Correlation (CORR) procedure. In the procedure, comparisons between the means of various laboratory tests and field distresses were made at the 95 percent confidence level. The strength of a relationship was measured by the Pearson correlation coefficient (r). Coefficients near 0 indicated poor relationships, whereas those near 1 or -1 represented strong relationships. Positive r values indicated direct relationships, whereas negative r values signified indirect relationships.

Service Life Projections

To conduct the four statistical analyses described above, a standard measure of long-term treatment performance was required. Some past research studies have used qualifier terms (e.g., good, fair, poor) or rating scales (e.g., 1-10, 1-100) to convey the overall performance of crack treatments, whereas others have used subjective estimates of crack treatment service life.

Because of the detail with which treatments were inspected for distresses and failures in this study and because of the number of inspections conducted over time, it was determined that field performance would best be framed in terms of service life, and that the service life should be defined as the estimated time for a treatment to reach the 75 percent effectiveness level. In other words, the service life is the time required for 25 percent of the crack length to develop failure.

Figure 37 illustrates this concept. In this figure, a particular crack treatment has exhibited varying losses in effectiveness over time. After 54 months, the treatment maintained an 88 percent effectiveness rating. However, after 66 months, the treatment dropped to a 69 percent effectiveness rating. At the level of 75 percent effectiveness, the corresponding estimated age (i.e., service life) is 62 months.

For the analyses conducted in this study, the estimated service lives of individual, treated cracks (i.e., 3.66-m transverse cracks and 7.63-m longitudinal crack divisions) were determined, and then the mean and standard deviation values of service life were computed for each treatment. This approach allowed for the consideration of the variation that exists in treatment performance from crack to crack.

Based on the appearances of the time-series performance data for many individual treated cracks, third-order polynomial regression was chosen to provide best-fit curves to each set of time-series data. The form of a third-order polynomial regression equation is as follows:

$$\%Eff = a_0 + (a_1 \times Age) + (a_2 \times Age^2) + (a_3 \times Age^3) \qquad \text{Eq. 1}$$

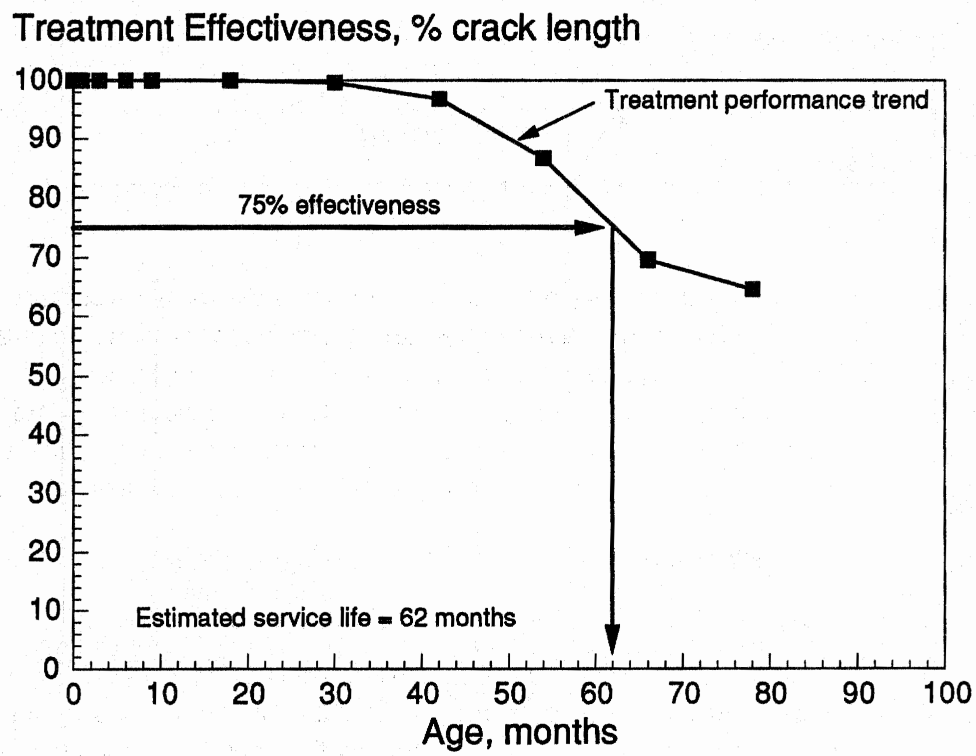


Figure 37. Illustration of service life estimation, based on 75 percent effectiveness.

where: *%Eff* = Treatment effectiveness, percent.
a_0, a_1, a_2, a_3 = Regression coefficients.
Age = Treatment age, months.

Following the completion of each regression, which was performed using the SAS® Regression (REG) procedure, the resulting *a* coefficient values were inserted into equation 1 and the *Age* term was solved for using the 75 percent effectiveness criterion (i.e., *%Eff* = 75). The resulting *Age* value represented the service life of the treatment applied to an individual crack (or crack division, in the case of the crack-fill study). In many instances, the resulting *Age* value for a particular treated crack was equal to or less than the time period spent evaluating the treated crack. In other words, the treated crack had reached 75 percent effectiveness on or prior to its final evaluation, and so the computed *Age* value represented an estimate of the actual life. In other instances, however, the treated crack had not reached 75 percent effectiveness by its final evaluation, and the computed *Age* value represented an estimate of the predicted life. Figure 38 illustrates these two cases.

To maintain somewhat conservative estimates of predicted life, a maximum service life of 120 months was established. Thus, if the *Age* value for a particular treated crack was computed to be greater than 120 months—this was usually the case if no more than 4 to 5 percent failure developed over the monitoring period—then the computed value was changed to 120 months.

As illustrated in table 14, the estimated service lives of all treated cracks (or crack divisions) evaluated as part of a particular crack treatment were used to compute a mean and standard

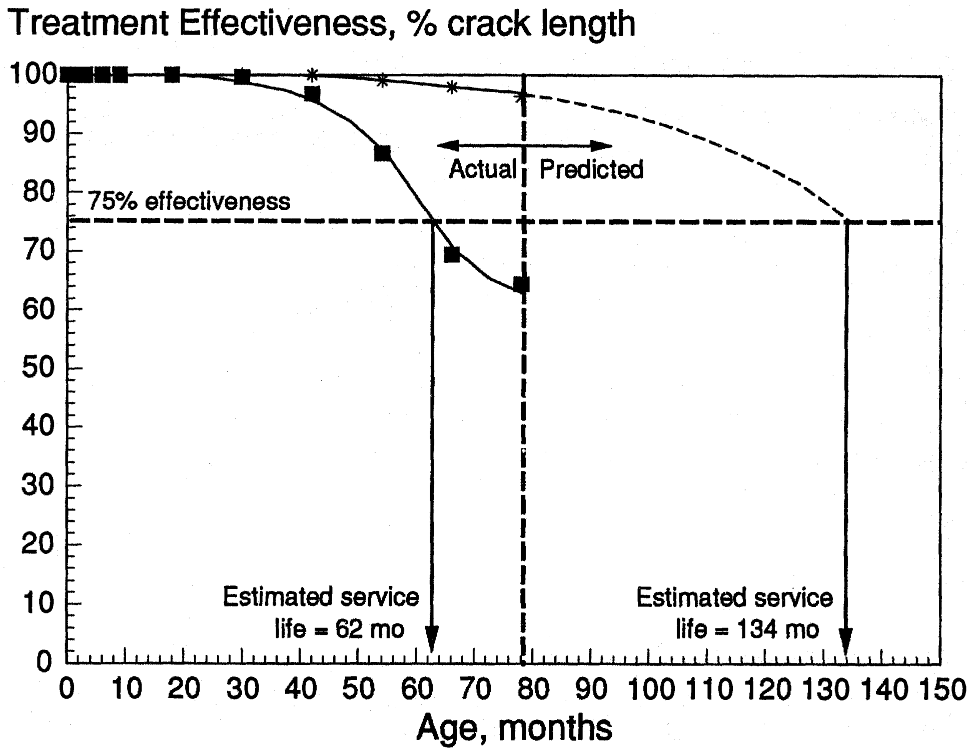


Figure 38. Illustration depicting estimates of actual versus predicted service lives.

Table 14. Illustration of service life statistics computation.

Replicate-Crack No.	Estimated Service Life, months	Replicate-Crack No.	Estimated Service Life, months
1-3	64.3	2-3	66.9
1-4	56.7	2-4	65.1
1-5	50.7	2-5	58.3
1-6	61.2	2-6	69.4
1-7	58.8	2-7	63.6
1-8	74.2	2-8	60.4
1-9	64.7	2-9	57.5
1-10	59.3	2-10	70.3
Mean = 62.6 Standard Deviation = 5.9			

deviation of service life for that treatment. In most instances, the number of individually treated cracks per treatment was 16, corresponding to 2 replicate sections in which 8 of the 10 cracks in each section were evaluated (see chapter 4). In a couple of instances, however, the number of individually treated cracks per treatment was eight. The resulting mean and standard deviation values of estimated service life for all treatments are summarized in table 15.

Comparative Analysis

This section provides an overall comparison of crack treatment performance among test sites and detailed comparisons of the performance characteristics of treatment materials, configurations, and procedures. The comparisons are based on the service-life estimates previously provided in table 15.

Comparison of Test Sites

Perhaps the most apparent observation to date regarding crack treatment performance has been the differences in mean estimated service life between the sites. Based on nine crack-seal treatments (Hi-Spec A-3, B-3, D-3, and D-4; RS 515 D-3; 9030 D-3; XLM D-3; BoniFiberized asphalt D-3; and 890-SL E-5) placed at Abilene, Wichita (ideal-conditions subsite), Elma, and Des Moines, the mean estimated service lives for these treatments were 113.8 months for Elma, 52.2 months for Des Moines, 49.0 months for Abilene, and 33.3 months for the Wichita ideal-conditions subsite. These differences are primarily the combined result of crack movement (a function of climate, pavement type, crack type, and crack spacing) and traffic.

Table 16 summarizes the mean horizontal crack movements observed at each site, based on P-K nail plug measurements taken during installation and during the coldest field inspection. As can be seen, Wichita had the highest recorded incidence of mean crack movement and, subsequently, the highest mean rate of crack movement (expressed in mm/°C). In comparison with the Abilene and Des Moines sites, both of which had similar crack spacings, the Wichita site exhibited a crack movement rate 2.5 times greater. It is believed that crack movements at the Abilene and Des Moines sites were, in large part, constrained by components (fabric, JRC base) within their pavement designs. Since the estimated daily traffic crossing the Wichita site was significantly lower than the estimated daily traffic crossing at the Abilene and Des Moines sites (3,500 vehicles/day versus 6,000 and 6,200 vehicles/day, respectively), crack movement is believed to be a much greater factor in performance than traffic at this site.

The moderate climate and low traffic level at Elma made it the least intensive crack-seal site. Even though the mean rate of crack movement at this site was nearly as high as the mean rates at the Wichita subsites, average annual temperature variations are considerably lower (roughly 5 to 21°C at Elma and 1 to 27°C at Wichita). Thus, on average, the observed crack movement at Elma was about half the crack movement observed at Wichita.

Table 15. Means and standard deviations of estimated service lives for all experimental crack treatments.

Treatment Material	Installation Method (cfg-prep proc)	Estimated Service Life in Terms of Mean±Standard Deviation, months					
		Abilene	Wichita Ideal	Wichita Adverse	Elma	Des Moines	Prescott
Meadows Hi-Spec	A-2					56.5±19.8	
	A-3	58.1±2.5	42.5±7.2	46.3±3.6	118.2±4.4	61.1±8.3	
	B-3	77.7±9.4	59.4±9.5	58.5±11.3	120.0±0.0	81.7±17.2	
	C-3		56.4±13.6	68.4±9.7		88.1±14.2	
	D-3	48.0±8.8	29.5±16.8	41.9±8.3	120.0±0.0	38.8±15.8	
	D-4	43.8±3.5	28.5±16.3	29.7±20.0	95.1±34.8	42.4±10.7	
Crafco RS 515	B-3	109.1±11.7			120.0±0.0	112.1±11.4	
	C-3		80.3±8.3	71.9±9.0		94.8±30.2	
	D-3	58.1±4.8	33.4±20.8	40.1±16.7	117.7±9.1	44.8±18.2	
Koch 9030	B-3	111.4±11.1			120.0±0.0	105.8±10.9	
	C-3		68.3±13.3	65.6±10.6		113.4±8.7	
	D-3	44.5±8.3	23.9±21.6	17.5±18.4	120.0±0.0	51.1±23.1	
Meadows XLM	B-3	85.8±13.4			120.0±0.0	113.7±11.4	
	C-3		69.6±5.4	41.5±17.2		111.6±17.8	
	D-3	48.3±6.6	29.0±17.8	47.1±2.5	119.2±3.2	58.5±7.0	
Kapejo BoniFiber + AC	D-3	9.0±6.2	6.2±2.9	5.7±2.9	105.4±25.1	19.4±13.7	
Dow 890-SL	E-5	53.5±27.4	47.8±15.3		108.8±17.7	71.6±18.2	
	E-6			28.9±14.9			
	F-7			36.1±12.6			
Crafco AR+	B-3		52.2±10.7	56.1±7.1			
Koch 9000-S	B-3		56.0±10.2	58.2±7.5			
Elf CRS-2P	G-4					5.6±0.8	
Crafco RS 211	B-3				120.0±0.0		
	H-4						74.1±10.6
AC	G-1						42.0±1.4
	G-4						42.3±2.5
Crafco AR2	D-4						97.7±15.9
	G-4						86.3±16.9
Hercules Fiber Pave + AC	D-4						78.6±12.8
Witco CRF	G-4						43.1±2.5
Hy-Grade Kold Flo	G-4						34.6±2.3

Configuration
A. Standard Reservoir-and-Flush
B. Standard Recessed Band-Aid
C. Shallow Recessed Band-Aid
D. Simple Band-Aid
E. Deep Reservoir-and-Recess
F. Standard Reservoir-and-Recess
G. Simple Flush-Fill
H. Capped

Preparation Procedure
1. None
2. Wire Brush and Compressed Air
3. Hot Compressed-Air Lance
4. Compressed Air
5. Light Sandblast, Compressed Air, and Backer Rod
6. Compressed Air and Backer Rod
7. Light Sandblast, Compressed Air, and Backer Tape

Table 16. Test site crack movement statistics.

Test Site	Pavement Type	Average Transverse Crack Spacing, m	Mean Air Temperature, °C			Crack Movement (Mean ± Std. Dev.), mm	Mean Rate of Crack Movement, mm/°C
			At Installation	At Coldest Inspection	Difference		
Abilene	Conventional AC (w/ fabric interlayer)	18	24	8	16	0.91 ± 0.51	0.057
Wichita (ideal)	Full-Depth AC	20	17	3	14	2.03 ± 0.90	0.145
Wichita (adverse)			16	4	12	1.63 ± 1.06	0.136
Elma	Full-Depth AC	25	14	6	8	1.04 ± 0.42	0.130
Des Moines	Composite AC/JRC	18	26	0	26	1.52 ± 0.94	0.058
Prescott	Composite AC/JPC	—	30	-9	39	1.17 ± 0.35	0.030

To give a sense of the effects of traffic on sealant overband wear, the mean time required for a 75 percent reduction in original overband thickness was computed for seven crack-seal treatments (Hi-Spec B-3, D-3, and D-4; RS 515 D-3; 9030 D-3; XLM D-3; and BoniFiberized asphalt D-3) placed at Abilene, Elma, Wichita, and Des Moines. The lowest trafficked site, Elma (estimated 2,880 vpd/lane and 9 percent trucks), showed a mean elapsed time of 35.8 months. The Wichita ideal-conditions subsite, which had a little heavier traffic (estimated 3,500 vpd/lane and 13 percent trucks), had a mean elapsed time of 30.1 months. The heavier loaded test sites, Abilene (estimated 6,000 vpd and 15 to 20 percent trucks) and Des Moines (estimated 6,200 vpd and 20.5 percent trucks), showed mean elapsed times of 26.8 months and 17.8 months, respectively.

The cold, damp sealing conditions typified by the adverse-conditions test sections at Wichita appear to have had no effect on seal performance. Based on 12 distinct treatments placed at both subsites, the mean estimated service lives were 43.9 months for the ideal-conditions subsite and 44.5 months for the adverse-conditions subsite. Half of the 12 treatments showed longer estimated service lives as part of the adverse-conditions subsite than as part of the ideal-conditions subsite. It is believed that the effectiveness of the HCA lance at drying pavement cracks was largely responsible for the resulting similarities in performance between the ideal- and adverse-conditions crack seals.

Comparison of Crack-Seal Materials, Configurations, and Procedures

The experimental design of the crack-seal study allowed for several direct performance comparisons between materials, configurations, and procedures. Many of the comparisons were possible at the overall experiment level and these are discussed below. However, a few comparisons made within test sites yielded the following observations.

- At Wichita (ideal conditions), the SHRP-specified control material Hi-Spec, placed using method B-3, performed somewhat better than the State-added materials AR+ and 9000-S, also placed using method B-3 (59.4 months versus 52.2 and 56.0 months, respectively).

- At Elma, the SHRP-specified control material Hi-Spec, placed using method B-3, performed the same (mean estimated service life of 120.0 months) as the State-added material RS 211, also placed using method B-3.

- At Des Moines, the 17 SHRP-specified treatments, on average, performed much better than the State-added emulsion material CRS-2P, placed using the G-4 method (74.4 months versus 5.6 months).

- At Wichita, 890-SL placed in a deep reservoir on top of backer rod, performed considerably better than when placed in a standard reservoir on top of backer tape (47.7 months versus 36.1 months).

- At Wichita, 890-SL placed in a sandblasted reservoir performed substantially better than when placed in a non-sandblasted reservoir (47.7 months versus 28.9 months).

- At Des Moines, slightly better performance was achieved with the hot-airblast cleaning procedure in comparison with the wirebrush–compressed-air cleaning procedure (Hi-Spec A-3 and A-2 methods, respectively) (61.1 months versus 56.5 months).

At the overall experiment level (i.e., based on the Abilene, Wichita [ideal conditions only], Elma, and Des Moines test sites), the following head-to-head comparisons were made with respect to material, configuration, and procedure performance:

- SHRP-specified rubberized asphalt sealants (Hi-Spec, RS 515, 9030, and XLM) placed using methods B-3, C-3, and D-3.

  ➛ RS 515 showed the longest estimated service life (85.6 months), followed closely by the two low-modulus sealants 9030 (84.3 months) and XLM (84.0 months). The standard modulus sealant Hi-Spec had a considerably shorter estimated service life (73.4 months).

- SHRP-specified asphalt-based sealants (Hi-Spec, RS 515, 9030, and XLM) placed using method D-3.

  ➛ XLM showed the longest estimated service life (63.8 months), followed very closely by RS 515 (63.5 months). 9030 had the next longest estimated service life (59.9 months), just edging out Hi-Spec (59.1 months). BoniFiberized AC had the shortest estimated service life (35.0 months).

- SHRP-specified asphalt-based treatments (all methods used with Hi-Spec, RS 515, 9030, XLM, and BoniFiberized asphalt) versus the SHRP-specified silicone-based treatment (890-SL with the E-5 method).

  ➛ The mean estimated service life of all SHRP-specified asphalt-based treatments was slightly higher than the mean estimated service life of the silicone-based treatment (73.8 months versus 70.4 months).

- Standard recessed band-aid (configuration B) versus shallow recessed band-aid (configuration C) versus simple band-aid (confiiguration D) used with SHRP-specified rubberized asphalt sealants (Hi-Spec, RS 515, 9030, and XLM).

  ➛ The standard recessed band-aid showed the longest estimated service life (94.5 months), followed very closely by the shallow recessed band-aid (92.9 months). The simple band-aid showed a substantially shorter estimated service life (44.5 months).

- Standard reservoir-and-flush (configuration A) versus standard recessed band-aid (configuration B), used with the SHRP-specified control material Hi-Spec.

  ➛ A considerably longer estimated service life was observed with the standard recessed band-aid as compared with the standard reservoir-and-flush (84.7 months versus 70.0 months).

- Hot airblasting (crack preparation procedure 3) versus conventional airblasting (procedure 4) used with the SHRP-specified control material Hi-Spec.

  ➛ A considerably longer estimated service life was observed with the hot airblasting procedure as compared with the conventional airblasting procedure (59.1 months versus 52.5 months).

Comparison of Crack-Fill Materials, Configurations, and Procedures

Direct comparisons of the crack-fill treatments at Prescott revealed the following performance findings:

- Based on the G-4 method (flush-fill configuration, conventional airblasting), the asphalt rubber material AR2 provided the longest estimated service life (86.3 months), followed distantly by the emulsion CRF (43.1 months), asphalt cement (42.3 months), and the rubberized emulsion Kold Flo (34.6 months).

- Based on the asphalt rubber material AR2, the simple band-aid appears to have outperformed the flush-fill configuration (97.7 months versus 86.3 months).

- The use of high-pressure air for cleaning cracks filled with asphalt cement does not appear to be beneficial. The service-life estimates of the asphalt cement G-1 and G-4 treatments are about the same (42.0 months and 42.3 months, respectively).

Analysis of Variance of Service Life

To make statistical performance distinctions between the various experimental treatments, an analysis of variance was conducted using the SAS® GLM procedure and the Tukey studentized range grouping method. The SAS® input file for this test consisted of the individual service-life estimates (corresponding to a threshold of 75 percent effectiveness) computed for each treated crack (or crack division). As previously mentioned, a confidence level of 95 percent (i.e., 1-α = 95 percent) was used.

The results of the Tukey comparisons of estimated treatment service life are illustrated in figures 39 through 44. These figures graphically show the estimated service life statistics of the treatments installed at the various test sites, in conjunction with the resulting Tukey performance groupings. The mean service life of each treatment is displayed and is represented by the solid square symbol. The corresponding variation in service life, in terms of one standard deviation above and below the mean, is depicted by the vertical line through the mean service life symbol.

The Tukey performance groupings are given by the "level" designations above the service life statistics. Each level represents a statistical distinction in performance, with level 1 representing highest performance, followed by level 2, level 3, and so on. Obviously, some treatments fell under two or more performance levels, indicating that they can be categorized in various ways.

The comparison observations listed earlier in the chapter were reviewed in light of the MANOVA–Tukey analysis results. A summary of that review is provided below.

- At Wichita (ideal conditions), the SHRP-specified control material Hi-Spec, placed using method B-3, performed somewhat better than the State-added materials AR+ and 9000-S, also placed using method B-3.

  ➛ No statistically significant differences were observed between the Hi-Spec and the two State-added materials.

- At Elma, the SHRP-specified control material Hi-Spec, placed using method B-3, performed the same as the State-added material RS 211, also placed using method B-3.

  ➛ No statistically significant difference between Hi-Spec and the State-added material.

- At Des Moines, the 17 SHRP-specified treatments, on average, performed much better than the State-added emulsion material CRS-2P, placed using the G-4 method (74.4 months versus 5.6 months).

  ➛ Direct comparisons with the 17 SHRP-specified treatments showed the performance of the CRS-2P G-4 treatment to be statistically inferior to 15 of those treatments. No statistically significant difference was observed between this treatment and the BoniFiberized asphalt D-3 and Hi-Spec D-3 treatments.

- At Des Moines, slightly better performance was achieved with the hot-airblast cleaning procedure in comparison with the wirebrush–compressed-air cleaning procedure (Hi-Spec A-3 and A-2 methods, respectively).

  ➛ No statistically significant difference was found to exist between the hot-airblast and wirebrush–compressed-air cleaning procedures.

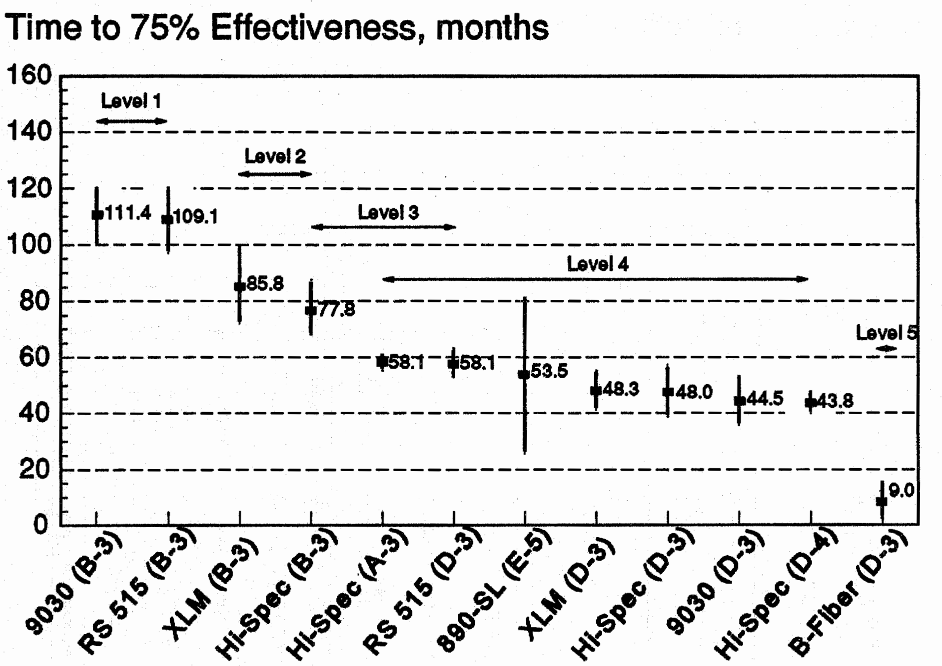


Figure 39. Tukey analysis of estimated treatment service lives at Abilene.

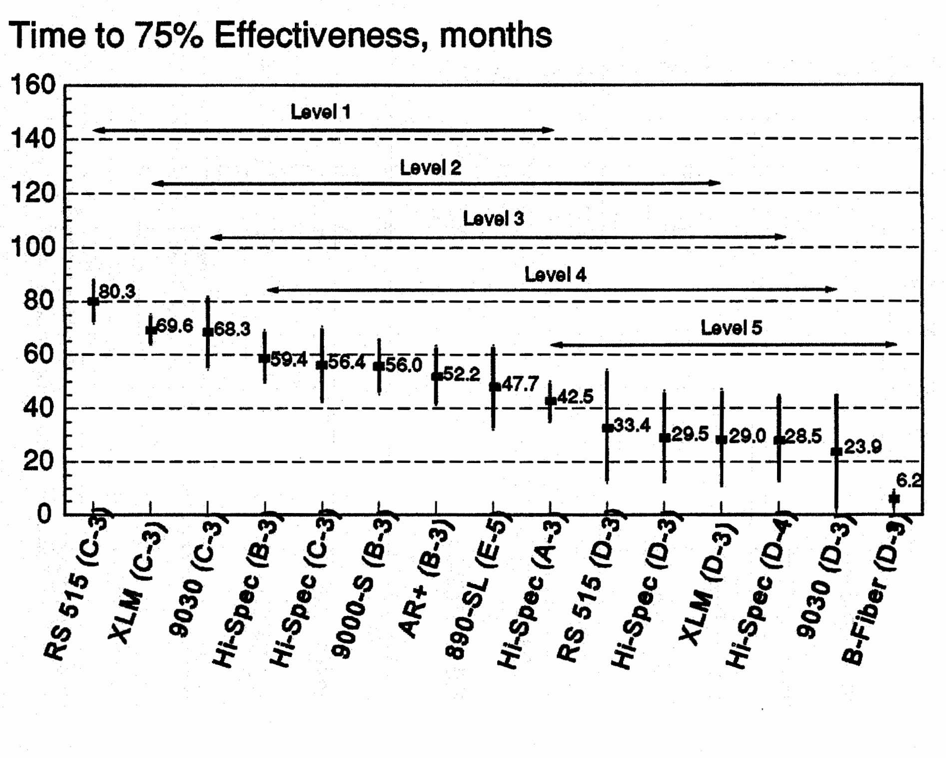


Figure 40. Tukey analysis of estimated treatment service lives at Wichita ideal-conditions subsite.

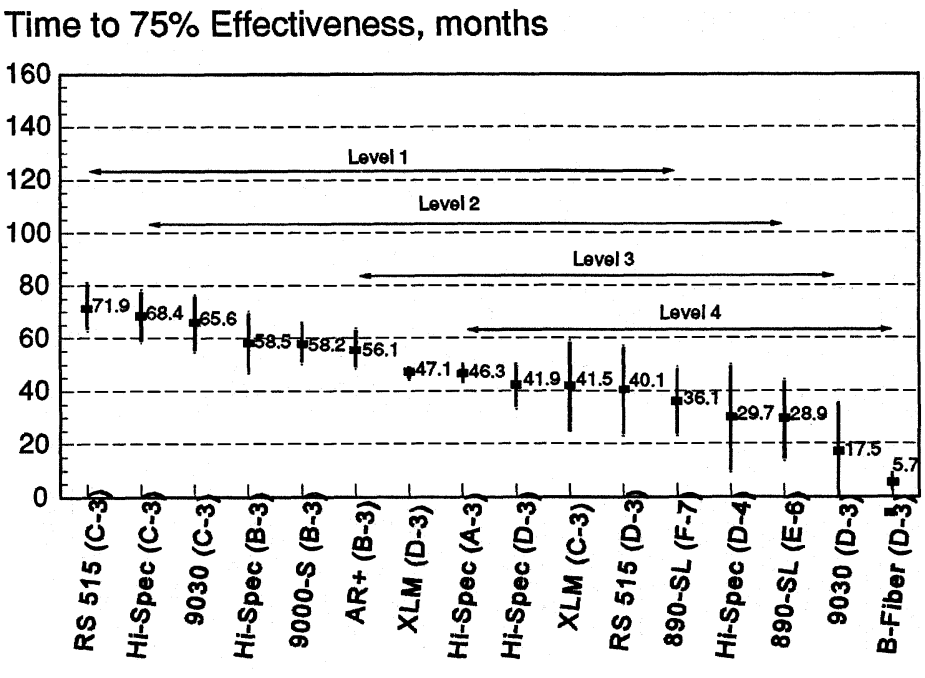


Figure 41. Tukey analysis of estimated treatment service lives at Wichita adverse-conditions subsite.

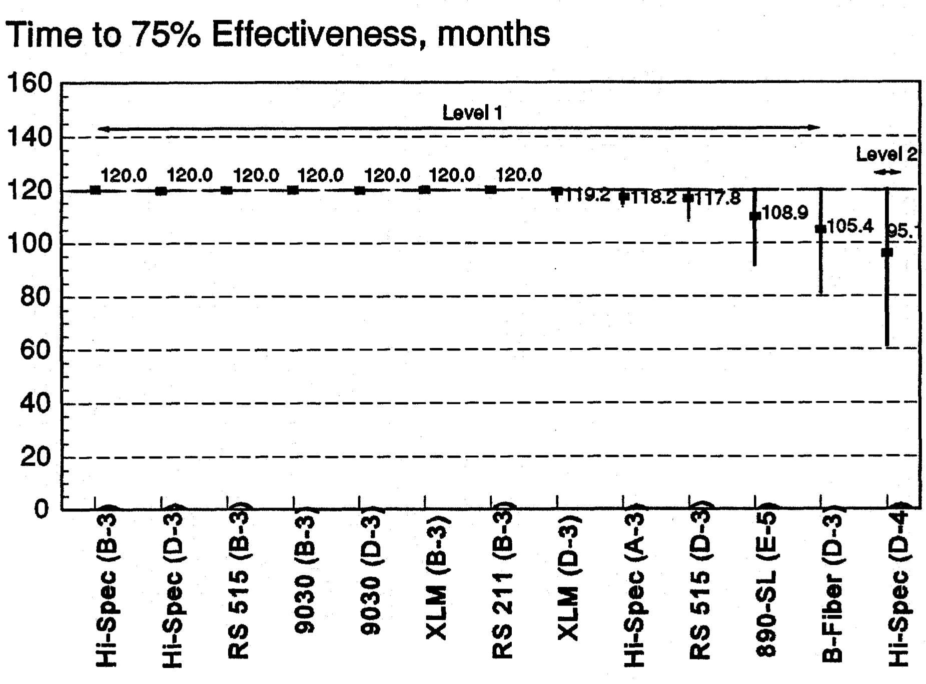


Figure 42. Tukey analysis of estimated treatment service lives at Elma.

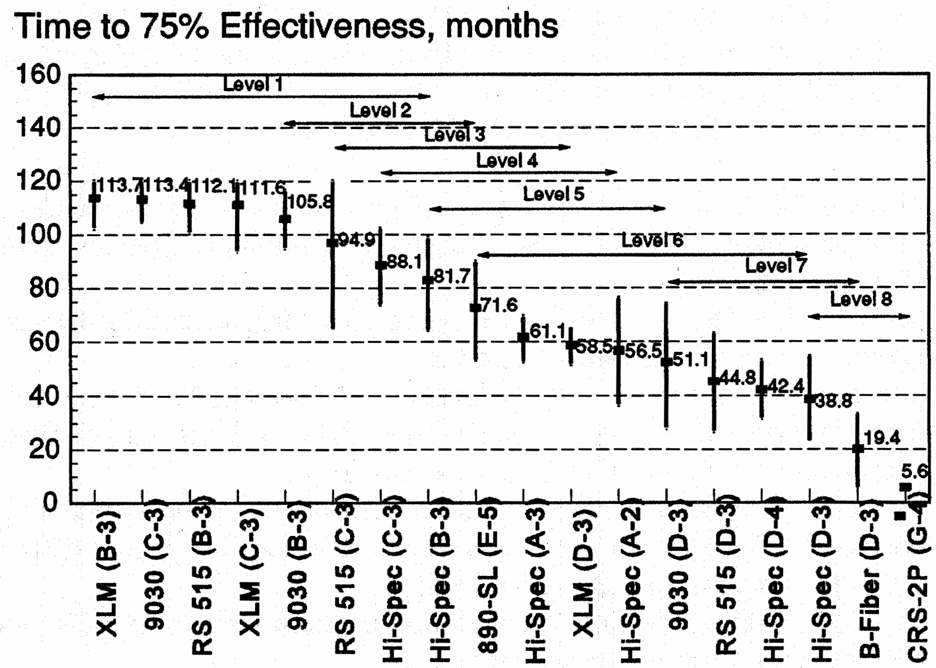


Figure 43. Tukey analysis of estimated treatment service lives at Des Moines.

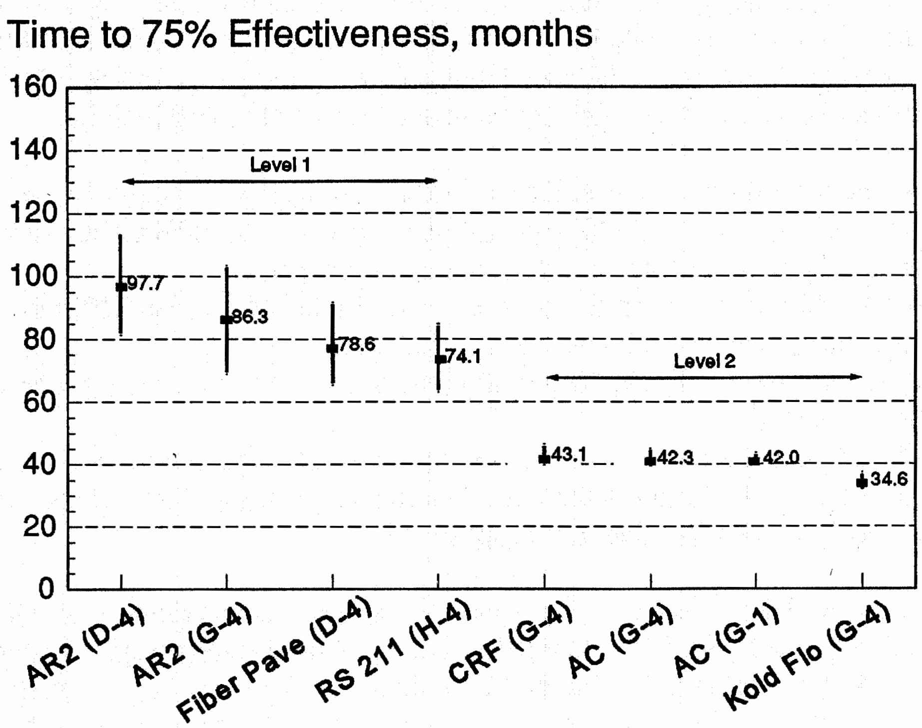


Figure 44. Tukey analysis of estimated treatment service lives at Prescott.

- Among the SHRP-specified rubberized asphalt sealants (Hi-Spec, RS 515, 9030, and XLM) placed using methods B-3, C-3, and D-3, RS 515 showed the longest estimated service life (85.6 months), followed closely by the two low-modulus sealants 9030 (84.3 months) and XLM (84.0 months). The standard modulus sealant Hi-Spec had a considerably shorter estimated service life (73.4 months).

  - 9030 versus XLM: In one of nine direct comparisons, 9030 showed statistically superior performance to XLM. No statistically significant differences existed in the other eight comparisons.
  - 9030 versus RS 515: In nine of nine direct comparisons, no statistically significant differences in performance were observed.
  - 9030 versus Hi-Spec: In one of nine direct comparisons, 9030 showed statistically better performance than Hi-Spec. In the other eight comparisons, no statistically significant differences in performance were observed.
  - XLM versus RS 515: In eight of nine direct comparisons, no statistically significant differences in performance were observed. In the other comparison, XLM showed statistically poorer performance than RS 515.
  - XLM versus Hi-Spec: In nine of nine direct comparisons, no statistically significant differences in performance were observed.
  - RS 515 versus Hi-Spec: In one of nine direct comparisons, RS 515 showed statistically better performance than Hi-Spec. In the other eight comparisons, no statistically significant differences in performance were found to exist.

- Among the SHRP-specified asphalt-based sealants (Hi-Spec, RS 515, 9030, XLM, and BoniFiberized asphalt) placed using method D-3, XLM showed the longest estimated service life (63.8 months), followed very closely by RS 515 (63.5 months). 9030 had the next longest estimated service life (59.9 months), just edging out Hi-Spec (59.1 months). BoniFiberized asphalt had the shortest estimated service life (35.0 months).

  - At Abilene, no statistically significant differences in performance were observed between XLM, RS 515, 9030, and Hi-Spec. However, BoniFiberized asphalt showed statistically poorer performance than these four sealants.
  - At the Wichita ideal-conditions subsite, no statistically significant differences in performance were noted among the five sealants.
  - At Elma, no statistically significant differences in performance were observed among the five sealants.
  - At Des Moines, XLM was found to be statistically better than BoniFiberized asphalt. No statistically significant differences in performance were observed between RS 515, 9030, Hi-Spec, and BoniFiberized asphalt.

- Comparing the SHRP-specified asphalt-based treatments (all methods used with Hi-Spec, RS 515, 9030, XLM, and BoniFiberized asphalt) and the SHRP-specified silicone-based treatment (890-SL with the E-5 method), the mean estimated service life of all asphalt-based treatments was slightly higher than the mean estimated service life of the silicone-based treatment (73.8 months versus 70.4 months).

- In 50 direct comparisons, the 890-SL E-5 treatment was statistically better than 4 asphalt-based treatments, statistically equivalent to 38 asphalt-based treatments, and statistically worse than 8 asphalt-based treatments.

- Comparing the standard recessed band-aid (configuration B), the shallow recessed band-aid (configuration C), and simple band-aid (confiiguration D) used with SHRP-specified rubberized asphalt sealants (Hi-Spec, RS 515, 9030, and XLM), the standard recessed band-aid showed the longest estimated service life (94.5 months), followed very closely by the shallow recessed band-aid (92.9 months). The simple band-aid showed a substantially shorter estimated service life (44.5 months).

  - Configuration B versus D: In 10 of 16 direct comparisons, configuration B showed statistically better performance. In the other six comparisons, no statistically significant differences in performance were observed.
  - Configuration C versus D: In six of eight direct comparisons, configuration C showed statistically better performance. In the other two comparisons, no statistically significant differences in performance were observed.
  - Configuration B versus C: In eight of eight direct comparisons, no statistically significant differences in performance were observed.

- Comparing the standard reservoir-and-flush (configuration A) and the standard recessed band-aid (configuration B) used with the SHRP-specified control material (Hi-Spec), a considerably longer estimated service life was observed with the standard recessed band-aid as compared with the standard reservoir-and-flush (84.7 months versus 70.0 months).

  - In four direct comparisons, no statistically significant differences in performance were observed.

- Comparing the hot airblasting procedure (crack preparation procedure 3) and the conventional airblasting procedure (procedure 4) used with the SHRP-specified control material Hi-Spec, a considerably longer estimated service life was observed with the hot airblasting procedure as compared with the conventional airblasting procedure (59.1 months versus 52.5 months).

  - In one of four direct comparisons, the hot airblasting procedure showed statistically better performance than the conventional airblasting procedure. In the other three comparisons, no statistically significant differences in performance were observed.

- Based on the G-4 method (flush-fill configuration, conventional airblasting), the asphalt rubber material AR2 provided the longest estimated service life (86.3 months), followed distantly by the emulsion CRF (43.1 months), asphalt cement (42.3 months), and the rubberized emulsion Kold Flo (34.6 months).

  - AR2 showed statistically superior performance to CRF, asphalt cement, and Kold Flo. No statistically significant differences in performance were observed among CRF, asphalt cement, and Kold Flo.

- Based on the asphalt rubber material AR2, the simple band-aid appears to have outperformed the flush-fill configuration (97.7 months versus 86.3 months).

  ➛ No statistically significant differences in performance were found to exist between these two configurations when used with AR2.

- The use of high-pressure air for cleaning cracks filled with asphalt cement does not appear to be beneficial. The service-life estimates of the asphalt cement G-1 and G-4 treatments are about the same (42.0 months and 42.3 months, respectively).

  ➛ No statistically significant differences in performance were found to exist between these two preparation procedures when used with asphalt cement.

Laboratory Test–Field Performance Correlation Analyses

Correlation analyses between laboratory test results and field performance indicators were performed using the SAS® Correlation (CORR) procedure. In this procedure, statistical comparisons were made at the 95 percent confidence level between the numerical results of various key laboratory tests and key field distresses. The strength of a relationship was indicated by the Pearson correlation coefficient (r-value) computed in the analysis. Coefficients near 0 represented poor relationships, whereas those near 1 or -1 represented strong relationships. Positive r-values indicated direct relationships, and negative r-values signified inverse relationships.

The correlation analysis involved the comparison of the results of 4 field performance indicators and 21 distinct tests, as measured on the 6 SHRP-specified sealant materials (Hi-Spec, RS 515, 9030, XLM, BoniFiberized asphalt, and 890-SL). The field performance indicators and laboratory tests included the following:

<u>Field Performance Indicators</u>
- Overband wear.
- Full-depth adhesion loss.
- Full-depth cohesion loss.
- Overall failure.

<u>Laboratory Tests</u>
- Cone penetration (ASTM D 3407) at -18 and 25°C.
- Flow (ASTM D 3407) at 60°C.
- Softening point (ASTM D 36).
- Force ductility (ASTM D 113 and Utah test) at 4°C.
- Tensile adhesion (ASTM D 3583) at 24°C using PCC blocks (standard), AC blocks (modified #1), and soaked AC blocks (modified #2).
- Tensile strength (ASTM D 412) at -18, 4, and 24°C.
- Ultimate elongation (ASTM D 412) at -18, 4, and 24°C.
- Stress at 150 percent elongation (ASTM D 412) at -18, 4, and 24°C.

- Bond (ASTM D 3407) at 25°C using channel (modified #1), recessed band-aid (modified #2), and band-aid (modified #3) test configurations.

The comparisons were made using treatment service life estimates (i.e., time until 75 percent overband thickness reduction for overband wear, time until 75 percent effectiveness for adhesion loss, cohesion loss, and overall failure) and mean laboratory test results. Comparisons were made on a site-by-site basis, as well as on an all-sites, or overall, basis. However, because of the small sampling of test results, the correlation analysis focused on overall comparisons only.

Results of the correlation analysis are given in table 17. In this table, shaded cells represent tests and field indicators not expected to be related to each other, whereas unshaded cells represent relationships expected to be at least reasonably strong. The listed correlation coefficients reflect the strength of relationships between laboratory testing data and field performance. A checkmark (✓) by a coefficient indicates an expected, or desired, relationship, whereas an X indicates an unexpected, or undesired, relationship.

Though correlations based on a level of significance of 0.05 (i.e., 95 percent confidence) were originally targeted, correlations based on a 0.10 significance level (i.e., 90 percent confidence) were also identified to expand the reach of potential relationships. The correlation coefficients for both significance levels are given in table 17, with those in brackets representing the 0.10 significance level. A brief discussion of each identified correlation at the all-sites level is given below.

- Cone penetration at 25°C versus overband wear. The higher the cone penetration at 25°C (i.e., the softer the material), the shorter the time required to reduce the overband thickness by 75 percent. A very high and desirable correlation was observed at the 0.10 significance level.

- Force ductility maximum elongation at 4°C versus cohesion failure. The greater the extensibility, the longer the time required for cohesion loss to reach 75 percent effectiveness. A high and desirable correlation was observed.

- Force ductility load at 150 percent elongation and 4°C versus cohesion failure. The greater the load at 150 percent elongation, the shorter the time required for cohesion loss to reach 75 percent effectiveness. A very high and desirable correlation was observed.

- Ultimate elongation at 4°C versus cohesion failure. The greater the ultimate elongation, the longer the time required for cohesion loss to reach 75 percent effectiveness. A high and desirable correlation was observed at the 0.10 significance level.

- Tensile strength at 24°C versus overall failure. The greater the tensile strength, the shorter the time required for overall failure to reach 25 percent (i.e., 75 percent effectiveness). A high, but undesirable, correlation was observed at the 0.10 significance level.

Table 17. Selected laboratory test–field performance correlation results.

Test Parameter	Pearson Correlation Coefficients (r) for Field Distresses[a]			
	Overband Wear	Full-Depth Cohesion Loss	Full-Depth Adhesion Loss	Overall Failure
Cone penetration at -18°C (3-A)				
Cone penetration at 25°C (4-A)	✓ [-0.919]			
Flow at 60°C (5-A)				
Softening point (8-A)				
Force ductility-maximum elongation at 4°C (11-A)		✓ 0.872		
Force ductility-load at 150% elongation and 4°C (11-K)		✓ -0.937		
Tensile adhesion at 24°C, std (12-B)				
Tensile adhesion at 24°C, mod #1 (13-B)				
Tensile adhesion at 24°C, mod #2 (14-B)				
Tensile strength at -18°C (15-A)				
Ultimate elongation at -18°C (15-B)				
Stress @ 150% elongation at -18°C (15-C)				
Tensile strength at 4°C (16-A)				
Ultimate elongation at 4°C (16-B)		✓ [0.895]		
Stress @ 150% elongation at 4°C (16-C)				
Tensile strength at 24°C (17-A)				X [-0.858]
Ultimate elongation at 24°C (17-B)		✓ 0.946		
Stress @ 150% elongation at 24°C (17-C)				✓ -0.922
Modified bond #1 at 25°C (19-B)			✓ -0.936	
Modified bond #2 at 25°C (20-B)				
Modified bond #3 at 25°C (21-B)				

Note: Shaded cells represent tests and field indicators not expected to relate to each other.

[a] Correlations based on level of significance = 0.05 (i.e., 95% confidence). Correlations based on level of significance of 0.10 (i.e., 90% confidence) are given in brackets.

- Ultimate elongation at 24°C versus cohesion failure. The greater the ultimate elongation, the longer the time required for cohesion loss to reach 75 percent effectiveness. A very high and desirable correlation was observed.

- Tensile stress at 150 percent elongation at 24°C versus overall failure. The greater the tensile stress, the shorter the time required for overall failure to reach 25 percent. A very high and desirable correlation was observed.

- Modified bond #1 at 25°C versus adhesion failure. The greater the percentage of debonding, the shorter the time required for adhesion loss to reach 75 percent effectiveness. A very high and desirable correlation was observed.

Cost-Effectiveness Analysis

Although treatment performance in itself is quite important, cost-effectiveness should be the main criterion in the selection of materials and procedures. A cost-effectiveness analysis indicates which treatments provide the best performance for the money spent and which treatments do not live up to their placement costs.

Presented in this section are the procedures that were used to assess crack treatment cost-effectiveness and the subsequent findings of such an analysis, based on the estimated treatment service life corresponding to 75 percent overall effectiveness. The cost-effectiveness analysis consisted of calculating and comparing the life-cycle costs ($/linear m of crack) of the experimental treatments. To accomplish this, a spreadsheet was developed that contained crucial installation and performance data, along with the necessary formulas for computing life-cycle costs. The following types of data were compiled for use in the spreadsheet computations:

- Material cost.
- Unit weight of material.
- Cross-sectional area of material placement configuration.
- Crew size.
- Estimated daily labor cost.
- Estimated daily equipment cost.
- Estimated daily user delay cost.
- Estimated production rate.
- Estimated (actual or predicted) service life at 75 percent effectiveness level.

Using this information and the following equation, the total cost of installing a crack sealant or crack filler material was calculated.

$$C_{inst} = (C_{mat} \times NAR) + (C_{place}/PR) + (C_{user}/PR) \qquad \text{Eq. 2}$$

where: C_{inst} = Total installation cost, \$/linear m of crack.
C_{mat} = Material cost, \$/kg.
NAR = Net application rate, kg/linear m of crack.
C_{place} = Estimated placement cost, \$/day.
PR = Estimated production rate, linear m of crack/day.
C_{user} = Estimated user delay cost, \$/day.

The net application rate is the amount of material required to treat a unit length of crack (1 m was used in this analysis). This quantity was computed using the cross-sectional area of a given placement configuration, the unit weight of the subject material, and a 15 percent waste factor.

The estimated placement cost is the sum of the daily costs of labor and equipment. In this analysis, the amount of labor was estimated based on the typical number of workers observed during the SHRP H-106 installations. For each type of treatment, one supervisor and X number of laborers defined the crew size. The following pay rates were assumed in the calculations:

- Supervisor—$200/day.
- Laborer—$120/day.

Table 18 provides the daily equipment cost estimates that were used in the analysis. The total cost of equipment for a particular treatment type was obtained by summing the equipment costs of the various operations required of that treatment type. An estimated user delay cost of $2,000/day was used in the computation of total installation cost.

Table 19 summarizes the installation requirements and the resulting total installation costs of the various experimental treatments. It also lists the estimated service lives of the treatments based on 75 percent effectiveness. As can be seen, the total installation costs of the hot-applied sealant materials placed in configuration D (simple band-aid) were generally in the range of $5.25 to $5.60/m. Those placed in configurations A, B, and C (standard reservoir-and-flush, standard recessed band-aid, and shallow recessed band-aid) were considerably more expensive ($7.00 to $8.00/m) because of the crack reservoirs. The silicone installation cost was nearly double the

Table 18. Estimated equipment costs for various installation processes.

Installation Process	Equipment Cost, $/day
Traffic control	400
Routing	150
Sawing	200
High-pressure airblasting	150
Hot airblasting	200
Wirebrushing	150
Sandblasting	200
Inserting backer rod	10
Sealant application and finishing	200

Table 19. Installation requirements and costs of experimental crack treatments.

Material	Method	Material Cost, $/kg	Net Application Rate, kg/m	Crew Size	Labor Cost, $/day	Equipment Cost, $/day	Estimated Production Rate, m/day	Total Installation Cost, $/m	Estimated Service Life at 75% Effectiveness, yrs
Abilene, Texas									
Hi-Spec	A-3	0.64	0.39	7	920	950	550	7.31	4.84
	B-3	0.64	0.86	7	920	950	550	7.57	6.48
	D-3	0.64	0.48	7	920	800	730	5.38	4.00
	D-4	0.64	0.48	7	920	750	730	5.31	3.65
RS 515	B-3	0.90	0.89	7	920	950	550	7.87	9.10
	D-3	0.90	0.49	7	920	800	730	5.54	4.84
9030	B-3	0.77	0.80	7	920	950	550	7.67	9.28
	D-3	0.77	0.43	7	920	800	730	5.41	3.71
XLM	B-3	1.32	0.74	7	920	950	550	8.03	7.15
	D-3	1.32	0.40	7	920	800	730	5.61	4.02
B-Fiber	D-3	0.44	0.55	7	920	800	730	5.31	0.75
890-SL	E-5	6.61	0.22	11	1,400	1,360	550	10.16	4.46
Wichita, Kansas (Adverse Conditions)									
Hi-Spec	A-3	0.64	0.39	7	920	950	550	7.31	3.86
	B-3	0.64	0.86	7	920	950	550	7.57	4.87
	C-3	0.64	0.70	7	920	950	600	6.92	5.70
	D-3	0.64	0.48	7	920	800	730	5.38	3.49
	D-4	0.64	0.48	7	920	750	730	5.31	2.48
RS 515	C-3	0.90	0.73	7	920	950	600	7.11	6.00
	D-3	0.90	0.49	7	920	800	730	5.54	3.34
9030	C-3	0.77	0.66	7	920	950	600	6.95	5.46
	D-3	0.77	0.43	7	920	800	730	5.41	1.46
XLM	C-3	1.32	0.61	7	920	950	600	7.28	3.46
	D-3	1.32	0.40	7	920	800	730	5.61	3.92
B-Fiber	D-3	0.44	0.55	7	920	800	730	5.31	0.47
890-SL	E-6	6.61	0.22	11	1,400	1,160	550	9.80	3.01
	F-7	6.61	0.22	11	1,400	1,360	550	10.16	2.41
AR+	B-3	0.55 (est)	0.85	7	920	950	550	7.51	4.68
9000-S	B-3	0.44 (est)	0.89	7	920	950	550	7.44	4.85
Wichita, Kansas (Ideal Conditions)									
Hi-Spec	A-3	0.64	0.39	7	920	950	550	7.31	3.54
	B-3	0.64	0.86	7	920	950	550	7.57	4.95
	C-3	0.64	0.70	7	920	950	600	6.92	4.70
	D-3	0.64	0.48	7	920	800	730	5.38	2.46
	D-4	0.64	0.48	7	920	750	730	5.31	2.37
RS 515	C-3	0.90	0.73	7	920	950	600	7.11	6.69
	D-3	0.90	0.49	7	920	800	730	5.54	2.78
9030	C-3	0.77	0.66	7	920	950	600	6.95	5.69
	D-3	0.77	0.43	7	920	800	730	5.41	2.00
XLM	C-3	1.32	0.61	7	920	950	600	7.28	5.80
	D-3	1.32	0.40	7	920	800	730	5.61	2.42
B-Fiber	D-3	0.44	0.55	7	920	800	730	5.31	0.51
890-SL	E-5	6.61	0.22	11	1,400	1,360	550	10.16	3.98
AR+	B-3	0.55 (est)	0.85	7	920	950	550	7.51	4.35
9000-S	B-3	0.44 (est)	0.89	7	920	950	550	7.44	4.66

Table 19. Installation requirements and costs of experimental crack treatments (continued).

Material	Method	Material Cost, $/kg	Net Application Rate, kg/m	Crew Size	Labor Cost, $/day	Equipment Cost, $/day	Estimated Production Rate, m/day	Total Installation Cost, $/m	Estimated Service Life at 75% Effectiveness, yrs
Elma, Washington									
Hi-Spec	A-3	0.64	0.39	7	920	950	550	7.31	9.85
	B-3	0.64	0.85	7	920	950	550	7.57	10.00
	D-3	0.64	0.48	7	920	800	730	5.38	10.00
	D-4	0.64	0.48	7	920	750	730	5.31	7.93
RS 515	B-3	0.90	0.89	7	920	950	550	7.87	10.00
	D-3	0.90	0.49	7	920	800	730	5.54	9.82
9030	B-3	0.77	0.80	7	920	950	550	7.67	10.00
	D-3	0.77	0.43	7	920	800	730	5.41	10.00
XLM	B-3	1.32	0.74	7	920	950	550	8.03	10.00
	D-3	1.32	0.40	7	920	800	730	5.61	9.93
B-Fiber	D-3	0.44	0.55	7	920	800	730	5.34	8.78
890-SL	E-5	6.61	0.22	11	1,400	1,360	550	10.16	9.08
RS 211	B-3	0.66	0.98	7	920	950	550	7.70	10.00
Des Moines, Iowa									
Hi-Spec	A-2	0.64	0.39	7	920	1,050	550	7.48	4.71
	A-3	0.64	0.39	7	920	950	550	7.31	5.09
	B-3	0.64	0.85	7	920	950	550	7.57	6.81
	C-3	0.64	0.70	7	920	950	600	6.92	7.34
	D-3	0.64	0.48	7	920	800	730	5.38	3.23
	D-4	0.64	0.48	7	920	750	730	5.31	3.53
RS 515	B-3	0.90	0.89	7	920	950	550	7.87	9.34
	C-3	0.90	0.73	7	920	950	600	7.11	7.90
	D-3	0.90	0.49	7	920	800	730	5.54	3.74
9030	B-3	0.77	0.80	7	920	950	550	7.67	8.82
	C-3	0.77	0.66	7	920	950	600	6.95	9.45
	D-3	0.77	0.43	7	920	800	730	5.41	4.25
XLM	B-3	1.32	0.74	7	920	950	550	8.03	9.48
	C-3	1.32	0.61	7	920	950	600	7.28	9.30
	D-3	1.32	0.40	7	920	800	730	5.61	4.88
B-Fiber	D-3	0.44	0.55	7	920	800	730	5.34	1.62
890-SL	E-5	6.61	0.22	11	1,400	1,360	550	10.16	5.97
CRS-2P	G-4	0.26 (est)	0.09	5	800	750	915	3.90	0.47
Prescott, Ontario									
RS 211	H-4	0.66 (est)	0.86	7	920	750	2,440	2.07	6.18
Asphalt Cement	G-1	0.26	0.42	7	680	600	2,745	1.31	3.50
	G-4	0.26	0.42	7	920	750	2,200	1.77	3.53
CRF	B-4	0.44 (est)	0.42	7	920	750	1,830	2.20	3.59
AR2	D-4	0.62	0.80	7	920	750	2.440	2.00	8.14
	G-4	0.62	0.45	7	920	750	2,200	1.93	7.19
Fiber Pave	D-4	0.53	0.67	7	920	750	2,440	1.87	6.55
Kold Flo	B-4	0.44 (est)	0.42	7	920	750	1,830	2.20	2.89

hot-applied configuration D treatments (approximately $10/m), primarily due to the cost of the material. Finally, the cheapest crack sealant to place was the CRS-2P at approximately $3.90/m. Though the exact purchase cost of this product was unknown, an estimate of $0.26/kg was used.

Among the crack filler materials, CRF and Kold Flo were the most costly to place ($2.20/m), despite purchase costs between 20 and 50 percent less than the hot-applied, polymerized asphalt materials. The primary reason for this was the slower production rate. The least expensive material to place was the asphalt cement, which had total installation costs between $1.31 and $1.77/m.

The total installation cost, estimated service life at 75 percent effectiveness, and a 5 percent interest rate were used to compute average annual cost via the following equation:

$$\overline{C}_{annual} = C_{inst} \times ((i \times (1 + i)^{SL})/((1 + i)^{SL} - 1)) \qquad \text{Eq. 3}$$

where:
- $\overline{C}_{annual}$ = Average annual cost, $/linear m of crack.
- SL = Estimated service life, yrs.
- C_{inst} = Total installation cost, $/linear m of crack.
- i = Interest rate, 5 percent.

Tables 20 and 21 list the average annual costs of each treatment, both at the test site level and overall, based on the estimated service lives. As can be seen, service life had a profound effect on average annual cost. Considering only the hot-applied sealants, those with estimated service lives less than 2.0 years had average annual costs greater than $2.90/m. Those with estimated service lives between 2.0 and 5.0 years had average annual costs between $1.30 and $2.60/m. And, those with estimated service lives greater than 5.0 years had average annual costs below $1.70/m.

Of the four SHRP-specified rubberized asphalt sealants, the most cost-effective sealant, based on a service life corresponding to 75 percent effectiveness, was RS 515. A comparison of the average overall annual costs for these materials, considering only non-adverse sites (Abilene, Des Moines, and Wichita ideal-conditions subsite) and installation methods common to all four sites (i.e., methods B-3, C-3, and D-3), yielded the following results:

RS 515 → $1.27/m
XLM → $1.35/m
9030 → $1.36/m
Hi-Spec → $1.44/m

Because of the silicone's significantly higher installation cost and less-than-desirable performance, it was not very cost-effective (overall average annual cost of $2.23/m for the E-5 installation method). Compared to other treatments with service life estimates between 4 and 6 years, the silicone had an average annual cost anywhere between 10 and 100 percent greater.

Table 20. Average annual cost comparisons of crack-seal treatments.

Sealant Material	Installation Method (configuration-preparation)	Average Annual Cost Based on Estimated Service Life Corresponding to 75% Effectiveness, $/linear m of crack					
		Abilene	Wichita (Ideal)	Wichita (Adverse)	Elma	Des Moines	Average of All Non-Adverse Test Sites (excludes Wichita adverse subsite)
Hi-Spec	A-2					1.82	1.82
	A-3	1.73	2.30	2.12	0.96	1.66	1.66
	B-3	1.40	1.77	1.79	0.98	1.34	1.37
	C-3		1.68	1.42		1.15	1.42
	D-3	1.52	2.38	1.72	0.70	1.84	1.61
	D-4	1.63	2.43	2.33	0.83	1.68	1.64
RS 515	B-3	1.10			1.02	1.07	1.06
	C-3		1.28	1.40		1.11	1.20
	D-3	1.31	2.18	1.84	0.72	1.66	1.47
9030	B-3	1.05			0.99	1.10	1.05
	C-3		1.44	1.49		0.94	1.19
	D-3	1.64	2.92	3.95	0.70	1.45	1.68
XLM	B-3	1.36			1.04	1.09	1.16
	C-3		1.48	2.34		1.00	1.24
	D-3	1.58	2.52	1.61	0.73	1.33	1.54
B-Fiber + AC	D-3	7.43	10.75	11.66	0.76	3.51	5.61
890-SL	E-5	2.60	2.88		1.42	2.01	2.23
	E-6			3.59			3.59
	F-7			4.58			4.58
AR+	B-3		1.96	1.84			1.90[a]
9000-S	B-3		1.83	1.77			1.80[a]
RS 211	B-3				1.00		1.00
CRS-2P	G-4					8.70	8.70

[a] Includes costs at Wichita adverse-conditions subsite, since those treatments were actually placed in ideal conditions.

Table 21. Average annual cost comparisons of crack-fill treatments.

Filler Material	Installation Method (configuration-preparation)	Average Annual Cost Based on Service Life Corresponding to 75% Effectiveness, $/linear m of crack
RS 211	H-4	0.40
Asphalt cement	G-1	0.42
	G-4	0.56
CRF	G-4	0.68
AR2	D-4	0.30
	G-4	0.33
Fiber Pave	D-4	0.34
Kold Flo	G-4	0.83

Finally, as can be seen, the SHRP-specified BoniFiberized asphalt was not very cost-effective because of its short service life. An average service life of about 2.92 years was achieved among the non-adverse test sites, which resulted in an overall average annual cost of $5.61/m for this material.

Though the range in average annual costs for the crack fillers is much smaller, there are significant cost differences worth noting. Clearly, the most cost-effective treatments were the AR2 D-4 and G-4 treatments and the Fiber Pave D-4 treatment, with average annual costs of $0.30, $0.33, and $0.34/m, respectively. Interestingly, although RS 211 provided more than 2.5 years of additional life compared to the asphalt cement G-1 treatment, the average annual costs of the two treatments were about the same—$0.40 and $0.42/m, respectively. This is directly attributed to material cost (RS 211 was about 2.5 times the cost of asphalt cement) and the absence of airblasting with the asphalt cement G-1 treatment.

CHAPTER 6. SUMMARY OF FINDINGS AND RECOMMENDATIONS

The SHRP H-106 experiment and subsequent FHWA LTM project represent the most comprehensive pavement surface maintenance study ever conducted. In the crack treatment portion of the study alone, more than 6,710 m of cracking was sealed or filled using 31 distinct treatment types (combinations of material, material placement configuration, and crack preparation procedure) at 5 test sites. Several of the treatment types were applied at more than 1 site, resulting in a total of 82 treatments in 4 distinct climatic zones.

Extensive laboratory testing of the experimental treatment materials was conducted at the outset of the study and the 82 treatments were routinely evaluated for field performance over a period of time ranging from 4.0 to 6.8 years, depending on the test site.

The details of the test sites constructed as part of the H-106 crack treatment study were provided in chapters 1 and 2 of this report. An in-depth discussion of the results of several laboratory tests performed on the experimental materials was provided in chapter 3. Complete documentation of the field performance collected in the study was given in chapter 4, and the results of various data analyses designed to distinguish treatment performance and cost-effectiveness were presented in chapter 5.

This chapter summarizes the major findings and observations of the crack treatment study. The findings are divided into general findings and specific findings about materials and methods. Also contained in this chapter are various recommendations concerning crack sealing and filling operations that could be useful to highway maintenance administrators, practitioners, and researchers.

Findings

General

- Excluding 13 treatments applied at the Elma site, which was overlaid after 4 years of service, only 9 of the 61 crack-seal treatments exhibited "favorable" performance (greater than 80 percent overall effectiveness) after the final round of evaluations (≈6.5 years). Moreover, 32 of the 61 treatments reached "failed" status (<50 percent effectiveness).

- Among the longitudinal crack fillers placed at the Prescott site, half of the eight treatments performed favorably after the 63-month evaluation period. The other half failed.

- Considerable differences in overall treatment performance were found to exist between some of the test sites. These differences were primarily attributed to the combination of crack movement (a function of several variables, including climate and crack type and spacing) and traffic. Generally speaking, the test sites with greater amounts of crack movement and traffic, such as the Wichita and Des Moines sites, had lower levels of treatment effectiveness than sites with less crack movement and traffic, such as the Elma site.

- Most laboratory test–field performance correlations investigated were either weak or non-existent. The strongest direct, positive relationships at the all-sites analysis level were as follows:

  - ➛ Force ductility maximum elongation at 4°C versus cohesion failure.
  - ➛ Force ductility load at 150 percent elongation and 4°C versus cohesion failure.
  - ➛ Ultimate elongation at 24°C versus cohesion failure.
  - ➛ Tensile stress at 150 percent elongation at 24°C versus overall failure.
  - ➛ Modified bond #1 (reservoir configuration) at 25°C versus adhesion failure.

- In hot-applied crack sealants placed in the reservoir-and-flush, standard recessed band-aid, and shallow recessed band-aid configurations (configurations A, B, and C), full-depth adhesion loss accounted for the majority of the overall failure. In hot-applied sealants placed in the simple band-aid configuration (configuration D), full-depth cohesion loss (i.e., ruptures in the band directly over the crack) was the main contributor to the overall seal failure. In silicone seals, the primary mode of failure was edge deterioration, stemming from low-severity spalls and secondary cracks created by saw cutting operations during installation.

- Although adhesion loss and edge deterioration contributed highly to the overall failure in some crack-fill treatments, the primary mode of failure in these treatments was cohesion loss.

<u>Materials</u>

- Among the four SHRP-specified rubberized asphalt sealants (Meadows Hi-Spec, Crafco RS 515, Koch 9030, and Meadows XLM) placed using three shared methods, RS 515 showed the longest estimated service life, followed closely by the two low-modulus sealants, 9030 and XLM. The standard modulus sealant Hi-Spec had a considerably shorter estimated service life.

  Despite the overall mathematical differences in estimated service life, very few statistical differences were noted. In 54 head-to-head comparisons involving the 4 sealants and 3 sealing methods, only 4 statistically significant differences were identified. At Abilene, the 9030 B-3 treatment showed statistically better performance than both the XLM and Hi-Spec B-3 treatments. Also at Abilene, the RS 515 B-3 treatment showed statistically better performance than both the XLM and Hi-Spec B-3 treatments.

- Among the five SHRP-specified hot-applied asphalt sealants (Hi-Spec, RS 515, 9030, XLM, and Kapejo BoniFiberized asphalt) placed in the simple band-aid configuration, XLM showed the longest estimated service life, followed closely by RS 515. 9030 and

Hi-Spec had the next longest estimated service lives, followed distantly by BoniFiberized asphalt.

Statistically, no significant differences in performance existed among Hi-Spec, RS 515, 9030, and XLM. However, BoniFiberized asphalt showed statistically poorer performance than all four of these materials at Abilene, and it showed statistically poorer performance than XLM at Des Moines.

- When compared with the SHRP-specified asphalt-based treatments (i.e., Hi-Spec, RS 515, 9030, XLM, and BoniFiberized asphalt used with all installation methods), the SHRP-specified silicone-based treatment (890-SL placed in the deep reservoir-and-recess configuration in cracks that were sandblasted and airblasted) showed a slightly lower mean estimated service life. Statistically, its performance was better than 4 treatments, equivalent to 38 treatments, and worse than 8 asphalt-based treatments.

- Although Hi-Spec placed in the standard recessed band-aid configuration at the Wichita ideal-conditions subsite had a mean estimated service life slightly higher than those of the two State-added sealants (Crafco AR+ and Koch 9000-S), no statistical differences in these treatments were identified.

- At the Elma site, the State-added sealant (Crafco RS 211) placed in the standard recessed band-aid configuration showed the same estimated service life as Hi-Spec placed in the same configuration.

- At the Des Moines site, the 17 SHRP-specified treatments performed, on average, much better than the State-added emulsion material CRS-2P placed in the flush-fill configuration. Statistically, 15 of the 17 SHRP-specified treatments showed better performance than the CRS-2P treatment, whereas the other 2 showed similar performances.

- With respect to the performance of longitudinal crack fillers, based on a flush-fill configuration and conventional airblasting, the asphalt rubber material Crafco AR2 provided the longest estimated service life, followed distantly by the Witco CRF modified emulsion, asphalt cement, and the Hy-Grade Kold Flo rubberized emulsion. Statistically, AR2 showed a performance superior to each of the latter three materials.

- Results of a cost-effectiveness analysis that considered the total installation cost and estimated service life of each treatment showed that the most cost-effective treatments were usually those consisting of rubberized asphalt placed in a standard or shallow recessed band-aid configuration. The next most cost-effective treatments were generally those consisting of rubberized asphalt placed in the simple band-aid or reservoir-and-flush configurations. Silicone treatments were considerably less cost-effective than the ones described above; however, the least cost-effective sealants were the fiberized asphalt and proprietary emulsion sealants.

- Among longitudinal crack-fill treatments, the most cost-effective treatments were the hot-applied, rubber- and fiber-modified asphalt materials placed in the overband and flush-fill configurations. Asphalt cement flush-fill treatments were the next most cost-effective treatments, followed by proprietary emulsions placed in the flush-fill configuration.

Methods

- A comparison of the standard recessed band-aid (configuration B), shallow recessed band-aid (configuration C), and simple band-aid (confiiguration D) configurations used with SHRP-specified rubberized asphalt sealants (Hi-Spec, RS 515, 9030, and XLM) showed that the standard recessed band-aid had the longest estimated service life, followed very closely by the shallow recessed band-aid. The simple band-aid showed a substantially shorter estimated service life. In eight of eight direct statistical comparisons between the standard recessed band-aid and the shallow recessed band-aid, no significant differences in performance were observed. Furthermore, in 10 of 16 direct comparisons, the recessed band-aid showed statistically better performance than the simple band-aid. Lastly, in six of eight direct comparisons, the shallow recessed band-aid showed statistically better performance than the simple band-aid.

- A comparison of the standard reservoir-and-flush (configuration A) and the standard recessed band-aid (configuration B) used with the SHRP-specified control material (Hi-Spec) showed the standard recessed band-aid with a considerably longer estimated service life. However, in four direct comparisons, no statistically significant differences in performance were observed between these configurations.

- A comparison of the hot airblasting and conventional airblasting crack preparation procedures (procedures 3 and 4) used with the SHRP-specified control material Hi-Spec showed the hot airblasting procedure with a considerably longer estimated service life. However, in only one of four direct comparisons did the hot airblasting procedure show statistically better performance.

Recommendations

Crack Sealing/Filling Operations

- Upon noticing the development of considerable cracking in an asphalt-surfaced pavement, the complete circumstances of the pavement should be carefully assessed prior to taking action. The type and orientation of the cracks to be treated should be established, along with the climatic conditions, pavement structure composition, traffic characteristics, and future rehabilitation plans. Each of these items will help determine the amount of annual crack movement that can be expected—and consequently the quality of the material required—and whether a short-, medium-, or long-term treatment of the cracks is most appropriate.

- For cost-effective, short-term crack-seal performance (between 1 and 3 years) in pavements with ordinary working cracks (2.5 to 5.0 mm of horizontal crack movement) and moderate traffic levels, a standard rubberized asphalt (e.g., Meadows Hi-Spec) placed in a simple band-aid configuration is considered most appropriate. After 1 or 2 years, the band will become significantly worn by traffic (particularly in the wheelpaths) and considerable amounts of cohesive failure will develop.

- For cost-effective, medium-term crack-seal performance (between 3 and 5 years) under the above conditions, a standard rubberized asphalt (e.g., Meadows Hi-Spec) placed in the recessed band-aid configuration or a modified rubberized asphalt (e.g., Crafco RS 515, Meadows XLM) placed in the simple band-aid configuration is considered most appropriate.

- For cost-effective, long-term crack-seal performance (say, between 5 and 8 years) under the above conditions, a modified rubberized asphalt sealant (e.g., Crafco RS 515, Koch 9030) installed in either a standard or shallow recessed band-aid configuration should be used. These materials provide a high level of flexibility and adhesiveness, so that annual crack movements can be accommodated. Moreover, the combination of a reservoir and an overband helps to maximize sealant performance. The use of an HCA lance to clean, dry, and warm the routed cracks appears to be justifiable in terms of the overall cost-effectiveness.

- For cost-effective, short-term crack filler performance (1 to 3 years) in pavements with non-working cracks (less than 2.5 mm of horizontal crack movement) and low to moderate traffic levels, asphalt cement placed in a flush-fill configuration is considered most appropriate. Though conventional airblasting with asphalt cement was shown to not be a cost-effective proposition in the H-106/LTM study, its use in this situation should be considered.

- For cost-effective, long-term crack filler performance (say, between 5 and 8 years) under the above conditions, an asphalt rubber or rubberized asphalt (e.g., Crafco AR2, Crafco RS 211) placed in either a flush-fill or overband configuration, or a fiberized asphalt (e.g., Hercules Fiber Pave) placed in an overband configuration is considered most appropriate. The higher quality of these materials and the added life provided by the overband make for the most cost-effective options in this scenario.

- The importance of quality control in crack sealing and filling operations cannot be over-emphasized. Care must be taken by all crewpersons involved in the crack preparation and material installation processes, so as to successfully manifest the designed treatment. A key to this element is an objective, hands-on inspector.

Education and Research

- The information gathered and findings developed under the H-106/LTM study should be disseminated to all individuals affiliated with crack treatment operations, including highway maintenance policy-makers, supervisors, and crewpersons, as well as researchers and new-products evaluation personnel. Such dissemination can occur through the distribution of this report and through presentations at conferences and workshops.

- Because many new advancements in materials and equipment have occurred since the start of the H-106 experiment, it is highly recommended that agencies conduct their own customized crack-seal experiments. The materials and methods commonly used by agency crews should be evaluated against the various materials and methods shown to be effective and economical in the H-106/LTM study. Also, new or promising technologies should be included in the experiment.

- Though the 890-SL self-leveling silicone showed mediocre performance and poor cost-effectiveness in the H-106/LTM study, field testing of this material should be continued, as it is believed that it could perform very well in a routed reservoir. The sawn reservoirs in which it was placed in the experiment contained many "missed crack" segments, which tended to deteriorate under traffic and cause the seal to incur edge deterioration failure. If tested, this material should be adequately recessed (minimum of 6 mm) below the pavement surface to keep traffic from tracking it as it cures and to minimize the potential for pull-outs.

- As a result of the lack of development of new substantive correlations between laboratory tests and field performance indicators, it is recommended that research in this area continue to be pursued. The identification of reliable performance-related laboratory tests would greatly help agencies ensure the proper selection of a material for a given project.

REFERENCES

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APPENDIX A. TEST SITE LAYOUTS

The AC crack treatment test sites were laid out end-to-end in two replicates. Each replicate contained test sections consisting of 10 cracks treated using 1 combination of material and method. The following tables present the sequential layout of experimental treatments in the form of test sections at each site.

Table A-1. Randomized order of treatments at Abilene crack-seal test site.

Test Section	Treatment (Material and Method)
1	Dow Corning 890-SL, E-5
2	Meadows Hi-Spec, D-3
3	Meadows Hi-Spec, B-3
4	Meadows Hi-Spec, D-4
5	Meadows SofSeal XLM, B-3
6	Koch 9030, B-3
7	Crafco RS 515, D-3
8	Kapejo BoniFibers + AC, D-3
9	Meadows Hi-Spec, A-3
10	Crafco RS 515, B-3
11	Meadows SofSeal XLM, D-3
12	Koch 9030, D-3

Table A-2. Randomized order of treatments at Elma crack-seal test site.

Test Section	Treatment (Material and Method)
A	Crafco RS 211, B-3
1	Dow Corning 890-SL, E-5
2	Koch 9030, D-3
3	Meadows Hi-Spec, B-3
4	Meadows Hi-Spec, D-4
5	Meadows SofSeal XLM, B-3
6	Koch 9030, B-3
7	Crafco RS 515, D-3
8	Kapejo BoniFibers + AC, D-3
9	Meadows Hi-Spec, A-3
10	Crafco RS 515, B-3
11	Meadows SofSeal XLM, D-3
12	Meadows Hi-Spec, D-3

Table A-3. Randomized order of treatments at Wichita crack-seal test site.

Test Section	Treatment (Material and Method)	
	Ideal-Conditions Lane	Adverse-Conditions Lane
1	Meadows SofSeal XLM, D-3	Meadows SofSeal XLM, D-3
2	Meadows Hi-Spec, C-3	Meadows Hi-Spec, C-3
3	Meadows Hi-Spec, D-4	Meadows Hi-Spec, D-4
4	Crafco RS 515, D-3	Crafco RS 515, D-3
5	Kapejo BoniFibers + AC, D-3	Kapejo BoniFibers + AC, D-3
6	Koch 9030, C-3	Koch 9030, C-3
7	Meadows Hi-Spec, D-3	Meadows Hi-Spec, D-3
8	Dow Corning 890-SL, E-5	Dow Corning 890-SL, E-6 and F-7
9	Meadows Hi-Spec, B-3	Meadows Hi-Spec, B-3
10	Koch 9030, D-3	Koch 9030, D-3
11	Crafco RS 515, C-3	Crafco RS 515, C-3
12	Meadows Hi-Spec, A-3	Meadows Hi-Spec, A-3
13	Meadows SofSeal XLM, C-3	Meadows SofSeal XLM, C-3
14	Crafco AR+, B-3	Crafco AR+, B-3
15	Koch 9000-S, B-3	Koch 9000-S, B-3

Table A-4. Randomized order of treatments at Des Moines crack-seal test site.

Test Section	Treatment (Material and Method)
1	Meadows SofSeal XLM, D-3
2	Meadows Hi-Spec, C-3
3	Koch 9030, C-3
4	Meadows Hi-Spec, D-4
5	Crafco RS 515, D-3
6	Kapejo BoniFibers + AC, D-3
7	Meadows SofSeal XLM, C-3
8	Koch 9030, B-3
9	Meadows Hi-Spec, D-3
10	Dow Corning 890-SL, E-5
11	Meadows Hi-Spec, B-3
12	Koch 9030, D-3
13	Crafco RS 515, B-3
14	Meadows Hi-Spec, A-3
15	Meadows SofSeal XLM, B-3
16	Crafco RS 515, C-3
17	Meadows Hi-Spec, A-2
18	Elf CRS-2P, G-4

Table A-5. Randomized order of treatments at Prescott crack-fill test site.

Test Section	Treatment (Material and Method)
A	Crafco RS 211, H-4
1	Crafco AR2, G-4
2	Witco CRF, G-4
3	Asphalt Cement, G-4
4	Hercules Fiber Pave + AC, D-4
5	Asphalt Cement, G-1
6	Crafco AR2, D-4
7	Hy-Grade Kold Flo, G-4

APPENDIX B. INSTALLATION DATA

Several types of data were collected at each field installation. Included in this appendix are descriptions of the types of data recorded and illustrations of the forms used to record the data. Tables B-1 through B-6 summarize the installation data collected for each experimental treatment.

Data Collection Forms

Work Log and Weather Conditions

Work accomplishments, construction occurrences, and ambient weather conditions were recorded for each day of the installation process. Air temperatures were taken periodically throughout each day, primarily for assessing crack widths as a function of temperature. Figure B-1 shows the field form used for documenting this data.

Test Section Layout

All experimental cracks, test section boundaries, roadway structures, and milepost markers were stationed with a survey wheel to the nearest foot, as illustrated in figure B-2.

Pre-Existing Crack Data

After a test site was fully laid out in the field (i.e., experimental cracks and test sections marked) in preparation for the installation process, the first group of installation data was collected. These data represented the pre-existing conditions of each experimental crack and were documented on copies of the form shown in figure B-3.

First, average crack widths were measured and recorded. Then, individual crack maps were sketched showing the general crack patterns and the approximate positions and dimensions of edge deterioration observed along the experimental cracks. To simplify analyses, distress dimensions were measured in the longitudinal and transverse directions. This information was recorded as a baseline condition for monitoring the development of additional edge deterioration caused by crack-cutting operations or traffic applications.

To facilitate the documentation of edge deterioration along a transverse crack, the crack was broken down into five positions. These positions were as follows:

- Inside edge (0.6 m).
- Inside wheelpath (0.6 m).
- Center (1.2 m).
- Outside wheelpath (0.6 m).
- Outside edge (0.6 m).

WORK JOURNAL / CLIMATIC CONDITION CHART

General Information [INSTALLATION]

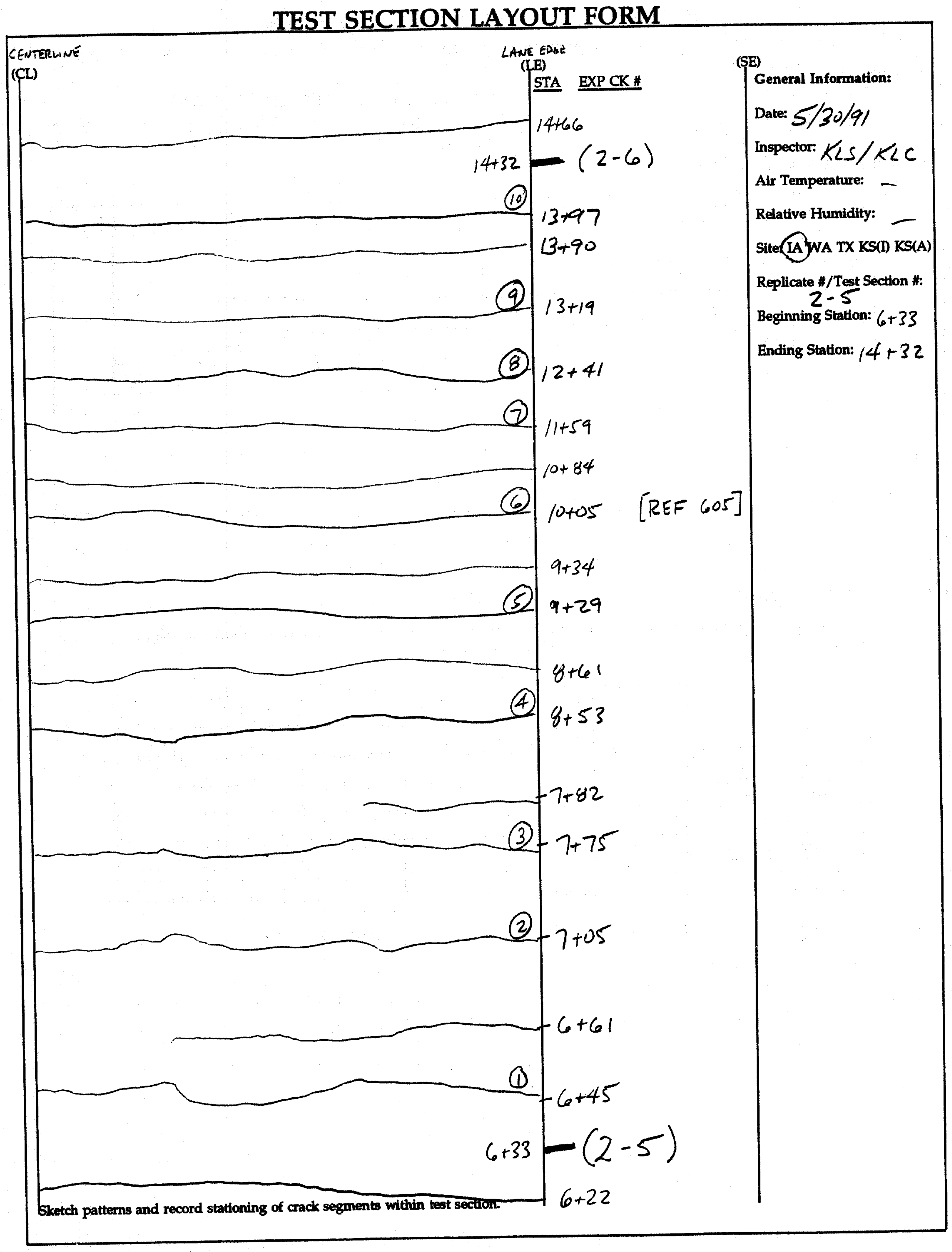
Date: 6/6/91

Inspector: KLS/KLC

Test Site: (IA) WA TX KS(I) KS(A) ONT

Time	Air Temperature (°F)	Relative Humidity (%)	Clouds (%)	Work Activity	Replicate #/ Test Section #
6:00 a.m.				6:15	
6:30				Initial Heating of:	
7:00	62	25	20	- XLM	
7:30				- 9030	
8:00					
8:30				8:45	
9:00	69	25	25	Final Heating	
9:30				9:30	
10:00				Sealing in Replicate #1	
10:30	75	30	25	Sections: 1-1 (XLM)	
11:00				1-3 (9030)	
11:30				1-7 (XLM)	
12:00 p.m.				1-8 (9030)	
12:30	80	30	15	1-12 (9030)	
1:00				1-15 (XLM)	
1:30					
2:00					
2:30				2:40 Sealing in Replicate #2	
3:00	81	35	40	Sections: 2-1 (XLM)	
3:30				2-3 (9030)	
4:00				2-7 (XLM)	
4:30				2-8 (9030)	
5:00				2-12 (9030)	
5:30	78	35	50	5:45 2-15 (XLM)	
6:00					

Figure B-1. Work journal and climatic condition chart.


TEST SECTION LAYOUT FORM

CENTERLINE (CL)

LANE EDGE (LE)

(SE)

STA | EXP CK #

14+66

14+32 (2-6)

⑩ 13+97

13+90

⑨ 13+19

⑧ 12+41

⑦ 11+59

10+84

⑥ 10+05 [REF 605]

9+34

⑤ 9+29

8+61

④ 8+53

7+82

③ 7+75

② 7+05

6+61

① 6+45

6+33 (2-5)

6+22

Sketch patterns and record stationing of crack segments within test section.

General Information:

Date: 5/30/91

Inspector: KLS/KLC

Air Temperature: —

Relative Humidity: —

Site: (IA) WA TX KS(I) KS(A)

Replicate #/Test Section #: 2-5

Beginning Station: 6+33

Ending Station: 14+32

Figure B-2. Test section layout form.

INITIAL CRACK INVENTORY FORM

General Information

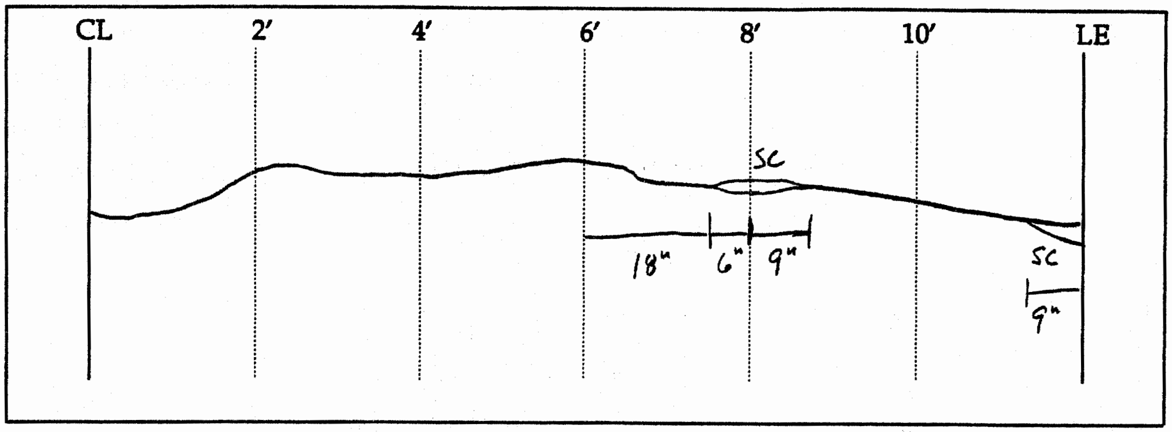
Date: 5/31/91

Inspector: KLS/KLC

Test Site: (IA) WA TX KS(I) KS(A)

Replicate #/Test Section #/Crack #: 1/17/3

Initial Crack Evaluation



Initial Crack Summary

Segment	Pavement Surround Distress - Existing (in)				Cupping	
	Spalling		Secondary Cracking			
	High	Low	High	Low	High	Low
Outside Edge (2 ft)			9			
Outside Wheelpath (2 ft)			9			
Center (4 ft)			6			
Inside Wheelpath (2 ft)						
Inside Edge (2 ft)						

Crack Width: 1/16 (1/8) 3/16 1/4 5/16 3/8 7/16 1/2 9/16 5/8 11/16 3/4 13/16 7/8

Figure B-3. Initial crack inventory form.

By partitioning the transverse cracks in this way, the effects of traffic on the sealant system could be evaluated. The 7.6-m longitudinal crack divisions at Prescott were broken down into five 1.5-m segments, but only to facilitate the evaluations.

Crack-Cutting Data

Information about crack-cutting operations and the resulting crack reservoir conditions was recorded on copies of the forms shown in figures B-4 and B-5. After specified experimental cracks were cut and quickly blown free of dust and debris, they were reinspected for edge deterioration as described in the previous section. During the reinspection, three additional distress phenomena were monitored: missed cracks, neglected cracks, and "islands." A missed crack denoted a segment of crack missed in the cutting operation because of the inability of the operator or the equipment to accurately follow the crack. Missed cracks resulted in two adjacent defects: the original crack and the nearby channel cut. In places where secondary cracks existed, the cutting operator had the option of cutting only the primary crack and neglecting the secondary crack or cutting both the primary crack and the secondary crack. In the latter case, an "island" of pavement surrounded by channel cuts was created. Although both cracks and crack reservoirs were eventually sealed, it was desirable to see how fast these distressed segments would deteriorate with time.

Material Preparation Data

For hot-applied materials, a material heating log was kept that showed the intermittent temperatures of a product in the kettle vat during the heating and application phases. Copies of the form shown in figure B-6 were used for documenting this information. Temperature readings were taken from both the temperature gauge mounted on the kettle and a hand-held thermometer probe that was inserted into the material in the vat.

Final Crack Preparation and Material Installation Data

Just prior to installation, a digital caliper was used to measure the distances between sets of dimpled P-K nails installed across each experimental crack during layout. These distances served as base references for determining the amount of horizontal movement a particular crack experiences at various times throughout the year. Distances were recorded using copies of the form illustrated in figure B-7.

Information regarding final crack preparation and material installation was documented on forms identical to the one shown in figure B-8. Due to the lack of a standard procedure for evaluating crack channels for cleanliness and moisture, subjective ratings were used to assess each crack following the cleaning/drying operations. A five-point scale, with "1" designating "dirty" and "5" designating "very clean", was used to evaluate crack channel cleanliness. Similarly, a five-point scale was used to gauge the presence of moisture, with "1" indicating "no moisture present" and "5" indicating "moisture present on bonding surfaces."

TEST SECTION INITIAL PREPARATION FORM

General Information

Date: 6/3/91
Inspector: KLC
Test Site: (IA) WA TX KS(I) KS(A)
Replicate #/Test Section #: 1 / 2 (Wide, Shallow Routing)

Refacing Operation

Saw/Router Type and Size: Crafco Model 200 Rotary-Impact Router
Number of Crewpersons [indicate F (foreman), D (driver), or L (laborer)]:
2 Laborers (Router)
1 Laborer (Flag)
1 Foreman
Time per Section (Begin/End): 10:12 am → 10:51 am

Airblasting Operation

Air Compressor Type and Capacity: Sullair 250 psi
Number of Crewpersons [indicate F (foreman), D (driver), or L (laborer)]:
1 Driver
1 Operator
Time per Section (Begin/End): 10:15 am → 10:53 am

Figure B-4. Test section initial preparation form.

REFACED CRACK INVENTORY FORM

General Information

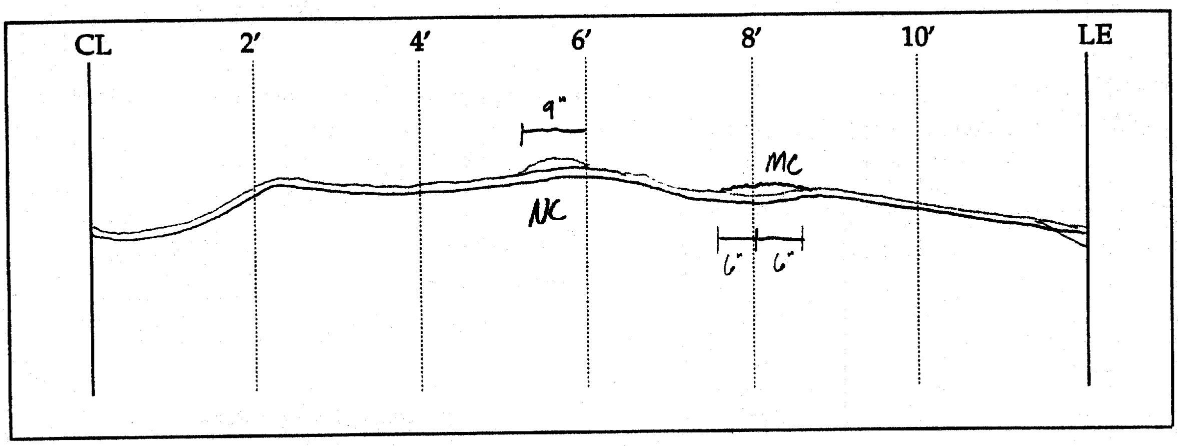
Date: 6/3/91

Inspector: KLS

Test Site: (IA) WA TX KS(I) KS(A)

Replicate #/Test Section #/Crack #: 1/1/7/13

Refaced Crack Evaluation



Refaced Crack Summary

Segment	Pavement Surround Distress Due to Channel Creation (in)				
	Spalling		Secondary Cracking		Missed Crack
	High	Low	High	Low	
Outside Edge (2 ft)					
Outside Wheelpath (2 ft)					6"
Center (4 ft)			9"		6"
Inside Wheelpath (2 ft)					
Inside Edge (2 ft)					

Average Channel Width (in): 9/16

Average Channel Depth (in): 11/16

Channel Creation Operation: [Saw] ([Router])

Figure B-5. Refaced crack inventory form.

KETTLE TEMPERATURE MONITORING CHART

This form is to be completed by the person responsible for each melter/applicator. Readings using the thermometer provided by the H-106 contractor will be taken at 30 min (± 5 min) time intervals. One form will be completed for each sealant/filler material and for each day. Temperatures will be reported in degrees Fahrenheit.

Date: 6-5-91
Name of Kettle Tender: Gary B.

Kettle Type: Cimline 200
Kettle Size (gal): 200 Gal

Sealant/Filler Mtl: M-HiSpec C-515 K-9030 M-XLM K-BoniFbrs (circled) C-AR2 H-FbrPave AC

Time	Thermometer Reading	Gage Reading
6:00 am		
6:30		
7:00	280	250
7:30	290	290
8:00	330	320
~~8:30~~ 8:15		320 (ADDED FIBERS)
9:00	310	310
9:30	310	320
10:00	310	320
10:30	300	310
11:00	310	330
11:30		
12:00 p.m.		
12:30		
1:00		
1:30		
2:00		
2:30		
3:00		
3:30		
4:00		
4:30		
5:00		
5:30		
6:00		

(INSTALLATION) [9:30 – 11:00]

The following times will be recorded as the sealant/filler is heated:

Begin Heating: 6:10 am

Product Liquified: ______

Product at Application Temp: ______

Nozzle Temperature Readings

Lines may be cleared and application temperature readings may be taken after the sealant/filler in the kettle has remained at application temperature for at least 30 minutes.

Trial 1

Time: 9:30 am/pm (am circled)

Nozzle Temp: 305 °F

Kettle Temp: 320 °F

Kettle Gage: 310 °F

Trial 2

Time: 11:00 am/pm (am circled)

Nozzle Temp: 305 °F

Kettle Temp: 330 °F

Kettle Gage: 315 °F

Figure B-6. Kettle temperature monitoring chart.

NAIL PLUG MONITORING CHART

[INSTALLATION]

General Information

Date: 6/7/91
Inspector: KLS/KLC

Test Site: Ⓘ IA WA TX KS(I) KS(A)
Material: ① 2 3 4 5 6 7 8

Material	Configuration	Cleaning Procedure
(1) Hi-Spec	(A) 0.63" x 0.75" Channel & Flush	(1) None
(2) 34515	(B) 0.63" x 0.75" Channel & Band-Aid	(2) Wire Brush & Compressed Air
(3) 9030	(C) 1.5" x 0.2" Channel & Band-Aid	(3) HCA Lance
(4) XLM	(D) Band-Aid	(4) Compressed Air
(5) BoniFibers	(E) Channel & Recess	(5) Light Sandblast, Compressed Air, & Backer Rod
(6) 890 SL		
(7) Other ______		
(8) Other ______		

Crack Movement Record

	(C-3)		(D-4)		(D-3)	
Crack Number	Replicate #/Test Section #: 1/2 Material: ① 2 3 4 5 6 7 8 Configuration: A B Ⓒ D E Preparation: 1 2 ③ 4 5		Replicate #/Test Section #: 1/4 Material: ① 2 3 4 5 6 7 8 Configuration: A B C Ⓓ E Preparation: 1 2 3 ④ 5		Replicate #/Test Section #: 1/9 Material: ① 2 3 4 5 6 7 8 Configuration: A B C Ⓓ E Preparation: 1 2 ③ 4 5	
	Time	Reading	Time	Reading	Time	Reading
1	9:08am	—	9:40am	—	10:40am	—
2		—		—		—
3		10.605		10.404		10.804
4		10.316		10.651		10.798
5		10.573		10.524		10.495
6		10.534		11.203		10.820
7		10.529		10.585		10.570
8		10.664		10.467		10.374
9		10.546		10.927		10.485
10	9:16am	10.859	9:45am	10.808	10:46am	10.595

	(B-3)		(A-3)		(A-2)	
Crack Number	Replicate #/Test Section #: 1/11 Material: ① 2 3 4 5 6 7 8 Configuration: A Ⓑ C D E Preparation: 1 2 ③ 4 5		Replicate #/Test Section #: 1/14 Material: ① 2 3 4 5 6 7 8 Configuration: Ⓐ B C D E Preparation: 1 2 ③ 4 5		Replicate #/Test Section #: 1/17 Material: ① 2 3 4 5 6 7 8 Configuration: Ⓐ B C D E Preparation: 1 ② 3 4 5	
	Time	Reading	Time	Reading	Time	Reading
1	11:04 am	—	11:38am	—	12:19pm	—
2		—		—		—
3		10.516		10.611		10.721
4		10.740		10.718		10.355
5		10.626		10.238		10.675
6		10.659		10.700		10.555
7		10.565		10.882		10.643
8		10.346		10.301		10.581
9		10.471		10.330		10.134
10	11:10am	10.573	11:45am	10.554	12:24pm	10.726

Figure B-7. Nail plug monitoring chart.

TEST SECTION FINAL PREPARATION & INSTALLATION FORM

General Information:
Date: 6/7/91
Inspector: KLS/KLC
Test Site: (IA) WA TX KS(I) KS(A)
Replicate #/Test Section #: 1 / 2 (Hi-Spec C-3 Treatment)

Material	Configuration	Preparation Procedure
(1) Hi-Spec (circled)	(1) 0.63" x 0.75" Channel & Flush	(1) None
(2) 34515	(2) 0.63" x 0.75" Channel & Band-Aid	(2) Wire Brush & Compressed Air
(3) 9030	(3) 1.5" x 0.2" Channel & Band-Aid (circled)	(3) HCA Lance (circled)
(4) XLM	(4) Band-Aid	(4) Compressed Air
(5) BoniFibers	(5) Channel & Recess	(5) Light Sandblast, Compressed Air, & Backer Rod
(6) 890 SL		
(7) Other ______		
(8) Other ______		

Final Preparation
Brush Type and Size: ——
Time (Begin/End): ——
Compressed Air Unit Type and Capacity: Sullair 250 psi
Heat Lance Type and Model: Cimline Hot Rod Lance
Time (Begin/End): 9:15 → 9:42
Total Number of Crewpersons [Indicate F, D, or L]:
1 Driver, 1 Operator

Installation & Finishing
Melter/Applicator Type and Size: Cimline 200 gal
Finishing Apparatus Type: Band-Aid Squeegee
Time (Begin/End): 9:20 → 9:45
Total Number of Crewpersons [Indicate F, D, or L]:
1 Driver
1 Applicator
1 Squeegeer

Application Checklist

	Crack Number 1	2	3	4	5	6	7	8	9	10	Comments
Sealant Overheating											No
Sealant Bubbling											Yes, small amounts
Crack Cleanliness	→	→	→	→	→	→	→	→	→	→	GOOD
Crack Moisture	→	→	→	→	→	→	→	→	→	→	NONE APPARENT
Overband Thickness, in	1/8	3/32	1/8	1/8	3/32	1/8	1/8	1/8	1/8	1/8	
Overband Width, in	→	→	→	→	→	→	→	→	→	→	3"
Depth to Backer Rod, in											—
Depth of Recess, in											—

Miscellaneous Information
Approximate Amount of Material Used (lb): ??
Blotting Required: Yes (If yes, sand or tp) (No) → Traffic Cones Set Up

Figure B-8. Final crack preparation and material installation form.

Table B-1. Des Moines test section installation summary.

Test Site	Material	Replicate	Configuration	Preparation Procedure	Date of Installation	Avg Original Crack Width, in	Avg Crack Reservoir Width, in	Avg Crack Reservoir Depth, in	Type of Cut (Rout, Saw)	Avg Final Crack Width, in	Avg Crack Cleanliness Rating	Avg Crack Moisture Rating	Avg Band-Aid Thickness, in	Avg Band-Aid Width, in	Avg Backer Rod Depth, in	Avg Depth of Recess, in	Material Overheating	Material Bubbling	Bubbles - Low, in	Bubbles - Medium, in	Bubbles - High, in	Sunken Material - Low, in	Sunken Material - High, in	Stone Intrusion - Low, in	Stone Intrusion - Med, in	Stone Intrusion - High, in
IA	1	1	A	2	31-May-91	0.106	0.563	0.727	Rout	0.563	4	2	N/A	N/A	N/A	N/A	No	2	18	0	0	0	0	0	0	0
IA	1	2	A	2	03-Jun-91	0.098	0.563	0.704	Rout	0.563	4	2	N/A	N/A	N/A	N/A	No	2	72	0	0	0	0	0	0	0
IA	1	1	A	3	31-May-91	0.106	0.563	0.711	Rout	0.563	4	2	N/A	N/A	N/A	N/A	No	2	90	0	0	0	0	0	0	0
IA	1	2	A	3	03-Jun-91	0.102	0.563	0.719	Rout	0.563	4	2	N/A	N/A	N/A	N/A	No	2	108	18	0	0	0	0	0	0
IA	1	1	B	3	31-May-91	0.110	0.563	0.625	Rout	0.563	4	2	0.094	2.75	N/A	N/A	No	2	90	0	0	0	0	0	0	0
IA	1	2	B	3	03-Jun-91	0.106	0.563	0.735	Rout	0.563	4	2	0.094	3.00	N/A	N/A	No	2	120	6	0	0	0	0	0	0
IA	1	1	C	3	31-May-91	0.106	1.500	0.235	Rout	1.500	4	2	0.094	2.75	N/A	N/A	No	2	126	18	0	0	0	0	0	0
IA	1	2	C	3	31-May-91	0.113	1.500	0.196	Rout	1.500	4	2	0.094	3.00	N/A	N/A	No	2	72	72	0	0	0	0	0	0
IA	1	1	D	3	31-May-91	0.102	N/A	N/A	N/A	0.102	4	2	0.094	2.75	N/A	N/A	No	2	114	12	0	0	0	0	0	0
IA	1	2	D	3	03-Jun-91	0.106	N/A	N/A	N/A	0.106	4	2	0.094	3.00	N/A	N/A	No	2	120	24	0	0	0	0	0	0
IA	1	1	D	4	31-May-91	0.106	N/A	N/A	N/A	0.106	3	2	0.094	2.75	N/A	N/A	No	2	108	36	0	0	0	0	0	0
IA	1	2	D	4	31-May-91	0.106	N/A	N/A	N/A	0.106	3	2	0.094	3.00	N/A	N/A	No	2	102	24	0	0	0	0	0	0
IA	2	1	B	3	31-May-91	0.106	0.563	0.696	Rout	0.563	4	2	0.094	3.00	N/A	N/A	No	2	44.3	0	0	0	0	0	0	0
IA	2	2	B	3	03-Jun-91	0.086	0.563	0.750	Rout	0.563	4	2	0.094	3.00	N/A	N/A	No	1	36	0	0	0	0	0	0	0
IA	2	1	C	3	31-May-91	0.106	1.500	0.211	Rout	1.500	4	1	0.094	3.00	N/A	N/A	No	1	144	0	0	0	0	0	0	0
IA	2	2	C	3	03-Jun-91	0.082	1.500	0.211	Rout	1.500	4	2	0.094	3.00	N/A	N/A	No	2	126	0	0	0	0	0	0	0
IA	2	1	D	3	31-May-91	0.110	N/A	N/A	N/A	0.110	4	1	0.094	3.00	N/A	N/A	No	1	0	0	0	0	0	0	0	0
IA	2	2	D	3	03-Jun-91	0.102	N/A	N/A	N/A	0.102	4	2	0.094	3.00	N/A	N/A	No	2	138	6	0	0	0	0	0	0
IA	3	1	B	3	31-May-91	0.106	0.563	0.672	Rout	0.563	4	2	0.094	3.00	N/A	N/A	No	2	0	0	0	0	0	0	0	0
IA	3	2	B	3	03-Jun-91	0.098	0.563	0.680	Rout	0.563	4	2	0.094	3.00	N/A	N/A	No	2	18	0	0	0	0	0	0	0
IA	3	1	C	3	31-May-91	0.110	1.500	0.243	Rout	1.500	4	2	0.094	3.00	N/A	N/A	No	2	0	0	0	0	0	0	0	0
IA	3	2	C	3	31-May-91	0.106	1.500	0.235	Rout	1.500	4	2	0.094	3.00	N/A	N/A	No	2	12	0	0	0	0	0	0	0
IA	3	1	D	3	31-May-91	0.102	N/A	N/A	N/A	0.102	4	2	0.094	3.00	N/A	N/A	No	2	0	0	0	0	0	0	0	0
IA	3	2	D	3	03-Jun-91	0.090	N/A	N/A	N/A	0.090	4	2	0.094	3.00	N/A	N/A	No	2	0.25	0	0	0	0	0	0	0
IA	4	1	B	3	31-May-91	0.106	0.563	0.704	Rout	0.563	4	2	0.094	3.00	N/A	N/A	No	2	0	0	0	0	0	0	0	0
IA	4	2	B	3	03-Jun-91	0.098	0.563	0.688	Rout	0.563	4	2	0.094	3.00	N/A	N/A	No	2	0	0	0	0	0	0	0	0
IA	4	1	C	3	31-May-91	0.117	1.501	0.235	Rout	1.501	4	2	0.094	3.06	N/A	N/A	No	2	0	0	0	0	0	0	0	0
IA	4	2	C	3	03-Jun-91	0.094	1.500	0.219	Rout	1.500	4	2	0.094	3.00	N/A	N/A	No	2	0	0	0	0	0	0	0	0
IA	4	1	D	3	31-May-91	0.110	N/A	N/A	N/A	0.110	4	2	0.094	3.00	N/A	N/A	No	2	0	0	0	0	0	0	0	0
IA	4	2	D	3	31-May-91	0.110	N/A	N/A	N/A	0.110	4	2	0.094	3.00	N/A	N/A	No	2	54	0	0	0	0	0	0	0
IA	5	1	D	3	31-May-91	0.110	N/A	N/A	N/A	0.110	4	1	0.094	3.00	N/A	N/A	No	1	0	0	0	0	0	0	0	0
IA	5	2	D	3	03-Jun-91	0.113	N/A	N/A	N/A	0.113	4	1	0.094	3.00	N/A	N/A	No	1	144	0	0	0	0	0	0	0
IA	6	1	E	5	31-May-91	0.098	0.563	1.617	Saw	0.563	5	1	N/A	N/A	0.657	0.235	No/A	N/A	0	0	0	0	0	0	0	0
IA	6	2	E	5	03-Jun-91	0.110	0.563	1.750	Saw	0.563	5	1	N/A	N/A	0.649	0.250	No/A	N/A	0	0	0	0	0.4	144	0	0
IA	E	1	G	4	31-May-91	0.106	N/A	N/A	N/A	0.106	NA	NA	N/A	N/A	N/A	N/A	NoA	NA	0	0	0	0	0	0	0	0
IA	E	2	G	4	03-Jun-91	0.106	N/A	N/A	N/A	0.106	NA	NA	N/A	N/A	N/A	N/A	NoA	NA	0	0	0	0	0	0	0	0

Table B-2. Abilene test section installation summary.

Test Site	Material	Replicate	Configuration	Preparation Procedure	Date of Installation	Avg Original Crack Width, in	Avg Crack Reservoir Width, in	Avg Crack Reservoir Depth, in	Type of Cut (Rout, Saw)	Avg Final Crack Width, in	Avg Crack Cleanliness Rating	Avg Crack Moisture Rating	Avg Band-Aid Thickness, in	Avg Band-Aid Width, in	Avg Backer Rod Depth, in	Avg Depth of Recess, in	Material Overheating	Material Bubbling	Bubbles - Low, in	Bubbles - Medium, in	Bubbles - High, in	Sunken Material - Low, in	Sunken Material - High, in	Stone Intrusion - Low, in	Stone Intrusion - Med, in	Stone Intrusion - High, in
TX	1	1	A	3	20-Mar-91	0.094	0.625	0.750	Rout	0.625	4	1	N/A	N/A	N/A	N/A	No	1	0	0	0	1.9	0	0	0	0
TX	1	2	A	3	20-Mar-91	0.094	0.625	0.750	Rout	0.625	4	1	N/A	N/A	N/A	N/A	No	1	0	0	0	0	0	0	0	0
TX	1	1	B	3	20-Mar-91	0.094	0.625	0.719	Rout	0.625	4	1	0.094	2.50	N/A	N/A	No	1	2.25	0	0	0	0	0	0	0
TX	1	2	B	3	20-Mar-91	0.094	0.625	0.750	Rout	0.625	4	1	0.094	2.50	N/A	N/A	No	1	0	0	0	0	0	0	0	0
TX	1	1	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	1	6	0	0	0	0	0	0	0
TX	1	2	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	1	72	0	0	0	0	0	0	0
TX	1	1	D	4	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	1	0	0	0	0	0	0	0	0
TX	1	2	D	4	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	1	72	0	0	0	0	0	0	0
TX	2	1	B	3	20-Mar-91	0.094	0.625	0.750	Rout	0.625	4	1	0.094	2.50	N/A	N/A	No	1	0	0	0	0	0	0	0	0
TX	2	2	B	3	20-Mar-91	0.094	0.625	0.750	Rout	0.625	4	1	0.094	2.50	N/A	N/A	No	1	0	0	0	0	0	0	0	0
TX	2	1	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	1	0	0	0	0	0	0	0	0
TX	2	2	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	1	0	0	0	0	0	0	0	0
TX	3	1	B	3	20-Mar-91	0.094	0.625	0.750	Rout	0.625	4	1	0.094	2.50	N/A	N/A	No	2	0	0	0	0	0	0	0	0
TX	3	2	B	3	20-Mar-91	0.094	0.625	0.750	Rout	0.625	4	1	0.094	2.50	N/A	N/A	No	2	0	0	0	0	4.1	0	0	0
TX	3	1	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	2	0	0	0	0	0	0	0	0
TX	3	2	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	2	0	0	0	0	0	0	0	0
TX	4	1	B	3	20-Mar-91	0.094	0.625	0.750	Rout	0.625	4	1	0.094	2.50	N/A	N/A	Yes	1	144	0	0	0	0	0	0	0
TX	4	2	B	3	20-Mar-91	0.094	0.625	0.734	Rout	0.625	4	1	0.094	2.50	N/A	N/A	Yes	1	0	144	0	0	0	0	0	0
TX	4	1	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	Yes	1	0	144	0	0	0	0	0	0
TX	4	2	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	Yes	1	0	144	0	0	0	0	0	0
TX	5	1	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	1	0	0	0	1.4	0	0	0	0
TX	5	2	D	3	20-Mar-91	0.094	N/A	N/A	N/A	0.094	4	1	0.094	2.50	N/A	N/A	No	1	0	0	0	0	0	0	0	0
TX	6	1	E	5	20-Mar-91	0.094	0.750	1.250	Rout	0.750	5	1	N/A	N/A	0.566	0.117	No/A	N/A	0	0	0	0	0	5	25.	0
TX	6	2	E	5	20-Mar-91	0.094	0.750	1.250	Rout	0.750	5	1	N/A	N/A	0.609	0.121	No/A	N/A	0	0	0	0	0	0	3	0

Table B-3. Wichita ideal subsite test section installation summary.

Test Site	Material	Replicate	Configuration	Preparation Procedure	Date of Installation	Avg Original Crack Width, in	Avg Crack Reservoir Width, in	Avg Crack Reservoir Depth, in	Type of Cut (Rout, Saw)	Avg Final Crack Width, in	Avg Crack Cleanliness Rating	Avg Crack Moisture Rating	Avg Band-Aid Thickness, in	Avg Band-Aid Width, in	Avg Backer Rod Depth, in	Avg Depth of Recess, in	Material Overheating	Material Bubbling	Bubbles - Low, in	Bubbles - Medium, in	Bubbles - High, in	Sunken Material - Low, in	Sunken Material - High, in	Stone Intrusion - Low, in	Stone Intrusion - Med, in	Stone Intrusion - High, in
KS (I)	1	1	A	3	11-Apr-91	0.156	0.563	0.836	Saw	0.563	4	2	N/A	N/A	N/A	N/A	No	3	19.9	0	0	1	0	0	0	0
KS (I)	1	2	A	3	12-Apr-91	0.156	0.563	0.719	Saw	0.563	4	2	N/A	N/A	N/A	N/A	No	3	128	0	0	0	0	0	0	0
KS (I)	1	1	B	3	11-Apr-91	0.180	0.563	0.797	Saw	0.563	4	2	0.094	3.00	N/A	N/A	No	3	125	0	0	0	0	0	0	0
KS (I)	1	2	B	3	12-Apr-91	0.156	0.563	0.696	Saw	0.563	4	2	0.094	3.00	N/A	N/A	No	3	120	6	0	0	0	0	0	0
KS (I)	1	1	C	3	11-Apr-91	0.113	1.375	0.204	Rout	1.375	4	1	0.094	3.00	N/A	N/A	No	1	139	4.88	0	0	0	0	0	0
KS (I)	1	2	C	3	11-Apr-91	0.156	1.375	0.352	Rout	1.375	4	2	0.094	3.00	N/A	N/A	No	3	120	10.1	0	0	0	0	0	0
KS (I)	1	1	D	3	16-Apr-91	0.137	N/A	N/A	N/A	0.137	4	1	0.094	3.00	N/A	N/A	No	1	135	0	0	0	0	0	0	0
KS (I)	1	2	D	3	17-Apr-91	0.156	N/A	N/A	N/A	0.156	4	2	0.094	3.00	N/A	N/A	No	3	131	7.5	0	0	0	0	0	0
KS (I)	1	1	D	4	16-Apr-91	0.133	N/A	N/A	N/A	0.133	3	1	0.094	3.00	N/A	N/A	No	1	36	0	0	0	0	0	0	0
KS (I)	1	2	D	4	17-Apr-91	0.156	N/A	N/A	N/A	0.156	3	2	0.094	3.00	N/A	N/A	No	3	132	0	0	0	0	0	0	0
KS (I)	2	1	C	3	11-Apr-91	0.180	1.375	0.227	Rout	1.375	4	3	0.094	2.50	N/A	N/A	No	3	0	0	0	16	4.5	0	0	0
KS (I)	2	2	C	3	12-Apr-91	0.156	1.375	0.188	Rout	1.375	4	3	0.094	2.50	N/A	N/A	No	3	76.9	3	0	1.5	0	0	0	0
KS (I)	2	1	D	3	16-Apr-91	0.152	N/A	N/A	N/A	0.152	4	3	0.094	2.50	N/A	N/A	No	4	67.1	10.5	0	0	0	0	0	0
KS (I)	2	2	D	3	17-Apr-91	0.156	N/A	N/A	N/A	0.156	4	3	0.094	2.50	N/A	N/A	No	3	36	0	0	0	0	0	0	0
KS (I)	3	1	C	3	11-Apr-91	0.168	1.375	0.196	Rout	1.375	4	1	0.094	2.50	N/A	N/A	No	1	3.75	0	0	88	4.5	6	0	0
KS (I)	3	2	C	3	11-Apr-91	0.156	1.375	0.235	Rout	1.375	4	1	0.094	2.50	N/A	N/A	No	1	8.25	0	0	16	0	0	0	0
KS (I)	3	1	D	3	17-Apr-91	0.156	N/A	N/A	N/A	0.156	4	1	0.094	2.50	N/A	N/A	No	1	3.38	0	0	0	0.3	0	0	0
KS (I)	3	2	D	3	17-Apr-91	0.172	N/A	N/A	N/A	0.172	4	1	0.094	2.50	N/A	N/A	No	1	101	0	0	0	0	0	0	0
KS (I)	4	1	C	3	11-Apr-91	0.184	1.375	0.258	Rout	1.375	4	1	0.094	3.00	N/A	N/A	No	1	119	6.75	0	0.8	0	0	0	0
KS (I)	4	2	C	3	12-Apr-91	0.156	1.375	0.211	Rout	1.375	4	1	0.094	3.00	N/A	N/A	No	1	144	0	0	5.6	0	0	0	0
KS (I)	4	1	D	3	15-Apr-91	0.133	N/A	N/A	N/A	0.133	4	1	0.094	3.00	N/A	N/A	No	1	126	0	0	0	0	0	0	0
KS (I)	4	2	D	3	17-Apr-91	0.156	N/A	N/A	N/A	0.156	4	1	0.094	3.00	N/A	N/A	No	1	90	0	0	0	0	0	0	0
KS (I)	5	1	D	3	16-Apr-91	0.125	N/A	N/A	N/A	0.125	4	1	0.094	2.50	N/A	N/A	No	1	96.4	0	0	39	0	0	0	0
KS (I)	5	2	D	3	17-Apr-91	0.156	N/A	N/A	N/A	0.156	4	1	0.094	2.50	N/A	N/A	No	1	87	0	0	0	0	0	0	0
KS (I)	6	1	E	5	16-Apr-91	0.133	0.625	1.430	Saw	0.625	5	1	N/A	N/A	0.625	0.242	No/A	N/A	0	0	0	0	0	146	0	0
KS (I)	6	2	E	5	17-Apr-91	0.156	0.625	1.453	Saw	0.625	5	1	N/A	N/A	0.625	0.250	No/A	N/A	0	0	0	0	1.1	108	0	0
KS (I)	8	1	B	3	11-Apr-91	0.168	0.563	0.860	Saw	0.563	NA	NA	NA	NA	N/A	N/A	NoA	NA	0	0	0	0	0	0	0	0
KS (I)	8	2	B	3	12-Apr-91	0.156	0.563	0.688	Saw	0.563	NA	NA	NA	NA	N/A	N/A	NoA	NA	0	0	0	0	0	0	0	0
KS (I)	9	1	B	3	11-Apr-91	0.164	0.563	0.867	Saw	0.563	NA	NA	NA	NA	N/A	N/A	NoA	NA	1.88	0	0	0	0	0	0	0
KS (I)	9	2	B	3	12-Apr-91	0.144	0.563	0.735	Saw	0.563	NA	NA	NA	NA	N/A	N/A	NoA	NA	54	0	0	0	0	0	0	0

Table B-4. Wichita adverse subsite test section installation summary.

Test Site	Material	Replicate	Configuration	Preparation Procedure	Date of Installation	Avg Original Crack Width, in	Avg Crack Reservoir Width, in	Avg Crack Reservoir Depth, in	Type of Cut (Rout, Saw)	Avg Final Crack Width, in	Avg Crack Cleanliness Rating	Avg Crack Moisture Rating	Avg Band-Aid Thickness, in	Avg Band-Aid Width, in	Avg Backer Rod Depth, in	Avg Depth of Recess, in	Material Overheating	Material Bubbling	Bubbles - Low, in	Bubbles - Medium, in	Bubbles - High, in	Sunken Material - Low, in	Sunken Material - High, in	Stone Intrusion - Low, in	Stone Intrusion - Med, in	Stone Intrusion - High, in
KS (A)	1	1	A	3	14-Apr-91	0.148	0.563	0.743	Saw	0.563	4	3	N/A	N/A	N/A	N/A	No	3	6.75	0	0	0	0	0	0	0
KS (A)	1	2	A	3	12-Apr-91	0.156	0.563	0.719	Saw	0.563	4	3	N/A	N/A	N/A	N/A	No	3	102	0	0	0	0	0	0	0
KS (A)	1	1	B	3	14-Apr-91	0.160	0.563	0.758	Saw	0.563	4	3	0.094	3.00	N/A	N/A	No	3	144	0	0	0	0	0	0	0
KS (A)	1	2	B	3	12-Apr-91	0.200	0.563	0.727	Saw	0.563	4	3	0.094	3.00	N/A	N/A	No	3	0	144	0	0	0	0	0	0
KS (A)	1	1	C	3	14-Apr-91	0.172	1.375	0.219	Rout	1.375	4	3	0.094	3.00	N/A	N/A	No	3	101	0	0	1	0	0	0	0
KS (A)	1	2	C	3	15-Apr-91	0.110	1.375	0.223	Rout	1.375	4	3	0.094	3.00	N/A	N/A	No	3	130	0	0	1.8	0	0	0	0
KS (A)	1	1	D	3	16-Apr-91	0.148	N/A	N/A	N/A	0.148	4	3	0.094	3.00	N/A	N/A	No	3	126	0	0	0	0	0	0	0
KS (A)	1	2	D	3	16-Apr-91	0.117	N/A	N/A	N/A	0.117	4	3	0.094	3.00	N/A	N/A	No	3	140	0	0	0	0	0	0	0
KS (A)	1	1	D	4	16-Apr-91	0.156	N/A	N/A	N/A	0.156	3	3	0.094	3.00	N/A	N/A	No	3	138	0	0	0	0	0	0	0
KS (A)	1	2	D	4	16-Apr-91	0.110	N/A	N/A	N/A	0.110	3	3	0.094	3.00	N/A	N/A	No	3	16.3	0	0	0	0	0	0	0
KS (A)	2	1	C	3	14-Apr-91	0.160	1.375	0.227	Rout	1.375	4	4	0.094	3.00	N/A	N/A	No	3	25.1	1.88	0	0	0	0	0	0
KS (A)	2	2	C	3	12-Apr-91	0.160	1.375	0.231	Rout	1.375	4	4	0.094	3.00	N/A	N/A	No	3	144	0	0	0.8	0	0	0	0
KS (A)	2	1	D	3	16-Apr-91	0.156	N/A	N/A	N/A	0.156	4	3	0.094	2.50	N/A	N/A	No	3	144	0	0	0	0	0	0	0
KS (A)	2	2	D	3	16-Apr-94	0.110	N/A	N/A	N/A	0.110	4	4	0.094	3.00	N/A	N/A	No	3	110	0	0	0	0	0	0	0
KS (A)	3	1	C	3	14-Apr-91	0.211	1.375	0.250	Rout	1.375	4	2	0.094	2.50	N/A	N/A	No	1	16.1	0	0	12	0	0	0	0
KS (A)	3	2	C	3	15-Apr-91	0.110	1.375	0.211	Rout	1.375	4	2	0.094	2.50	N/A	N/A	No	1	14.6	0	0	6.3	0	0	0	0
KS (A)	3	1	D	3	16-Apr-91	0.156	N/A	N/A	N/A	0.156	4	2	0.094	2.50	N/A	N/A	No	1	72	0	0	0	0	0	0	0
KS (A)	3	2	D	3	16-Apr-91	0.148	N/A	N/A	N/A	0.148	4	2	0.094	2.50	N/A	N/A	No	1	21.8	0	0	0	0	0	0	0
KS (A)	4	1	C	3	15-Apr-91	0.168	1.375	0.215	Rout	1.375	4	2	0.094	3.00	N/A	N/A	No	2	5.25	0	0	0	0	0	0	0
KS (A)	4	2	C	3	14-Apr-91	0.117	1.375	0.239	Rout	1.375	4	1	0.094	3.00	N/A	N/A	No	1	38.3	0	0	0	0	0	0	0
KS (A)	4	1	D	3	16-Apr-91	0.156	N/A	N/A	N/A	0.156	4	2	0.094	3.00	N/A	N/A	No	2	75.8	0	0	0	0	0	0	0
KS (A)	4	2	D	3	16-Apr-91	0.141	N/A	N/A	N/A	0.141	4	1	0.094	3.00	N/A	N/A	No	1	34.1	0	0	0	0	0	0	0
KS (A)	5	1	D	3	16-Apr-91	0.141	N/A	N/A	N/A	0.141	4	3	0.094	2.50	N/A	N/A	No	3	132	0	0	0	0	0	0	0
KS (A)	5	2	D	3	16-Apr-91	0.125	N/A	N/A	N/A	0.125	4	3	0.094	2.50	N/A	N/A	No	3	137	0	0	0	0	0	0	0
KS (A)	6	2	E	6	16-Apr-91	0.133	0.617	1.446	Saw	0.617	3	1	N/A	N/A	0.641	0.250	No/A	N/A	0	0	0	0	0	0	0	0
KS (A)	6	1	F	7	16-Apr-91	0.133	0.602	1.438	Saw	0.602	5	1	N/A	N/A	0.625	0.250	No/A	N/A	0	0	0	0	0	144	0	0
KS (A)	8	1	B	3	15-Apr-91	0.117	0.563	0.766	Saw	0.563	NA	NA	NA	NA	N/A	N/A	NoA	NA	0	0	0	0	0	0	0	0
KS (A)	8	2	B	3	15-Apr-91	0.148	0.563	0.758	Saw	0.563	NA	NA	NA	NA	N/A	N/A	NoA	NA	0	0	0	0	0	0	0	0
KS (A)	9	1	B	3	15-Apr-91	0.133	0.563	0.750	Saw	0.563	NA	NA	NA	NA	N/A	N/A	NoA	NA	0	0	0	4.9	0	0	0	0
KS (A)	9	2	B	3	15-Apr-91	0.133	0.563	0.750	Saw	0.563	NA	NA	NA	NA	N/A	N/A	NoA	NA	2.63	0	0	0.5	0	0	0	0

Table B-5. Elma test section installation summary.

Test Site	Material	Replicate	Configuration	Preparation Procedure	Date of Installation	Avg Original Crack Width, in	Avg Crack Reservoir Width, in	Avg Crack Reservoir Depth, in	Type of Cut (Rout, Saw)	Avg Final Crack Width, in	Avg Crack Cleanliness Rating	Avg Crack Moisture Rating	Avg Band-Aid Thickness, in	Avg Band-Aid Width, in	Avg Backer Rod Depth, in	Avg Depth of Recess, in	Material Overheating	Material Bubbling	Bubbles - Low, in	Bubbles - Medium, in	Bubbles - High, in	Sunken Material - Low, in	Sunken Material - High, in	Stone Intrusion - Low, in	Stone Intrusion - Med, in	Stone Intrusion - High, in
WA	1	1	A	3	22-Apr-91	0.180	0.625	0.719	Rout	0.625	4	3	N/A	N/A	N/A	N/A	No	1	144	0	0	24	0	0	0	0
WA	1	2	A	3	22-Apr-91	0.156	0.625	0.774	Rout	0.625	4	3	N/A	N/A	N/A	N/A	No	3	72	54	0	61	0.8	0	0	0
WA	1	1	B	3	22-Apr-91	0.164	0.625	0.742	Rout	0.625	4	3	0.094	3.00	N/A	N/A	No	3	130	0	0	68	1.5	0	0	0
WA	1	2	B	3	22-Apr-91	0.160	0.625	0.750	Rout	0.625	4	3	0.094	2.50	N/A	N/A	No	3	76.1	55.9	0	35	0	0	0	0
WA	1	1	D	3	23-Apr-91	0.141	N/A	N/A	N/A	0.141	4	3	0.063	3.00	N/A	N/A	No	3	54	90	0	3.8	0	0	0	0
WA	1	2	D	3	23-Apr-91	0.152	N/A	N/A	N/A	0.152	4	3	0.086	2.50	N/A	N/A	No	3	54	90	0	1.5	0	0	0	0
WA	1	1	D	4	23-Apr-91	0.121	N/A	N/A	N/A	0.121	3	3	0.094	3.00	N/A	N/A	No	3	40.1	0	0	59	0	0	0	0
WA	1	2	D	4	23-Apr-91	0.149	N/A	N/A	N/A	0.149	3	3	0.094	2.50	N/A	N/A	No	3	144	0	0	0	0.6	0	0	0
WA	2	1	B	3	22-Apr-91	0.160	0.625	0.766	Rout	0.625	4	3	0.094	2.50	N/A	N/A	No	3	129	0	0	16	0	0	0	0
WA	2	2	B	3	22-Apr-91	0.133	0.625	0.750	Rout	0.625	4	3	0.094	2.50	N/A	N/A	No	3	126	18	0	20	0	0	0	0
WA	2	1	D	3	22-Apr-91	0.156	N/A	N/A	N/A	0.156	4	3	0.094	2.50	N/A	N/A	No	3	144	0	0	1.3	0	0	0	0
WA	2	2	D	3	22-Apr-91	0.160	N/A	N/A	N/A	0.160	4	3	0.094	2.50	N/A	N/A	No	3	144	0	0	0	0	0	0	0
WA	3	1	B	3	22-Apr-91	0.144	0.625	0.735	Rout	0.625	4	3	0.094	3.00	N/A	N/A	No	3	144	0	0	33	5.3	0	0	0
WA	3	2	B	3	22-Apr-91	0.156	0.625	0.789	Rout	0.625	4	3	0.094	3.00	N/A	N/A	No	3	113	19.5	0	35	5.3	0	0	0
WA	3	1	D	3	23-Apr-91	0.102	N/A	N/A	N/A	0.102	4	3	0.094	3.00	N/A	N/A	No	3	3.38	0	0	13	0	0	0	0
WA	3	2	D	3	23-Apr-91	0.141	N/A	N/A	N/A	0.141	4	3	0.094	3.00	N/A	N/A	No	3	72	72	0	3.1	0	0	0	0
WA	4	1	B	3	22-Apr-91	0.156	0.625	0.735	Rout	0.625	4	3	0.094	3.00	N/A	N/A	No	3	144	0	0	29	1.4	0	0	0
WA	4	2	B	3	22-Apr-91	0.152	0.625	0.766	Rout	0.625	4	3	0.094	3.00	N/A	N/A	No	3	144	0	0	25	0	0	0	0
WA	4	1	D	3	23-Apr-91	0.129	N/A	N/A	N/A	0.129	4	3	0.070	3.00	N/A	N/A	No	3	108	18	0	6.8	2.6	0	0	0
WA	4	2	D	3	23-Apr-91	0.164	N/A	N/A	N/A	0.164	4	3	0.094	3.00	N/A	N/A	No	3	144	0	0	2.8	0	0	0	0
WA	5	1	D	3	23-Apr-91	0.148	N/A	N/A	N/A	0.148	4	3	0.094	2.50	N/A	N/A	No	3	0	0	0	2.6	1	0	0	0
WA	5	2	D	3	23-Apr-91	0.137	N/A	N/A	N/A	0.137	4	3	0.094	2.50	N/A	N/A	No	1	0	0	0	11	0.5	0	0	0
WA	6	1	E	5	22-Apr-91	0.148	0.688	1.414	Rout	0.688	5	1	N/A	N/A	0.617	0.235	No/A	N/A	0	0	0	0	0	126	0	0
WA	6	2	E	5	22-Apr-91	0.152	0.688	1.399	Rout	0.688	5	1	N/A	N/A	0.625	0.242	No/A	N/A	0	0	0	0	0	144	0	0
WA	7	1	B	3	23-May-91	0.125	0.625	0.750	Rout	0.625	4	1	0.094	3.00	N/A	N/A	No	1	0	0	0	0	0	0	0	0
WA	7	2	B	3	23-May-91	0.121	0.625	0.703	Rout	0.625	4	1	0.094	3.00	N/A	N/A	No	1	0	0	0	4.3	0	0	0	0

Table B-6. Prescott test section installation summary.

Test Site	Material	Replicate	Configuration	Preparation Procedure	Date of Installation	Avg Original Crack Width, in	Avg Crack Reservoir Width, in	Avg Crack Reservoir Depth, in	Type of Cut (Rout, Saw)	Avg Final Crack Width, in	Avg Crack Cleanliness Rating	Avg Crack Moisture Rating	Avg Band-Aid Thickness, in	Avg Band-Aid Width, in	Avg Backer Rod Depth, in	Avg Depth of Recess, in	Material Overheating	Material Bubbling	Bubbles - Low, in	Bubbles - Medium, in	Bubbles - High, in	Sunken Material - Low, in	Sunken Material - High, in	Stone Intrusion - Low, in	Stone Intrusion - Med, in	Stone Intrusion - High, in
ON	7	1	H	4	NA	NA	N/A	N/A	N/A	NA	NA	NA	N/A	N/A	N/A	N/A	NoA	NA	0	300	0	0	0	0	0	0
ON	7	2	H	4	NA	0.152	N/A	N/A	N/A	0.152	NA	NA	N/A	N/A	N/A	N/A	NoA	NA	0	300	0	0	0	0	0	0
ON	A	1	G	1	27-Aug-91	0.121	N/A	N/A	N/A	0.121	1	1	N/A	N/A	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	A	2	G	1	27-Aug-91	0.137	N/A	N/A	N/A	0.137	1	1	N/A	N/A	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	A	1	G	4	27-Aug-91	0.125	N/A	N/A	N/A	0.125	3	1	N/A	N/A	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	A	2	G	4	27-Aug-91	0.144	N/A	N/A	N/A	0.144	3	1	N/A	N/A	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	B	1	G	4	27-Aug-91	0.144	N/A	N/A	N/A	0.144	3	1	N/A	N/A	N/A	N/A	No/A	N/A	0	0	0	286	14	0	0	2
ON	B	2	G	4	27-Aug-91	0.137	N/A	N/A	N/A	0.137	3	1	N/A	N/A	N/A	N/A	No/A	N/A	0	0	0	295	4.9	0	0	2
ON	C	1	D	4	27-Aug-91	0.148	N/A	N/A	N/A	0.148	3	1	0.094	4.00	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	C	2	D	4	27-Aug-91	0.137	N/A	N/A	N/A	0.137	3	1	0.094	4.00	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	C	1	G	4	27-Aug-91	0.137	N/A	N/A	N/A	0.137	3	1	N/A	N/A	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	C	2	G	4	27-Aug-91	0.168	N/A	N/A	N/A	0.168	3	1	N/A	N/A	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	D	1	D	4	27-Aug-91	0.152	N/A	N/A	N/A	0.152	3	1	0.156	4.00	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	D	2	D	4	27-Aug-91	0.152	N/A	N/A	N/A	0.152	3	1	0.156	4.00	N/A	N/A	No	1	0	0	0	0	0	0	0	0
ON	F	1	G	4	27-Aug-91	0.156	N/A	N/A	N/A	0.156	3	1	N/A	N/A	N/A	N/A	No/A	N/A	0	0	0	300	0	0	0	1
ON	F	2	G	4	27-Aug-91	0.133	N/A	N/A	N/A	0.133	3	1	N/A	N/A	N/A	N/A	No/A	N/A	0	0	0	299	1.5	0	0	1

APPENDIX C. MATERIAL TESTING DATA

This appendix includes tables showing the initial test requirements and complete test results (initial and supplemental performance tests) for the primary experimental materials. Tables C-1 and C-2 show the requirements set forth in the initial testing program for each primary material. Table C-3 shows the entire list of tests conducted and the corresponding mean results of each test parameter for the various materials.

Illustrations of the load-deformation characteristics of various primary sealants subjected to ASTM D 412 (modulus) and ASTM D 3583 (tensile adhesion) tests are provided in figures C-1 through C-10.

Table C-1. Initial test requirements for rubber-modified asphalt materials.

Test	Procedure	Requirement		
		Rubberized Asphalt (Hi-Spec)	Modified Rubberized Asphalt (RS 515, 9030, XLM)	Asphalt Rubber (AR2)
Bond (-29°C, 3 cycles, 50% extension)	ASTM D 3407	3 cycles - No Failure		
Bond (-29°C, 3 cycles, 100% extension)	ASTM D 3407		3 cycles - No Failure	
Cone Penetration, dmm (4°C)	ASTM D 3407 Modified			≥ 15
Cone Penetration, dmm (25°C)	ASTM D 3407	≤ 90	60 - 180	≤ 70
Flow, mm (60°C)	ASTM D 3407	≤ 3	≤ 5	
Resilience, % (25°C)	ASTM D 3407	≥ 60	≥ 35	≥ 30
Asphalt Compatibility (60°C)	ASTM D 3407	No Failure	No Failure	No Failure
Softening Point	ASTM D 36			≥ 150
Specific Gravity (16°C)	ASTM D 70	1.071 - 1.183	RS 515: 1.116 - 1.234 9030: 1.002 - 1.108 XLM: 0.922 - 1.020	0.968 - 1.070

Table C-2. Initial test requirements for silicone, fiber, and emulsion materials.

Test	Procedure	Requirement			
		Silicone (890-SL)	Fiber		Emulsion (CRF)
			(BoniFiber)	(Fiber Pave)	
Ultimate Elongation, % (24°C)	ASTM D 412	≥ 1400			
Tensile Stress @ 150% Elongation (24°C), kPa	ASTM D 412	≤ 138			
Extrusion Rate, gm/min (23°C, 50% Relative Humidity [RH])	ASTM C 603	300 - 400			
Tack-Free Time, min (23°C, 50% RH)	ASTM C 679	180 - 300			
Shore 00 Durometer Hardness, (23°C, 50% RH)	ASTM D 2240	35 - 45			
Density, gm/mL (25°C)	ASTM D 1475	1.283 - 1.418			
Denier (Fineness)	ASTM D 1557		3.0 - 6.0	13.0 - 17.0	
Length, mm	As Measured		5.8 - 7.0	8 - 12	
Crimps	ASTM D 3937		None	None	
Color	As Observed		White	Gray	
Break Elongation, %	ASTM D 2256		24 - 42	≥ 33	
Tensile Strength, MPa	ASTM D 882		≥ 482	≥ 276	
Moisture Regain, % (21°C, 50% RH)	ASTM D 2654		—	< 0.1	
Saybolt Viscosity, sec (25°C)	ASTM D 244				25 - 150
Residue, %	ASTM D 244				≥ 64
Miscibility	ASTM D 244				No Coagulation
Sieve, %	ASTM D 244				≤ 0.10

Table C-3. Mean laboratory test results for primary material products.

Test Designation	Test Description	Number of Test Replicates	Mean Test Results								
			Hi-Spec	RS 515	9030	XLM	B-Fiber + AC	890-SL	CRF	AR2	Fiber Pave + AC
1-A	Bond (-29°C, 3 cycles, 50% ext)	3	Pass								
2-A	Bond (-29°C, 3 cycles, 100% ext)	3		Pass	Pass	Pass					
3-A	Cone Penetration, dmm (-18°C)	2	15	27	60	60	0		23	4	0
4-A	Cone Penetration, dmm (25°C)	2	63	76	115	148				55	
5-A	Flow, mm (60°C)	2	0	1	0	2.5					
6-A	Resilience, % recovery (25°C)	3	64	38	84	16				39	
7-A	Asphalt Compatibility (60°C)	1	Pass	Pass	Pass	Pass				Pass	
8-A	Softening Point	2	186	211	199	192	122		78	162	123
9-A	Specific Gravity (16°C)	1	1.1	1.2	1.1	1.0		1.3		1.1	
10-A	Cold Bend (-18°C)	2	Pass	Pass	Pass	Pass					
11-A	Force Ductility - Max Elongation, mm (4°C)	2	432	432	305	279	51			305	1,397
11-B	Force Ductility - Max Load, kg		2.35	1.18	2.04	0.40	8.15			1.49	5.88
11-C	Force Ductility - Max Engineering Stress, kPa		227	117	200	41	779			145	593
11-D	Force Ductility - Max Engineering Strain, mm/mm		15	15	22	22	1.7			10	24
11-E	Force Ductility - Max True Stress, kPa		3,413	1,613	4,358	393	1,448			1,448	972
11-F	Force Ductility - Max True Strain, mm/mm		2.8	2.8	3.1	2.4	1.0			2.5	3.1
11-G	Force Ductility - Area Under Engineering Curve, kPa		359	193	427	35	138			179	248
11-H	Force Ductility - Area Under True Curve, kPa		2,303	1,255	2,772	228	889			1,172	1,634
11-I	Force Ductility - Asphalt Modulus, kPa		221	103	145	31	2,923			317	2,275
11-J	Force Ductility - Polymer Modulus, kPa		3,896	1,455	5,020	441	NA			1,434	NA
11-K	Force Ductility - Load @ 150% Elongation, kg		0.95	0.50	0.63	0.14	7.24			0.45	3.35
12-A	Tensile Adhesion (Std - PCC blocks) - Max Elongation, mm	3	89	66	56	69		79			
12-B	Tensile Adhesion (Std) - Max Elongation, %		704	515	441	547		606			
12-C	Tensile Adhesion (Std) - Type of Failure		Adh	Adh	Adh	Adh		Adh/Coh			
13-A	Tensile Adhesion (Mod #1: AC blocks) - Max Elongation, mm	3	89	97	38	76		79			
13-B	Tensile Adhesion (Mod #1) - Max Elongation, %		690	760	303	607		627			
13-C	Tensile Adhesion (Mod #1) - Type of Failure		Adh	Adh	Adh	Adh		Adh/Coh			

Table C-3. Mean laboratory test results for primary material products (continued).

Test Designation	Test Description	Number of Test Replicates	Mean Test Results								
			Hi-Spec	RS 515	9030	XLM	B-Fiber + AC	890-SL	CRF	AR2	Fiber Pave + AC
14-A	Tensile Adhesion (Mod #2: AC blocks, H_2O-soaked) - Max Elongation, mm	3	86	86	43	69		61			
14-B	Tensile Adhesion (Mod #2) - Max Elongation, %		683	680	337	539		485			
14-C	Tensile Adhesion (Mod #2) - Type of Failure		Adh	Adh	Adh	Adh		Adh			
15-A	412 Test (-18°C) - Tensile Strength, kPa	2	421	455	110	103		310			
15-B	412 Test (-18°C) - Ultimate Elongation, %		425	868	1093	1035		4566			
15-C	412 Test (-18°C) - Tensile Stress @ 150% Elongation, kPa		317	262	50	30		65			
15-D	412 Test (-18°C) - Midpoint Thickness, mm		7.6	5.1	7.6	7.6		5.1			
16-A	412 Test (4°C) - Tensile Strength, kPa	2	228	186	53	69					
16-B	412 Test (4°C) - Ultimate Elongation, %		960	1255	620	960					
16-C	412 Test (4°C) - Tensile Stress @ 150% Elongation, kPa		131	97	32	19					
16-D	412 Test (4°C) - Midpoint Thickness, mm		5.1	5.1	7.6	7.6					
17-A	412 Test (24°C) - Tensile Strength, kPa	2	76	53	59	33		303			
17-B	412 Test (24°C) - Ultimate Elongation, %		863	910	832	915		2096			
17-C	412 Test (24°C) - Tensile Stress @ 150% Elongation, kPa		49	26	32	14		76			
17-D	412 Test (24°C) - Midpoint Thickness, mm		7.6	7.6	7.6	7.6		5.1			
18-A	412 Test After Weathering (24°C) - Tensile Strength, kPa	3	NA	NA	NA	NA		284			
18-B	412 Test After Weathering (24°C) - Ultimate Elongation, %		NA	NA	NA	NA		1552			
18-C	412 Test After Weathering (24°C) - Tensile Stress @ 150% Elongation, kPa		NA	NA	NA	NA		66			
18-D	412 Test After Weathering (24°C) - Midpoint Thickness, mm		NA	NA	NA	NA		4.1			
19-A	Modified Bond #1 (Channel) - Type of Failure	2	Adh	Adh	None	None		None			
19-B	Modified Bond #1 (Channel), % Debonding		1.15	0.18	0.0	0.0		0.0			
20-A	Modified Bond #2 (Recessed Band-Aid) - Type of Failure	2	Adh	Adh	Adh	None					
20-B	Modified Bond #2 (Recessed Band-Aid), % Debonding		0.52	5.21	6.25	0.0					
21-A	Modified Bond #3 (Band-Aid) - Type of Failure	2	Adh	Adh	Adh	None					
21-B	Modified Bond #3 (Band-Aid), % Debonding		0.71	2.86	0.71	0.0					
22-A	Brookfield Viscosity, cPs	2	3,738	3,338	1,275	3,720					

Table C-3. Mean laboratory test results for primary material products (continued).

Test Designation	Test Description	Number of Test Replicates	Mean Test Results								
			Hi-Spec	RS 515	9030	XLM	B-Fiber + AC	890-SL	CRF	AR2	Fiber Pave + AC
23-A	Denier (Fineness)	3					4.27				4.4
24-A	Length, mm	3					7				9
25-A	Crimps	3					None				None
26-A	Color	3					White				Gray
27-A	Break Elongation, %	3					29.27				32.8
28-A	Tensile Strength, MPa	3					682,143				238,581
29-A	Moisture Regain, %	3					0.443				0.457
30-A	Saybolt Viscosity, sec	2							51.5		
31-A	Residue, %	2							67		
32-A	Miscibility	2							Pass		
33-A	Sieve Test, %	2							0.1		
34-A	Extrusion Rate, gm/min (23°C and 50% RH)	1						2.8			
35-A	Tack-Free Time, min (25°C and 50% RH)	1						180			
36-A	Shore 00 Durometer (25°C and 50% RH)	3						50			

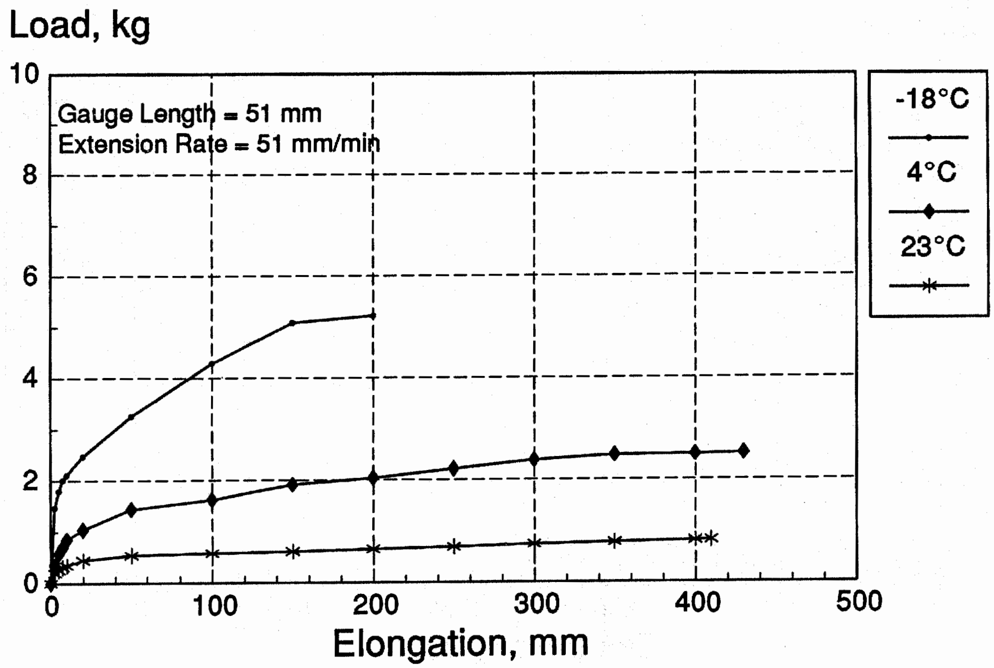


Figure C-1. ASTM D 412 load-deformation curves for Hi-Spec.

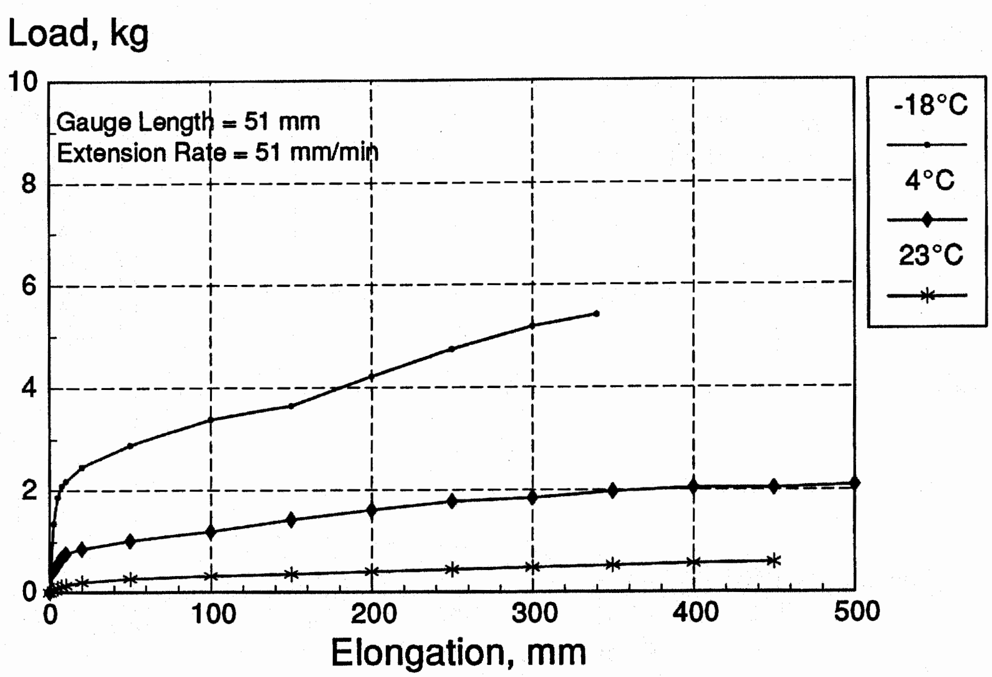


Figure C-2. ASTM D 412 load-deformation curves for RS 515.

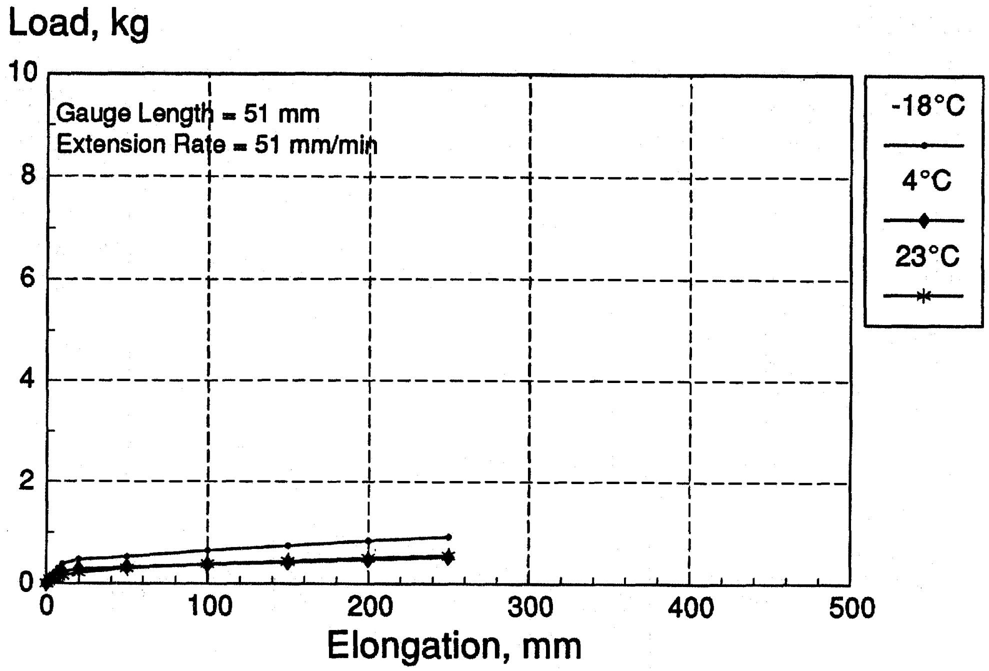


Figure C-3. ASTM D 412 load-deformation curves for 9030.

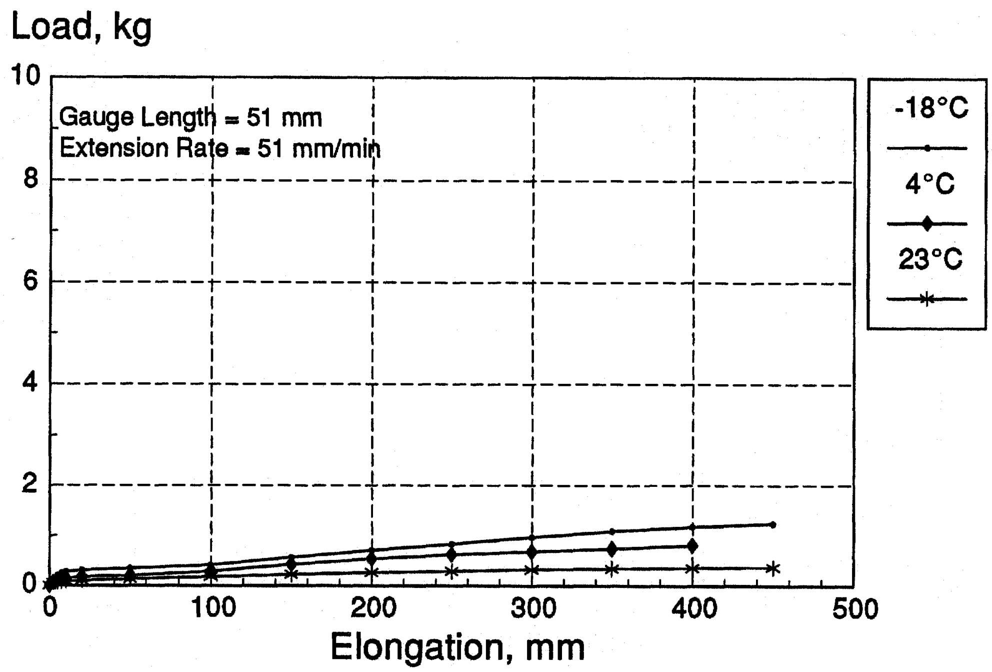


Figure C-4. ASTM D 412 load-deformation curves for XLM.

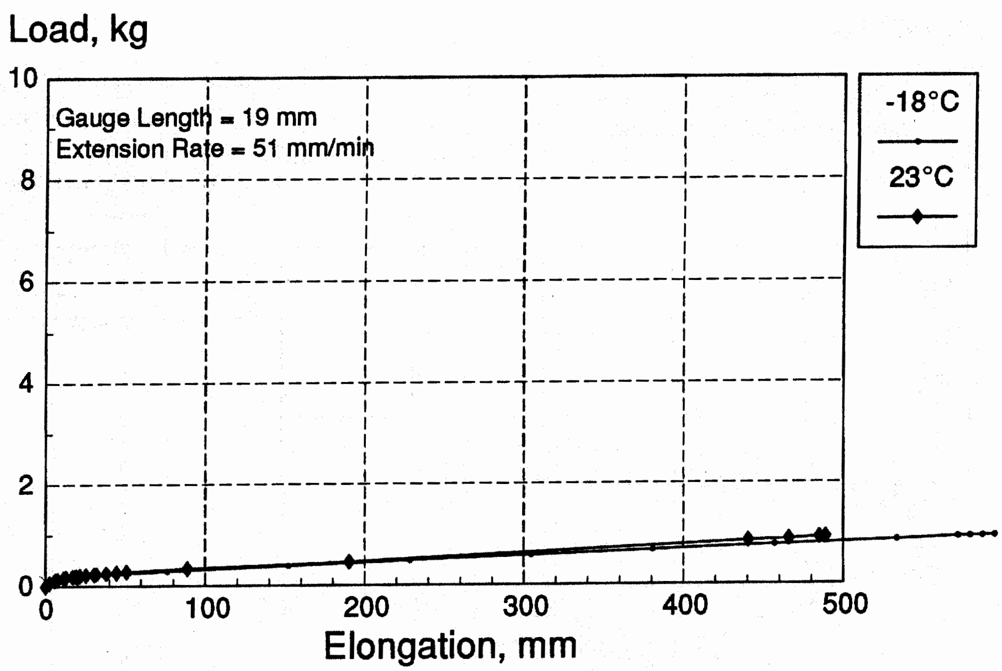


Figure C-5. ASTM D 412 load-deformation curves for 890-SL

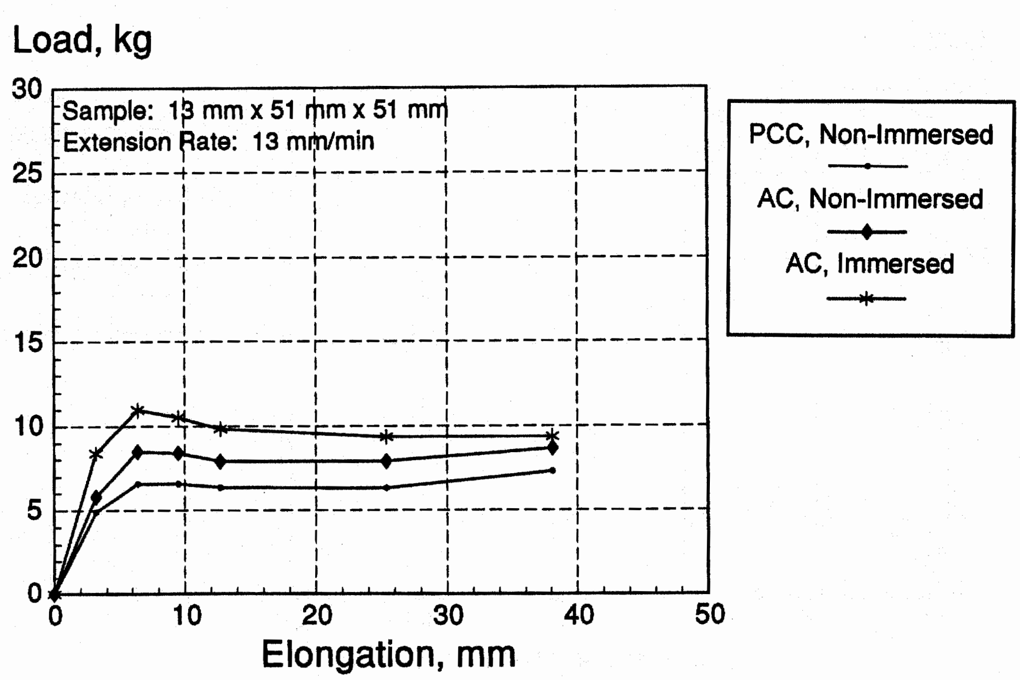


Figure C-6. ASTM D 3583 load-deformation curves for Hi-Spec.

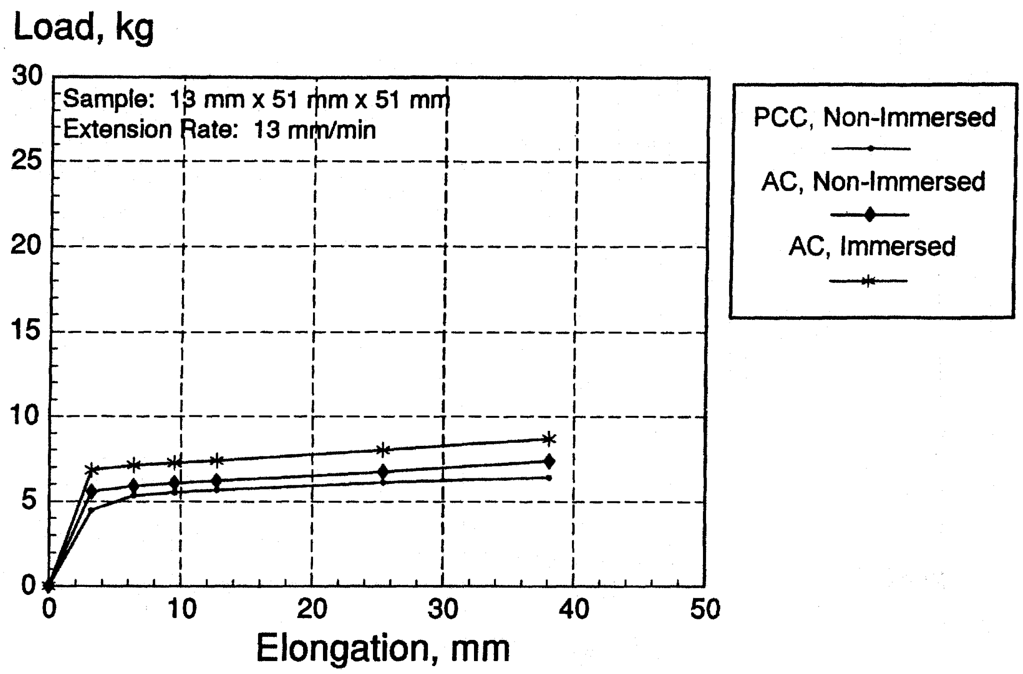


Figure C-7. ASTM D 3583 load-deformation curves for RS 515.

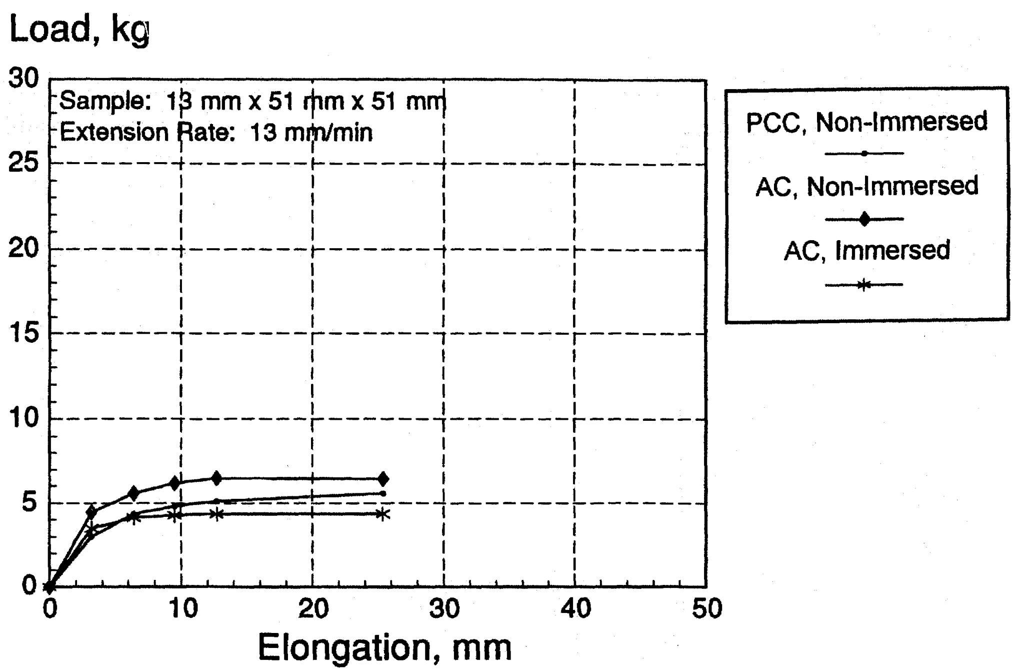


Figure C-8. ASTM D 3583 load-deformation curves for 9030.

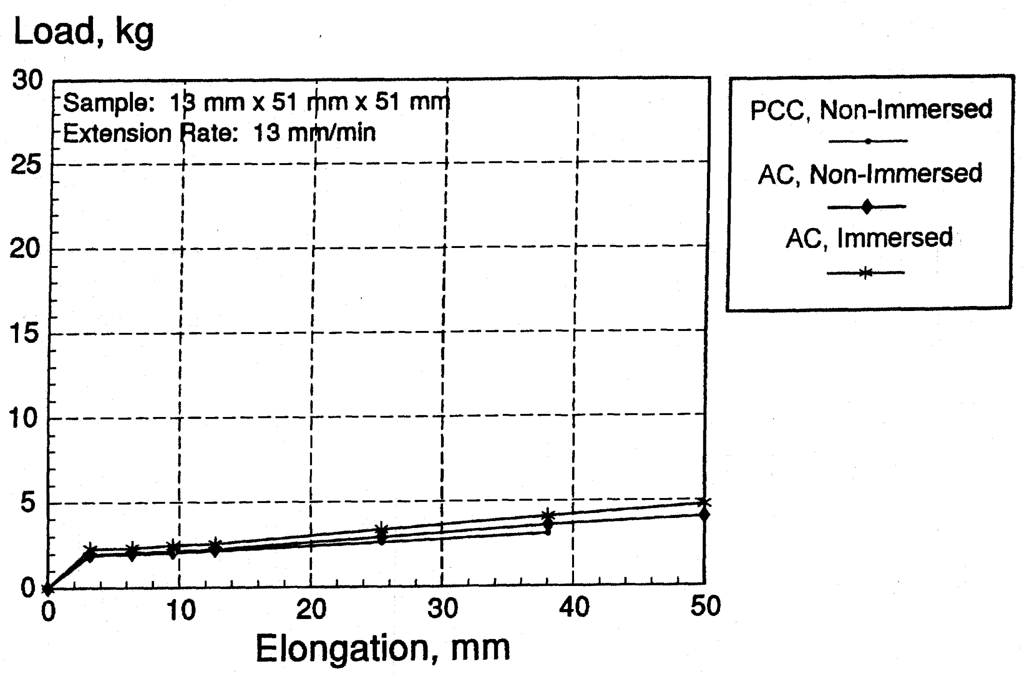


Figure C-9. ASTM D 3583 load-deformation curves for XLM.

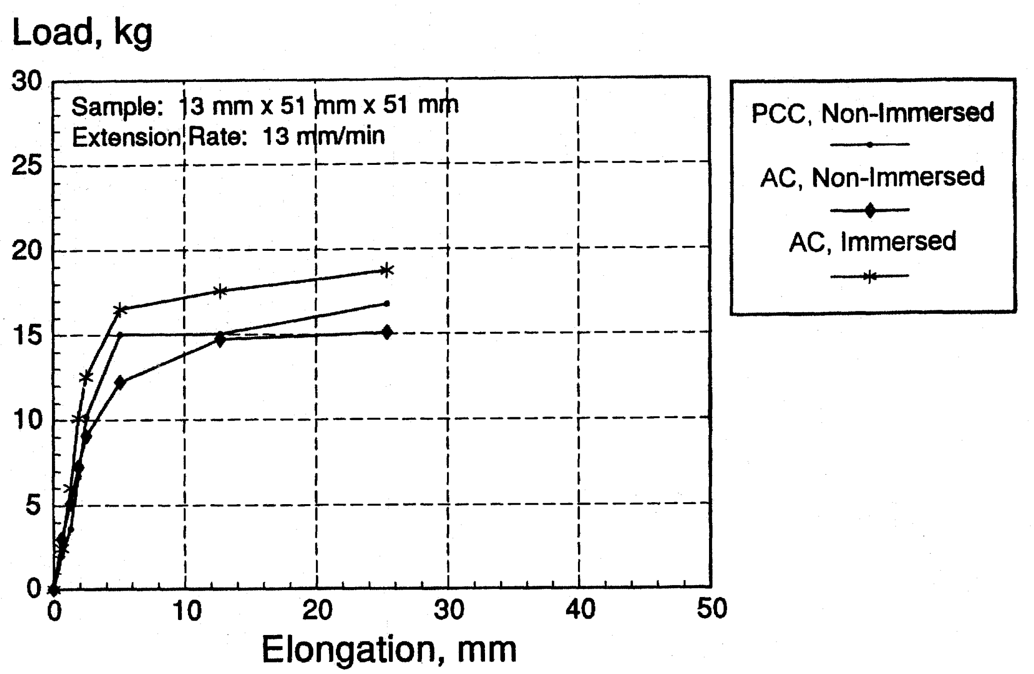


Figure C-10. ASTM D 3583 load-deformation curves for 890-SL,

APPENDIX D. FIELD PERFORMANCE

This appendix includes the various documentation forms and summary tables and charts associated with the field performance of the experimental treatments. Figure D-1 shows the performance documentation forms used at each test site evaluation. Summaries of the key performance distresses observed over the duration of the study are provided in tables D-1 through D-6.

Rep-Sect	Material	Config	Prep	Crack	Segment	Pull-outs (in) Eval 5 Ptl Dpth	Pull-outs (in) Eval 5 Full Dpth	Pull-outs (in) Eval 6 Ptl Dpth	Pull-outs (in) Eval 6 Full Dpth	Pull-outs (in) Eval 7 Ptl Dpth	Pull-outs (in) Eval 7 Full Dpth	Pull-outs (in) Eval 8 Ptl Dpth	Pull-outs (in) Eval 8 Full Dpth	Pull-outs (in) Eval 9 Ptl Dpth	Pull-outs (in) Eval 9 Full Dpth	Pull-outs (in) Eval 10 Ptl Dpth	Pull-outs (in) Eval 10 Full Dpth	Edge Deterioration (in) Eval 5 Low Severity	Edge Deterioration (in) Eval 5 High Severity	Edge Deterioration (in) Eval 6 Low Severity	Edge Deterioration (in) Eval 6 High Severity	Edge Deterioration (in) Eval 7 Low Severity	Edge Deterioration (in) Eval 7 High Severity	Edge Deterioration (in) Eval 8 Low Severity	Edge Deterioration (in) Eval 8 High Severity	Edge Deterioration (in) Eval 9 Low Severity	Edge Deterioration (in) Eval 9 High Severity	Edge Deterioration (in) Eval 10 Low Severity	Edge Deterioration (in) Eval 10 High Severity	Overband Wear (N, L, H, E) Eval 5	Overband Wear (N, L, H, E) Eval 6	Overband Wear (N, L, H, E) Eval 7	Overband Wear (N, L, H, E) Eval 8	Overband Wear (N, L, H, E) Eval 9	Overband Wear (N, L, H, E) Eval 10
1-1	4	D	3	3	ISE																														
	4	D	3	3	IWP																														
	4	D	3	3	JCN																														
	4	D	3	3	OWP																														
	4	D	3	3	POE																														
	4	D	3	4	ISE																														
	4	D	3	4	IWP																														
	4	D	3	4	JCN																														
	4	D	3	4	OWP																														
	4	D	3	4	POE																														
	4	D	3	5	ISE																														
	4	D	3	5	IWP																														
	4	D	3	5	JCN																														
	4	D	3	5	OWP																														
	4	D	3	5	POE																														
	4	D	3	6	ISE																														
	4	D	3	6	IWP																														
	4	D	3	6	JCN																														
	4	D	3	6	OWP																														
	4	D	3	6	POE																														

Figure D-1. Field performance evaluation form.

Rep-Sect	Material	Config	Prep	Crack	Segment	Adhesion Loss (in) Eval 5 Ptl Dpth	Adhesion Loss (in) Eval 5 Full Dpth	Adhesion Loss (in) Eval 6 Ptl Dpth	Adhesion Loss (in) Eval 6 Full Dpth	Adhesion Loss (in) Eval 7 Ptl Dpth	Adhesion Loss (in) Eval 7 Full Dpth	Adhesion Loss (in) Eval 8 Ptl Dpth	Adhesion Loss (in) Eval 8 Full Dpth	Adhesion Loss (in) Eval 9 Ptl Dpth	Adhesion Loss (in) Eval 9 Full Dpth	Adhesion Loss (in) Eval 10 Ptl Dpth	Adhesion Loss (in) Eval 10 Full Dpth	Cohesion Loss (in) Eval 5 Ptl Dpth-Tens	Cohesion Loss (in) Eval 5 Full Dpth-Tens	Cohesion Loss (in) Eval 5 Ptl Dpth-Bub	Cohesion Loss (in) Eval 5 Full Dpth-Bub	Cohesion Loss (in) Eval 6 Ptl Dpth-Tens	Cohesion Loss (in) Eval 6 Full Dpth-Tens	Cohesion Loss (in) Eval 6 Ptl Dpth-Bub	Cohesion Loss (in) Eval 6 Full Dpth-Bub	Cohesion Loss (in) Eval 7 Ptl Dpth-Tens	Cohesion Loss (in) Eval 7 Full Dpth-Tens	Cohesion Loss (in) Eval 7 Ptl Dpth-Bub	Cohesion Loss (in) Eval 7 Full Dpth-Bub	Cohesion Loss (in) Eval 8 Ptl Dpth-Tens	Cohesion Loss (in) Eval 8 Full Dpth-Tens	Cohesion Loss (in) Eval 8 Ptl Dpth-Bub	Cohesion Loss (in) Eval 8 Full Dpth-Bub	Cohesion Loss (in) Eval 9 Ptl Dpth-Tens	Cohesion Loss (in) Eval 9 Full Dpth-Tens	Cohesion Loss (in) Eval 9 Ptl Dpth-Bub	Cohesion Loss (in) Eval 9 Full Dpth-Bub	Cohesion Loss (in) Eval 10 Ptl Dpth-Tens	Cohesion Loss (in) Eval 10 Full Dpth-Tens	Cohesion Loss (in) Eval 10 Ptl Dpth-Bub	Cohesion Loss (in) Eval 10 Full Dpth-Bub	Overall Failure (in) Eval 5	Overall Failure (in) Eval 6	Overall Failure (in) Eval 7	Overall Failure (in) Eval 8	Overall Failure (in) Eval 9	Overall Failure (in) Eval 10
1-1	4	D	3	3	ISE																																										
	4	D	3	3	IWP																																										
	4	D	3	3	JCN																																										
	4	D	3	3	OWP																																										
	4	D	3	3	POE																																										
	4	D	3	4	ISE																																										
	4	D	3	4	IWP																																										
	4	D	3	4	JCN																																										
	4	D	3	4	OWP																																										
	4	D	3	4	POE																																										
	4	D	3	5	ISE																																										
	4	D	3	5	IWP																																										
	4	D	3	5	JCN																																										
	4	D	3	5	OWP																																										
	4	D	3	5	POE																																										
	4	D	3	6	ISE																																										
	4	D	3	6	IWP																																										
	4	D	3	6	JCN																																										
	4	D	3	6	OWP																																										
	4	D	3	6	POE																																										

Figure D-1. Field performance evaluation form (continued).

Rep-Sect	Material	Config	Prep	Crack	Segment	Pull-outs (in)											
						Eval 5		Eval 6		Eval 7		Eval 8		Eval 9		Eval 10	
						Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth
	4	D	3	7	ISE												
	4	D	3	7	IWP												
	4	D	3	7	JCN												
	4	D	3	7	OWP												
	4	D	3	7	POE												
	4	D	3	8	ISE												
	4	D	3	8	IWP												
	4	D	3	8	JCN												
	4	D	3	8	OWP												
	4	D	3	8	POE												
	4	D	3	9	ISE												
	4	D	3	9	IWP												
	4	D	3	9	JCN												
	4	D	3	9	OWP												
	4	D	3	9	POE												
	4	D	3	10	ISE												
	4	D	3	10	IWP												
	4	D	3	10	JCN												
	4	D	3	10	OWP												
	4	D	3	10	POE												

Rep-Sect	Material	Config	Prep	Crack	Segment	Edge Deterioration (in)											
						Eval 5		Eval 6		Eval 7		Eval 8		Eval 9		Eval 10	
						Low Severity	High Severity	Low Severity	High Severity	Low Severity	High Severity	Low Severity	High Severity	Low Severity	High Severity	Low Severity	High Severity
	4	D	3	7	ISE												
	4	D	3	7	IWP												
	4	D	3	7	JCN												
	4	D	3	7	OWP												
	4	D	3	7	POE												
	4	D	3	8	ISE												
	4	D	3	8	IWP												
	4	D	3	8	JCN												
	4	D	3	8	OWP												
	4	D	3	8	POE												
	4	D	3	9	ISE												
	4	D	3	9	IWP												
	4	D	3	9	JCN												
	4	D	3	9	OWP												
	4	D	3	9	POE												
	4	D	3	10	ISE												
	4	D	3	10	IWP												
	4	D	3	10	JCN												
	4	D	3	10	OWP												
	4	D	3	10	POE												

Rep-Sect	Material	Config	Prep	Crack	Segment	Overband Wear (N, L, H, E)					
						Eval 5	Eval 6	Eval 7	Eval 8	Eval 9	Eval 10
	4	D	3	7	ISE						
	4	D	3	7	IWP						
	4	D	3	7	JCN						
	4	D	3	7	OWP						
	4	D	3	7	POE						
	4	D	3	8	ISE						
	4	D	3	8	IWP						
	4	D	3	8	JCN						
	4	D	3	8	OWP						
	4	D	3	8	POE						
	4	D	3	9	ISE						
	4	D	3	9	IWP						
	4	D	3	9	JCN						
	4	D	3	9	OWP						
	4	D	3	9	POE						
	4	D	3	10	ISE						
	4	D	3	10	IWP						
	4	D	3	10	JCN						
	4	D	3	10	OWP						
	4	D	3	10	POE						

Figure D-1. Field performance evaluation form (continued).

Rep-Sect	Material	Config	Prep	Crack	Segment	Adhesion Loss (in)												Cohesion Loss (in)																								Overall Failure (in)					
						Eval 5		Eval 6		Eval 7		Eval 8		Eval 9		Eval 10		Eval 5				Eval 6				Eval 7				Eval 8				Eval 9				Eval 10				Eval 5	Eval 6	Eval 7	Eval 8	Eval 9	Eval 10
						Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth	Full Dpth	Ptl Dpth-Tens	Full Dpth-Tens	Ptl Dpth-Bub	Full Dpth-Bub	Ptl Dpth-Tens	Full Dpth-Tens	Ptl Dpth-Bub	Full Dpth-Bub	Ptl Dpth-Tens	Full Dpth-Tens	Ptl Dpth-Bub	Full Dpth-Bub	Ptl Dpth-Tens	Full Dpth-Tens	Ptl Dpth-Bub	Full Dpth-Bub	Ptl Dpth-Tens	Full Dpth-Tens	Ptl Dpth-Bub	Full Dpth-Bub	Ptl Dpth-Tens	Full Dpth-Tens	Ptl Dpth-Bub	Full Dpth-Bub						
	4	D	3	7	ISE																																										
	4	D	3	7	IWP																																										
	4	D	3	7	JCN																																										
	4	D	3	7	OWP																																										
	4	D	3	7	POE																																										
	4	D	3	8	ISE																																										
	4	D	3	8	IWP																																										
	4	D	3	8	JCN																																										
	4	D	3	8	OWP																																										
	4	D	3	8	POE																																										
	4	D	3	9	ISE																																										
	4	D	3	9	IWP																																										
	4	D	3	9	JCN																																										
	4	D	3	9	OWP																																										
	4	D	3	9	POE																																										
	4	D	3	10	ISE																																										
	4	D	3	10	IWP																																										
	4	D	3	10	JCN																																										
	4	D	3	10	OWP																																										
	4	D	3	10	POE																																										

Figure D-1. Field performance evaluation form (continued).

Table D-1. Des Moines, IA crack treatment performance summaries.

		Placement	Crack	Adhesion Effectiveness (%) Over Time (months)											Cohesion Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	1	3	8	11	17	29	40	53	69	77	0	1	3	8	11	17	29	40	53	69	77
Hi-Spec	1	Std Reservoir-and-Flush	Wirebrush, Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	94.7	69.8	64.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Reservoir-and-Flush	Wirebrush, Airblast	100.0	100.0	100.0	88.7	88.7	88.7	88.6	88.6	80.6	55.6	49.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	94.4	94.4	94.4	94.3	94.3	87.7	62.7	56.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.8	99.8	84.1	70.7	64.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.8	99.8	94.0	69.4	62.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.8	99.8	99.8	99.8	99.8	89.1	70.1	63.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.2	99.2	89.8	77.3	75.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	91.1	89.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.9	99.9	99.9	99.6	99.6	94.9	84.2	82.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.8	99.7	99.6	99.6	98.4	91.5	87.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.3	91.1	86.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	99.9	99.8	99.8	99.8	98.3	91.3	87.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	84.4	84.4	84.2	73.4	69.3	34.6	24.7	---
Hi-Spec	2	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	99.7	99.7	99.7	99.7	98.4	56.9	33.2	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	92.0	92.0	91.9	86.5	83.8	45.7	28.9	---
Hi-Spec	1	Simple Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	90.4	90.4	90.4	87.8	83.2	38.5	29.2	---
Hi-Spec	2	Simple Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	99.6	99.6	99.6	99.6	94.8	56.2	20.4	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	95.0	95.0	95.0	93.7	89.0	47.4	24.8	---
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.7	93.6	92.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.4	96.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	95.5	94.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.8	98.8	98.8	98.8	98.7	98.6	95.8	95.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	90.5	89.8	89.8	89.1	89.1	84.3	82.4	81.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	94.7	94.3	94.3	93.9	93.9	91.4	89.1	88.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	1	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	84.4	84.4	84.4	84.4	83.8	49.4	36.5	---
RS 515	2	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	94.4	94.2	94.2	94.2	94.2	88.7	44.4	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	89.4	89.3	89.3	89.3	89.0	69.1	40.4	---
9030	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.1	98.1	98.1	98.1	98.1	97.5	95.3	93.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.4	99.4	99.4	99.4	99.4	98.7	97.7	94.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	98.7	98.7	98.7	98.7	98.7	98.1	96.5	94.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.9	99.9	99.9	99.2	98.8	98.1	96.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	99.8	99.8	99.8	99.8	99.8	99.2	99.1	95.5	94.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	99.9	99.9	99.9	99.9	99.9	99.2	99.0	96.8	95.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	1	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	94.9	94.8	94.8	94.8	91.8	81.5	52.0	---
9030	2	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	81.9	81.9	81.9	81.6	80.8	73.3	41.8	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	88.4	88.3	88.3	88.2	86.3	77.4	46.9	---
XLM	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.4	97.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.7	98.7	98.6	98.6	98.6	97.9	96.8	95.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.3	99.3	99.3	99.3	99.3	98.9	98.1	96.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.6	95.7	94.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.0	96.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.3	96.3	95.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	1	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	99.4	97.2	85.6	64.7	42.8
XLM	2	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	98.7	98.7	98.7	98.5	96.2	73.2	49.9	37.3
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	99.3	99.3	99.3	99.0	96.7	79.4	57.3	40.1
B-Fiber	1	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	68.9	68.9	68.0	51.3	43.3	18.3	---	---
B-Fiber	2	Simple Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	82.3	82.2	80.0	77.7	59.5	15.9	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	75.6	75.6	74.0	64.5	51.4	17.1	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	98.3	96.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.0	97.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	98.1	96.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CRS-2P	1	Flush-Fill	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	0.0	---	---	---	---	---	---	---
CRS-2P	2	Flush-Fill	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	0.0	---	---	---	---	---	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	0.0	---	---	---	---	---	---	---

Table D-1. Des Moines, IA crack treatment performance summaries (continued).

		Placement	Crack	Pull-Out Effectiveness (%) Over Time (months)											Edge Deterioration Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	1	3	8	11	17	29	40	53	69	77	0	1	3	8	11	17	29	40	53	69	77
Hi-Spec	1	Std Reservoir-and-Flush	Wirebrush, Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7	99.7	99.3	94.1	90.0	88.9
Hi-Spec	2	Std Reservoir-and-Flush	Wirebrush, Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	99.4	99.3	97.1	94.2	92.2
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	99.7	99.6	99.3	95.6	92.1	90.5
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	99.7	99.1	97.9	89.8	87.3	84.9
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.2	96.0	94.2	90.6
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	100.0	100.0	100.0	99.9	99.8	99.8	99.5	98.6	92.9	90.8	87.8
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.7	99.3	96.6	95.1	93.7
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.3	98.1	95.1
	Avg			100.0	100.0	100.0	100.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.6	98.0	96.6	94.4
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	97.9	97.4
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	96.7	94.1	94.4
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	97.9	96.0	95.9
Hi-Spec	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.6	99.6	---
Hi-Spec	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	98.6	98.5	98.4	98.1	98.1	97.7	97.7	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.3	---
	Avg			100.0	100.0	100.0	99.3	99.3	99.2	99.0	99.0	98.8	98.8	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.4	---
Hi-Spec	1	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.7	99.7	99.5	99.5	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.5	99.3	---
Hi-Spec	2	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	99.0	99.0	99.0	99.0	98.8	98.8	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	---
	Avg			100.0	100.0	100.0	99.9	99.4	99.4	99.3	99.3	99.1	99.1	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	99.4	---
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.6	99.5
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.4
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.7	99.4
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	99.1	98.2
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.3	99.3	99.0	99.0	99.0	99.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	99.6	99.3	97.9	96.4	95.0
	Avg			100.0	100.0	100.0	100.0	99.7	99.7	99.5	99.5	99.4	99.4	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.8	99.7	98.6	97.8	96.6
RS 515	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.8	99.8	99.3	99.3	---	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7	99.7	---
RS 515	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	97.3	96.7	97.8	97.1	96.2	95.6	95.3	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.0	---
	Avg			100.0	100.0	100.0	98.6	98.3	98.8	98.5	98.0	97.4	97.3	---	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.7	99.4	---
9030	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.5	98.4	98.3
9030	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7	99.1	97.6	96.6	96.1
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.9	99.4	98.5	97.5	97.2
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7	99.6	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	98.8	98.1
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.1	99.1
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.8	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	99.0	98.6
9030	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	99.2	99.2	99.2	99.1	99.0	99.0	99.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.6	---
9030	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.2	99.2	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.6	---
	Avg			100.0	100.0	100.0	99.6	99.6	99.6	99.6	99.5	99.1	99.1	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.1	---
XLM	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7	99.7	99.7	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.2
XLM	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	98.4	97.9
	Avg			100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.9	99.8	99.8	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.0	98.6
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.3	99.1
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.2	97.8	97.8
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	98.6	98.5
XLM	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.5	98.8	98.5
XLM	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.7	99.7	99.7	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.3
	Avg			100.0	100.0	100.0	100.0	99.9	99.9	99.9	99.9	99.8	99.8	99.8	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.7	99.4	97.9
B-Fiber	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	98.6	98.6	98.6	98.4	95.7	96.2	---	---	100.0	100.0	100.0	99.7	97.7	97.4	97.2	95.8	95.7	---	---
B-Fiber	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.1	99.1	97.9	95.0	94.9	---	---	100.0	100.0	100.0	100.0	99.9	99.9	99.2	97.3	96.4	---	---
	Avg			100.0	100.0	100.0	99.3	98.9	98.9	98.2	95.3	95.5	---	---	100.0	100.0	100.0	99.9	98.8	98.7	98.2	96.6	96.0	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	92.7	91.1	90.7	86.4	85.0	76.6	69.6	67.2
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.0	95.7	95.2	92.6	91.1	87.6	83.4	81.1
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	94.4	93.4	93.0	89.5	88.0	82.1	76.5	74.1
CRS-2P	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	---	---	---	---	---	---	---	100.0	100.0	100.0	100.0	---	---	---	---	---	---	---
CRS-2P	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	---	---	---	---	---	---	---	100.0	100.0	100.0	100.0	---	---	---	---	---	---	---
	Avg			100.0	100.0	100.0	100.0	---	---	---	---	---	---	---	100.0	100.0	100.0	100.0	---	---	---	---	---	---	---

Table D-1. Des Moines, IA crack treatment performance summaries (continued).

		Placement	Crack	Overall Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	1	3	8	11	17	29	40	53	69	77
Hi-Spec	1	Std Reservoir-and-Flush	Wirebrush, Airblast	100.0	100.0	100.0	99.7	99.7	99.7	99.7	99.3	88.8	59.8	53.4
Hi-Spec	2	Std Reservoir-and-Flush	Wirebrush, Airblast	100.0	100.0	100.0	89.3	88.5	88.5	88.3	88.3	77.8	51.0	43.0
	Avg			100.0	100.0	100.0	94.5	94.1	94.1	94.0	93.8	83.3	55.4	48.2
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	99.7	99.7	99.7	99.1	97.7	73.4	58.1	49.2
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	99.8	99.7	99.7	99.7	99.0	90.0	63.6	53.0
	Avg			100.0	100.0	100.0	99.7	99.7	99.7	99.4	98.4	81.7	60.9	51.1
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.7	99.7	99.1	98.5	86.5	72.5	68.8
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	99.8	99.8	99.8	99.6	99.8	99.8	99.7	98.9	89.2	84.8
	Avg			100.0	99.9	99.9	99.8	99.7	99.8	99.5	99.1	92.7	80.9	76.8
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.8	99.7	99.6	99.5	97.8	89.4	85.1
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.8	100.0	100.0	99.6	95.0	85.2	80.8
	Avg			100.0	100.0	100.0	99.9	99.8	99.8	99.8	99.5	96.4	87.3	82.9
Hi-Spec	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	84.4	84.4	84.2	73.4	68.9	35.1	24.2	---
Hi-Spec	2	Simple Band-Aid	Hot Airblast	100.0	99.8	99.8	98.1	98.0	97.9	97.6	95.9	53.6	29.9	---
	Avg			100.0	99.9	99.9	91.2	91.2	91.1	85.5	82.4	44.4	27.1	---
Hi-Spec	1	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	90.2	90.2	90.2	87.5	82.5	37.1	28.0	---
Hi-Spec	2	Simple Band-Aid	Conv Airblast	100.0	100.0	99.9	99.0	98.4	98.4	98.4	93.6	55.5	19.7	---
	Avg			100.0	100.0	100.0	94.6	94.3	94.3	92.9	88.0	46.3	23.8	---
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	98.5	93.1	92.4
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	96.8	95.1
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.1	95.0	93.7
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.8	98.8	98.8	98.8	98.7	97.4	94.9	93.1
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	90.5	89.0	88.9	88.3	87.9	81.7	78.5	76.1
	Avg			100.0	100.0	100.0	94.7	93.9	93.8	93.5	93.3	89.5	86.7	84.6
RS 515	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	84.2	84.2	84.2	83.9	83.3	48.7	35.5	---
RS 515	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	92.5	92.0	92.0	91.8	90.4	84.3	38.8	---
	Avg			100.0	100.0	100.0	88.4	88.1	88.1	87.9	86.8	66.5	37.2	---
9030	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.1	98.1	98.1	98.1	98.1	97.2	93.8	92.1
9030	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.4	99.1	99.1	99.1	98.5	95.9	94.4	90.9
	Avg			100.0	100.0	100.0	98.7	98.6	98.6	98.6	98.3	96.6	94.1	91.5
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.9	99.9	99.6	98.9	97.4	96.4	93.9
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	99.8	99.8	99.8	99.8	99.8	99.2	98.7	94.6	93.8
	Avg			100.0	100.0	99.9	99.9	99.9	99.9	99.7	99.0	98.0	95.5	93.8
9030	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	94.1	94.0	94.0	94.0	90.9	80.5	49.6	---
9030	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	81.9	81.9	81.9	81.6	80.6	72.1	40.7	---
	Avg			100.0	100.0	100.0	88.0	87.9	87.9	87.8	85.8	76.3	45.1	---
XLM	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7	99.6	98.7	95.9
XLM	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.6	98.6	98.6	98.6	98.6	96.8	95.1	93.5
	Avg			100.0	100.0	100.0	99.3	99.3	99.2	99.2	99.1	98.2	96.9	94.7
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.1	95.0	94.0
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.2	94.8	93.8
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.7	94.9	93.9
XLM	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.4	97.2	85.9	63.5	41.3
XLM	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	98.7	98.5	98.5	98.4	95.9	72.8	49.6	36.1
	Avg			100.0	100.0	100.0	99.3	99.3	99.3	98.9	96.6	79.4	56.6	38.7
B-Fiber	1	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	67.3	66.5	65.6	49.9	42.3	17.1	---	---
B-Fiber	2	Simple Band-Aid	Hot Airblast	100.0	100.0	100.0	82.3	81.3	79.5	76.2	54.0	10.8	---	---
	Avg			100.0	100.0	100.0	74.8	73.9	72.6	63.1	48.1	13.9	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	92.7	91.1	90.7	86.4	84.8	76.4	68.1	64.1
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	99.7	99.7	95.7	95.4	95.0	92.4	90.9	87.6	81.4	78.0
	Avg			100.0	99.9	99.9	94.2	93.3	92.8	89.4	87.8	82.0	74.8	71.1
CRS-2P	1	Flush-Fill	Conv Airblast	100.0	96.4	96.4	0.3	---	---	---	---	---	---	---
CRS-2P	2	Flush-Fill	Conv Airblast	100.0	96.2	94.4	0.0	---	---	---	---	---	---	---
	Avg			100.0	96.3	95.4	0.1	---	---	---	---	---	---	---

Table D-2. Wichita, KS adverse-conditions crack treatment performance summaries.

Material	Rep #	Placement Configuration	Crack Prep Procedure	Adhesion Effectiveness (%) Over Time (months)											Cohesion Effectiveness (%) Over Time (months)										
				0	2	3	10	12	18	31	42	55	68	79	0	2	3	10	12	18	31	42	55	68	79
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	—	98.2	97.9	97.9	—	94.9	47.2	—	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	—	96.3	95.5	95.0	86.5	84.6	52.0	—	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	97.2	96.7	96.4	—	89.8	49.6	—	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.6	98.5	98.3	—	97.2	66.1	54.3	42.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	—	99.8	99.8	99.8	98.6	97.9	86.5	70.8	58.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	99.2	99.2	99.0	—	97.6	76.3	62.6	50.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.9	99.9	—	99.3	78.9	75.5	69.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	—	98.9	98.9	98.9	98.3	97.8	92.2	81.0	67.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	99.4	99.4	99.4	—	98.6	85.5	78.3	68.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	97.2	96.9	96.9	—	89.3	21.1	—	—
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	91.7	91.7	91.2	78.5	77.6	22.0	—	—
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	94.4	94.3	94.1	—	83.5	21.5	—	—
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	95.3	95.1	95.1	—	89.8	25.7	—	—
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	68.2	67.7	67.7	57.0	55.9	20.0	—	—
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	81.8	81.4	81.4	—	72.8	22.8	—	—
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	—	99.7	99.5	99.5	—	99.5	82.7	74.4	65.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	—	99.7	99.5	99.5	97.8	97.6	96.2	82.6	74.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	99.7	99.5	99.5	—	98.5	89.5	78.5	70.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	89.3	89.3	89.3	—	88.5	16.9	—	—
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	85.4	85.4	85.4	81.5	81.5	46.8	—	—
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	87.4	87.4	87.4	—	85.0	31.9	—	—
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	94.4	93.5	93.4	—	91.0	84.5	78.1	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	—	99.2	99.1	99.0	97.9	96.6	91.7	71.6	66.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	96.8	96.3	96.2	—	93.8	88.1	74.9	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	71.4	71.3	71.3	—	70.0	29.9	—	—
9030	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	55.1	55.1	55.1	48.2	50.6	29.9	—	—
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	63.3	63.2	63.2	—	60.3	29.9	—	—
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	—	96.7	96.4	96.3	—	95.5	85.3	74.8	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	—	85.5	85.1	85.3	83.7	83.7	73.4	62.8	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	91.1	90.7	90.8	—	89.6	79.3	68.8	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	99.0	98.7	98.2	—	93.8	42.0	—	—
XLM	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	98.7	98.7	98.4	96.7	95.6	51.2	—	—
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	98.8	98.7	98.3	—	94.7	46.6	—	—
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	33.9	32.8	30.9	—	14.4	—	—	—
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	41.0	38.9	35.1	6.4	1.6	—	—	—
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	—	37.5	35.9	33.0	—	8.0	—	—	—
890-SL	1	Std Reservoir-and-Recess	Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	100.0	—	99.8	91.5	91.1	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Tape	100.0	100.0	—	98.1	98.1	98.0	95.5	95.3	92.4	91.0	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	99.0	99.0	99.0	—	97.6	92.0	91.0	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AR+	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	—	99.9	99.8	99.8	—	98.9	65.6	53.8	43.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AR+	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	—	98.8	98.8	98.6	97.2	96.9	74.2	64.2	51.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	99.3	99.3	99.2	—	97.9	69.9	59.0	47.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
[illegible]-S	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	—	100.0	100.0	100.0	—	98.9	70.7	54.1	43.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
[illegible]-S	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	—	100.0	100.0	100.0	99.6	99.0	86.2	65.5	50.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	—	100.0	100.0	100.0	—	99.0	78.5	59.8	46.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-2. Wichita, KS adverse-conditions crack treatment performance summaries (continued).

		Placement	Crack	Pull-Out Effectiveness (%) Over Time (months)											Edge Deterioration Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	2	3	10	12	18	31	42	55	68	79	0	2	3	10	12	18	31	42	55	68	79
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	---	100.0	100.0	99.8	---	99.0	96.4	---	---
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	---	99.9	99.9	99.9	98.1	97.4	92.7	---	---
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	---	100.0	100.0	99.9	---	98.2	94.5	---	---
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	99.0	97.6	93.9	92.8
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	99.5	99.5	96.1	95.7	95.4
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	---	99.2	96.8	94.8	94.1
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.6	99.6	---	98.4	96.1	95.4	94.9
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	98.1	98.0	100.0	100.0	---	100.0	100.0	100.0	99.7	99.7	98.2	97.9	97.5
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	99.0	99.0	100.0	100.0	---	99.8	99.8	99.8	---	99.0	97.1	96.7	96.2
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.7	99.7	99.7	---	98.8	97.9	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	99.4	100.0	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	---	100.0	100.0	100.0	100.0	99.7	98.2	---	---
	Avg			100.0	100.0	---	99.8	99.8	99.8	---	99.4	99.0	---	---	100.0	100.0	---	100.0	100.0	100.0	---	99.6	99.1	---	---
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	99.0	99.5	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	---	100.0	100.0	100.0	97.1	95.8	94.1	---	---	100.0	100.0	---	100.0	100.0	100.0	99.3	99.3	99.3	---	---
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	97.9	97.0	---	---	100.0	100.0	---	100.0	100.0	100.0	---	99.1	99.4	---	---
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	---	99.4	98.6	98.0	97.7
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	99.9	99.9	99.9	99.7	99.1	98.9	98.4
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	---	99.6	98.9	98.4	98.1
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	98.1	---	---
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	99.7	99.7	99.0	---	---	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	---
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	99.9	99.5	---	---	100.0	100.0	---	100.0	100.0	100.0	---	100.0	99.0	---	---
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	98.8	97.0	96.9	96.8	100.0	100.0	100.0	100.0	100.0	100.0	---	99.7	94.8	81.2	80.7
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	99.4	98.5	98.4	98.4	100.0	100.0	---	100.0	100.0	100.0	---	99.9	97.2	90.4	90.2
9030	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	---	100.0	99.7	---	---	100.0	100.0	---	100.0	100.0	100.0	---	97.3	93.9	---	---
9030	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	97.6	90.5	---	---	100.0	100.0	---	100.0	100.0	100.0	99.3	98.1	93.1	---	---
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	98.8	95.1	---	---	100.0	100.0	---	100.0	100.0	100.0	---	97.7	93.5	---	---
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	---	91.8	80.3	79.9	---	100.0	100.0	---	100.0	100.0	100.0	---	99.7	99.2	99.0	---
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	82.4	82.4	80.0	76.6	76.4	---	100.0	100.0	---	99.7	99.7	99.7	99.4	99.1	97.2	97.1	---
	Avg			100.0	100.0	---	100.0	100.0	91.2	---	85.9	78.5	78.1	---	100.0	100.0	---	99.9	99.9	99.8	---	99.4	98.2	98.0	---
XLM	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.7	99.7	99.7	---	95.9	91.4	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	97.8	92.2	---	---
XLM	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	99.8	98.6	97.2	97.0	---	---	100.0	100.0	---	100.0	100.0	100.0	99.0	99.7	96.9	---	---
	Avg			100.0	100.0	---	99.9	99.9	99.8	---	96.6	94.2	---	---	100.0	100.0	---	100.0	100.0	100.0	---	98.7	94.5	---	---
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	---	---	---	100.0	100.0	100.0	79.3	76.6	84.5	---	76.6	---	---	---
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	---	---	---	100.0	100.0	---	74.3	70.5	88.1	85.2	86.6	---	---	---
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	100.0	---	---	---	100.0	100.0	---	76.8	73.6	86.3	---	81.6	---	---	---
890-SL	1	Std Reservoir-and-Recess	Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	100.0	---	96.6	87.1	85.7	---	100.0	100.0	100.0	88.5	87.7	87.2	---	78.9	75.3	71.2	---
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Tape	100.0	100.0	---	100.0	100.0	100.0	100.0	95.1	84.0	83.1	---	100.0	100.0	---	91.8	91.1	90.6	73.9	66.5	62.3	60.0	---
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	95.8	85.5	84.4	---	100.0	100.0	---	90.1	89.4	88.9	---	72.7	68.8	65.6	---
AR+	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	---	99.7	98.2	96.8	96.4
AR+	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	99.9	99.3	99.0	98.6
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	---	99.8	98.7	97.9	97.5
9000-S	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	---	100.0	96.5	95.1	94.6
9000-S	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	99.5	99.4	99.4	100.0	100.0	---	100.0	100.0	100.0	99.1	98.4	98.1	97.4	97.3
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	100.0	99.7	99.7	99.7	100.0	100.0	---	100.0	100.0	100.0	---	99.2	97.3	96.3	96.0

Table D-2. Wichita, KS adverse-conditions crack treatment performance summaries (continued).

		Placement	Crack	Overall Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	2	3	10	12	18	31	42	55	68	79
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	---	98.2	97.9	97.9	---	94.2	43.6	---	---
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	---	96.2	95.9	95.7	84.9	82.0	44.6	---	---
	Avg			100.0	100.0	---	97.2	96.9	96.8	---	88.1	44.1	---	---
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.6	98.5	98.3	---	96.2	63.7	48.3	36.9
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	99.8	99.8	99.8	98.1	97.4	82.9	66.5	54.3
	Avg			100.0	100.0	---	99.2	99.2	99.0	---	96.8	73.3	57.4	45.6
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.7	99.5	99.5	---	98.9	74.9	70.9	64.8
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	98.9	98.9	98.9	97.9	97.4	90.3	78.9	63.0
	Avg			100.0	100.0	---	99.3	99.2	99.2	---	98.1	82.6	74.9	63.9
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	96.9	96.5	96.5	---	87.5	19.0	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	91.1	91.1	91.1	78.3	77.2	20.1	---	---
	Avg			100.0	100.0	---	94.0	93.8	93.8	---	82.3	19.6	---	---
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	100.0	95.3	95.1	95.0	---	88.6	25.7	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	100.0	98.4	---	66.7	66.1	66.3	54.9	53.0	13.2	---	---
	Avg			100.0	99.2	---	81.0	80.6	80.6	---	70.8	19.4	---	---
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	99.7	99.5	99.2	---	98.9	81.3	72.4	63.5
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	99.7	99.6	99.6	97.7	97.3	95.6	81.5	72.7
	Avg			100.0	100.0	---	99.7	99.5	99.4	---	98.1	88.5	77.0	68.1
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	89.3	89.3	89.3	---	88.5	16.9	---	---
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	85.4	85.4	85.4	81.3	81.3	46.4	---	---
	Avg			100.0	100.0	---	87.4	87.4	87.4	---	84.9	31.7	---	---
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	94.4	93.6	93.4	---	90.8	76.6	61.4	51.8
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	99.2	99.1	99.0	97.9	96.6	91.3	71.3	66.1
	Avg			100.0	100.0	---	96.8	96.4	96.2	---	93.7	84.0	66.3	59.0
9030	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	71.4	71.3	71.3	---	67.8	25.7	---	---
9030	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	55.1	55.1	55.1	47.5	46.3	2.5	---	---
	Avg			100.0	100.0	---	63.3	63.2	63.2	---	57.0	14.1	---	---
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	96.5	96.4	96.3	---	87.2	66.8	54.1	---
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	---	85.2	84.8	84.8	65.5	63.1	51.6	38.2	---
	Avg			100.0	100.0	---	90.9	90.6	90.5	---	75.1	59.2	46.1	---
XLM	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.3	97.7	97.7	---	88.3	26.0	---	---
XLM	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	98.3	98.2	96.9	94.1	91.7	46.9	---	---
	Avg			100.0	100.0	---	98.3	98.0	97.3	---	90.0	36.5	---	---
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	33.9	32.8	30.0	---	14.4	---	---	---
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	---	41.0	38.9	35.1	6.4	1.6	---	---	---
	Avg			100.0	100.0	---	37.5	35.9	32.6	---	8.0	---	---	---
890-SL	1	Std Reservoir-and-Recess	Airblast, Back Rod	100.0	100.0	100.0	87.8	87.0	87.2	---	76.8	53.7	47.9	---
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Tape	100.0	100.0	---	89.9	89.2	88.6	68.5	60.8	49.9	44.9	---
	Avg			100.0	100.0	---	88.8	88.1	87.9	---	68.8	51.8	46.4	---
AR+	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	99.9	99.8	99.8	---	98.6	63.8	50.6	39.9
AR+	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	98.8	98.8	98.8	97.2	96.8	73.5	63.2	49.7
	Avg			100.0	100.0	---	99.3	99.3	99.3	---	97.7	68.7	56.9	44.8
9000-S	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	99.9	99.9	100.0	---	98.9	66.8	49.5	38.2
9000-S	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	---	100.0	100.0	100.0	98.7	97.5	83.8	62.2	47.0
	Avg			100.0	100.0	---	100.0	100.0	100.0	---	98.2	75.3	55.9	42.6

Table D-3. Wichita, KS ideal-conditions crack treatment performance summaries.

Material	Rep #	Placement Configuration	Crack Prep Procedure	Adhesion Effectiveness (%) Over Time (months)											Cohesion Effectiveness (%) Over Time (months)										
				0	2	3	10	12	18	31	42	55	68	79	0	2	3	10	12	18	31	42	55	68	79
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	95.7	95.3	94.4	81.4	80.2	15.5	---	---	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	98.2	97.9	97.7	---	96.7	36.9	---	---	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	97.0	96.6	96.1	---	88.5	26.2	---	---	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.7	98.6	98.6	96.1	94.3	67.9	57.1	41.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.8	99.8	---	98.5	81.3	71.3	53.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.3	99.2	99.2	---	96.4	74.6	64.2	47.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	87.2	75.3	65.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.9	98.6	98.6	---	96.6	51.7	43.9	41.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.4	99.3	99.3	---	98.1	69.5	59.6	53.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	83.5	82.4	82.0	71.3	66.8	3.1	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	85.0	84.5	84.3	---	83.8	2.6	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	84.2	83.5	83.2	---	75.3	2.9	---	---
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	86.1	83.6	83.5	79.9	68.2	8.9	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	72.6	72.6	71.7	---	70.1	2.4	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	79.3	78.1	77.6	---	69.2	5.7	---	---
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.8	99.8	98.4	98.2	91.7	82.6	75.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	95.4	87.9	80.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	99.9	99.9	---	99.1	93.5	85.2	78.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	96.4	95.8	95.9	95.3	94.3	59.9	---	---
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	66.3	65.8	65.8	---	65.4	8.8	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	81.3	80.8	80.9	---	79.8	34.3	---	---
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	94.4	93.5	93.3	92.3	91.1	83.9	76.1	60.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	95.6	95.3	95.1	---	93.1	86.5	77.7	69.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	95.0	94.4	94.2	---	92.1	85.2	76.9	65.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	51.0	51.0	51.0	46.9	46.6	15.8	---	---
9030	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	74.8	74.8	74.8	---	74.7	37.6	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	62.9	62.9	62.9	---	60.6	26.7	---	---
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.9	99.9	99.6	99.5	94.1	76.8	68.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.8	98.8	98.8	---	96.1	86.9	72.7	57.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.3	99.3	99.3	---	97.8	90.5	74.8	62.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	75.9	72.5	71.6	64.5	76.6	48.1	---	---
XLM	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	86.1	86.1	85.9	---	84.0	18.1	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	81.0	79.3	78.8	---	80.3	33.1	---	---
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	39.1	37.9	37.7	21.4	15.9	---	---	---
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	46.4	43.7	42.1	---	31.9	---	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	42.7	40.8	39.9	---	23.9	---	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	99.9	99.8	99.8	99.2	97.8	81.8	77.6	76.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	99.7	---	98.9	94.9	93.5	91.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	99.9	99.7	---	98.4	88.3	85.5	83.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AR+	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.7	98.7	99.6	97.1	95.2	78.7	72.1	58.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AR+	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.9	99.9	---	98.4	86.2	82.7	68.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.3	99.3	99.7	---	96.8	82.5	77.4	63.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9000-S	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.1	96.9	93.4	86.8	70.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9000-S	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.8	99.8	---	99.7	83.2	76.7	54.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.8	99.8	99.8	---	98.3	88.3	81.8	62.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-3. Wichita, KS ideal-conditions crack treatment performance summaries (continued).

		Placement	Crack	Pull-Out Effectiveness (%) Over Time (months)											Edge Deterioration Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	2	3	10	12	18	31	42	55	68	79	0	2	3	10	12	18	31	42	55	68	79
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	100.0	98.5	97.6	97.5	95.4	94.2	91.9	---	---
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	99.8	99.8	99.8	---	99.0	94.4	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	99.2	98.7	98.7	---	96.6	93.2	---	---
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.5	98.5	98.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	98.4	98.4
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	99.4	99.2	99.2
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	99.3	99.3	99.3	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	99.3	98.8	98.8
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	97.9	97.8	97.8	97.5	97.5	100.0	100.0	100.0	100.0	100.0	100.0	97.9	100.0	99.1	98.6	98.4
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	99.7	99.7	99.7	99.7
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	98.9	98.9	98.7	98.7	100.0	100.0	100.0	100.0	100.0	100.0	---	99.9	99.4	99.2	99.0
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	98.2	98.2	97.9	---	---	100.0	100.0	100.0	100.0	100.0	100.0	99.4	99.4	99.4	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	99.7	99.7	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	99.1	99.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	99.6	99.6	---	---
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	99.8	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	99.7	97.9	97.9	96.9
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	99.9	99.0	99.0	98.4
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.8	---	---
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	98.2	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	97.0	---	---
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.0	99.0	98.6
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	97.8	97.7	97.6
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	98.4	98.3	98.1
9030	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.7	---	---	100.0	100.0	100.0	100.0	99.7	100.0	100.0	100.0	97.2	---	---
9030	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	---	---	100.0	100.0	100.0	99.9	99.9	99.9	---	99.5	97.8	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	97.9	---	---	100.0	100.0	100.0	100.0	99.8	100.0	---	99.7	97.5	---	---
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.1	99.1	98.1	97.9	97.8
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	---	99.7	99.7	99.7	99.7
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	---	99.4	98.9	98.8	98.7
XLM	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.9	99.9	94.2	85.7	61.8	---	---	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	98.6	---	---
XLM	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.5	99.5	99.5	---	99.5	99.2	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	99.7	96.3	---	---
	Avg			100.0	100.0	100.0	99.7	99.7	99.7	---	92.6	80.5	---	---	100.0	100.0	100.0	100.0	100.0	100.0	---	99.8	97.4	---	---
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	---	100.0	100.0	100.0	98.2	96.6	97.2	94.4	94.2	---	---	---
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	---	---	---	100.0	100.0	100.0	94.3	93.4	95.4	---	93.3	---	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	---	---	---	100.0	100.0	100.0	96.2	95.0	96.3	---	93.8	---	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.4	96.3	96.0	100.0	99.8	99.8	95.9	94.0	92.8	82.3	77.3	67.4	63.1	59.5
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.8	96.7	96.3	---	85.9	74.3	69.7	65.0
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	98.2	98.1	98.0	100.0	99.9	99.9	96.4	95.4	94.5	---	81.6	70.9	66.4	62.3
AR+	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	98.9	76.2	75.5	74.8
AR+	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	74.6	73.1	72.6
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	99.4	75.4	74.3	73.7
9000-S	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	64.7	60.2	58.5
9000-S	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	87.9	86.3	85.8
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	76.3	73.3	72.1

Table D-3. Wichita, KS ideal-conditions crack treatment performance summaries (continued).

		Placement	Crack	Overall Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	2	3	10	12	18	31	42	55	68	79
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	94.8	93.7	92.8	78.1	74.4	15.4	---	---
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	98.0	97.8	97.3	---	95.7	32.2	---	---
	Avg			100.0	100.0	100.0	96.4	95.7	95.1	---	85.1	23.8	---	---
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.7	98.6	98.6	96.1	94.2	66.2	54.5	38.5
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.3	99.2	99.6	---	98.0	80.6	70.5	52.6
	Avg			100.0	100.0	100.0	99.0	98.9	99.1	---	96.1	73.4	62.5	45.5
Hi-Spec	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	97.9	97.4	83.5	72.0	62.2
Hi-Spec	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.9	98.6	98.6	---	96.4	51.5	43.7	41.6
	Avg			100.0	100.0	100.0	99.4	99.3	99.3	---	96.9	67.5	57.8	51.9
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	82.5	81.3	81.0	68.4	63.3	3.1	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	84.0	83.6	83.5	---	82.6	2.3	---	---
	Avg			100.0	100.0	100.0	83.2	82.5	82.2	---	72.9	2.7	---	---
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	100.0	85.7	83.1	83.1	79.9	68.2	8.6	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	100.0	72.0	73.6	71.2	---	69.6	2.3	---	---
	Avg			100.0	100.0	100.0	78.9	78.3	77.1	---	68.9	5.4	---	---
RS 515	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.8	99.8	98.4	98.1	91.6	82.6	75.0
RS 515	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	---	99.7	93.3	85.9	77.7
	Avg			100.0	100.0	100.0	100.0	99.9	99.9	---	98.9	92.4	84.2	76.3
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	96.3	95.9	95.9	95.3	94.3	56.3	---	---
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	65.9	65.4	65.4	---	64.9	6.9	---	---
	Avg			100.0	100.0	100.0	81.1	80.6	80.6	---	79.6	31.6	---	---
9030	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	94.4	94.0	93.3	92.3	91.1	83.2	75.1	59.4
9030	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	95.2	95.0	95.1	---	93.1	84.4	75.3	67.0
	Avg			100.0	100.0	100.0	94.8	94.5	94.2	---	92.1	83.8	75.2	63.2
9030	1	Simple Recessed Band-Aid	Hot Airblast	100.0	99.8	99.8	51.0	51.0	51.0	46.9	46.6	11.1	---	---
9030	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	74.7	74.7	74.7	---	74.0	36.0	---	---
	Avg			100.0	99.9	99.9	62.8	62.8	62.8	---	60.3	23.6	---	---
XLM	1	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.9	99.9	98.7	98.6	92.2	74.7	66.0
XLM	2	Shallow Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.6	98.6	98.5	---	95.7	86.5	72.5	56.9
	Avg			100.0	100.0	100.0	99.3	99.3	99.2	---	97.1	89.3	73.6	61.5
XLM	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	75.8	72.5	71.5	64.5	62.7	10.2	---	---
XLM	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	85.2	85.2	85.1	---	82.7	14.0	---	---
	Avg			100.0	100.0	100.0	80.5	78.9	78.3	---	72.7	12.1	---	---
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	39.1	37.9	37.7	21.4	15.9	---	---	---
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	46.7	43.7	42.0	---	31.9	---	---	---
	Avg			100.0	100.0	100.0	42.9	40.8	39.8	---	23.9	---	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	99.8	99.8	95.8	93.8	92.6	81.5	75.3	58.8	50.3	45.6
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	99.2	99.2	96.0	96.0	95.5	---	84.8	70.3	63.8	57.2
	Avg			100.0	99.5	99.5	95.9	94.9	94.1	---	80.1	64.5	57.0	51.4
AR+	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	98.7	98.7	99.6	96.0	94.0	55.1	47.5	34.2
AR+	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.9	99.9	99.9	---	98.4	60.9	55.8	43.2
	Avg			100.0	100.0	100.0	99.3	99.3	99.7	---	96.2	58.0	51.6	38.7
9000-S	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.1	96.9	58.2	47.6	33.0
9000-S	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.8	99.8	---	99.7	71.4	63.0	40.6
	Avg			100.0	100.0	100.0	99.8	99.8	99.8	---	98.3	64.8	55.3	36.8

Table D-4. Abilene, TX crack treatment performance summaries.

		Placement	Crack	Adhesion Effectiveness (%) Over Time (months)											Cohesion Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	2	3	10	12	18	33	44	57	69	82	0	2	3	10	12	18	33	44	57	69	82
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	98.1	97.5	97.5	96.8	95.7	80.7	55.3	---	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	100.0	99.1	99.1	98.6	98.4	71.4	49.4	---	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.0	98.3	98.3	97.7	97.0	76.1	52.3	---	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.3	90.3	81.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	89.0	74.4	68.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	93.6	82.3	75.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	99.8	99.7	99.7	91.0	86.9	26.0	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	99.7	99.7	96.2	92.3	26.4	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	99.9	99.7	99.7	93.6	89.6	26.2	---	---
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	98.9	98.9	86.5	76.6	16.4	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	98.5	98.3	93.1	84.1	21.2	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	98.7	98.6	89.8	80.3	18.8	---	---
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	98.5	96.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	99.5	99.5	99.5	99.5	99.5	99.5	96.8	94.4	92.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	99.7	99.7	99.7	99.7	99.7	99.7	98.2	96.4	94.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	97.7	97.2	68.9	51.7	---
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.6	73.4	49.5	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	98.6	98.4	71.1	50.6	---
9030	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.4	93.6	90.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	99.8	99.8	99.8	99.8	99.8	99.8	96.6	94.2	93.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	99.9	99.9	99.9	99.9	99.9	99.9	97.5	93.9	91.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	89.1	89.0	33.2	---	---
9030	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	92.0	75.4	29.0	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	90.5	82.2	31.1	---	---
XLM	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	95.5	88.5	82.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.2	99.2	98.4	98.2	90.1	82.1	79.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	99.9	99.6	99.6	99.1	99.0	92.8	85.3	81.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	98.7	98.7	88.7	84.8	30.3	---	---
XLM	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	99.7	98.2	90.2	51.6	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	99.3	99.2	93.4	87.5	40.9	---	---
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	66.2	59.7	60.4	51.6	38.3	---	---	---
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	55.6	49.9	49.9	42.9	30.9	---	---	---
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	60.9	54.8	55.2	47.2	34.6	---	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	99.3	98.8	97.0	95.4	92.8	83.3	74.0	69.9	68.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	100.0	98.7	98.4	97.7	95.9	90.6	88.5	84.2	72.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	99.7	98.7	97.7	96.5	94.4	87.0	81.3	77.0	70.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-4. Abilene, TX crack treatment performance summaries (continued).

		Placement	Crack	Pull-Out Effectiveness (%) Over Time (months)											Edge Deterioration Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	2	3	10	12	18	33	44	57	69	82	0	2	3	10	12	18	33	44	57	69	82
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.3	96.0	95.5	---
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	99.9	99.9	99.9	99.9	99.7	98.8	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.6	97.8	97.1	---
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.1	94.1	93.2
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.9	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	100.0	98.7	96.4
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	98.6	96.4	94.8
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	99.1	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.5	---	---
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	100.0	99.2	99.1	99.1	99.1	99.1	99.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	---	---
	Avg			100.0	100.0	100.0	99.6	99.6	99.6	99.6	99.6	99.5	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	---	---
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	98.4	95.4
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.4	98.4	97.5
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.7	98.4	96.4
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	---
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	---
9030	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.5	99.5	99.5	99.0	99.0	98.5
9030	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.7	99.7	99.5	99.5	99.3
9030	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---
9030	2	Simple Recessed Band-Aid	Hot Airblast	100.0	97.1	97.1	95.7	95.7	95.7	95.7	95.7	95.7	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	99.0	---	---
	Avg			100.0	98.6	98.6	97.9	97.9	97.9	97.9	97.9	97.9	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.5	---	---
XLM	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.6	99.1	99.1	97.7	96.5	93.7
XLM	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.7	99.7	99.7	100.0	100.0	100.0	99.8	99.9	99.9	99.4	99.2	98.9	98.3	98.1
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.9	99.9	99.9	100.0	100.0	100.0	99.9	99.7	99.7	99.3	99.2	98.3	97.4	95.9
XLM	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	100.0	100.0	100.0	100.0	99.7	100.0	100.0	99.5	99.5	---	---
XLM	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.5	99.5	---	---	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.2	99.0	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	99.7	---	---	100.0	100.0	100.0	100.0	99.8	100.0	100.0	99.3	99.2	---	---
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.8	---	---	---	100.0	100.0	100.0	100.0	99.3	97.0	97.0	98.5	---	---	---
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	---	---	---	100.0	100.0	100.0	100.0	98.8	98.0	97.7	95.5	---	---	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	---	---	---	100.0	100.0	100.0	100.0	99.0	97.5	97.3	97.0	---	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	96.4	96.4	96.4	97.3	96.9	90.4	88.8	86.4	86.3	100.0	100.0	100.0	96.1	91.8	90.6	89.9	87.9	88.0	83.2	82.5
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	99.5	99.2	99.2	99.2	99.5	99.5	99.2	97.4	94.0	93.8	100.0	100.0	100.0	99.2	98.0	97.1	96.0	95.5	94.6	91.3	90.0
	Avg			100.0	99.7	97.8	97.8	97.8	98.4	98.2	94.8	93.1	90.2	90.0	100.0	100.0	100.0	97.7	94.9	93.9	93.0	91.7	91.3	87.2	86.2

Table D-4. Abilene, TX crack treatment performance summaries (continued).

		Placement	Crack	Overall Effectiveness (%) Over Time (months)										
Material	Rep #	Configuration	Prep Procedure	0	2	3	10	12	18	33	44	57	69	82
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	98.1	97.5	97.5	96.4	95.0	77.0	51.0	---
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100.0	100.0	100.0	100.0	98.9	98.9	98.5	98.4	71.1	48.6	---
	Avg			100.0	100.0	100.0	99.0	98.2	98.2	97.5	96.7	74.0	49.8	---
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	95.1	84.4	75.2
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	88.4	73.1	65.1
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.7	91.7	78.7	70.1
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.7	99.7	91.0	86.0	24.8	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.7	99.7	96.1	92.2	24.5	---	---
	Avg			100.0	100.0	100.0	100.0	99.7	99.7	93.5	89.1	24.7	---	---
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	99.7	99.7	98.6	98.6	85.6	76.6	16.0	---	---
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	100.0	100.0	98.7	98.6	96.9	96.6	91.5	82.6	19.7	---	---
	Avg			100.0	100.0	99.2	99.2	97.7	97.6	88.5	79.6	17.8	---	---
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.4	96.9	91.9
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	99.5	99.5	99.5	99.5	99.5	99.5	95.9	92.7	90.3
	Avg			100.0	100.0	99.7	99.7	99.7	99.7	99.7	99.7	97.2	94.8	91.1
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	97.7	97.2	68.9	50.2	---
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.6	73.4	48.4	---
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	98.6	98.4	71.1	49.3	---
9030	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.5	99.5	99.5	99.5	97.4	92.5	89.3
9030	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	99.8	99.8	99.8	99.8	99.8	99.8	96.6	94.2	93.0
	Avg			100.0	100.0	99.9	99.9	99.7	99.7	99.7	99.7	97.0	93.4	91.1
9030	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	100.0	100.0	89.1	89.0	33.2	---	---
9030	2	Simple Recessed Band-Aid	Hot Airblast	100.0	97.1	97.1	95.7	95.7	95.7	87.9	70.8	24.0	---	---
	Avg			100.0	98.6	98.6	97.9	97.9	97.9	88.5	79.9	28.6	---	---
XLM	1	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	100.0	99.3	99.3	98.7	98.4	93.1	85.1	76.4
XLM	2	Std Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.8	99.1	99.1	97.7	97.4	89.5	79.8	77.7
	Avg			100.0	100.0	100.0	99.9	99.2	99.2	98.2	97.9	91.3	82.4	77.0
XLM	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	99.2	99.2	97.5	97.5	88.5	84.1	30.3	---	---
XLM	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	99.7	99.7	99.7	97.8	88.9	50.2	---	---
	Avg			100.0	100.0	99.6	99.4	98.6	98.6	93.2	86.5	40.2	---	---
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	100.0	66.2	59.7	59.7	50.9	35.4	---	---	---
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	100.0	100.0	99.7	55.8	50.1	49.9	42.9	30.0	---	---	---
	Avg			100.0	100.0	99.9	61.0	54.9	54.8	46.9	32.7	---	---	---
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	100.0	95.7	92.7	86.7	83.8	81.3	61.6	52.0	42.6	40.6
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100.0	99.5	99.2	97.4	95.7	94.3	91.5	85.6	81.4	70.1	56.6
	Avg			100.0	99.7	97.5	95.1	91.2	89.0	86.4	73.6	66.7	56.4	48.6

Table D-5. Elma, WA crack treatment performance summaries.

		Placement	Crack	Adhesion Effectiveness (%) Over Time (months)									Cohesion Effectiveness (%) Over Time (months)								
Material	Rep #	Configuration	Prep Procedure	0	1	3	9	13	18	31	44	48	0	1	3	9	13	18	31	44	48
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100	100	100	100	100	100	100	100	99.913	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100	100	100	100	100	100	100	100	99.957	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	100	100
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	99.913	100	100
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	99.957	100	100
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	99.913	99.913	99.219	97.743	80.99	80.99
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	99.392	99.306
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	99.957	99.957	99.609	98.872	90.191	90.148
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	100	100
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	100	100
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	100	100
9030	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9030	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	99.826	99.74	99.74
9030	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	100	100
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	99.913	99.87	99.87
XLM	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
XLM	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	100	100
XLM	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	100	100
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	100	100
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	100	99.566	99.566
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	98.611	91.059	90.972
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100	100	100	100	99.306	95.313	95.269
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100	99.566	99.566	99.566	99.566	99.566	99.479	99.219	99.132	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100	99.783	99.783	99.783	99.783	99.783	99.74	99.609	99.566	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 211	1	Std Recesssed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 211	2	Std Recesssed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100	100	100	100	100	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-5. Elma, WA crack treatment performance summaries (continued).

		Placement	Crack	Pull-Out Effectiveness (%) Over Time (months)									Edge Deterioration Effectiveness (%) Over Time (months)								
Material	Rep #	Configuration	Prep Procedure	0	1	3	9	13	18	31	44	48	0	1	3	9	13	18	31	44	48
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99.913	99.913	99.913
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99.957	99.957	99.957
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	99.913	99.913	100	100	100	100	100	100	100	100	100
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	99.957	99.957	100	100	100	100	100	100	100	100	100
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	100	99.74	99.74	99.74	99.74	99.74	99.74	99.74	99.653	100	100	100	100	100	100	100	100	100
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	99.87	99.87	99.87	99.87	99.87	99.87	99.87	99.826	100	100	100	100	100	100	100	100	100
9030	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
9030	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
9030	1	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
9030	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
XLM	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
XLM	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
XLM	1	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
XLM	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99.913
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99.957
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	99.826	99.74	100	100	100	100	100	100	100	100	100
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	99.826	99.826	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	99.826	99.783	100	100	100	100	100	100	100	100	100
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100	100	100	100	100	100	100	100	100	100	99.566	99.566	99.219	99.219	98.958	98.611	98.351	98.351
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100	100	100	100	100	100	100	100	100	100	100	100	100	99.74	98.785	98.264	98.003	97.743
	Avg			100	100	100	100	100	100	100	100	100	100	99.783	99.783	99.609	99.479	98.872	98.438	98.177	98.047
RS 211	1	Std Recesssed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
RS 211	2	Std Recesssed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table D-5. Elma, WA crack treatment performance summaries (continued).

Material	Rep #	Placement Configuration	Crack Prep Procedure	Overall Effectiveness (%) Over Time (months): 0	1	3	9	13	18	31	44	48
Hi-Spec	1	Std Reservoir-and-Flush	Hot Airblast	100	100	100	100	100	99.913	99.913	99.913	99.826
Hi-Spec	2	Std Reservoir-and-Flush	Hot Airblast	100	100	100	99.913	99.913	99.826	99.826	99.74	99.653
	Avg			100	100	100	99.957	99.957	99.87	99.87	99.826	99.74
Hi-Spec	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
Hi-Spec	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100
Hi-Spec	1	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
Hi-Spec	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	99.913	99.913
	Avg			100	100	100	100	100	100	100	99.957	99.957
Hi-Spec	1	Simple Recessed Band-Aid	Conv Airblast	100	100	100	99.913	99.306	99.219	97.743	81.597	80.903
Hi-Spec	2	Simple Recessed Band-Aid	Conv Airblast	100	100	100	100	100	100	100	99.392	99.306
	Avg			100	100	100	99.957	99.653	99.609	98.872	90.495	90.104
RS 515	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
RS 515	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100
RS 515	1	Simple Recessed Band-Aid	Hot Airblast	100	99.74	99.74	99.74	99.74	99.74	99.74	99.74	99.653
RS 515	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
	Avg			100	99.87	99.87	99.87	99.87	99.87	99.87	99.87	99.826
9030	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
9030	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100
9030	1	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
9030	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	99.826	99.74	99.74
	Avg			100	100	100	100	100	100	99.913	99.87	99.87
XLM	1	Std Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
XLM	2	Std Recessed Band-Aid	Hot Airblast	100	100	100	99.913	99.913	99.913	99.826	99.826	99.826
	Avg			100	100	100	99.957	99.957	99.957	99.913	99.913	99.913
XLM	1	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	99.913	99.913	99.913
XLM	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	99.913
	Avg			100	100	100	100	100	100	99.957	99.957	99.913
B-Fiber	1	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	99.392	99.306
B-Fiber	2	Simple Recessed Band-Aid	Hot Airblast	100	100	100	100	100	100	98.524	90.799	90.712
	Avg			100	100	100	100	100	100	99.262	95.095	95.009
890-SL	1	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100	99.132	99.132	98.785	98.785	98.524	98.09	97.569	97.483
890-SL	2	Deep Reservoir-and-Recess	Sand/Airblast, Back Rod	100	100	100	100	99.74	98.785	98.264	98.003	97.743
	Avg			100	99.566	99.566	99.392	99.262	98.655	98.177	97.786	97.613
RS 211	1	Std Recesssed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
RS 211	2	Std Recesssed Band-Aid	Hot Airblast	100	100	100	100	100	100	100	100	100
	Avg			100	100	100	100	100	100	100	100	100

Table D-6. Prescott, ON crack treatment performance summaries.

		Placement	Crack	Adhesion Effectiveness (%) Over Time (months)										Cohesion Effectiveness (%) Over Time (months)									
Material	Rep #	Configuration	Prep Procedure	0	1	3	6	10	15	26	38	50	63	0	1	3	6	10	15	26	38	50	63
RS 211	1	Capped	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.8	98.9	97.3	94.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RS 211	2	Capped	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.4	97.3	92.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	99.9	98.6	97.3	93.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AC	1	Flush-Fill	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	99.8	94.8	48.8	14.2
AC	2	Flush-Fill	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	99.4	95.5	44.6	18.5
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	99.6	95.1	46.7	16.3
AC	1	Flush-Fill	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	98.4	91.8	45.7	19.3
AC	2	Flush-Fill	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	99.3	94.0	54.3	8.4
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	98.9	92.9	50.0	13.8
CRF	1	Flush-Fill	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	94.3	87.0	61.8	30.8
CRF	2	Flush-Fill	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	99.8	98.8	89.4	55.9	19.8
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	99.9	96.5	88.2	58.8	25.3
AR2	1	Simple Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.2	97.7	96.0
AR2	2	Simple Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	98.6	95.9
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	98.2	96.0
AR2	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.2	97.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AR2	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	98.5	96.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	98.8	96.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fiber Pave	1	Simple Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	99.8	99.1	96.3	93.0	91.0
Fiber Pave	2	Simple Band-Aid	Conv Airblast	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	100.0	99.5	97.2	95.9	94.1
	Avg			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.0	100.0	100.0	100.0	100.0	99.9	99.3	96.8	94.4	92.6
Kold Flo	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	99.1	98.8	98.6	64.4	38.1	11.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kold Flo	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	99.2	98.0	95.6	73.0	39.4	5.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Avg			100.0	100.0	100.0	100.0	99.1	98.4	97.1	68.7	38.8	8.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-6. Prescott, ON crack treatment performance summaries (continued).

		Placement	Crack	Pull-Out Effectiveness (%) Over Time (months)										Edge Deterioration Effectiveness (%) Over Time (months)									
Material	Rep #	Configuration	Prep Procedure	0	1	3	6	10	15	26	38	50	63	0	1	3	6	10	15	26	38	50	63
RS 211	1	Capped	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.5	98.6	98.6	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	98.5	86.5
RS 211	2	Capped	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	96.1
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	99.3	99.3	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	99.2	91.3
AC	1	Flush-Fill	None	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	100.0	99.2	95.1	94.3	88.4
AC	2	Flush-Fill	None	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	100.0	98.7	95.7	97.7	85.3
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	100.0	98.9	95.4	96.0	86.8
AC	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	100.0	97.9	94.8	92.9	85.0
AC	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.8	99.6	95.2	94.7	91.6
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.9	98.8	95.0	93.8	88.3
CRF	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.5	97.8	97.5	95.1
CRF	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	98.7	98.4	97.5
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.7	98.2	98.0	96.3
AR2	1	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.6	96.9
AR2	2	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	98.2
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.7	97.6
AR2	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.2	99.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	90.8
AR2	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.2
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	94.5
Fiber Pave	1	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.4	98.9	92.3
Fiber Pave	2	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.8	99.8	99.8	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.5	94.9
	Avg			100.0	100.0	100.0	99.9	99.9	99.9	99.9	99.9	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.5	99.2	93.6
Kold Flo	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	98.6	94.7	91.3
Kold Flo	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	98.8	97.3
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	98.9	96.7	94.3

Table D-6. Prescott, ON crack treatment performance summaries (continued).

		Placement	Crack	Overall Effectiveness (%) Over Time (months)									
Material	Rep #	Configuration	Prep Procedure	0	1	3	6	10	15	26	38	50	63
RS 211	1	Capped	Conv Airblast	100.0	100.0	100.0	100.0	99.1	99.1	98.4	98.0	95.2	81.0
RS 211	2	Capped	Conv Airblast	100.0	100.0	100.0	100.0	99.8	99.8	99.8	98.0	97.0	88.6
	Avg			100.0	100.0	100.0	100.0	99.5	99.5	99.1	98.0	96.1	84.8
AC	1	Flush-Fill	None	100.0	100.0	100.0	100.0	99.9	99.9	98.9	90.2	48.4	2.2
AC	2	Flush-Fill	None	100.0	100.0	100.0	100.0	99.6	98.0	96.6	90.0	44.6	3.7
	Avg			100.0	100.0	100.0	100.0	99.7	98.9	97.7	90.1	46.5	3.0
AC	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	99.5	99.5	96.3	86.6	45.7	4.2
AC	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	99.7	99.5	98.7	89.8	54.3	0.0
	Avg			100.0	100.0	100.0	100.0	99.6	99.5	97.5	88.2	50.0	2.1
CRF	1	Flush-Fill	Conv Airblast	100.0	99.4	99.4	98.8	98.7	98.7	91.5	84.6	61.7	25.8
CRF	2	Flush-Fill	Conv Airblast	100.0	99.2	99.2	98.6	98.4	98.2	96.3	86.5	55.6	17.3
	Avg			100.0	99.3	99.3	98.7	98.5	98.4	93.9	85.5	58.7	21.6
AR2	1	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.8	97.3	93.0
AR2	2	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	98.4	94.1
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.6	97.9	93.5
AR2	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	98.4	88.2
AR2	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	98.5	94.2
	Avg			100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	98.4	91.2
Fiber Pave	1	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	100.0	100.0	99.8	99.0	95.7	91.9	83.3
Fiber Pave	2	Simple Band-Aid	Conv Airblast	100.0	100.0	100.0	99.8	99.8	99.8	99.3	96.7	95.5	88.8
	Avg			100.0	100.0	100.0	99.9	99.9	99.8	99.1	96.2	93.7	86.1
Kold Flo	1	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	99.1	98.8	97.5	63.0	31.7	2.3
Kold Flo	2	Flush-Fill	Conv Airblast	100.0	100.0	100.0	100.0	99.2	97.7	95.3	71.4	39.5	2.3
	Avg			100.0	100.0	100.0	100.0	99.1	98.3	96.4	67.2	35.6	2.3

APPENDIX E. COST-EFFECTIVENESS

The following is an illustration of the method for computing material cost-effectiveness using complete cost, performance, and productivity information, and the equations presented in chapter 5. In the exercise, two treatment options are being considered by a maintenance agency for an AC transverse crack-sealing project. They are as follows:

<u>Option #1</u>
Rubberized Asphalt, unit weight = 1.14 kg/L (or 1,140 kg/m^3)
Standard Recessed Band-Aid Configuration (Configuration B)
Material and Shipping Cost: $1.43/kg
Estimated Production Rate: 762 lin m of crack/day
Estimated Service Life: 3 years (based on 75 percent effectiveness level)

<u>Option #2</u>
Low-Modulus Rubberized Asphalt, unit weight = 1.07 kg/L (or 1,070 kg/m^3)
Shallow Recessed Band-Aid Configuration (Configuration C)
Material and Shipping Cost: $1.90/kg
Estimated Production Rate: 915 lin m of crack/day
Estimated Service Life: 5 years (based on 75 percent effectiveness level)

The following assumptions are made for both options:

- Same wastage factors (15 percent)
- 10 laborers @ $120/day each
- 1 supervisor @ $200/day
- Equipment costs = $500/day
- User delay cost = $2,000/day

Application rates are computed on the following pages and the actual cost-effectiveness analysis is illustrated in figure E-1.

<u>Option #1</u>

Cross-sectional area of reservoir	= (13 mm × 13 mm) + (102 mm × 3 mm) = 475 mm^2 (0.000475 m^2)
Volume of reservoir (1 lin m of crack)	= 1 m × 0.000475 m^2 = 0.000475 m^3
Gross Application Rate (no waste)	= 1,140 kg/m^3 × 0.000475 m^3 = 0.54 kg/lin m of crack
Net Application Rate (15% waste)	= 1.15 × 0.54 kg/lin m = 0.62 kg/lin m of crack

Option #2

Cross-sectional area of reservoir	= (38 mm × 5 mm) + (102 mm × 3 mm)
	= 496 mm^2 (0.000496 m^2)
Volume of reservoir (1 lin m of crack)	= 1 m × 0.000496 m^2
	= 0.000496 m^3
Gross Application Rate (no waste)	= 1,070 kg/m^3 × 0.000496 m^3
	= 0.53 kg/lin m of crack
Net Application Rate (15% waste)	= 1.15 × 0.53 kg/lin m
	= 0.61 kg/lin m of crack

Placement Cost (both options)

Labor cost	= (10 lab x $120/lab) + (1 sup x $200/sup)
	= $1400/day
Equipment cost	= $500/day
Placement cost	= $1400/day + $500/day
	= $1900/day

Based on the calculations in figure E-1, option #2, with an average annual cost of $1.25/lin m, is more cost-effective than option #1, with an average annual cost of $2.20/lin m.

	Option #1	Option #2
A. Cost of purchasing and shipping material	\$ 1.43/kg	\$ 1.90/kg
B. Net application rate	0.62 kg/lin m	0.61 kg/lin m
C. Placement cost (labor & equipment)	\$ 1,900/day	\$ 1,900/day
D. Production rate	762 lin m/day	915 lin m/day
E. User delay cost	\$ 2,000/day	\$ 2,000/day
F. Total installation cost $F = (A \times B) + (C/D) + (E/D)$	$(1.43 \times 0.62) + (1900/762) + (2000/762)$ = \$ 6.00/lin m	$(1.90 \times 0.61) + (1900/915) + (2000/915)$ = \$ 5.46/lin m
G. Interest rate	5.0 percent	5.0 percent
H. Estimated service life (time to 75 percent effectiveness)	3 years	5 years
I. Average annual cost $I = \frac{F \times [G \times (1+G)^H]}{(1+G)^H - 1}$	$\frac{6.00 \times [0.05 \times (1+0.05)^3]}{[(1+0.05)^3 - 1]}$ = \$ 2.20/lin m	$\frac{5.46 \times [0.05 \times (1+0.05)^5]}{[(1+0.05)^5 - 1]}$ = \$ 1.25/lin m

Figure E-1. Example cost-effectiveness analysis.

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