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SHORT-TERM CRACK SEALANT PERFORMANCE AND REDUCING BUMPS AND TRANSVERSE CRACKING IN NEW HOT MIX ASPHALT OVERLAYS OVER CRACK SEALANTS

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November 2009

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16. Abstract

This interim report is intended to provide preliminary information regarding the performance of crack sealants produced by three manufacturers during a two-year period in service in three pavements in Colorado. In addition, preliminary conclusions have been developed regarding the propensity of three of these sealants to contribute to bumps in new overlay hot mix asphalt. Results of performance evaluations made, to date, indicate that the crack sealants failed at a surprising rate after only one winter. However, subsequent performance surveys after twelve months and twenty-one months indicate a tendency for the sealants to heal. Routing the cracks prior to filling appears to provide the best performance when the filler is overbanded, and filling the cracks to within ¼ inch of the surface instead of flush with the surface or overbanding produced the poorest performance.

Bumps accompanied by transverse cracking occurred over the crack sealants when a new hot mix overlay was placed after the crack sealants had been in service two years. The bumps and transverse cracks were exacerbated by utilizing steel rollers with vibration on breakdown of the hot mix asphalt overlay. The number of passes of the vibrating steel rollers further exacerbated the presence of the bumps and cracks. The same rollers used in static mode reduced the effect, and pneumatic rollers used for breakdown eliminated it. The ambient temperature and temperature of the substrate pavement during construction appears to have had little effect, as the same bumps and cracking occurred during vibratory breakdown after a small rain shower moistened the substrate pavement surface prior to the overlay hot mix asphalt placement.

Implementation:

The use of vibratory steel rollers during breakdown compaction of hot mix asphalt overlays on asphalt pavements containing crack sealants appears to exacerbate the presence of bumps and transverse cracks in the new asphalt directly over and in front of the cracks. These bumps and cracking may be mitigated by the use of pneumatic rollers on breakdown.

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by

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Thank you all.

EXECUTIVE SUMMARY

This interim report is intended to provide preliminary information regarding the performance of crack sealants produced by three manufacturers during a two-year period in service in three pavements in Colorado. In addition, preliminary conclusions have been developed regarding the propensity of three of these sealants to contribute to bumps in new overlay hot mix asphalt. Results of performance evaluations made, to date, indicate that the crack sealants failed at a surprising rate after only one winter. However, subsequent performance surveys after twelve months and twenty-one months indicate a tendency for the sealants to heal. Routing the cracks prior to filling appears to provide the best performance when the filler is overbanded, and filling the cracks to within ¼ inch of the surface instead of flush with the surface or overbanding produced the poorest performance.

Bumps accompanied by transverse cracking occurred over the crack sealants when a new hot mix overlay was placed after the crack sealants had been in service two years. The bumps and transverse cracks were exacerbated by utilizing steel rollers with vibration on breakdown of the hot mix asphalt overlay. The number of passes of the vibrating steel rollers further exacerbated the presence of the bumps and cracks. The same rollers used in static mode reduced the effect, and pneumatic rollers used for breakdown eliminated it. The ambient temperature and temperature of the substrate pavement during construction appears to have had little effect, as the same bumps and cracking occurred during vibratory breakdown after a small rain shower moistened the substrate pavement surface prior to the overlay hot mix asphalt placement. Use of vibrating steel-wheel rollers for breakdown of hot mix asphalt is common practice. Therefore, a certain amount of scrutiny may be prudent when constructing thin overlays over pavements with crack sealant to avoid creating bumps and transverse cracks.

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INTRODUCTION

Crack sealing is a common method of pavement preservation conducted by most highway agencies. The sealing is done to reduce moisture and debris infiltration into the pavement structure, thereby, theoretically improving pavement performance. However, because of the number of materials and methods available to seal cracks, and because opinions among maintenance personnel often vary widely regarding which techniques offer the best solutions, an experiment was conducted to measure the effectiveness of three products applied using several methods, in three different environments.

A common method of installation used by maintenance personnel is to blow debris from the crack using compressed air, then follow with hot applied crack sealant, and finally squeegee the excess sealant smooth with the surrounding pavement surface. Another method includes using a torch or heat lance to first heat the crack walls and evaporate any moisture in the crack, followed by, or simultaneously applying compressed air and then the sealant application. And finally, a third approach uses a router to create a well-defined trench along the path of the crack, spraying with compressed air to remove resulting debris, and then filling with sealant. The first method is often used in lieu of the other procedures because it is faster, requires less equipment and personnel, and is therefore viewed as less expensive. However, if the life cycle of the crack sealant is reduced compared with the other methods, the simple air blowing technique may cost more.

The result was an experiment including three material suppliers, three installation techniques each with two levels of sealant at three locations. Six cracks were filled for each combination of variables resulting in a total of 426 cracks to study at three sites. Each crack was surveyed prior to the installation so that as equal an application was obtained for each site, supplier and method. That is, only cracks of equal severity and length were included in the study at each site. Each crack was numbered on the shoulder prior to installation and each supplier was provided a plan indicating which cracks should be filled by which method.

Performance of the sealants was evaluated by measuring the amount and severity of cracking as a function of the original filled crack length.

Objectives

The first objective of the experiment was to determine short- and long-term performance characteristics of each combination of material, method and location. Performance of the sealants was evaluated by measuring the amount and severity of cracking as a function of the original filled crack length. This was done visually by walking each pavement and physically measuring the amount of cracking present.

The second objective of this project was to determine the cause or causes of bumps and transverse cracks that sometimes appear in a new hot mix overlay placed over crack sealants.

LITERATURE REVIEW

Much has been written on joint and crack sealant performance (*1, 2, 3, 4, 5, 6, 12, 13*). Benefits include preventing moisture and debris infiltration into the pavement, resulting in improved performance with respect to raveling and joint spalling (*6, 7*). Various techniques and materials have been described in the literature with varying degrees of success due to differences in climate, traffic, installation procedures and materials. Some states and provinces have constructed test sections and evaluated performance over time (*3, 4, 5, 8*). In Canada, thirteen crack sealants were evaluated and recommendations for preparing and sealing the cracks were made (*9*). Results indicate that cracks should not be sealed if moisture is present, all cracks were routed so a comparison to non-routed preparation could not be made, and air blowing the cracks should immediately precede filling. Some cracks were squeegeed to provide an overbanded application but results regarding effectiveness were inconclusive. An extensive questionnaire (*6*) sent to forty-three highway agencies indicates that routing, compressed air, sand blasting, high pressure water, flame cleaning, squeegees and melting pots are common tools used for sealing cracks in asphalt pavements. In addition, with all of the research that has been conducted regarding preparation, materials and methods, there is evidence that when hot air lances are utilized to dry the cracks prior to installation of sealant that the temperature of the lance should be reduced below previously recommended values due to the potential for embrittlement of the binder at the crack face (10, 11).

METHODOLOGY

Experiment Design

Independent Variables

Independent variables in this experiment are shown below:

Suppliers:	A, B, C
Crack Preparation:	Routing, Hot Air Lance, Air Blow
Sealant Treatment:	Overband, Flush, Recessed

Suppliers were three different manufacturers of hot poured crack sealant. The manufacturers were instructed to supply materials meeting ASTM D6690 Types I, II or IV specifications. All suppliers provided equipment and personnel needed to install the products according to the preparation techniques shown above during one day. The research team provided traffic control and inspection personnel to monitor installation to assure that materials desired were applied to the correct cracks using the methods specified. Crack preparation methods included simply blowing out the cracks using 100-psi compressed air, heating the cracks using a torch lance then blowing with compressed air, and routing the cracks to ½ inch width and ½ inch depth and blowing with compressed air. Sealants were applied to the cracks by hot pouring using a pressure wand and either filling to level with the surrounding pavement or filling to slightly over full and then spreading the excess off the surface with a V-shaped squeegee (the overband process).

The experimental matrices are shown in Figure 1 for all materials and methods at each location. A total of 426 cracks were filled for this study. The properties of these materials are presented in Table 1. Note that the Y1 and X3 materials were the only ones to pass the bond strength tests required by specification.

The three locations for the experiments were on SH 151 near Chimney Rock, CO (location 1) from the intersection of US 160 south from milepost 30.02 to 32.70, on US 285 south of Saguache, CO from milepost 82.98 to 85.08 (location 2) and on US 350 northeast of Trinidad, CO from milepost 20.51 to 23.20 (location 3) as shown in Figure 2.

All three sites are two-lane asphalt concrete pavements with crushed stone base course. Distress on all three sites consisted of transverse thermal cracks and some longitudinal cracking. The cracks included in the experiment were 0.25 inch to 0.50 inch in width, equally distributed among each manufacturer to minimize bias. The length of crack sealant applied to each crack was recorded during the installation on October 2, 2007 for SH151, October 3, 2007 for US285, and October 4, 2007 for US350.

Location 1 - SH 151

		Sealant Application		
Supplier-D6690 Type	Preparation	Flush	Overband	Recessed
A-IV	Rout	x	x	x
	HAL	x	x	x
	Air	x	x	
B-IV	Rout	x	x	x
	HAL	x	x	x
	Air	x	x	
C-II	Rout	x	x	x
	HAL	x	x	x
	Air		x	

Location 2 - US 285

		Sealant Application		
Supplier-D6690 Type	Preparation	Flush	Overband	Recessed
A-IV	Rout	x	x	x
	HAL	x	x	
	Air	x	x	
B-IV	Rout	x	x	x
	HAL	x	x	
	Air	x	x	
C-II	Rout	x	x	x
	HAL	x	x	
	Air	x	x	

Location 3 - US 350

		Sealant Application		
Supplier-D6690 Type	Preparation	Flush	Overband	Recessed
A-II	Rout	x	x	x
	HAL	x	x	
	Air	x	x	
A-I	Rout	x	x	x
	HAL	x	x	
	Air	x	x	
B-II	Rout	x	x	x
	HAL	x	x	
	Air	x	x	
C-II	Rout	x	x	x
	HAL	x	x	
	Air	x	x	

Figure 1. Experimental Matrices for Each Test Location

Figure 2. Experiment Site Locations

Table 1. Physical Properties of Crack Sealants

D6690 Type IV

	Material >>	X1	Y1
Cone Penetration @ 25°C	90 - 150	77	119
Softening Point	80°C min.	84°C	87°C
Bond - Non-Immersed	3 of 3, 12.7 mm pass 3 cycles @ 200% -29°C	Fail	Pass
Resilience 25°C, %	60% min.	57%	61%
Asphalt Compatibility	@ 60°C - 72 hrs Pass	Pass	Pass

D6690 Type II

	Material >>	X2	Y2	Z
Cone Penetration @ 25°C	90 max.	64	81	70
Softening Point	80°C min.	89°C	90°C	90°C
Bond - Non-Immersed	3 of 3, 12.7 mm pass 3 cycles @ 50% -29°C	Fail	Fail	Fail
Resilience 25°C - %	60% min.	69%	62%	58%
Asphalt Compatibility	@ 60°C - 72 hrs Pass	Pass	Pass	Pass

D6690 Type I

	Material >>	X3
Cone Penetration @ 25°C	90 max.	67
Softening Point	80°C min.	84°C
Bond - Non-Immersed	2 of 3, 25.4 mm pass 5 cycles 50% -18°C	Pass
Asphalt Compatibility	@ 60°C - 72 hrs Pass	Pass

Dependent Variables

Performance of the sealants was evaluated by conducting three visual condition surveys of the sites on March 22 and 23, 2008, October 15 and 16, 2008, and July 7 and 8, 2009. These condition surveys evaluated performance by measuring cracking as a function of the length of crack sealant applied on October 2 and 3, 2007. The percent cracking was then calculated as the length of crack in March 2008, October 2008 and July 2009 relative to the original crack length filled in October 2007.

Installation

Installation of the crack sealants was on October 2 and 3, 2007. Each crack to be filled was identified prior to installation and numbered on the edge of the pavement. Installation was done by companies supplying the sealants using one team of two members to prepare the cracks and another team of two members to fill the cracks. The sequence was consistent throughout the installations with crack filling following crack preparation within one hour for each group of six cracks. Installers determined whether cracks were prepared for filling by observing debris removal after air blowing and the edge of the crack after heating was observed for melted asphalt. According to the suppliers, temperature gauges had been calibrated prior to operation of the sealant kettles and materials were installed in accordance with manufacturers recommendations.

Each supplier was given a map showing which cracks to fill and by which method for each site. Members of the research team and state DOT served as observers to help suppliers with any questions and document installation at each site. The three sites were chosen because of differences with respect to climates and traffic. Table 2 is a summary of these characteristics and Table 3 summarizes the equipment used and the operating characteristics.

Table 2. Test Site Characteristics

Site	Elevation	Mean Annual Temp, F	Annual Traffic, ESALs
US285	7795	41-45	1,000,000
SH151	7520	43-47	30,000
US350	6025	47-51	18,000

Table 3. Equipment Utilized During Installation

Supplier	Hot Air Lance (HAL)	HAL Temp, F	Sealant Kettle	Avg. Sealant Temp, F	Router
A	LAB*, Model C on Wheels	2600	Crafco	350	Crafco
B	LAB, Model C	2600	Cimline	360	N/A
C	LAB, Model C	2600	Bearcat	350	N/A

***LAB Manufacturing Inc.** PO Box 62065 Cincinnati, OH 45262 U.S.A.

The weather conditions and pavement temperature during installation were as shown in Table 4.

Table 4. Environment During Sealant Installation

Location	Pavement Temp, F	Weather	Crack Moisture
SH151	94-102	Clear/Dry	Dry
US285	57-94	Clear/Dry	Dry
US350	94-98	Clear/Dry	Dry

RESULTS

Sealant Performance

The results of the visual condition surveys conducted at each of the three sites at five, twelve, and twenty-one months after initial installation of the sealants is presented in the following section. These results are presented on three graphs for each location separated by installation method. That is, all routed results are shown on one graph, followed by the hot air lance results, then the air blown results. All of the application methods are included on each graph. This was done to reduce the number of graphs from 21 to 9 for publication size limitations. Unfortunately, this produces a few busy graphs that are somewhat difficult to interpret, at times. However, it also provides an improved means for comparing results for each preparation technique for most of the data. To help clarify the graphs the following convention was established: overbanded sealant applications are the white lines, flush sealant applications are gray, and recessed sealant applications are black. Supplier A is designated by the circle and dashed lines, B by the square and dotted lines, and C by the triangle connected by solid lines.

Figures 3, 4, and 5 are the results from SH151 for routed, overbanded, and air blown cracks, respectively. Figures 6, 7 and 8 are the results from US285 for routed, overbanded and air blown cracks, respectively. And, Figures 9, 10 and 11 are the results from US350 for routed, overbanded and air blown cracks, respectively.

Table 5 is a summary of the air temperatures recorded during the field condition surveys.

Table 5. Environmental Conditions During Condition Surveys

Location	Air Temperature, F (C)		
	March 2008	October 2008	July 2009
SH151	40 (4)	47 (8)	73 (23)
US285	26 (-3)	22 (6)	46 (8)
US350	32 (0)	55 (13)	58 (14)

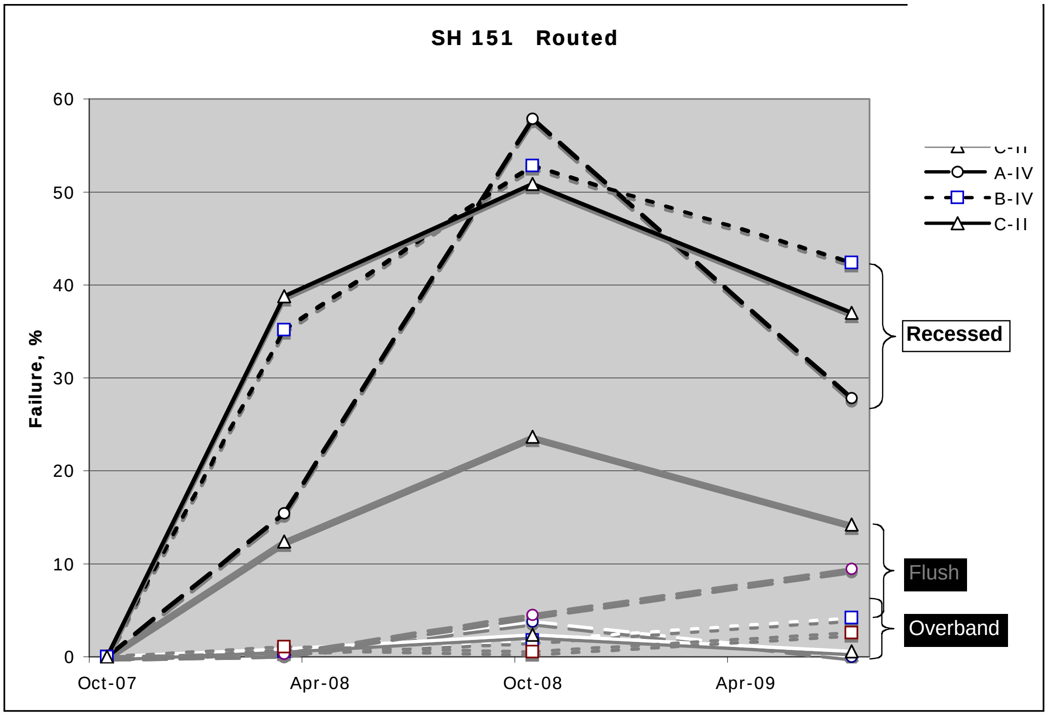

Figure 3. Sealant Performance on SH151-Cracks Prepared by Routing

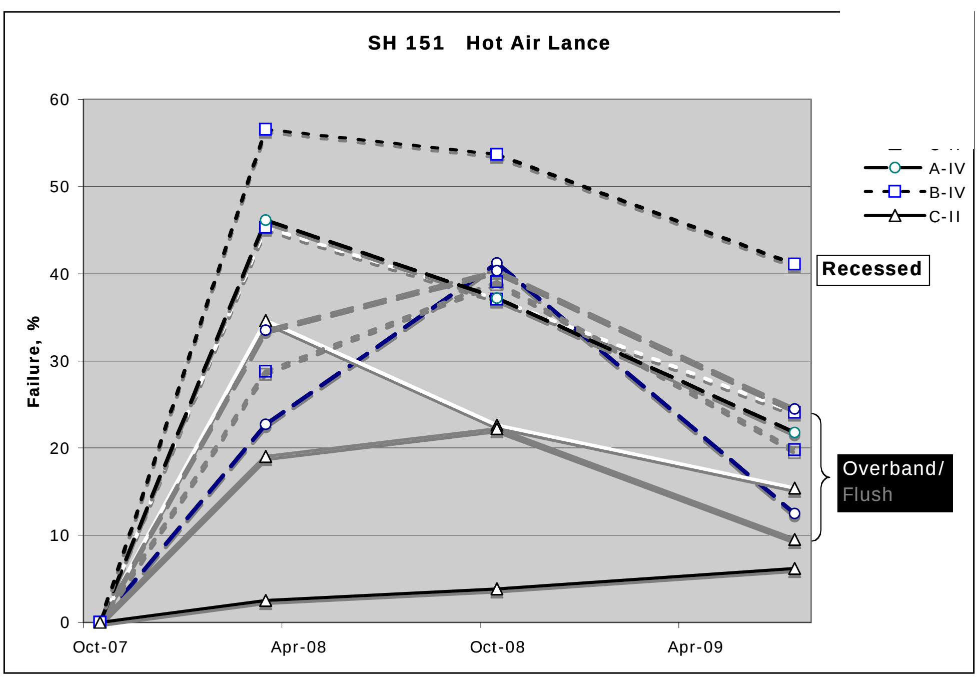

Figure 4. Sealant Performance on SH151-Cracks Prepared by Hot Air Lance

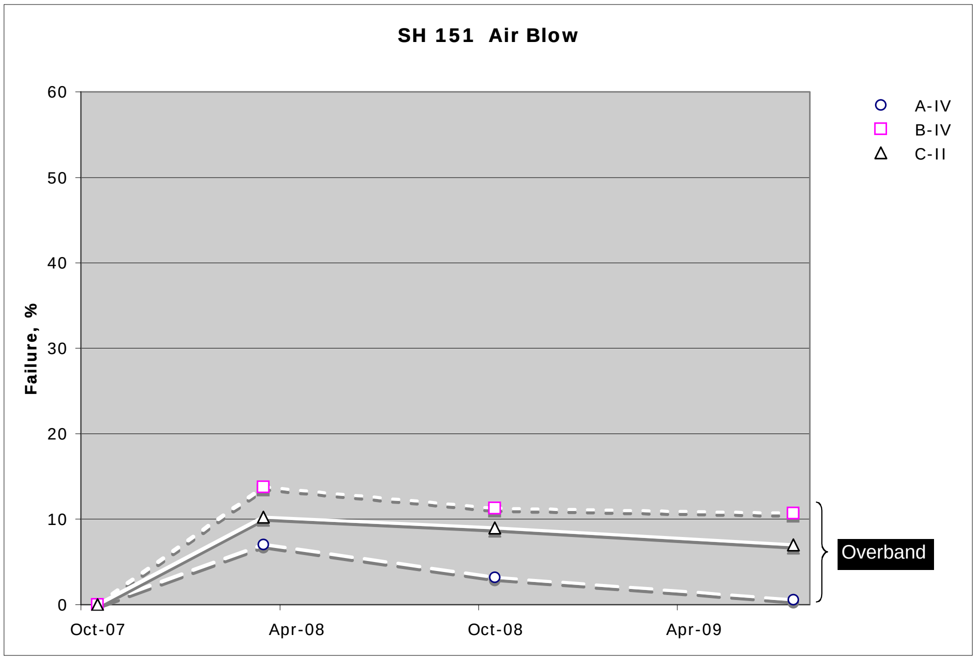

Figure 5. Sealant Performance on SH151-Cracks Prepared by Air Blowing

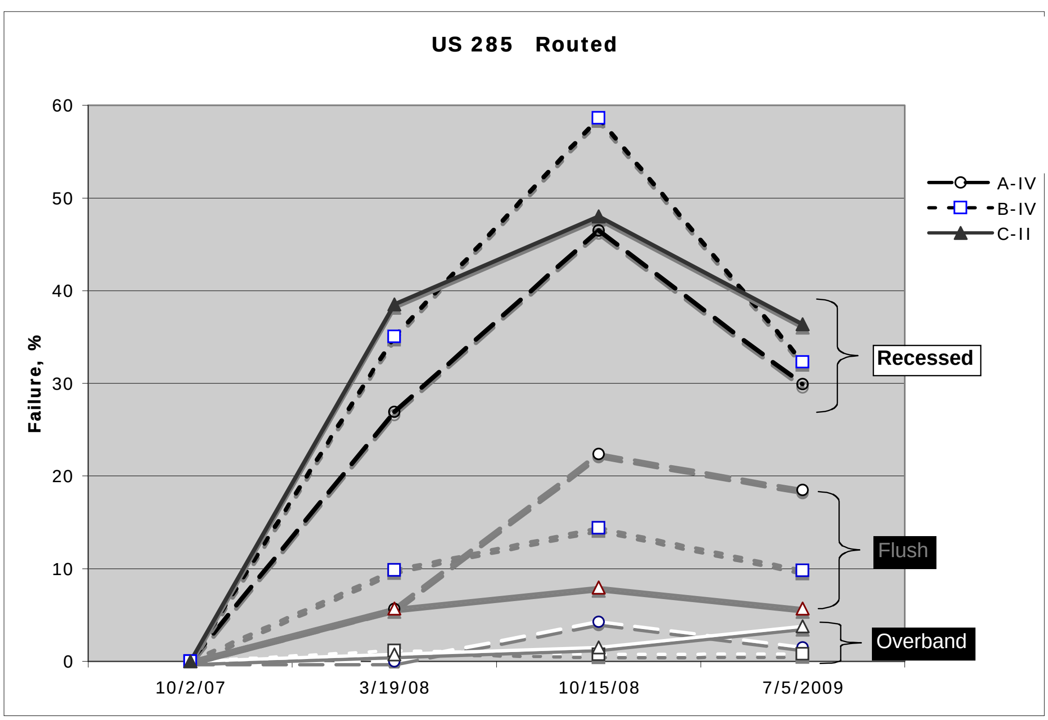

Figure 6. Sealant Performance on US285-Cracks Prepared by Routing

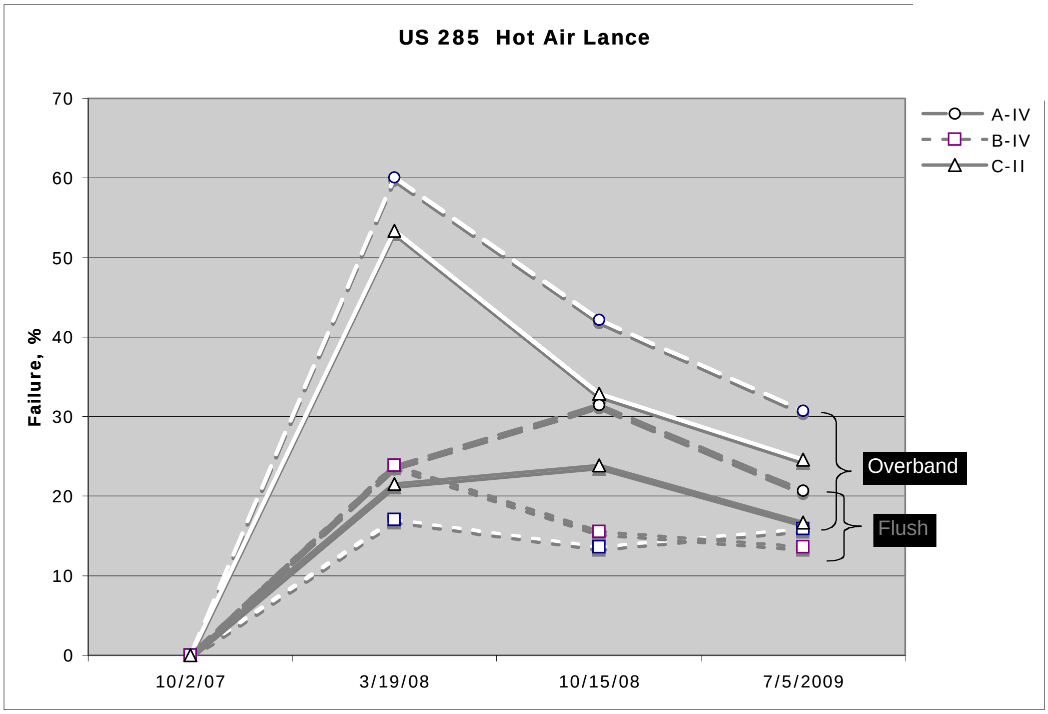

Figure 7. Sealant Performance on US285-Cracks Prepared by Hot Air Lance

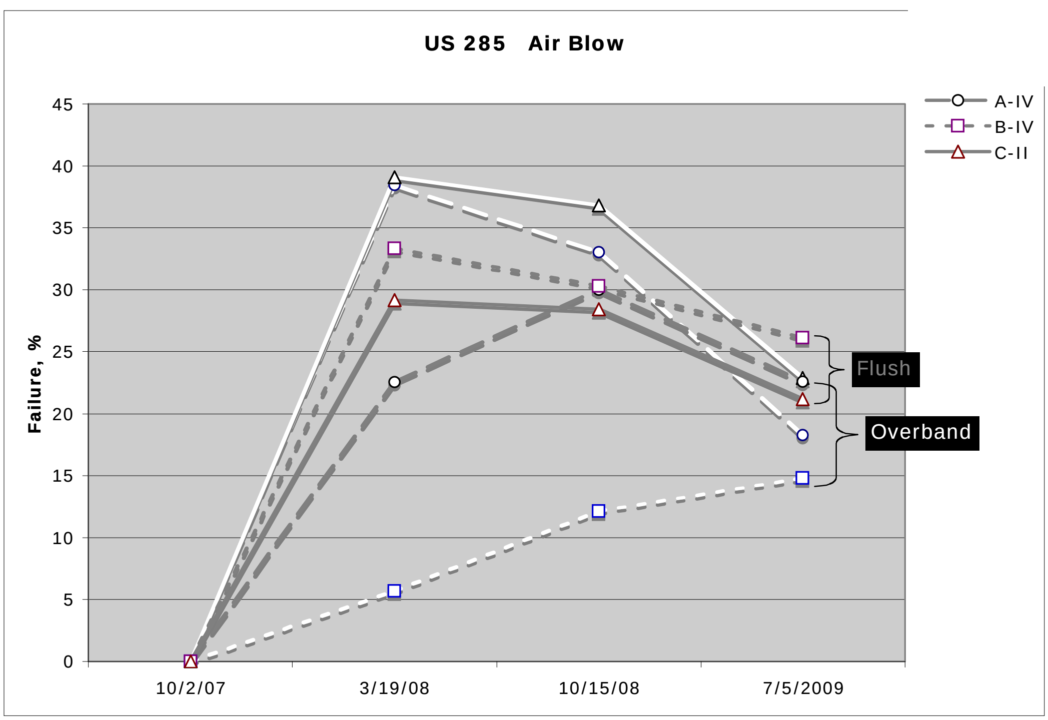

Figure 8. Sealant Performance on US285-Cracks Prepared by Air Blowing

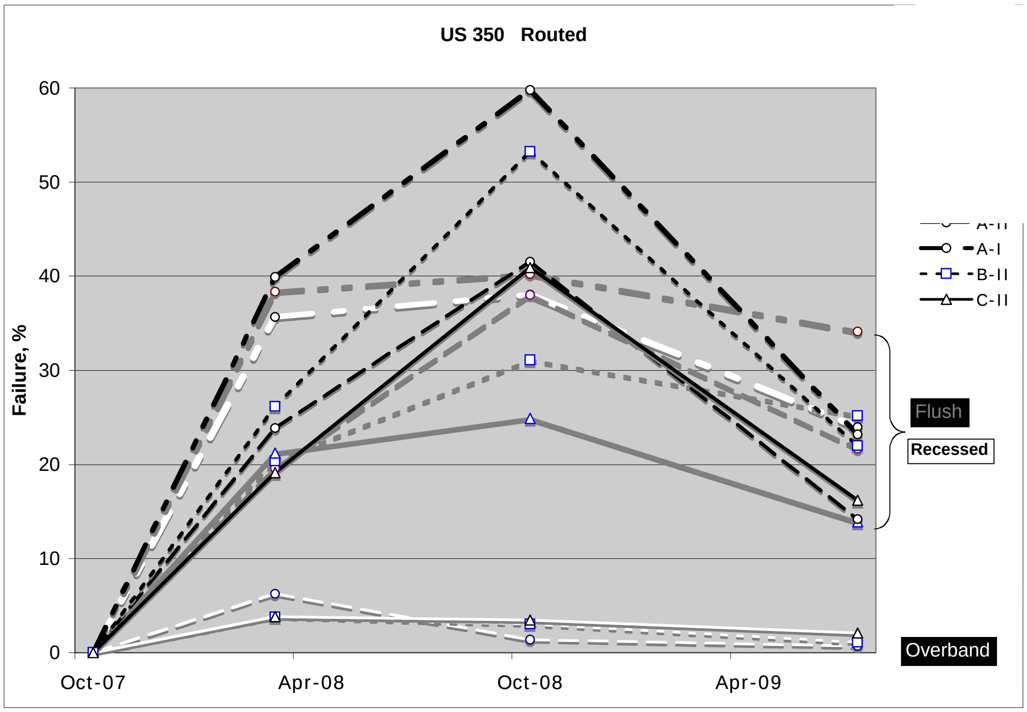

Figure 9. Sealant Performance on US350-Cracks Prepared by Routing

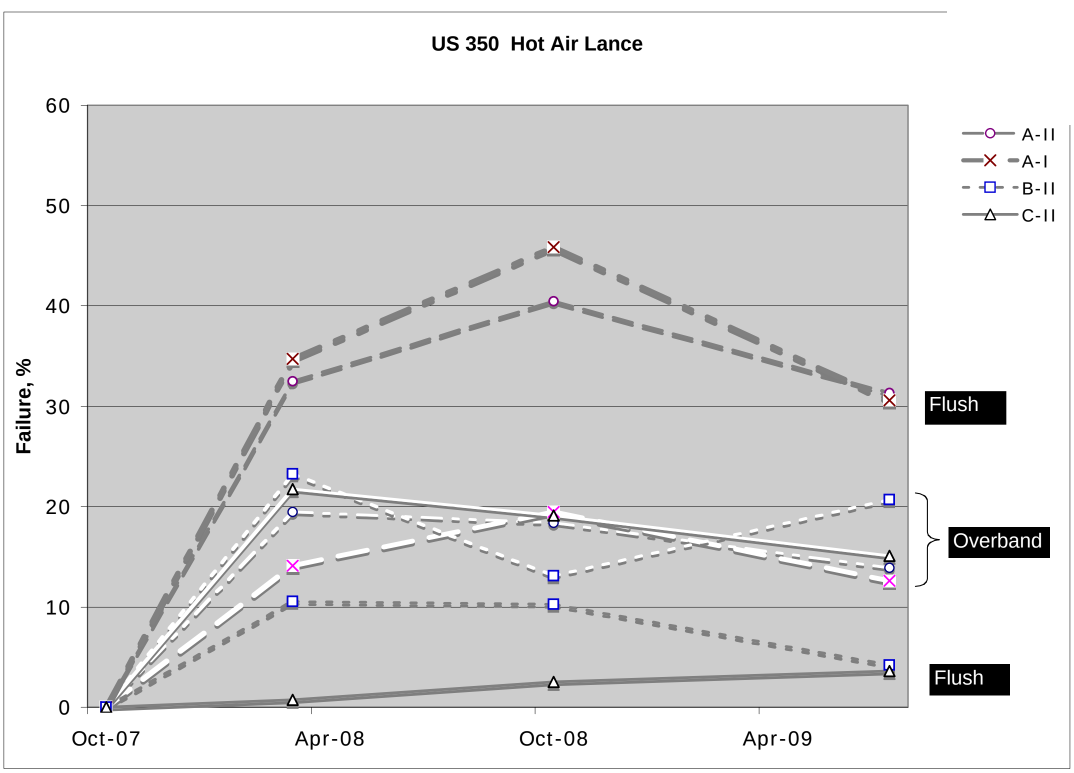

Figure 10. Sealant Performance on US350-Cracks Prepared by Hot Air Lance

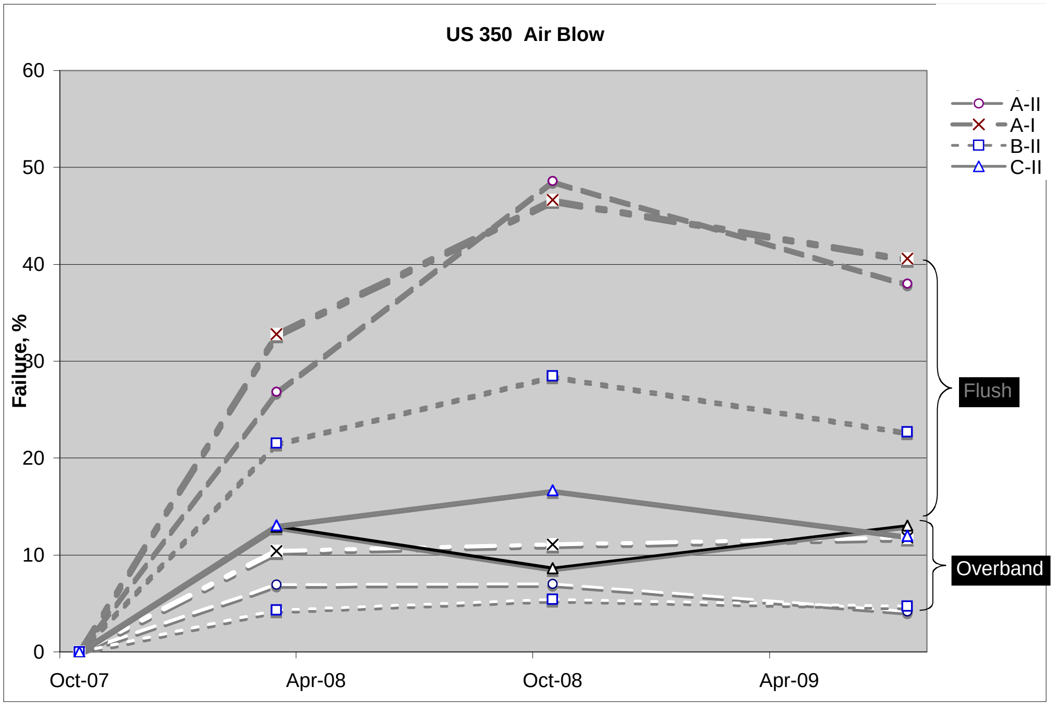

Figure 11. Sealant Performance on US350-Cracks Prepared by Air Blowing

Analysis of Performance

Analysis of the results from this study is challenging. There is variation in the data and few trends stand out consistently with the exception of one. It appears that for most of the conditions studied performance of the crack sealants has not followed a linear path of an increase in failure over time, as might be expected. Instead, the failures increased from installation in October 2007 to the first survey in March 2008, continued to increase until the second survey in October 2008, then declined at the third survey in July 2009 to levels of failure approximately equal to that observed in March 2008. There are eight exceptions to this. These are on Figure 3, where Supplier A for the flush, routed application shows a consistent increase in failure rate over time to a total of 10 percent failure and Supplier B for the flush and overband, routed application shows a consistent increase in failure rate over time to a total of 3 and 4 percent failure. Also, from Figure 4 Supplier C increases to approximately 7 percent failure for the hot air lance and recessed application. Products B and C in Figure 6 for routed and overbanded application on

US285 reach approximately 2 and 4 percent failure. And Figure 8 indicates that Supplier B reaches 15 percent failure for the air blow and overband process on US285. Supplier C reaches 4 percent failure on US350 in Figure 10 for a hot air lance and flush application and Supplier A-I has an 11 percent failure rate on US350 for the air blow and overband application shown on Figure 11.

Therefore, of a total of 72 installations of various crack sealants, preparation methods and sealant application techniques only eight examples continued to fail over time to a maximum of 11 percent after 21 months. The other 65 installations display a behavior that suggests less failure at 21 months than at 12 months, or some form of healing of the sealant, that is, the opening in the sealant observed at 12 months has closed at 21 months Of the eight installations that failed in a relative linear manner over time, the magnitude of the failures is significantly less than installations where healing occurred. For example, in Figure 3 all of the suppliers in recessed applications reached failure levels of from 50 to 58 percent at the October 2008 survey, and then recovered to 28 to 42 percent at the July 2009 survey. An exception to this trend is Supplier C in Figure 3 that appears to reach about 3 percent failure by October 2008, and then rebounds to nearly 0 percent in July 2009.

Expansion and contraction of the pavements might explain these observations. If the surveys in October 2008 were conducted when the pavements were cold, cracks should appear wider and more frequent. Then, if subsequent surveys were conducted during warm or hot weather, the crack sealants might appear healed when the pavement expanded. This could be true of SH151 and US285 where 20 and 30 degree F differential (2 to 15 C) temperatures were observed between October 2008 and July 2009. However, it does not explain the behavior on US350 where temperatures were approximately equal in October 2008 and July 2009. To test this thesis an estimation of change in crack width can be done. Cracks on SH151 average 28 feet apart. The thermal coefficient of expansion can be assumed at approximately 10 E-06 in/in/C, so the change in crack width would be 0.05 inches for a 15C difference on SH151. Since the cracks on SH151 were open at about 0.125 inch to 0.25 inch during the October 2008 survey, if they closed

0.025 inches at each end of the slab at the July 2009 survey due to expansion, the difference would have been difficult to see without a micrometer. Therefore, the apparent ‘healing’ cannot be explained by slab expansion and contraction, alone.

The recessed crack sealant installation process on SH151 and US285 performed significantly poorer than the flush or overband processes at the same locations. The recessed process performed poorer than other techniques on US350 during the October 2008 survey. However, these cracks healed between October 2008 and July 2009 with performance approximately equal that of the other treatments.

Bumps in Leveling Course on US285

Hot mix asphalt leveling courses were placed over the test sections on US285 on September 2 and 3, 2009. The leveling courses consisted of a grading SX ? hot mix asphalt one inch thick in the southbound lanes and one and one-half inches thick in the northbound lanes. The two thicknesses were utilized to determine if the thickness of the overlay contributed to the potential for bumps and transverse cracks to appear in the overlay over the crack sealants. Construction began by placing the one inch leveling course first in the southbound driving lane and shoulder on September 2 and then placing the one and one-half inch leveling course in the northbound driving lane and shoulder on September 3.

Bumps and transverse cracks began to appear on the project during previous leveling course construction south of the test sections at approximately Station 150+00 as shown in Figure 12. The contractor mitigated further occurrence of this distress by changing from vibratory steel rollers in vibrating mode on breakdown compaction to pneumatic tired rollers. The vibratory steel rollers being used were a Bomag BW190AD and a Caterpillar CB534C. The pneumatic rollers were a Hypac C530AH and a Caterpillar PS150B. However, the material properties of the crack sealant used at Station 150+00 were unknown, therefore, it was not possible to conclude that the bumps and

Figure 12. Bumps and Transverse Cracks at Station 150+00

transverse cracks in the leveling course at Station 150+00 were not material related. Therefore, an experiment was developed to determine if the bumps and cracks could be reproduced within the crack sealant test sections. The experiment was developed as shown in Table 6. Paving was northbound in the southbound driving lane and shoulder with rollers used for breakdown as shown.

Table 6. Compaction Experiment on US285 Southbound, September 2

<table>
<tr><th>Crack*</th><th>Product</th><th>Method</th><th>Shoulder</th><th>Driving Lane</th><th>Bumps /Cracks?</th></tr>
<tr><td>1-6</td><td>A</td><td rowspan="3">Rout Overband</td><td rowspan="3">Vibrating Steel</td><td rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>19-24</td><td>B</td><td>No</td></tr>
<tr><td>31-36</td><td>C</td><td>No</td></tr>
<tr><td>43-48</td><td>A</td><td rowspan="3">Rout Flush</td><td rowspan="3">Vibrating Steel</td><td rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>61-66</td><td>B</td><td>No</td></tr>
<tr><td>73-78</td><td>C</td><td>No</td></tr>
<tr><td>85-90</td><td>A</td><td rowspan="3">Rout Recessed</td><td rowspan="3">Vibrating Steel</td><td rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>103-108</td><td>B</td><td>No</td></tr>
<tr><td>115-120</td><td>C</td><td>No</td></tr>
<tr><td>127-132</td><td>A</td><td rowspan="3">Hot Air Lance Overband</td><td rowspan="3">Vibrating Steel</td><td rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>145-150</td><td>B</td><td>No</td></tr>
<tr><td>157-162</td><td>C</td><td>No</td></tr>
<tr><td>169-174</td><td>A</td><td rowspan="3">Hot Air Lance Overband</td><td rowspan="3">Vibrating Steel</td><td rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>187-192</td><td>B</td><td>No</td></tr>
<tr><td>199-204</td><td>C</td><td>No</td></tr>
<tr><td>253-258</td><td>A</td><td rowspan="3">Hot Air Lance Overband</td><td rowspan="3" colspan="2">Vibrating Steel</td><td>No</td></tr>
<tr><td>271-276</td><td>B</td><td>Yes**</td></tr>
<tr><td>283-288</td><td>C</td><td>No</td></tr>
<tr><td>295-300</td><td>A</td><td rowspan="3">Hot Air Lance Overband</td><td rowspan="3" colspan="2">Pneumatic</td><td>No</td></tr>
<tr><td>313-318</td><td>B</td><td>No</td></tr>
<tr><td>325-330</td><td>C</td><td>No</td></tr>
</table>

***** Cracks are numbered from north to south

** Cracks 271 and 272 were the only ones with evidence of bumps and transverse cracks during construction on September 2.

The contractor had been using pneumatic tired rollers for breakdown upon entering the test sections at crack 330 from the south. The contractor was asked to switch to vibratory steel rollers for breakdown starting with crack number 288 moving north. Upon switching to vibratory steel at crack 288, the first transverse cracks and bumps appeared at crack 272 and 271 over the crack seal. Because of concern regarding loss of incentive for smoothness, the contractor switched to pneumatic rollers in the driving lane and vibratory rollers on the shoulder. No further bumps or transverse cracks were observed in the overlay in the southbound lane, even where the vibratory rollers were used for breakdown on the shoulders.

The second day of overlay construction occurred on September 3, 2009 on the northbound lane of US285. A 1-1/2 inch overlay was placed in this direction from crack

330 to crack 1. The experiment was repeated with some exceptions as shown in Table 7 in an attempt to create the bumps and transverse cracks witnessed at cracks 271 and 272 in the southbound lane on September 2. The first evidence of bumps and cracks occurred at cracks 271 to 275 as shown in Figure 13. These bumps were much more severe than those witnessed on September 2 in the southbound lane.

Table 7. Compaction Experiment on US285 Northbound, September 3

<table>
<tr><th>Crack*</th><th>Product</th><th>Method</th><th>Shoulder</th><th>Driving Lane</th><th>Bumps /Cracks?</th></tr>
<tr><td>1-6</td><td>A</td><td rowspan="3">Rout Overband</td><td rowspan="3">Vibrating Steel</td><td rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>19-24</td><td>B</td><td>No</td></tr>
<tr><td>31-36</td><td>C</td><td>No</td></tr>
<tr><td>43-48</td><td>A</td><td rowspan="3">Rout Flush</td><td rowspan="3">Vibrating Steel</td><td rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>61-66</td><td>B</td><td>No</td></tr>
<tr><td>73-78</td><td>C</td><td>No</td></tr>
<tr><td>85-90</td><td>A</td><td rowspan="3">Rout Recessed</td><td rowspan="3">Vibrating Steel</td><td rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>103-108</td><td>B</td><td>No</td></tr>
<tr><td>115-120</td><td>C</td><td>No</td></tr>
<tr><td>127-132</td><td>A</td><td rowspan="3">Hot Air Lance Overband</td><td colspan="2">Vibrating Steel</td><td>Yes**</td></tr>
<tr><td>145-150</td><td>B</td><td>Vibrating Steel</td><td>Pneumatic</td><td>No</td></tr>
<tr><td>157-162</td><td>C</td><td>Vibrating Steel</td><td>Pneumatic</td><td>No</td></tr>
<tr><td>169-174</td><td>A</td><td rowspan="3">Hot Air Lance Overband</td><td colspan="2" rowspan="3">Vibrating Steel</td><td>No</td></tr>
<tr><td>187-192</td><td>B</td><td>No</td></tr>
<tr><td>199-204</td><td>C</td><td>Yes**</td></tr>
<tr><td>253-258</td><td>A</td><td rowspan="3">Hot Air Lance Overband</td><td colspan="2" rowspan="3">Vibrating Steel</td><td>No</td></tr>
<tr><td>271-276</td><td>B</td><td>Yes**</td></tr>
<tr><td>283-288</td><td>C</td><td>No</td></tr>
<tr><td>295-300</td><td>A</td><td rowspan="3">Hot Air Lance Overband</td><td colspan="2" rowspan="3">Pneumatic</td><td>No</td></tr>
<tr><td>313-318</td><td>B</td><td>No</td></tr>
<tr><td>325-330</td><td>C</td><td>No</td></tr>
</table>

* Cracks are numbered from north to south
** Significant evidence of bumps and transverse cracks

Figure 13. Bump and Transverse Cracks Over Crack 271

A second and third attempt to create the bumps and transverse cracks was done over cracks 199 to 204 and again at cracks 127 to 132. The results of this experiment are shown in Figures 14 and 15. The severity of the cracks and bumps appeared directly related to the number of passes of the vibrating roller. As cracks began to appear after the first pass of the roller, the contractor was reluctant to continue the experiment with additional roller passes. The severity of the cracks and bump shown over crack 271 was not observed over cracks 199 to 204 or 127 to 131 due to fewer passes of the vibrating rollers.

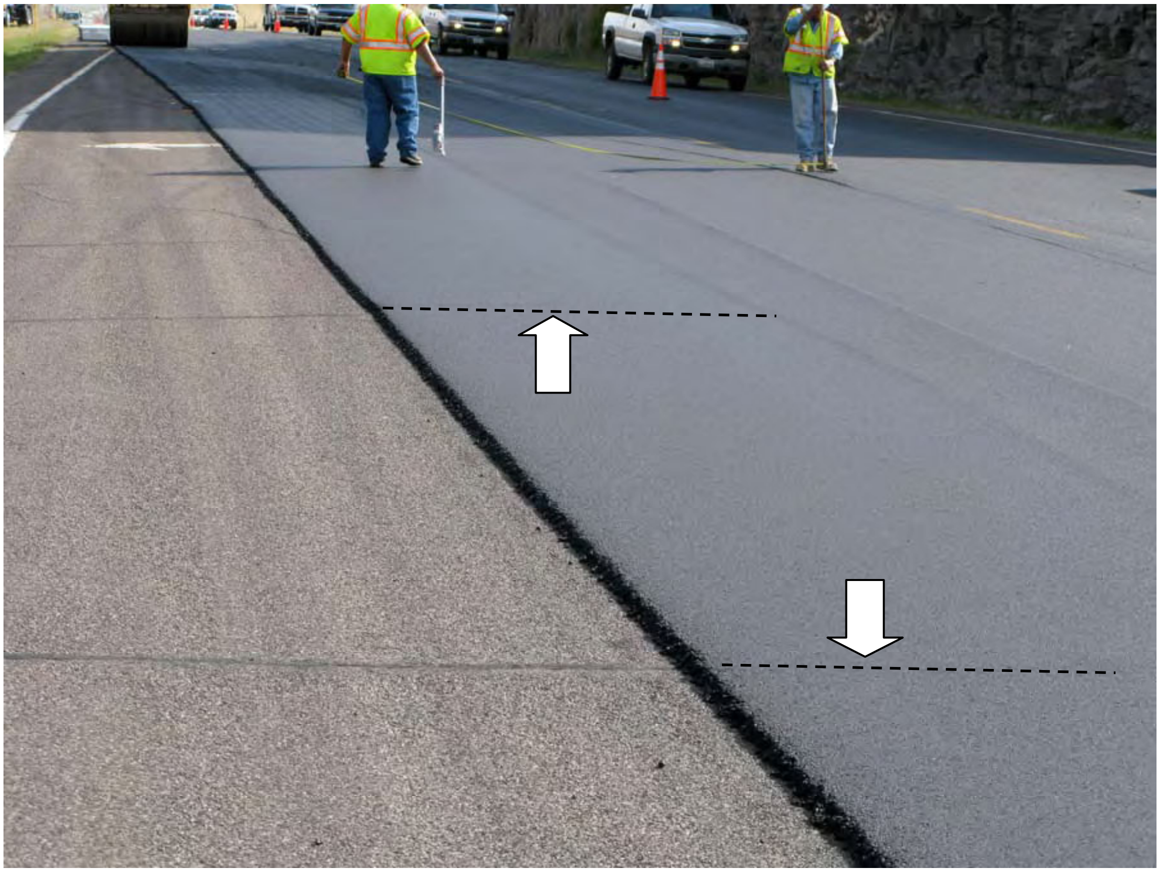

Figure 14. Bumps and Transverse Cracks Over Cracks 129, 130 and 131 Northbound

Figure 15. Transverse Crack Forming Over Crack 201 Northbound

CONCLUSIONS

1. A simple proportional failure with respect to time model does not seem to apply to the crack sealants studied in this research. For most of the treatments evaluated failure increased with time during the first year, then decreased. This behavior appears to be the result of a healing mechanism in the crack sealants and cannot be explained simply as a result of expansion and contraction of the pavement slabs between the transverse cracks. This mechanism does not appear to be related to materials, application methods, or location and therefore, may not be unique to the pavements studied in this research.
2. Bumps and transverse cracks that sometimes appear when thin hot mix overlays are placed over substrate pavements where crack sealants have been previously placed were created at will in this research on US285 south of Saguache, CO.
3. The bumps and transverse cracks that were created occurred two years after each of three manufacturers' crack sealants were installed on US285.
4. The severity of the bumps and transverse cracks appear directly proportional to the number of passes of steel rollers operated in vibrating mode for breakdown compaction.
5. The bumps and transverse cracks did not appear to be related to the temperature of the substrate pavement since this phenomenon was observed after a short rain shower cooled the substrate pavement prior to overlay in one location.

RECOMMENDATIONS

The conclusions above are based on only one location . To verify that a vibrating steel roller is the cause of the bumps and transverse cracks observed, an experiment should be designed to create the effect under various circumstances.   For example, it is not clear from this preliminary experiment why the cracks and bumps did not occur as frequently in the southbound lane when vibratory rollers were used on the shoulders. It is also unknown whether the thickness of the overlay in the northbound direction exacerbated the bumps and cracking phenomenon since this was the only difference between the northbound and southbound lanes.

Finally, since numerous cracks have been mapped and can be identified for future use, an opportunity exists to study the rate of reflection cracking in this pavement. There is some evidence (Sharma, 1991) that crack sealers reduce the rate of reflection cracking in overlays containing transverse thermal cracks. This pavement would provide an excellent opportunity to study this crack growth rate and provide economic data regarding the value of crack sealants. A section of US285 north of the test sections is to be constructed with Glasgrid underlayment prior to overlay later in September, 2009. Comparison of the crack reflection rate in this section to crack reflection in the test sections would provide valuable information regarding crack reflection reduction tools.

It is also possible the cracks and bumps created during breakdown rolling may reflect to the surface sooner than other existing cracks. If this occurs, it could provide reason to revise breakdown roller compaction processes.

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