Technical Report Documentation Page

1. Report No. FHWA/TX-05/0-4061-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle COMPARISON OF HOT RUBBER CRACK SEALANTS TO EMULSIFIED ASPHALT CRACK SEALANTS (FIRST REPORT OF A THREE-YEAR STUDY)		5. Report Date October 2001, Revised May 2002, Revised March 2003, Revised August 2004
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9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, TX 78705-2650		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0-4061
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Texas Department of Transportation Austin, Texas 78763-5080		13. Type of Report and Period Covered Research Report (9/00 – 10/01) 14. Sponsoring Agency Code
15. Supplementary Notes Project conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration, and Texas Department of Transportation.		

16. Abstract

This is the first report from Center for Transportation Research on the Project 4061. It presents the results, findings, conclusions, and recommendations based on the surveys, lab tests, and information collected on test sections for the first year of a 3 year study. Sealing and filling cracks has always been an important consideration in pavement maintenance. Hot rubber asphalt has been the most commonly used material for this purpose providing good performance in most cases. However, safety has been an issue with the use of hot rubber asphalt crack sealants because they must be applied at approximately 350°F - 400°F. In addition, vehicle tires can easily pick up material if sufficient adherence is not developed between the sealant and the crack sides. Some Texas Department of Transportation districts have been using cold pour asphalt emulsion crack sealants to address the safety problem. However, cold pour crack sealant requires longer setting and curing time, especially in areas of high humidity. In addition, the performance history of these cold sealants is not known or not well documented in comparison to the performance of hot pour crack sealants. Furthermore, the cost associated with the use of this material versus hot pour rubber asphalt is not well documented or determined. This research project is intended to compare the cost-effectiveness, ease and safety of installation, performance, and life-cycle cost for hot rubber asphalt crack sealant, cold pour asphalt emulsion crack sealant, and cold pour asphalt emulsion joint sealant. The comparison includes seven different crack and joint sealants: three cold pour and four hot pour. Eight different roads in five districts were selected for comparison of sealants. A total of thirty-three different test sections were obtained through this operation. Ease and speed of construction, as well as the original sealing cost were compared for these sealants. The crack-sealed sections in all five districts were visited approximately 3 months after construction. It is observed that the sealants show relatively good performance. However, in some of the test sections, some loss of cold pour sealants was noticed.

17. Key Words Hot Poured Crack Sealants, Cold Poured Crack Sealants, Emulsified Crack Sealants, Asphalt Pavements	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.		
19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 126	22. Price

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Comparison of Hot Rubber Crack Sealants to Emulsified Asphalt Crack Sealants (First Report of a Three-Year Study)

by

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Research Report 0-4061-1

Research Project 0-4061

conducted for the
Texas Department of Transportation by the
CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
The University of Texas at Austin

October 2001
1st Revision May 2002
2nd Revision March 2003
3rd Revision August 2004

Preface

This is the first report from the Center for Transportation Research on the Project 4061. It presents the results, findings, conclusions, and recommendations based on the surveys, lab tests, and information collected on test sections for the first year of a 3-year study. The surveys were conducted to gather information on crack sealing practices from different states and Texas Department of Transportation (TxDOT) districts.

Acknowledgments

This project has been initiated and sponsored by the Texas Department of Transportation (TxDOT). The financial support of TxDOT is greatly appreciated. The authors would like to thank TxDOT Project Director John Bohuslav for his guidance. Special thanks are extended to Darren Hazlett, Gerry Peterson, and Larry Miller of TxDOT for their great assistance in conducting the laboratory tests. The assistance of the participating district maintenance personnel through the advisory committee, as well as other district personnel in crack sealing the test sections, is greatly appreciated. We are also grateful to Joe Rohmer and his crew for their perseverance in carrying forward and conducting the sealing operations.

Disclaimers

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

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Chapter 1. Introduction

Summary

Sealing and filling cracks has always been an important consideration in pavement maintenance. Hot rubber asphalt has been the most commonly used material for this purpose providing good performance in most cases. However, safety has been an issue with the use of hot rubber asphalt crack sealants because they must be applied at approximately 350°F - 400°F. In addition, vehicle tires can easily pick up material if sufficient adherence is not developed between the sealant and the crack sides. Some Texas Department of Transportation (TxDOT) districts have been using cold pour asphalt emulsion crack sealants to address the safety problem. However, cold pour crack sealant requires longer setting and curing time, especially in areas of high humidity. In addition, the performance history of these cold sealants is not known or not well documented in comparison to the performance of hot rubber crack sealants. Furthermore, the cost associated with the use of this material versus hot rubber asphalt is not well documented or determined. This research project is intended to compare the cost-effectiveness, ease and safety of installation, performance, and life-cycle cost for hot rubber asphalt crack sealant, cold pour asphalt emulsion crack sealant, and cold pour asphalt emulsion joint sealant. The comparison includes seven different crack and joint sealants: three cold pour and four hot rubber. Eight different roads in five districts were selected for comparison of sealants. Sealants were applied to these roads between January and April 2001. A total of thirty-three different test sections were obtained through this operation. Ease and speed of construction, as well as the original sealing cost were compared for these sealants. The crack-sealed sections in all five districts were visited approximately 3 months after construction and they will continue to be monitored at regular intervals for 2 more years. It was observed that the sealants show relatively good performance. However, in some of the test sections, some loss of seal was noticed for cold pour sealants.

Background

One of the most common maintenance activities performed on bituminous pavements by local governmental agencies relates to crack treatment. Crack treatments include crack sealing, crack filling, and crack repair. Crack sealing is the method of placing material in a crack to create a watertight barrier. Transverse and longitudinal crack sealing is performed frequently in order to extend pavement life by preventing or substantially reducing the infiltration of water into the pavement structure. Generally, rubberized materials, due to their ductile properties are considered to be effective crack sealants.

Sealing cracks in asphalt cement concrete pavements has long been regarded as an annual preventive maintenance procedure. With limited maintenance budgets and increasing labor and material costs, some means of reducing the life-cycle cost of crack seals is required. Polymer modified asphalt crack sealer materials, as defined by ASTM D3405, have demonstrated the potential to deliver 5 years of service life, or more.

Highway agencies use different materials and methods to treat cracks in asphalt concrete 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 hot-air lance (HAL) is used in some states in crack-sealing work because it is believed that it improves sealant adhesion. However, the effectiveness of HAL in promoting adhesion is uncertain.

For many years, TxDOT and other state highway agencies have used hot rubber asphalt crack sealants. While this material has generally performed well, it is somewhat hazardous to apply. Hot rubber asphalt crack sealant must be heated to approximately 350 °F (177 °C) before it is applied to the pavement surface. This heating time can take several hours of setup time before work can begin. Burns and skin damage are safety concerns with hot rubber if a hose or nozzle blows off and any material accidentally lands on workers, inspectors, or the traveling public during this process. In addition, if the material does not cure properly or if it does not adhere properly to the pavement, it can be picked up by vehicle tires and may become very difficult to remove. Normally, the hot rubber crack sealant provides an elastic sealant that will generally adhere to the pavement and contract/expand very well with movement of the pavement. However, In some cases when excessive sealant is applied on the surface of cracks, the sealant does not perform as intended and can cause other maintenance problems.

In some TxDOT districts, use of cold pour asphalt emulsion crack sealant has replaced use of hot rubber asphalt. Cold pour asphalt emulsion crack sealant is typically applied at ambient temperature, which makes its use much safer for the workers, inspectors, and traveling public. However, it may require longer setting and curing times making it more difficult to use in high-traffic areas. High-humidity conditions can also slow the cure time for cold pour crack sealant. Immediate freezing weather conditions after application of the cold sealant can also adversely affect its effectiveness. There is much less setup time for cold pour work because cold pour is applied at ambient temperature. Since the cold pour sealant has very low viscosity, it can penetrate and fill cracks more easily than the hot rubber. However, there is little known about the long-term performance of cold pour crack sealant.

Since hot rubber sealant is provided in solid blocks, it is generally measured and paid by the pound. On the other hand, cold pour sealant is provided in liquid form in drums. Therefore, it is generally measured and paid by the gallon. Due to the extreme difference in the characteristics of each material, there can be wide variations in pounds of hot rubber sealant versus gallons of cold pour sealant to seal the same crack. Thus, it is often quite difficult to determine a unit cost comparison (such as cost per foot of crack sealed) for the work completed with each type of material. Since there is little or no research available on the cost for use of each material on the same road under the same conditions and in the same types of cracks, the cost per foot of crack sealed is generally not known. In TxDOT, there has been no formal follow up research study on the performance difference between hot rubber sealant versus cold pour sealant at 1 year, 2 years, or 3 years after the material is applied. Although it may be somewhat simple to determine the initial cost of installation for each type of material, it is more important to determine the general life-cycle cost for each type of material used.

Finally, if maintenance engineers and maintenance managers can determine the life of a crack seal, they can more easily determine when a seal coat or overlay project should be applied.

Past Research and Experience

Smith and Romine (1) report of a comprehensive study of crack treatment methods, 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. The result of this investigation was an asphalt pavement repair manual of practice.

Masson and Lacasse (2) conducted a study to measure the adhesion strength of bituminous crack sealant to dry asphalt concrete (AC) and assess the effect of the hot-air lance (HAL) on adhesion. The results showed that sealant adhesion and failure mechanisms were governed by the sealant source, the type of aggregate in the AC mix, and the heat treatment on the rout prior to pouring the sealant. HAL does not oxidize the binder, but it may cause embrittlement by raising the asphaltenes content of the binder. Normal heat treatment has little effect on sealant adhesion to dry AC, but overheating can cause a 50% reduction in adhesion strength and lead to premature sealant failure. To retain the possible benefits of the HAL in sealing damp cracks and to prevent overheating, the HAL should be operated at reduced temperatures.

One should also pay attention to the hazard that might be created through over-application of crack sealing. An article in Transafety Reporter (3) discusses the possible link between the over-application of pavement seal for joints or cracks in pavement roadways with asphalt cement and motorcycle accidents. When the asphalt cement applications become too wide the crack sealer may cause motorcycle tires to skid and result in injury or death. The article describes a case of an experienced motorcycle driver whose fatal crash may be directly related to asphalt cement crack sealer. Following this incident, the Federal Highway Administration (FHWA) alerted field representatives in all fifty states to the potential danger to motorcyclists caused by wide patches of asphalt cement.

Bruggeman et al. (4) studied the performance of some pavements sealed with polymerized crack sealants in Minnesota. They observed relatively higher failure rates than expected. The following types of failure were noted: the elasticity limits of the material were exceeded; the sealant pulled away from the edges; routing was inadequate; and the material was unsuitable for the extreme temperature variations experienced in northern Minnesota. The solutions were to specify a proven sealant; change the routing width and depth requirements to provide sufficient reservoir for the sealant; increase the training provided to county employees; set weather condition limits; and develop a new specification with special provisions to address the conditions that northern Minnesota experiences. These conditions, such as extreme variations in seasonal temperatures, heavy clay soils, and high-water tables cause the subsoils and base and pavement surface to move more than those of highways farther south.

Ward (5) reports studying twelve crack sealants evaluated over forty months in Indiana. Only one had an overall "group" success rate above 70% (a crumb rubber product). The best performing sealant/treatment combination was a single component polymer placed in a rout cleaned with compressed air that had a success rate of 81.4% after forty months. The current Indiana Department of Transportation (INDOT) asphaltic emulsion sealant had an overall group success rate of 6.5% after forty months. All asphaltic emulsion sealant treatment combinations reached near total failure after two years. The field process currently used by INDOT (straight squeegee and compressed air cleaning) had a success rate of 4.9% after one and a half years. The functional life of the asphaltic emulsion as placed by INDOT maintenance crews is believed to be significantly less than one year. Several of the "better" sealants evaluated (+70% success rate) are projected to have functional lives of 4 to 6 years. According to Ward this is supported by the experience of other DOTs.

Chichak (6) reports that on a limited scale the Alberta Department of Transportation has been testing ASTM D3405 materials since the early 1980's. Wide scale testing of this class of sealer took place throughout Alberta (Canada) in 1990, which was monitored by the Research and

Development Branch. It was concluded that properly installed seals can deliver a five year service life and, in spite of the higher material and installation cost, will be cost effective, compared to traditional materials and methods, after three years of service.

A state-of-the-art survey of flexible pavement crack sealing procedures in the United States is reported by Eaton and Ashcraft (7). The survey included all 50 States and was conducted in September 1990. The results were tabulated and a summary report prepared. The result identified the need for a trade organization to develop uniform specifications and terminology, and to promote proper equipment, methodology, materials, training, and education in the pavement crack sealing industry.

Objectives of Presented Work

The main objective of this research has been to compare the performance, ease and safety of installation, cost effectiveness, and the life-cycle cost for the following types of pavement crack sealants:

- Hot rubber asphalt crack sealants
- Hot rubber asphalt joint sealants
- Cold pour asphalt emulsion crack sealants
- Cold pour asphalt emulsion joint sealants

Crack sealant refers to the sealant used to seal the cracks generated in asphalt pavements. Joint sealant refers to sealant used to seal the joints between concrete slabs, joints between adjacent layers of asphalt concrete, or joints between asphalt and cement concrete pavements.

In this research report, Chapter 2 gives information on the surveys conducted in other states and TxDOT districts. In this chapter crack sealing techniques and materials in Texas and other states were summarized. Chapter 3 presents information on the materials used in the test section constructed for this research project. Performance and cost comparison of the sealants were presented in Chapter 4. Information on cost effectiveness, ease and safety of installation, and performance were included in this chapter. Finally, Chapter 5 provides conclusions.

Chapter 2. Survey on Crack Sealing Techniques and Materials

In the first step of this research project, two surveys were conducted to understand existing techniques utilized for crack sealing. For the first survey, personnel from 21 districts were contacted and their opinions on the crack sealing techniques and materials were gathered. The level of satisfaction in terms of performance, safety, ease of use, and cost were evaluated through the district correspondence.

In the second survey, information was gathered from other states on the crack and joint sealing material and techniques. Nine states returned the survey forms. Information on different states' experience on hot and cold pour sealant techniques, safety, ease of installation, performance, and the associated costs were collected. For these two surveys, the same questionnaire was used. A copy of the questionnaire used in these surveys is included as Appendix A.

Survey of TxDOT Districts

Responses from 21 of the 25 TxDOT districts indicates that hot poured crack sealant is still the common material used in most of the TxDOT districts. All the districts have used hot rubber sealants. Atlanta, Austin, Childress, El Paso, Lubbock, Odessa, Paris, Pharr, Tyler, Wichita Falls and Yoakum have also used cold pour sealants.

Among the districts, all of them used the compressed air method for crack cleaning. Only the districts of Dallas, Houston and Paris used routing. No districts used sawing, wire brush or hot compressed air lance. Hot rubber cost varied between $ 0.10 and $ 0.36 per foot of crack, whereas cold pour cost varied between $ 0.13 and $ 0.20 per foot of crack. The type of cracks that were sealed also varied. All districts reported sealing transverse cracks. With an exception of Lubbock, districts reported sealing of longitudinal cracks. Sealing of reflection and edge cracks are also reported by 18 districts. Twelve districts stated that they seal fatigue and block cracks. The width of the cracks sealed was typically under ½ inch. Some reported to seal wider cracks, but cracks wider than 1 inch were rarely reported to be sealed. When sealing the cracks, the majority of the districts used rubber squeegee for hot and cold pour sealants. The sealing shoe was used only by four districts, whereas the metal squeegee was used by only three districts. Detailed documentation of the survey conducted on different districts is included in Appendix B.

The participating districts rated performance of the hot pour and cold pour sealants for 10 different questions. Ratings used were “poor”, “fair”, “good” and “excellent”. Tables 2.1 through 2.10 summarize the ratings in terms of the percentage of the survey results.

Table 2.1. Percentage of TxDOT Survey Results for Resistance to Being Forced Out by Traffic for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	25	42	33
Hot Pour	0	11	63	26

Table 2.2. Percentage of TxDOT Survey Results for Resistance to Oxidation for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	19	45	36
Hot Pour	0	11	50	39

Table 2.3. Percentage of TxDOT Survey Results for Resistance to Becoming Brittle for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	0	58	42
Hot Pour	0	11	56	33

Table 2.4. Percentage of TxDOT Survey Results for Resistance to Particles Entering Cracks for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	27	55	18
Hot Pour	0	22	56	22

Table 2.5. Percentage of TxDOT Survey Results for Resistance to Flushing or Bleeding for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	8	42	50
Hot Pour	39	39	11	11

Table 2.6. Percentage of TxDOT Survey Results for Ability to Bond to Pavement for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	17	50	33
Hot Pour	0	0	53	47

Table 2.7. Percentage of TxDOT Survey Results for Abrasion Resistance for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	10	60	30
Hot Pour	0	14	64	22

Table 2.8. Percentage of TxDOT Survey Results for Ability to Rebond for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	9	27	46	18
Hot Pour	17	5	67	11

Table 2.9. Percentage of TxDOT Survey Results for Effectiveness of Sealing for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	8	59	33
Hot Pour	0	0	47	53

Table 2.10. Percentage of TxDOT Survey Results for the Period the Sealant is Effective for Cold and Hot Pour Sealants

	1 Year	2 Years	3 Years	4 Years	5 Years
Cold Pour	25	25	25	12	12
Hot Pour	0	7	40	33	20

Hot pour sealants were ranked poor or fair for resistance to flushing or bleeding by the majority of the districts as can be seen in Table 2.5. In overall evaluation of the survey, hot pour performed better than the cold pour sealants.

Survey of Other States

Among the 9 states, only New Jersey used wire brush. All the other states used compressed air. New York, Oregon and Pennsylvania also used routing. Sawing was used as a method by the states of North Carolina and Oregon. Hot compressed air was used by Alaska, North Carolina, Oregon and Pennsylvania. The type of sealants used also varied among different states. All the states used hot pour sealants. Alaska, New Jersey, Maryland, North Carolina and Oregon also used cold pour sealants. Hot pour cost varied between \$ 0.13 and \$ 1.7 per foot of crack, whereas cold pour cost varied between \$ 0.17 and \$ 0.30 per foot of crack. All states reported to seal transverse, longitudinal and reflection cracks. Most of the states reported sealing of edge cracks. Some of the participating states stated that they seal fatigue and block cracks. The width of the cracks sealed was typically between ½ and 1 inch. Six of them reported to seal cracks under ½ inch, however sealing of cracks wider than 1 inch was not reported. When sealing the cracks, the majority of the states used a rubber squeegee for hot and cold pour sealants. The sealing shoe was also commonly used by nearly half of the participating states, whereas usage of the metal squeegee was not reported. Detailed documentation of the survey conducted on different states is included in Appendix B.

Performance of the hot pour and cold pour sealants were rated by the participating states for 10 different questions. Ratings used were "poor", "fair", "good" and "excellent". Tables 2.11 through 2.20 summarize the ratings in terms of the percentage of the survey results. Appendix B gives more detailed data on this part of the survey.

Table 2.11. Percentage of Other States Survey Results for Resistance to Being Forced Out by Traffic for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	33	67	0	0
Hot Pour	0	22	33	45

Table 2.12. Percentage of Other States Survey Results for Resistance to Oxidation for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	33	0	67	0
Hot Pour	0	45	22	33

Table 2.13. Percentage of Other States Survey Results for Resistance to Becoming Brittle for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	67	0	33	0
Hot Pour	0	22	45	33

Table 2.14. Percentage of Other States Survey Results for Resistance to Particles Entering Cracks for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	67	33	0
Hot Pour	0	0	56	44

Table 2.15. Percentage of Other States Survey Results for Resistance to Flushing or Bleeding for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	0	100	0	0
Hot Pour	11	11	67	11

Table 2.16. Percentage of Other States Survey Results for Ability to Bond to Pavement for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	33	67	0	0
Hot Pour	0	22	22	56

Table 2.17. Percentage of Other States Survey Results for Abrasion Resistance for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	33	33	33	0
Hot Pour	0	45	33	22

Table 2.18. Percentage of Other States Survey Results for Ability to Rebond for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	33	33	33	0
Hot Pour	0	57	43	0

Table 2.19. Percentage of Other States Survey Results for Effectiveness of Sealing for Cold and Hot Pour Sealants

	Poor	Fair	Good	Excellent
Cold Pour	25	75	0	0
Hot Pour	0	11	44	44

Table 2.20. Percentage of Other States Survey Results for the Period the Sealant is Effective for Cold and Hot Pour Sealants

	1 Year	2 Years	3 Years	4 Years	5 Years
Cold Pour	20	40	40	0	0
Hot Pour	0	12	25	25	38

For 7 out of 9 questions, cold pour sealants were ranked poor by some of the participating states. Hot pour sealants were ranked poor only for resistance to flushing or bleeding by some of the states as can be seen in Table 2.15. In overall evaluation of the survey, hot pour performed evidently better than the cold pour sealants.

Chapter 3. Materials Used in the Test Sections

Through coordination with TxDOT, eight asphalt pavement roads in five different districts were selected for application of different sealants. Both cold and hot sealants were applied to the roads. Applying both types of sealants to the cracks of the same pavement was intended to make the results of the analysis more reliable because the influencing factors such as traffic, climate, and pavement type and condition remain the same for both types of sealants. Table 3.1 and Table 3.2 show the districts and sealants used for comparison.

Table 3.1. Crack-Sealed Highway Test Sections with No Subsequent Seal Coat or Overlay within 3 Years

Sealant	Cold Pour C1	Cold Pour C2	Cold Pour C3	Hot Pour H1	Hot Pour H2	Hot Pour H3	Hot Pour H4
	Crack Seal	Crack Seal	Joint Seal	Crack Seal	Crack Seal	Crack Seal	Joint Seal
TxDOT Spec. TxDOT District	Item 3127	Item 3127	DMS-6310, Class 9	GSD 745-80-25, Type I, Class A	GSD 745-80-25, Type III, Class B	GSD 745-80-25, Type I, Class A	DMS-6310, Class 3 (Joint Seal)
Atlanta	√	√	√	√	√		
El Paso	√	√			√	√	
Lufkin		√	√	√			√
Amarillo	√		√	√		√	√
San Antonio	√	√	√	√	√	√	√
Total	4	4	4	4	3	3	3

Table 3.2. Crack-Sealed Highway Test Sections, Overlaid or Seal Coated during Summer 2001

Sealant	Cold Pour C1	Cold Pour C2	Cold Pour C3	Hot Pour H1	Hot Pour H2	Hot Pour H3	Hot Pour H4
	Crack Seal	Crack Seal	Joint Seal	Crack Seal	Crack Seal	Crack Seal	Joint Seal
Spec. District	Item 3127	Item 3127	DMS-6310, Class 9 (Joint S.)	GSD 745-80-25, Type I, Class A	GSD 745-80-25, Type III, Class B	GSD 745-80-25, Type I, Class A	DMS-6310, Class 3 (Joint Seal)
Atlanta		√		√			
El Paso							
Lufkin	√	√		√		√	
Amarillo	√					√	
San Antonio							
Total	2	2	0	2	0	2	0

In labeling the sealants in Tables 3.1 and 3.2, numbers 1, 2, etc. are used simply to distinguish between different brands of sealants. Letters C and H in the label refer to the type of sealant and the temperature at which the sealant is applied. Cold pour sealants (those labeled C in the table) are in liquid form and are applied at ambient temperature. Hot pour rubber sealants (those labeled H in the table) are in the form of solid blocks and are applied at hot temperatures exceeding 380° F.

As presented in the preceding tables, a total of thirty-three test sections were crack sealed during the period of January through April 2001. Table 3.1 presents those test sections, which will not be covered (overlaid or seal coated) for at least 3 years after they are crack sealed. This will allow the effectiveness of the sealants to be evaluated through the regular visits. Table 3.2 presents those test sections that were scheduled to be covered with hot mix asphalt concrete or a chip seal during the Summer 2001. For these test sections, the idea is to evaluate the tendency for certain crack sealants to bleed or flush through the overlaying hot mix asphalt concrete or chip seal.

Specification Requirements and Laboratory Testing of the Sealants

Samples from the three cold pour and four hot rubber sealants were tested in the TxDOT laboratory to ensure they met the specification requirements. The results are presented in Table 3.3.

Table 3.3. Laboratory Test Results for Crack Sealants Used in Test Sections

Mat.	BrkF Visc @ 77° F Centi Poise	Evap. Resid. %	Rubber Content %	Flash Point °F	Pen.@ 39.2° F	Pen.@ 77° F	Resilience @ 77° F %	Flow @ 77 °F mm	Ductility @ 39.2° F cm	Bond Test @ 0° F	Soft. Point °F
C1	12900	67.8	0	455	12	42	15	Fail	100+	Broke	202
C2	13600	65	0	540	12	45	23	Fail	100+	Broke	158
C3	32560	67	0	580	14	60	20	Fail	100+	Pass	160
H1	N/A	N/A	25.8	400	13	34	59	Fail	7.5	Broke	168
H2	N/A	N/A	14.6	540	21	47	69	Fail	16	Pass	183
H3	N/A	N/A	24.6	410	11	33	54	Fail	8	Broke	155
H4	N/A	N/A	0	415	48	82	72	Pass	49	Pass	190

Currently, TxDOT uses four distinct specifications regarding the sealants. Special specification item 3127 deals with cold pour crack sealants. Under this specification, this sealant is a single component modified asphalt emulsion material complying with requirements on viscosity, storage stability, sieve test, and percent residue from evaporation. The residue should also meet requirements on penetration, softening point, and ductility. Sealants C1 and C2 presented in the preceding table satisfy requirements of specification item 3127. Specification requirements for item 3127 can be found in Appendix C.

Hot rubber asphalt crack sealant is covered under specification item 300 under Classes A and B, and under Types I, II, and III. Class A should satisfy requirements on penetration and softening point, and Class B should also meet requirements on the bond test. Hot rubber sealants H1 and H3 satisfy Class A requirements of Item GSD 745-80-25 and H2 meets Class B requirements of Item GSD 745-80-25. Specifications for Item GSD 745-80-25 Class A and Class B are in Appendix C.

TxDOT DMS-6310 specification deals with joint sealants in 10 different classes. The cold pour polymer modified asphalt emulsion joint sealant (C3 in Table 3.3) meets requirements for Class 9 of this specification. The sealer should satisfy requirements on viscosity and percent residue from evaporation. The residue should comply with requirements on penetration, softening point, and bond. The bond test is conducted at 0 ºF and is considered to pass specification requirements if it can take three cycles of bond. After the bond and extension test, there shall be no evidence of cracking, separation, or other opening that is over 3 millimeters deep at any point in the sealer or between the sealer and test blocks. Sealant H4 is a hot pour joint sealant meeting Class 3 requirements of DMS-6310 specification. It should comply with requirements on penetration, flow, resilience, and bond tests. Both sealants C3 and H4 are intended for portland cement concrete pavement joints and the joints between concrete and asphalt pavements. However, for this study, they were applied to cracks of asphalt pavement and their performance and cost were compared with those of typical asphalt crack sealants. Specification requirements for DMS-6310 Classes 3 and 9 can be found in Appendix C.

Not all the tests presented in Table 3.3 are needed as specification tests for all the sealants. However, because this was a study comparing performance of different sealants, all the laboratory tests were applied to all of the sealants.

Chapter 4. Comparison of Sealant Costs and Performance

Calculations for Cost Comparison

The cost analysis for this project is based on the comparison of all aspects related to the placement of hot and cold pour sealants on five highways in Texas. The test sections included in the cost comparison are ones that will not be covered with a seal coat or overlay within the next 3 years. Calculations included 25 test sections in five districts. The cost comparison was conducted in two different ways. One set was based on the cost per foot analysis for the construction of the test sections and the other based on sealing work performed on an imaginary road with a 50,000 ft crack length. The data used for analysis was subdivided into five categories: sealing materials, equipment for traffic control, sealing equipment, hot pour equipment, and personnel.

In the first cost per foot analysis, the results obtained presented similarities, except for the Amarillo district. To obtain the cost per foot of the given sealant, the total cost values were divided by the crack length of the section being sealed. Thus, a longer crack length resulted in a lower cost per foot and vice versa. This case was more evident in the Amarillo district where the total crack length being sealed was 2,800 ft. while the other test sections were around 10,000 ft. For calculations and tables refer to Appendix D.

For a better comparison, the second analysis assumed a crack length of 50,000 ft for all crack sealants. The production rate (feet per hour) from the test sections was used to calculate the days required to seal 50,000 feet of crack. The traffic set up and removal time was included in the number of days to seal 50,000 ft. The time for the hot pour tank heating was included for all hot pour sealants. There was no additional time required for preparing the cold pour equipment or material. First, the speed of sealing operation was calculated in terms of ft per hour for each sealant in each test section. Then, based on this information length of crack sealed per day was calculated. This information was used to calculate the number of days to seal 50,000 feet of crack. Total cost to seal 50,000 feet of crack was the summation of the cost for complete days and the cost for the last partial day.

The cost for the complete days was calculated based on an 8-hour workday. The duration for equipment preparation, traffic control setup and removal, and curing time were summed and this value subtracted from 8 hour to calculate the time for sealing. Itemized costs for equipment preparation time, traffic control setup and removal time, curing time and sealing cracks time were calculated separately and added together to find the cost for the complete days.

The cost for the last partial day calculated based on the work to complete the rest of the project. Same tasks were considered to calculate the total cost for the last day of the project. Cost for sealing time calculated based on the sealing work to complete the project. Table 4.1 summarizes the findings of these analyses. This approach gave a more detailed analysis of each sealant and detailed calculation tables can be found in Appendix E. The explanations for the calculations are included in Appendix G.

The initial sealing cost typically should not be the deciding economic factor for selection of the sealant type. This cost should be considered with respect to sealant performance and should be used in the life-cycle cost analysis once the long-term performance results become available. While performance is important, cost-effectiveness is often the deciding factor in determining which materials and procedures to use. The values from Table 4.1 will be used to calculate life-cycle cost at the end of the project.

Table 4.1. Summary of the Construction Cost Analyses for Each Material

	SECTION	50,000 ft COST	$/ft for 50,000 ft	Days for 50,000 ft
C1	Amarillo FM 1151	11,037.83	0.22	13.19
	Atlanta US 259	4,419.65	0.09	5.05
	El Paso Loop 375	6,317.58	0.13	7.21
	San Antonio US 87	5,031.42	0.10	6.65
C2	Atlanta US 259	4,400.99	0.09	5.09
	El Paso Loop 375	9,179.92	0.18	11.5
	Lufkin US 59	5,688.80	0.11	6.98
	San Antonio US 87	4,970.63	0.10	6.45
C3 Joint Seal	Amarillo FM 1151	11,061.05	0.22	14.62
	Atlanta US 259	5,895.86	0.12	8.44
	Lufkin US 59	6,215.87	0.12	7.21
	San Antonio US 87	5,254.48	0.11	6.76
H1	Amarillo FM 1151	9,140.31	0.18	8.08
	Atlanta US 259	3,713.97	0.07	3.51
	Lufkin US 59	4,666.06	0.09	3.52
	San Antonio US 87	4,484.45	0.09	3.23
H2	Atlanta US 259	3,649.32	0.07	2.92
	El Paso Loop 375	6,423.95	0.13	5.12
	San Antonio US 87	6,646.10	0.13	5.54
H3	Amarillo FM 1151	10,352.95	0.21	9.13
	El Paso Loop 375	6,276.01	0.13	4.33
	San Antonio US 87	2,946.79	0.06	2.43
H4 Joint Seal	Amarillo FM 1151	9,438.94	0.19	9.04
	Lufkin US 259	5,325.40	0.11	3.65
	San Antonio US 87	5,459.81	0.11	3.94

Performance Evaluation

In this project, the short and long-term performance of the crack sealants on 8 selected roads and 33 sections will be monitored. These test sections are composed of two groups. The first group includes 25 test sections that will not be overlaid or seal coated within 3 years. We will refer to these as the "not covered" test sections. The second group includes 8 test sections, which were scheduled to be overlaid or seal coated during the Summer of 2001. We will refer to these as the "covered" test sections.

"Not Covered" Test Sections

In this group, the sealant in each crack within the sample sections will be visually examined to determine how well the material is performing its function of sealing and preventing the ingress of water. Test sections will be examined for the existence of treatment failures like adhesion loss, cohesion loss, complete pullout of material, development of secondary cracks and/or other distresses such as potholes. Initially, for the short-term performance, a pointed tool like a knife was used to pull on the seal to determine its bond to the crack faces and cohesive properties.

Frequency of Inspection for the "Not Covered" Test Sections

In order to monitor the performance of the different crack sealants, the test sections are visited for visual inspection regularly. In all inspections the test sections are visited to chart the rate of failure. For this study, short-term performance refers to the performance of the sealant within the first 4 months after installation. Long-term performance refers to the sealant performance more than 4 months after installation, until the time a new treatment for the pavement is required, or until the end of this study, whichever occurs first. The crack performance is monitored during the following intervals:

Short-Term Performance:

Within 4 months after crack sealing

Long-Term Performance:

Once every winter (i.e., Jan.-Feb.) and
Once every summer (i.e., July-Aug.) for 2 years

The regular inspection provides the information required to chart the rate of failure. This way, a comparison of performance becomes more meaningful. Each of the test sections installed under this study is evaluated at the intervals specified above.

Performance Evaluation Procedure for the "Not Covered" Test Sections

First, the sealant in each crack within the sample section was visually examined to determine how well the material was performing its function of sealing and preventing the ingress of water. The inspections provided the information required to chart the rate of failure and treatment effectiveness. Items that might indicate treatment failures include the following:

- Open crack where previously sealed
- Full-depth adhesion loss
- Full-depth cohesion loss
- Spalls or secondary cracks in or near the sealed crack
- Other distresses

A good estimate of the percentage of treatment failure can be calculated by measuring and summing the lengths of failed segments and dividing this figure by the total length of the treated cracks inspected.

Percent Failure = 100 X (Failed Length/Total Length)

Treatment effectiveness can then be determined by subtracting the percentage of treatment failure from 100 %

Percent Effectiveness = 100 – Percent Failure

After a few inspections, a graph of effectiveness versus time can be constructed (Figure 4.6).

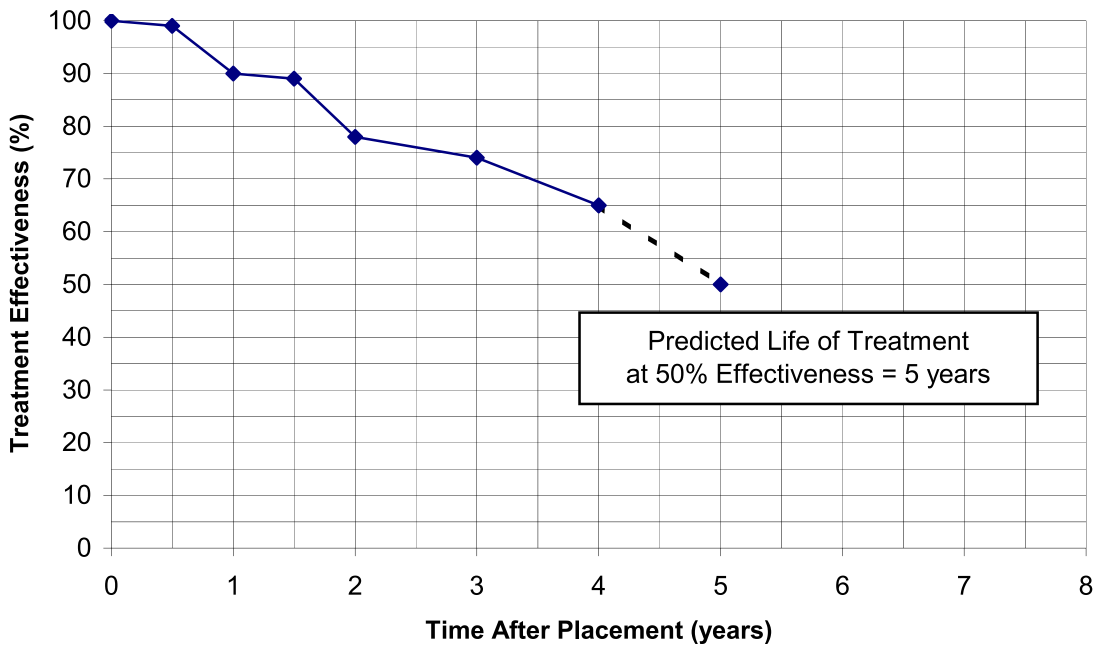

Figure 4.1. Example graph of treatment effectiveness versus time

Other than visual examination, the pullout tests were conducted during the short-term performance to see the relative cohesion and adhesion of the materials in a certain test section. To conduct the test, sealant in the previously sealed crack was removed using a knife. Tests were conducted by two different people in each section to achieve more reliable test results. Ranking of the test results were "Difficult", "Medium", and "Easy" Removal of the material. This Removal can be caused by two different kinds of failure:

- Failure in cohesive strength
- Failure in adhesive strength

Another factor, which was monitored during inspections, was the settlement or height of the sealant from the pavement surface. In general, cold pour sealants show settlement inside the crack below the level of the pavement surface, whereas hot rubber crack sealants do not settle below the pavement surface. Water or incompressible materials might be accumulated at the places where settlement below the pavement occurs. Accumulation of water could increase the amount of water penetrating the crack and accumulation of incompressible materials could result in cohesive or adhesive failures of the sealant. On the other hand; after sealing, part of the hot rubber crack sealant stays on the surface of the pavement. The height of a hot rubber crack sealant is important in terms of any adverse impact on ride quality and the possibility of bleeding through subsequent seal coats or overlays. The height and depression of the sealant was measured with respect to the pavement surface.

"Covered" Test Sections

The second group includes 8 test sections that were overlaid or seal coated during the summer of 2001. These test sections will be evaluated to determine their tendency to cause asphalt bleeding through the subsequent seal coat or overlay based on the effect of the crack sealant on the performance of the overlay or surface treatment. The amount of bleeding after the placement of the hot mix overlay or a surface treatment such as chip seal or microsurface will be recorded.

Frequency of Inspection for "Covered" Test Sections

In order to monitor their performance, the test sections are visited regularly for visual inspection. For this study, short-term performance refers to the performance of the sealant within the first 3 months after installation of the overlay or seal coat. Long-term performance refers to the sealant performance more than 3 months after installation of the overlay or seal coat, until the time a new treatment for the pavement is required, or until the end of this study, whichever occurs first. The crack performance is monitored during the following intervals:

Short-Term Performance:

Within 3 months after installation of overlay or seal coat

Long-Term Performance:

Once every winter (i.e., Jan.-Feb.) and

Once every summer (i.e., July-Aug.) for 2 years

Performance Evaluation Procedure for "Covered" Test Sections

These test sections will be visually examined to determine how the material may have caused bleeding through the overlay or surface treatment. The inspections provided the information required to chart the rate of failure and treatment effectiveness.

Areas where bleeding occurred will be determined by visual observation. Total area of bleeding will be measured for each test section. These results will be tabulated to compare the relative tendency for the sealant to bleed through a subsequent overlay or seal coat.

Short Term Performance on "Not Covered" Test Sections

The "not covered" test sections were visited 3 to 4 months after sealing. The findings of these visits were recorded and tabulated to compare relative results. The following was evaluated during these visits:

- loss of seal in previously sealed crack,
- existence of newly developed cracks,
- magnitude of settlement (depression) of the cold pour sealants,
- height of the hot rubber sealants material on the cracks,
- resistance to pullout testing and temperature of the sealants at the time of investigation.

Hot rubber (H2) Cold Pour (C3)

Figure 4.2. Hot rubber and cold pour sealant 3 months after construction

In the Atlanta district, the test sections were visited to monitor the performance of the sealants 16 weeks after the sealing operation. The first two sections were H1 and H2 (hot rubber sealants). These two sections showed very similar performance. In these sections, no newly developed cracks were observed. Cracks were still sealed, no sealant loss in the previously sealed cracks was observed. A pullout test was conducted on the sealant materials. Both H1 and H2 showed very high cohesion and adhesion and were ranked "Difficult" to pullout. The third section was C3 (cold pour). In this section, there were not any newly developed cracks, but some parts of the cracks were observed to be no longer sealed. The total length of the cracks where the sealant had failed was 145 ft. This material ranked "Easy" for the pullout test. Figure 4.7 shows sections from H2 and C3. The fourth section was C1. In this section, there were not any newly developed cracks. However, material in this section showed both cohesive and adhesive failures. Total crack length of the failed sections was 207 ft. This material ranked "Medium" for the pullout test. The fifth section was C2. Just like preceding two sections, there were not any newly developed cracks. Material in this section showed both cohesive and adhesive failures. Total crack length of the failed sections was 84 ft. Table 4.2 summarizes the results of the visit.

In El Paso, similar performance results were observed. This test section was built on Loop 375, which carries very heavy border truck traffic. It is observed that sealant failures were on the wheel path. It can be concluded that failures were caused by heavy traffic. Also, in these test sections all the failures were observed on cold pour crack sealant. Results of the performance evaluation are shown in Table 4.3.

In Amarillo, failure percentages were higher. Unlike El Paso, failure spots were not specific to wheel path, but distributed over other areas. This observation was possibly an indication of sealant loss because of cold weather and freezing. After sealing, test sections were exposed to several freeze-thaw cycles. Different than all other test sections, the first test section (C1) showed very high failure rate. The last three test sections (H3, H4 and H1) showed very high treatment effectiveness. Table 4.4 summarizes the performance evaluation results for these test sections.

In San Antonio, on C1 there were some thin cracks but it was very difficult to determine if they cracked all the way through the thickness of the sealant or not. On the sections sealed with cold sealant, it is observed that the sealant depressed into the crack more than what is observed in other districts. On these sections, accumulation of incompressible materials into cracks caused failures on these sections. These incompressible materials broke into sealant due to traffic and thereby reduced the performance of the sealant. Table 4.5 summarizes the performance evaluation for San Antonio.

In Lufkin, all sections showed very good performance. In these test sections, no failure was observed on cold or hot rubber crack sealants. Just like the test sections in other districts, cold pour sealants were softer than hot rubber sealants. Results of the performance evaluation are shown in Table 4.6.

Table 4.2. Summary of Short Term Performance for US 259 in Atlanta District ("Not Covered" Test Section)

	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Developed Cracks (ft)	Length of Cracks No Longer Sealed (ft)	Percentage of Cracks No Longer Sealed (%)	Treatment Effectiveness (%)	Average Height or Depth of Sealant from Pavement Surface (mm)	Resistance to Pull Out	Sealant Temperature (°F)
H1	1,500	4,200	0	0	0	100.0	+ 1.5	D	100
H2	1,500	4,125	0	0	0	100.0	+ 2.0	D	100
C3	1,500	4,200	0	145	3.4	96.6	- 1.75	E	107
C1	1,500	4,250	0	207	4.9	95.1	- 0.5	M	107
C2	1,000	2,750	0	84	3.0	97.0	-0.5 to + 0.5 mm	E	107

The test section in the Atlanta District was installed on US 259 in the southbound outside lane on a 5 lane undivided highway (2 southbound lanes, 2 northbound lanes, and 1 turning lane) in a rural area in Morris County. See Appendix F for more information about sealants and their construction sequences.

Table 4.3. Summary of Short Term Performance for Loop 375 in El Paso District ("Not Covered" Test Section)

	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Developed Cracks (ft)	Length of Cracks No Longer Sealed (ft)	Percentage of Cracks No Longer Sealed (%)	Treatment Effectiveness (%)	Average Height or Depth of Sealant from Pavement Surface (mm)	Resistance to Pull Out	Sealant Temperature (°F)
C2	3,000	2,750	20	182	6.6	93.4	- 0.5	E	112
H3	3,000	2,138	0	0	0	100	0 to 0.5	D	119
C1	3,000	2,518	0	28	1.1	98.9	0 to- 0.5	M	121
H2	3,000	2,750	0	0	0	100	0 to+ 0.5	M	126

The test section in the El Paso District was installed on Loop 375 (Border Highway) in the eastbound outside lane on a 4 lane divided highway in an urban area in El Paso in El Paso County. See Appendix F for more information about sealants and their construction sequences.

Table 4.4. Summary of Short Term Performance for FM 1151 in Amarillo District ("Not Covered" Test Section)

	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Developed Cracks (ft)	Length of Cracks No Longer Sealed (ft)	Percentage of Cracks No Longer Sealed (%)	Treatment Effectiveness (%)	Average Height or Depth of Sealant from Pavement Surface (mm)	Resistance to Pull Out	Sealant Temperature (°F)
C1	2,000	350	0	148	42.3	57.7	- 1.5	E	68
C3	2,000	500	0	79	15.8	84.2	- 1.0	M	70
H3	2,000	480	0	4	0.8	99.2	0.5	D	72
H4	2,000	500	0	3	0.6	99.4	0.5	M	75
H1	2,000	1,000	0	2	0.2	99.8	0.5	E	89

The test section in the Amarillo District was installed on FM 1151 in the eastbound lane on a 2 lane undivided highway in a rural area in Randall County. See Appendix F for more information about sealants and their construction sequences.

Table 4.5. Summary of Short Term Performance for US 87 in San Antonio District ("Not Covered" Test Section)

	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Developed Cracks (ft)	Length of Cracks No Longer Sealed (ft)	Percentage of Cracks No Longer Sealed (%)	Treatment Effectiveness (%)	Average Height or Depth of Sealant from Pavement Surface (mm)	Resistance to Pull Out	Sealant Temperature (°F)
H2	1,000	2,653	0	6	0.2	99.8	0 to 0.5	D	90
C1	1,000	2,704	0	26	0.9	99.1	-1.5	D	92
H1	1,000	2,547	0	6	0.2	99.8	0 to 0.5	D	93
H4	1,000	2,541	0	0	0	100	0 to 0.5	M	95
C2	1,000	3,269	0	47	1.4	98.6	-1.5	E	95
H3	1,000	3,868	0	5	0.1	99.9	0 to 0.5	D	108
C3	886	1,733	0	24	1.4	98.6	-1	E	109

The test section in the San Antonio District was installed on US 87 in the southbound outside lane on a 4 lane undivided highway in a urban area in San Antonio in Bexar County. See Appendix F for more information about sealants and their construction sequences.

Table 4.6. Summary of Short Term Performance for US 59 in Lufkin District ("Not Covered" Test Section)

	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Developed Cracks (ft)	Length of Cracks No Longer Sealed (ft)	Percentage of Cracks No Longer Sealed (%)	Treatment Effectiveness (%)	Average Height or Depth of Sealant from Pavement Surface (mm)	Resistance to Pull Out	Sealant Temperature (°F)
C2	3,000	3,020	0	0	0	100	N/D	N/D	N/D
H3	3,000	2,421	0	0	0	100	N/D	N/D	N/D
C1	3,000	2,251	0	0	0	100	N/D	N/D	N/D
H2	3,000	1,475	0	0	0	100	N/D	N/D	N/D

The test section in the Lufkin District was installed on US 59 in the southbound outside lane on a 5 lane undivided highway (2 southbound lanes, 2 northbound lanes, and 1 turning lane) in a urban area in Livingston in Polk County. See Appendix F for more information about sealants and their construction sequences.

Short Term Performance on "Covered" Test Sections

For this part of the research project, three test sections in Atlanta, Lufkin and Amarillo Districts were selected. The test section in the Atlanta District was installed on Loop 281 in the southbound outside lane on a 4 lane divided highway in a rural area in Harrison County. The test section in the Lufkin District was installed on US 190 in the westbound lane on a 2 lane undivided highway in a rural area in Polk County. Finally, the test section in the Amarillo District was installed on FM 1541 in the southbound lane on a 2 lane undivided highway in a rural area in Randall County. See Appendix F for more information about sealants and their construction sequences.

In these test sections, first installation of the sealants was completed. Table 4.7 shows the type of crack sealant used in the test sections and the construction dates. In Atlanta and Amarillo District, one cold pour and hot rubber sealant was installed while in Lufkin District two cold pour and two hot rubber sealants were used.

Table 4.7. Crack Sealant Used and Their Application Dates

	Cold Pour	**Hot rubber**	**Sealing Date**
Atlanta	C2	H1	1/31/01
Lufkin	C1 and C2	H1 and H3	2/7/01 and 2/8/01
Amarillo	C1	H3	2/20/01

The test sections built in Atlanta and Amarillo Districts were covered by chip seal. The test section in Lufkin District was covered in Spring 2002. Table 4.8 gives information about chip seal designs and construction dates for the test sections in Atlanta and Amarillo Districts. In both of the test sections, grade 4 aggregates were used with AC-15-5TR binders. AC-15-5TR consists of an asphalt cement with a minimum of %5 ground tire rubber.

Table 4.8. Chip Seal Design and Construction Dates

	Aggregate Grade	Aggregate Spread Rate	Asphalt Grade	Asphalt Rate	Application Temperature	Construction Date
Atlanta	4	150 sy/cy	AC-15-5TR	0.32 gal/sy	320°F	6/20/01
Amarillo	4	106 sy/cy	AC-15-5TR	0.46 gal/sy	350°F	8/17/01

Covered test sections were visually examined to observe the quantity of bleeding of the sealant through the surface treatment or subsequent cracking on the test sections. Bleeding is the main concern for the chip-sealed sections, which are previously crack sealed. Bleeding can be caused by excessive crack sealant between the pavement and the chip seal. Bleeding is a film of bituminous material on the pavement surface, which creates a shiny, glass-like, reflecting surface that decreases traction. It occurs when asphalt fills the voids and then expands onto the pavement surface. Strategic Highway Research Program (SHRP) Distress Identification Manual defines three severity levels for bleeding: Low, Moderate and High.

Low – Coloring of pavement surface is visible.
Moderate – Distinctive appearance with excess asphalt already free.
High – Free asphalt gives the pavement surface a wet look; tire marks are evident.

The test sections built in Atlanta and Amarillo Districts were visited and areas where bleeding occurred were determined by visual observation. Although SHRP Distress Identification Manual recommends measuring the area of bleeding surface, in this research, the length of the bleeding sections were measured to evaluate the performance of the crack seal test sections.

The test section in Atlanta District was visited two months after the application of chip seal on August 31, 2001. In this test section, one cold pour C2 and one hot rubber H1 crack sealants were used. Figure 4.5 and Figure 4.6 show the test sections crack sealed with C2 and H1 respectively. As can be seen from the pictures, the section sealed with

H1 hot rubber crack sealant showed bleeding over the sealed cracks. Crack patterns can be easily recognized because of the bleeding. The level of bleeding was very low. The total length of the bleeding section was 700 feet. On the other hand, bleeding over the sealed cracks was not observed on the section crack sealed with C2 cold pour.

Figure 4.3. Test section crack sealed with C2 in Atlanta District

Figure 4.4. Test section crack sealed with H1 in Atlanta District

Test sections in Amarillo were visited approximately two months after construction on October 24, 2001. In this test section, one cold pour C1 and one hot rubber H3 crack sealants were used. No bleeding was observed over the sealed cracks on the test sections. Figure 4.7 and Figure 4.8 are showing the test sections crack sealed with C1 and H3 respectively.

Figure 4.5. Test section crack sealed with C1 in Amarillo District

Figure 4.6. Test section crack sealed with H3 in Amarillo District

Chapter 5. Conclusions

This report included information on the first year findings of a three-year research project on comparison of cold pour and hot rubber crack sealants. In the first year, all the tasks were achieved as scheduled. Surveys on crack sealants were conducted on districts and states. Construction of 33 test sections in 5 districts was completed. Installation costs were analyzed and initial performance evaluations on the sections that will not be covered in the next 3 years were completed.

The survey of districts showed that all participating districts used hot rubber sealants, whereas only one-third of the districts used cold pour sealants. Overall, it is reported that the hot rubber performed better than the cold pour sealants. For most of the performance evaluation questions, neither hot rubber nor cold pour ranked poor by the participating districts. Hot rubber sealants were ranked poor or fair for resistance to bleeding by the majority of the districts.

The survey of states showed that all participating states used hot rubber sealants. Only half of the participating states used cold pour sealants. For two-thirds of the questions, cold pour sealants were ranked poor by some of the participating states. Hot rubber sealants were ranked poor only for resistance to bleeding by the some of the states. In overall evaluation of the survey, hot rubber clearly performed better than cold pour sealants.

Test sections were crack sealed in five districts of Texas between January and April 2001. The sections were visited approximately 3 to 4 months after construction. Overall short term evaluations for both hot pour and cold pour materials is good for both not-covered and covered sections in that no bleeding is observed. The initial results indicate very good performance of hot rubber sealants. While cold pour sealants in most cases exhibit good behavior, in other cases a loss of seal was observed. Better evaluation of the sealants can be made after the completion of all the site visits for long term performance evaluation during the 3-year period of this study. Life cycle cost comparisons will be made after monitoring performance and failures over the 3-year period of the study.

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Appendix A
Questionnaire Used for the Surveys

Questionnaire for the Project 4061

1. Has sealing cracks in flexible pavements been practiced in your district as a form of maintenance? Yes No

2. What method of cleaning the cracks before sealing is used?

   a. wire brush b. routing c. compressed air

   d. hot compressed air lance e. pressurized water f. sawing

   g. other (please specify)

3. What type of sealant(s) is (are) now being used?

   Hot Pour: yes, no, brand name if available

   Cold Pour: yes, no, brand name if available

   Reason(s) for use

   Hot Pour: ____

   Cold Pour: ____

   Approximate range of cost per linear foot of crack including labor, material, equipment, and traffic control.

   Hot Pour: ___________ Cold Pour: ___________

4. If you have been using a different type of sealant in the past, what type was it and what is the reason for transition to the new type of sealant?

5. What type of cracks do you seal with the method used?

   Fatigue Cracking, Block Cracking, Edge Cracking, Longitudinal Cracking, Reflection Cracking at Joints, Transverse Cracking

6. What width of cracks do you typically seal?

   a. <1/2” b. >1/2”and < 1” c. > 1”

7. In your opinion, which type of the following squeegees provides a better seal for each type of crack sealant? (Pick the best squeegee for hot pour and the best squeegee for cold pour).

   a. sealing shoe (disk) b. rubber squeegee c. metal squeegee

8. How would you rate the sealant in the following areas (please write 'id' if there is not sufficient data). (1-poor; 2-fair; 3-good; 4-excellent)

Resistance to being forced out by traffic.	Cold Pour _____, Hot Pour _____
Resistance to oxidation.	Cold Pour _____, Hot Pour _____
Resistance to becoming brittle.	Cold Pour _____, Hot Pour _____
Resistance to particles entering crack.	Cold Pour _____, Hot Pour _____
Resistance to flushing or bleeding.	Cold Pour _____, Hot Pour _____
Ability to bond to pavement.	Cold Pour _____, Hot Pour _____
Abrasion resistance.	Cold Pour _____, Hot Pour _____
Ability to rebond (adhere to the sides again).	Cold Pour _____, Hot Pour _____
Effectiveness in sealing cracks.	Cold Pour _____, Hot Pour _____

9. How long is the sealant effective in sealing cracks? Cold Pour _____, Hot Pour _____

10. Approximately how many lane miles of roads do you crack seal in a year?

11. How many people are in a typical crew? Cold Pour ______, Hot Pour ______

12. During which months do you typically seal cracks?

13. What range of ambient temperatures do you apply the sealant at?

14. Is the crack sealing in your district performed by,

    a) State force b) Contractor c) Both

15. Do you recommend any changes to a) material specification, b) work specification, for both cold and hot pours?

    If so, why?

16. Would you kindly provide the following information?

    District providing this information:

    Person providing this information:

    Contact Information (phone, fax, e-mail):

    Please provide any additional remarks below:

Please return the completed questionnaire to:

Dr. Yetkin Yildirim

Superpave and Asphalt Research Program

Civil Engineering Department

ECJ 6.10

University of Texas at Austin

Austin, TX 78712

Appendix B
Documentation of the Survey Conducted on TxDOT Districts and Other States

Table B.1. Summary of Surveys on Crack Cleaning Method, Sealant and Cost/Ft

SUMMARY OF TX DOT SURVEYS

DISTRICT	CRACK CLEANING METHOD					SEALANT		COST $ / FT	
	Wire Brush	Comp. Air	Routing	Sawing	Hot Comp Air Lance	Hot Pour	Cold Pour	Hot Pour	Cold Pour
Abilene		x				x		0.15-0.2	-
Amarillo		x				x		-	-
Atlanta		x					x	-	0.14-0.16
Austin		x				x	x	0.8/lb	0.11/gal
Beaumont		x				x		-	-
Brownwood		x				x		-	-
Childress		x				x	x	-	-
Dallas		x	x			x		0.50	
El Paso		x				x	x	0.1-0.13	0.15-0.17
Houston		x	x					0.15	-
Lubbock		x				x	x	-	-
Laredo		x				x		-	-
Lufkin		x						0.10	-
Odessa		x				x	x	0.50/lb	2.7-3/lb
Paris		x	x			x	x	0.21-0.36	0.20
Pharr		x				x	x	0.125	0.13
San Antonio		x				x		0.6-0.8/lb	-
Tyler		x				x	x	0.495/lb	0.33/lb
Waco		x				x		600/ln-mi	-
Wichita Falls		x				x	x	0.10	-
Yoakum		x				x	x	540/ln-mi	10/gal
STATE									
Alaska		x			x	x	x	0.55	0.30
Arizona		x				x		0.13	-
Maryland		x				x	x	0.27	0.17
New Jersey	x					x	x	0.54	-
New York		x	x			x		-	-
North Carolina		x		x	x	x	x	1.70	-
Oregon		x	x	x	x	x	x	-	-
Pennsylvania		x	x		x	x		7.80	-
Utah		x				x		0.2/yd^2	-

Table B.2. Summary of Surveys on Type of Crack Seals for Methods Used and Width of Crack Seals

DISTRICT	TYPE OF CRACKING SEALED						WIDTH OF CRACKS SEALED		
	Fatigue Crack	Block Crack	Edge Crack	Longitudinal Crack	Reflection Crack J	Transverse Crack	< 1/2"	>1/2" & <1"	> 1"
Abilene	x	x	x	x		x	x	x	x
Amarillo	x	x	x	x	x	x	x	x	
Atlanta				x	x	x	x		
Austin	x	x	x	x	x	x	x	x	
Beaumont			x	x	x	x	x		
Brownwood	x	x	x	x	x	x	x	x	
Childress		x	x	x	x	x	x	x	x
Dallas		x	x	x	x	x		x	
El Paso	x	x	x	x	x	x	x		
Houston	x		x	x	x	x	x	x	
Lubbock	x		x		x	x	x		
Laredo	x		x	x	x	x	x		
Lufkin			x	x	x	x	x		
Odessa	x	x	x	x		x	x	x	
Paris			x	x	x	x	x	x	x
Pharr		x	x	x		x	x	x	
San Antonio		x	x	x	x	x	x		
Tyler		x		x	x	x	x		
Waco	x	x	x	x	x	x	x	x	
Wichita Falls	x	x	x	x	x	x	x	x	
Yoakum	x			x	x	x	x	x	
STATE									
Alaska		x	x	x	x	x	x	x	
Arizona	x	x	x	x	x	x	x	x	
Maryland	x	x	x	x	x	x		x	
New Jersey			x	x	x	x	x		
New York			x	x	x	x	x		
North Carolina	x	x	x	x	x	x	x	x	
Oregon		x		x	x	x	x	x	
Pennsylvania	x			x	x	x		x	
Utah			x	x	x	x		x	

Table B.3. Summary of Surveys on Squeegee Type Used for Crack Sealing

DISTRICT	TYPE OF SQUEEGEE FOR CRACK SEAL		
	Sealing Shoe	Rubber Squeegee	Metal Squeegee
Abilene	-	hot/cold pour	-
Amarillo	-	-	hot pour
Atlanta	-	hot/cold pour	-
Austin		cold pour	hot pour
Beaumont	-	hot pour	-
Brownwood	-	-	-
Childress	-	hot/cold pour	-
Dallas			hot pour
El Paso	-	hot/cold pour	-
Houston	cold pour	hot pour	-
Lubbock	-	hot/cold pour	-
Laredo	-	hot pour	-
Lufkin	-	hot pour	-
Odessa	hot pour	cold pour	-
Paris	-	hot/cold pour	-
Pharr	-	hot/cold pour	-
San Antonio	hot pour	cold pour	-
Tyler	-	hot/cold pour	-
Waco	-	hot/cold pour	-
Wichita Falls	cold pour	hot pour	-
Yoakum	-	hot/cold pour	-
STATE			
Alaska	-	hot pour	-
Arizona	-	hot pour	-
Maryland	-	hot/cold pour	-
New Jersey	hot pour	cold pour	-
New York	-	hot pour	-
North Carolina	hot pour	-	-
Oregon	hot/cold pour	-	-
Pennsylvania	hot pour	hot pour	-
Utah	hot pour	-	-

Table B.4.1. Summary of Surveys on Sealant Rating

DISTRICT	**PERFORMANCE OF SEALANT**					
	Resistance to being forced out by traffic		**Resistance to oxidation**		**Resistance to becoming brittle**	
	Cold Pour	Hot Pour	Cold Pour	Hot Pour	Cold Pour	Hot Pour
Abilene	-	good	-	fair	-	good
Amarillo	-	excellent	-	good	-	good
Atlanta	good	good	good	good	good	good
Austin	good	good	good	good	good	good
Beaumont	-	fair	-	good	-	-
Brownwood	-	-	-	-	-	-
Childress	fair	excellent	-	-	good	excellent
Dallas	-	good	-	excellent	-	excellent
El Paso	excellent	good	good	good	excellent	good
Houston	-	fair	-	fair	-	fair
Lubbock	good	-	fair	-	excellent	-
Laredo	-	good	-	good	-	good
Lufkin	-	good	-	good	-	excellent
Odessa	good	good	good	good	good	fair
Paris	fair	good	fair	excellent	good	good
Pharr	excellent	good	excellent	excellent	good	good
San Antonio	-	good	-	excellent	-	good
Tyler	excellent	excellent	excellent	excellent	excellent	excellent
Waco	fair	excellent	excellent	excellent	excellent	excellent
Wichita Falls	good	good	good	excellent	good	good
Yoakum	excellent	excellent	excellent	good	excellent	excellent
STATE						
Alaska	-	excellent	-	excellent	-	excellent
Arizona	-	good	-	fair	-	good
Maryland	poor	good	good	good	poor	good
New Jersey	fair	fair	poor	fair	poor	fair
New York	-	excellent	-	good	-	good
North Carolina	-	excellent	-	excellent	-	excellent
Oregon	fair	fair	good	fair	good	fair
Pennsylvania	-	excellent	-	excellent	-	excellent
Utah	-	good	-	fair	-	good

Table B.4.2. Summary of Surveys on Sealant Rating

DISTRICT	PERFORMANCE OF SEALANT					
	Resistance to particles entering crack		Resistance to flushing or bleeding		Ability to bond to pavement	
	Cold Pour	Hot Pour	Cold Pour	Hot Pour	Cold Pour	Hot Pour
Abilene	-	fair	-	poor	-	good
Amarillo	-	good	-	good	-	excellent
Atlanta	-	-	excellent	poor	good	good
Austin	good	good	good	poor	good	good
Beaumont	-	excellent	-	-	-	good
Brownwood	-	-	-	-	-	-
Childress	fair	good	excellent	fair	fair	excellent
Dallas	-	fair	-	good	-	excellent
El Paso	good	good	excellent	fair	excellent	excellent
Houston	-	fair	-	fair	-	good
Lubbock	fair	-	good	-	excellent	-
Laredo	-	good	-	poor	-	good
Lufkin	-	good	-	poor	-	good
Odessa	good	good	excellent	fair	good	good
Paris	fair	good	good	excellent	good	excellent
Pharr	excellent	good	excellent	poor	excellent	excellent
San Antonio	-	good	-	fair	-	good
Tyler	excellent	excellent	good	fair	excellent	excellent
Waco	good	excellent	fair	excellent	good	excellent
Wichita Falls	good	fair	good	poor	fair	good
Yoakum	good	excellent	excellent	fair	good	excellent
STATE						
Alaska	-	excellent	-	good	-	excellent
Arizona	-	good	-	good	-	good
Maryland	fair	good	fair	fair	fair	excellent
New Jersey	fair	good	fair	poor	poor	fair
New York	-	excellent	-	excellent	-	excellent
North Carolina	-	excellent	-	good	-	excellent
Oregon	good	good	fair	good	fair	fair
Pennsylvania	-	excellent	-	good	-	excellent
Utah	-	good	-	good	-	good

Table B.4.3. Summary of Surveys on Sealant Rating

DISTRICT	PERFORMANCE OF SEALANT					
	Abrassion Resistance		Ability to rebond		Effectiveness in sealing cracks	
	Cold Pour	Hot Pour	Cold Pour	Hot Pour	Cold Pour	Hot Pour
Abilene	-	good	-	fair	-	good
Amarillo	-	-	-	excellent	-	good
Atlanta	-	-	-	-	excellent	excellent
Austin	good	good	good	good	good	good
Beaumont	-	-	-	good	-	good
Brownwood	-	-	-	-	-	-
Childress	-	-	fair	good	fair	excellent
Dallas	-	good	-	good	-	excellent
El Paso	good	good	excellent	good	good	excellent
Houston	-	fair	-	poor	-	good
Lubbock	good	-	good	-	excellent	-
Laredo	-	good	-	good	-	good
Lufkin	-	good	-	poor	-	good
Odessa	good	fair	good	good	good	excellent
Paris	good	good	good	good	good	excellent
Pharr	excellent	good	excellent	good	good	good
San Antonio	-	-	-	good	-	good
Tyler	excellent	excellent	good	excellent	excellent	excellent
Waco	excellent	excellent	poor	poor	good	excellent
Wichita Falls	fair	good	fair	good	good	excellent
Yoakum	good	excellent	fair	good	excellent	excellent
STATE						
Alaska	-	good	-	good	fair	excellent
Arizona	-	good	-	fair	-	good
Maryland	good	good	fair	good	fair	excellent
New Jersey	poor	fair	poor	fair	poor	good
New York	-	excellent	-	-	-	good
North Carolina	-	fair	-	good	-	excellent
Oregon	fair	fair	good	fair	fair	fair
Pennsylvania	-	excellent	-	-	-	excellent
Utah	-	fair	-	fair	-	good

Table B.4.4. Summary of Surveys on Sealant Rating

DISTRICT	PERFORMANCE OF SEALANT	
	Period the sealant is effective	
	Cold Pour	Hot Pour
Abilene	-	3 yrs
Amarillo	-	3-4 yrs
Atlanta	-	-
Austin	-	-
Beaumont	-	-
Brownwood	-	-
Childress	1 yr	2-4 yrs
Dallas	-	4 yrs
El Paso	-	4 yrs
Houston	-	5 yrs
Lubbock	2 yrs	-
Laredo	-	4-5 yrs
Lufkin	-	3-5 yrs
Odessa	3 yrs	3 yrs
Paris	4-5 yrs	5-6 yrs
Pharr	2-4yrs	2-3 yrs
San Antonio	-	2-3 yrs
Tyler	4 yrs	4 yrs
Waco	1 yr	-
Wichita Falls	2 yrs	2-3 yrs
Yoakum	-	2 yrs
STATE		
Alaska	1-2 yrs	3 yrs
Arizona	-	5 yrs
Maryland	1 yr	2-5 yrs
New Jersey	3 mths	-
New York	-	3-6 yrs
North Carolina	-	4 yrs
Oregon	3yrs	2yrs
Pennsylvania	-	4+yrs
Utah	-	2-3yrs

Table B.5. Summary of Surveys on Miles Sealed Per Year, Crew Size, Sealing Months and Temperature Range for Sealants

DISTRICT	Ln. miles paved per ear	Typical crew size		Sealing months	Ambient temperature range for sealing
		Cold Pour	Hot Pour		°F
Abilene	375-400	-	5	Dec-Feb	40-60
Amarillo	1390	-	4	Dec- Apr	45+
Atlanta	40-50	4-5	4-5	Dec-Feb	40-65
Austin	400	4-5	5-6	Nov-April	85-
Beaumont	-	-	6-7	Summer	70-100
Brownwood	-	-	6-8	Feb	-
Childress	250-750	4	6	Year round	hp 40+ | cp 50+
Dallas	150	-	4	Oct-Mar	35-70
El Paso	250	5-6	6-8	Dec-Feb	45+
Houston	200	-	5	Year round	-
Lubbock	100	4	-	Oct-Mar	hp 400 | cp 140+
Laredo	-	-	8	Dec-Mar	40-85
Lufkin	70-80	-	9	Nov-Mar	30-60
Odessa	70,000 lb	3	5	Nov-Mar	32-60
Paris	70-100	6	6	Oct-May	40-80
Pharr	300-400	5	6	Nov-Mar	40-90
San Antonio	(600-800)k lb	-	5	Feb-Mar	50-80
Tyler	60	5	6	cp-summer |hp-winter	40+
Waco	350	4	4	Nov-Mar	40-70
Wichita Falls	200	5	6	Dec-Feb	35-65
Yoakum	1300	6	6	Dec-Feb	45-85
STATE					
Alaska	500	2	6-8	Apr-Oct	45+
Arizona	50	-	6-8	Oct-May	40-
Maryland	-	8	7	Nov-Apr	45-10
New Jersey	-	5	3	May-Nov	40+
New York	5500	-	4-5	spring/fall	32+
North Carolina	-	-	9	Dec-Mar	35-60
Oregon	-	6	8	Apr/May & Sep/Oct	40-60
Pennsylvania	5600	-	-	Mar-May & Sep-Nov	40+
Utah	300	-	5	Sept-Apr	25-60

Table B.6. Contact Information

DISTRICT	CONTACT INFORMATION			
	Name	Telephone No.	Fax	E-mail
Abilene	Martin Turentine, Dist Maint. Mgr.	(915)676-6850	(915)676-6957	mturent@dot.state.tx.us
Amarillo	Mike Taylor	(806)356-3270	(806)356-3265	mtaylor@dot.state.tx.us
Atlanta	E.G. Childress, P.E., Dir. of Maintenance	(903)799-1280	(903)799-1288	gchildre@dot.state.tx.us
Austin	Gene Stabeno	(512)832-7063	-	-
Beaumont	John M. Pitre	(409)924-6522	-	-
Brownwood	Gary Humes	(915)643-0416	(915)643-0306	ghumes@dot.state.tx.us
Childress	Alvin C. Harper	(940)937-7185	-	-
Dallas	Gary Charlton	(214)320-6200	(214)320-6615	gcharlt@dot.state.us
El Paso	Roberto Tejada, P.E.	(915)774-4267	-	-
Houston	Mike Alford	(713)802-5551	-	-
Lubbock	George M. Dozier	(806)748-4445	-	-
Laredo	Rosa E. Trevino, P.E. Dir Maintenance	(956)712-7483	(956)712-7402	-
Lufkin	Walter Hearnsberger	-	-	-
Odessa	Carolyn Dill, P.E.	(915)498-4745	(915)498-4680	cdill@dot.state.tx.us
Paris	J.B. Hutchinson, Jr. P.E., DDE. DOM	(903)737-9248	(903)737-9363	-
Pharr	Chano Falcon, Jr. Dist. Maint. Manager	(956)702-6304	(956)702-6223	cfalcon@dot.state.tx.us
San Antonio	John Bohuslav, P.E.	(210)615-5856	(210)615-6073	jbohusl@mailgw.dot.state.tx.us
Tyler	Eldon L. McCurley	(903)592-8991	(903)597-0803	-
Waco	Mike Heise	(254)867-2816	(254)867-2894	mheise@dot.state.tx.us
Wichita Falls	Brady Woolseyy	(940)720-7710	(940)720-7707	bwoolsey@dot.state.tx.us
Yoakum	Carl O'neill	(361)293-4353	(361)293-4372	coneill@dot.state.tx.us
STATE				
Alaska	Scott Gartin	(907)269-6200	-	scott_gartin@dot.state.ak.us
Arizona	Jim Dorre, State Maintenance Eng.	(602)712-7949	(602)712-6745	jdorre@dot.state.az.us

Maryland	Kevin J. Opper	(410)677-4050	(410)523-6724	-
New Jersey	J. Walker, Prin. Engineer	(609)530-3706	-	-
New York	Edward J. Denehy	(518)457-6914	(518)457-4203	edenehy@gw.dot.state.ny.us
North Carolina	Lex Kelly, Project Engineer	(910)944-2344	-	-
Oregon	-	-	-	-
Pennsylvania	Mike LeLack, Manager Section Q/A	(717)783-2526	(717)787-7839	-
Utah	Craig Ide Engineer	(801)965-4789	-	cide@dot.state.tx.us

Appendix C
Specifications for Crack Sealing and Joint Sealing Materials

Table C.1. Item 3127, Cold Pour Crack Sealants

Properties	Minimum	Maximum	Test Procedure
Viscosity, Brookfield, 77°F, Centipoise	10,000	25,000	ASTM D 2196 Method A
Storage Stability Test One Day, Percent	-	1	AASHTO T 59
Sieve Test, Percent	-	0.10	AASHTO T 59
Evaporation* Residue, Percent	65	-	
Penetration, 25C (77°F) 100 G, 5 seconds, (0.1mm)	35	75	AASHTO T 49
Softening Point, R & B.,°F	140	-	AASHTO T 53
Ductility, 39.2°F 5 cm/min, cm	100	-	AASHTO T 51

Table C.2. Item DMS-6310, Class 9, Joint Sealants and Seals, Polymer Modified Asphalt Emulsion Joint Seal

Properties	Minimum	Maximum	Test Procedure
Viscosity, Brookfield, 25C (77°F) Pa*s	30	70	ASTM D 2196 Method A
Evaporation Residue, Percent	65	-	Residue evaporation Procedure
Penetration, 25C (77°F) 100 G, 5 seconds, (0.1mm)	35	75	AASHTO T 49
Softening Point, F & B, C (°F)	70 (160)	-	AASHTO T 53
Bond, 3 cycles at –17.8C (0°F), 50% extension	Pass		TEX-525-C.

Table C.3. Item DMS-6310, Class 3, Joint Sealants and Seal, Hot Poured Rubber

Properties	**Minimum**	**Maximum**	**Test Procedure**
Penetration, 25C (77°F) 150 G, 5 seconds, (0.1mm)	-	90	TEX-525-C
Flow (5h, 60C [140°F]), 75 degree incline	-	3 mm (1/8 in.)	TEX-525-C
Resilience: 25C (77°F), original material, Percent	60		TEX-525-C
Bond, 3 cycles at -29C (-20°F)	Pass		TEX-525-C.

Table C.4. Item GSD 745-80-25, Rubber Asphalt Crack Sealing Compound

Percent Retained

Sieve Size	**Type I**	**Type II**	**Type III**
2.36mm (No. 8)	0	0	-
2.00 mm (No. 10)	0-5	-	0
600 µm (No. 30)	90-100	50-70	45-60
300 µm (No. 50)	95-100	70-95	75-90
150 µm (No. 100)	-	95-100	90-100

Table C.5. Item GSD 745-80-25, Class A, Rubber Asphalt Crack Sealing Compound

Properties	**Minimum**	**Maximum**	**Test Procedure**
Rubber Content			
Granulated vulcanized rubber, percent by weight	22	26	
Virgin rubber polymer, percent by weight			
Penetration, 25C (77°F) 100 G, 5 seconds, (0.1mm)	30	50	ASTM D5 except the cone specified in ASTEM D217 shall be substituted for the penetration needle
Penetration, 0C (32°F), 200g. 60 sec	12	-	ASTM D5 except the cone specified in ASTEM D217 shall be substituted for the penetration needle

Table C.6. Item GSD 745-80-25, Class B, Rubber Asphalt Crack Sealing Compound

Properties	**Minimum**	**Maximum**	**Test Procedure**
Rubber Content			
Granulated vulcanized rubber, percent by weight	13	17	
Virgin rubber polymer, percent by weight	2	-	
Penetration, 25C (77°F) 100 G, 5 seconds, (0.1mm)	30	50	ASTM D5 except the cone specified in ASTEM D217 shall be substituted for the penetration needle
Penetration, 0C (32°F), 200g. 60 sec	12	-	ASTM D5 except the cone specified in ASTEM D217 shall be substituted for the penetration needle
Softening Point: R&B	76.6C (-170°F)	-	
Bond: 3 cylces at -6.7C (20°F)			TEX-525-C

Appendix D
Cost Comparison for Crack Sealants

Table D.1. Cost Analysis Data on Materials for Amarillo District FM 1151

Cost Item	Sealant Sequence Number	Type	Quantity	Units	$/Unit	Total $	Crack Length ft	Matl. Only $/ft.	Ambient Temperature °F	Weather Conditions	Time of reading
Material	1	C1	6.5	gal.	2.89	18.79	350.00	0.05	67	Sunny and windy	11.40 AM
	2	C3	6.5	gal.	3.00	19.50	500.00	0.04	70	Sunny and windy	12.07 PM
	3	H3	130	lb	0.15	19.83	480.00	0.04	72	Sunny and windy	1.30 PM
	4	H4	53	lb	0.23	11.96	500.00	0.02	74	Sunny and windy	2.15 PM
	5	H1	200	lb	0.18	35.52	1,000.00	0.04	45	Sunny	8.30 AM
						TOTAL	**2,830.00**				

Table D.2. Cost Analysis Data on Materials for Atlanta District US 259

Cost Item	Sealant Sequence Number	Type	Quantity	Units	$/Unit	Total $	Crack Length ft	Matl. Only $/ft.	Ambient Temperature °F	Weather Conditions	Time of reading
Material	1	H1	360	lb	0.18	63.94	4,200.00	0.02	49	Sunny	8.15 AM
	2	H2	750	lb	0.18	135.68	4,125.00	0.03	59	Sunny	10.29 AM
	3	C3	47	gal.	3.00	139.50	4,200.00	0.03	64	Sunny	12.00 PM
	4	C1	52	gal.	2.89	150.28	4,250.00	0.04	46	Sunny	9.30 AM
	5	C2	32	gal.	3.00	96.00	2,750.00	0.03	47	Sunny	10.30 AM
						TOTAL	**19,525.00**				

Table D.3. Cost Analysis Data on Materials for Lufkin District US 59

Cost Item	Sealant Sequence Number	Type	Quantity	Units	$/Unit	Total $	Crack Length ft	Matl. Only $/ft.	Ambient Temperature °F	Weather Conditions	Time of reading
Material	1	C3	22	gal.	3.00	65.52	3,020.00	0.02	76	Partly Cloudy	2.45 PM
	2	H4	377	lb	0.23	85.05	2,421.00	0.04	75	Sunny	4.30 PM
	3	C2	14	gal.	3.00	41.25	2,251.00	0.02	61	Partly Cloudy	8.40 AM
	4	H1	177	lb	0.18	31.44	1,475.00	0.02	70	Sunny	10.00 AM
						TOTAL	**9,167.00**				

Table D.4. Cost Analysis Data on Materials for El Paso District Loop 375

Cost Item	Sealant Sequence Number	Type	Quantity	Units	$/Unit	Total $	Crack Length ft	Matl. Only $/ft.	Ambient Temperature °F	Weather Conditions	Time of reading
Material	1	C2	12	gal.	3.00	36.39	3,043.00	0.01	68	Sunny	10.05 AM
	2	H3	432	lb	0.15	65.88	2,138.00	0.03	77	Sunny	2.08 PM
	3	C1	15	gal.	2.89	44.42	2,518.00	0.02	65	Sunny	8.20 AM
	4	H2	209	lb	0.18	37.81	2,724.00	0.01	66	Sunny	10.30 AM
						TOTAL	**10,423.00**				

Table D.5. Cost Analysis Data on Materials for San Antonio District US 87

Cost Item	Sealant Sequence Number	Type	Quantity	Units	$/Unit	Total $	Crack Length ft	Matl. Only $/ft.	Ambient Temperature °F	Weather Conditions	Time of reading
Material	1	H2	322	lb	0.18	58.25	2,653.00	0.02	77	Sunny	10.30 AM
	2	C1	15	gal.	2.89	44.51	2,704.00	0.02	77	Sunny	1.00 PM
	3	H1	360	lb	0.18	63.94	2,547.00	0.03	82	Sunny	3.00 PM
	4	H4	430	lb	0.23	97.01	2,541.00	0.04	73	Cloudy	9.00 AM
	5	C2	19	gal.	3.00	55.80	3,269.00	0.02	75	Cloudy	11.00 AM
	6	H3	277	lb	0.15	42.24	3,868.00	0.01	78	Sunny	1.00 PM
	7	C3	12	gal.	3.00	35.10	1,733.00	0.02		Sunny	
						TOTAL	**13,714.00**				

Table D.6. Cost Analysis Data for Amarillo District FM 1151

Cost Item	Type	Quantity	Measured Units	Rental Rate $	Rental Rate Units	Assumed / Product
Equipment for Traffic Control	Arrow Board			4.00	hour	
	Cone Truck			0.37	mile	
	Dump Truck			0.56	mile	
	Pickup Truck			0.33	mile	
Equipment for Sealing	Air Compressor			11.00	hour	
	Dump Truck			0.56	mile	
	Pickup Truck			0.33	mile	
Hot Pour Equipment	Hot Pour Tank Pre-heating	60.0	Min.	18.00	hour	Each Day
	Hot Pour Tank & Equip. Use			18.00	hour	
Personnel	Traffic Setup (4 people)	50.0	Min.	13.29	Emp-hr	Each Setup
	Traffic Removal (4 people)	50.0	Min.	13.29	Emp-hr	Each Remov.
	Traffic Control (4 people)			13.29	Emp-hr	
	Crack Cleaning (2 people)			13.29	Emp-hr	
	Sealing Crew (3 people)	24.0	Min.	13.29	Emp-hr	1 - C1
	Sealing Crew (3 people)	38.0	Min.	13.29	Emp-hr	2 - C3
	Sealing Crew (4 people)	32.0	Min.	13.29	Emp-hr	3 - H3
	Sealing Crew (4 people)	33.0	Min.	13.29	Emp-hr	4 - H4
	Sealing Crew (4 people)	59.0	Min.	13.29	Emp-hr	5 - H1
Curing Time	Hot Pour	15	Min.			
	Cold Pour	120	Min.			

Table D.7. Cost Analysis Data for Atlanta District US 259

Cost Item	Type	Quantity	Measured Units	Rental Rate $	Rental Rate Units	Assumed / Product
Equipment for Traffic Control	Arrow Board			4.00	hour	
	Cone Truck			0.37	mile	
	Dump Truck			0.56	mile	
	Pickup Truck			0.33	mile	
Equipment for Sealing	Air Compressor			11.00	hour	
	Dump Truck			0.56	mile	
	Pickup Truck			0.33	mile	
Hot Pour Equipment	Hot Pour Tank Pre-heating	60.0	Min.	18.00	hour	Each Day
	Hot Pour Tank & Equip. Use			18.00	hour	
Personnel	Traffic Setup (2 people)	46.0	Min.	13.29	Emp-hr	Each Setup
	Traffic Removal (2 people)	46.0	Min.	13.29	Emp-hr	Each Remov.
	Traffic Control (1 person)			13.29	Emp-hr	
	Crack Cleaning (2 people)			13.29	Emp-hr	
	Sealing Crew (4 people)	110.0	Min.	13.29	Emp-hr	1 - H1
	Sealing Crew (4 people)	90.0	Min.	13.29	Emp-hr	2 - H2
	Sealing Crew (3 people)	190.0	Min.	13.29	Emp-hr	3 - C3
	Sealing Crew (3 people)	115.0	Min.	13.29	Emp-hr	4 - C1
	Sealing Crew (3 people)	75.0	Min.	13.29	Emp-hr	5 - C2
Curing Time	Hot Pour	15	Min.			
	Cold Pour	120	Min.			

Table D.8. Cost Analysis Data for El Paso District Loop 375

Cost Item	Type	Quantity	Measured Units	Rental Rate $	Rental Rate Units	Assumed / Product
Equipment for Traffic Control	Arrow Board Cone Truck Dump Truck Pickup Truck			4.00 0.37 0.56 0.33	hour mile mile mile	
Equipment for Sealing	Air Compressor Dump Truck Pickup Truck			11.00 0.56 0.33	hour mile mile	
Hot Pour Equipment	Hot Pour Tank Pre-heating Hot Pour Tank & Equip. Use	60.0	Min.	18.00 18.00	hour hour	Each Day
Personnel	Traffic Setup (3 people) Traffic Removal (2 people) Traffic Control (3 people) Crack Cleaning (2 people)	30.0 30.0	Min. Min.	13.29 13.29 13.29 13.29	Emp-hr Emp-hr Emp-hr Emp-hr	Each Setup Each Remv.
	Sealing Crew (3 people) Sealing Crew (4 people) Sealing Crew (3 people) Sealing Crew (4 people)	210.0 75.0 109.0 113.0	Min. Min. Min. Min.	13.29 13.29 13.29 13.29	Emp-hr Emp-hr Emp-hr Emp-hr	1 - C2 2 - H3 3 - C1 4 - H2
Curing Time	Hot Pour Cold Pour	15 120	Min. Min.			

Table D.9. Cost Analysis Data for Lufkin District US 59

Cost Item	Type	Quantity	Measured Units	Rental Rate $	Rental Rate Units	Assumed / Product
Equipment for Traffic Control	Arrow Board			4.00	hour	
	Cone Truck			0.37	mile	
	Dump Truck			0.56	mile	
	Pickup Truck			0.33	mile	
Equipment for Sealing	Air Compressor			11.00	hour	
	Dump Truck			0.56	mile	
	Pickup Truck			0.33	mile	
Hot Pour Equipment	Hot Pour Tank Pre-heating	60.0	Min.	18.00	hour	Each Day
	Hot Pour Tank & Equip. Use			18.00	hour	
Personnel	Traffic Setup (2 people)	40.0	Min.	13.29	Emp-hr	Each Setup
	Traffic Removal (2 people)	40.0	Min.	13.29	Emp-hr	Each Remov.
	Traffic Control (3 people)			13.29	Emp-hr	
	Crack Cleaning (2 people)			13.29	Emp-hr	
	Sealing Crew (3 people)	122.0	Min.	13.29	Emp-hr	1 - C3
	Sealing Crew (4 people)	68.0	Min.	13.29	Emp-hr	2 - H4
	Sealing Crew (3 people)	88.0	Min.	13.29	Emp-hr	3 - C2
	Sealing Crew (4 people)	40.0	Min.	13.29	Emp-hr	4 - H1
Curing Time	Hot Pour	15	Min.			
	Cold Pour	120	Min.			

Table D.10. Cost Analysis Data for San Antonio District US 87

Cost Item	Type	Quantity	Measured Units	Rental Rate $	Rental Rate Units	Assumed / Product
Equipment for Traffic Control	Arrow Board Cone Truck Dump Truck Pickup Truck			4.00 0.37 0.56 0.33	hour mile mile mile	
Equipment for Sealing	Air Compressor Dump Truck Pickup Truck			11.00 0.56 0.33	hour mile mile	
Hot Pour Equipment	Hot Pour Tank Pre-heating Hot Pour Tank & Equip. Use	60.0	Min.	18.00 18.00	hour hour	Each Day
Personnel	Traffic Setup (2 people) Traffic Removal (2 people) Traffic Control (2 people) Crack Cleaning (2 people)	20.0 20.0	Min. Min.	13.29 13.29 13.29 13.29	Emp-hr Emp-hr Emp-hr Emp-hr	Each Setup Each Remov.
	Sealing Crew (4 people) Sealing Crew (3 people) Sealing Crew (4 people) Sealing Crew (4 people) Sealing Crew (3 people) Sealing Crew (4 people) Sealing Crew (3 people)	125.0 115.0 70.0 85.0 75.0 80.0 75.0	Min. Min. Min. Min. Min. Min. Min.	13.29 13.29 13.29 13.29 13.29 14.29 15.29	Emp-hr Emp-hr Emp-hr Emp-hr Emp-hr Emp-hr Emp-hr	1 - H2 2 - C1 3 - H1 4 - H4 5 - C2 6 - H3 7 - C3
Curing Time	Hot Pour Cold Pour	15 120	Min. Min.			

Appendix E
Cost Analysis for Imaginary Road with 50,000 ft Crack Length

Table E.1. Cost Analysis for Amarillo District for One Day

C1	875.00	ft/hr
C3	789.47	ft/hr
H3	900.00	ft/hr
H4	909.09	ft/hr
H5	1,016.95	ft/hr

District	Type of Sealant	Units	Equipment Preparation Time	Traffic Control Setup	Sealing Cracks	Cure Time	Traffic Removal	Length Sealed ft/day	Material Cost $/day	Total Cost $/day	Unit Cost $/ft
Amarillo 1151	C1	Hr	0.00	0.83	4.33	2.00	0.83			826.99	
		$us	0.00	47.63	413.90	114.32	47.63	3,791.67	203.50		0.22
	C3	Hr	0.00	0.83	4.33	2.00	0.83			756.91	
		$us	0.00	47.63	413.90	114.32	47.63	3,421.05	133.42		0.22
	H3	Hr	1.00	0.83	6.08	0.25	0.83			1123.55	
		$us	31.29	47.63	756.57	14.29	47.63	5,475.00	226.13		0.21
	H4	Hr	1.00	0.83	6.08	0.25	0.83			1029.67	
		$us	31.29	47.63	756.57	14.29	47.63	5,530.30	132.25		0.19
	H1	Hr	1.00	0.83	6.08	0.25	0.83			1117.16	
		$us	31.29	47.63	756.57	14.29	47.63	6,186.44	219.74		0.18

Table E.2. Cost Analysis for Atlanta District for One Day

H1	2,290.91	ft/hr
H2	2,750.00	ft/hr
C3	1,326.32	ft/hr
C1	2,217.39	ft/hr
C2	2,200.00	ft/hr

District	Type of Sealant	Units	Equipment Preparation Time	Traffic Control Setup	Sealing Cracks	Cure Time	Traffic Removal	Length Sealed ft/day	Material Cost $/day	Total Cost $/day	Unit Cost $/ft
Atlanta US259	H1	Hr	1.00	0.77	6.22	0.25	0.77	14,241.82	216.80	1077.92	0.08
		$us	31.29	23.44	778.62	4.32	23.44				
	H2	Hr	1.00	0.77	6.22	0.25	0.77	17,095.83	562.30	1423.42	0.08
		$us	31.29	23.44	778.62	4.32	23.44				
	C3	Hr	0.00	0.77	4.47	2.00	0.77	5,924.21	196.77	703.42	0.12
		$us	0.00	23.44	425.18	34.58	23.44				
	C1	Hr	0.00	0.77	4.47	2.00	0.77	9,904.35	350.22	863.47	0.09
		$us	0.00	23.44	431.78	34.58	23.44				
	C2	Hr	0.00	0.77	4.47	2.00	0.77	9,826.67	343.04	856.29	0.09
		$us	0.00	23.44	431.78	34.58	23.44				

Table E.3. Cost Analysis for El Paso District for One Day

C2	869.43	ft/hr
H3	1,710.40	ft/hr
C1	1,386.06	ft/hr
H2	1,446.37	ft/hr

District	Type of Sealant	Units	Equipment Preparation Time	Traffic Control Setup	Sealing Cracks	Cure Time	Traffic Removal	Length Sealed ft/day	Material Cost $/day	Total Cost $/day	Unit Cost $/ft
El Paso 375	C2	Hr	0.00	0.50	5.00	2.00	0.50			794.70	
		$us	0.00	21.94	611.10	87.74	21.94	4,347.14	51.99		0.18
	H3	Hr	1.00	0.50	6.75	0.25	0.50			1463.02	
		$us	31.29	21.94	1021.14	10.97	21.94	11,545.20	355.75		0.13
	C1	Hr	0.00	0.50	5.00	2.00	0.50			864.96	
		$us	0.00	21.94	611.10	87.74	21.94	6,930.28	122.25		0.12
	H2	Hr	1.00	0.50	6.75	0.25	0.50			1242.78	
		$us	31.29	21.94	1021.14	10.97	21.94	9,763.01	135.51		0.13

Table E.4. Cost Analysis for Lufkin District for One Day

C3	1,485.25	ft/hr
H4	2,136.18	ft/hr
C2	1,534.77	ft/hr
H1	2,212.50	ft/hr

District	Type of Sealant	Units	Equipment Preparation Time	Traffic Control Setup	Sealing Cracks	Cure Time	Traffic Removal	Length Sealed ft/day	Material Cost $/day	Total Cost $/day	Unit Cost $/ft
Lufkin US59	C3	Hr	0.00	0.67	4.67	2.00	0.67	6,931.15	150.37	852.11	0.12
		$us	0.00	20.39	573.23	87.74	20.39				
	H4	Hr	1.00	0.67	6.42	0.25	0.67	13,707.13	481.54	1537.41	0.11
		$us	31.29	20.39	972.84	10.97	20.39				
	C2	Hr	0.00	0.67	4.67	2.00	0.67	7,162.27	131.25	832.99	0.12
		$us	0.00	20.39	573.23	87.74	20.39				
	H1	Hr	1.00	0.67	6.42	0.25	0.67	14,196.88	302.56	1358.43	0.10
		$us	31.29	20.39	972.84	10.97	20.39				

Table E.5. Cost Analysis for San Antonio District for One Day

H2	1,273.44	ft/hr
C1	1,410.78	ft/hr
H1	2,183.14	ft/hr
H4	1,793.65	ft/hr
C2	1,452.89	ft/hr
H3	2,901.00	ft/hr
C3	1,386.40	ft/hr

District	Type of Sealant	Units	Equipment Preparation Time	Traffic Control Setup	Sealing Cracks	Cure Time	Traffic Removal	Length Sealed ft/day	Material Cost $/day	Total Cost $/day	Unit Cost $/ft
San Antonio US87	H2	Hr	1.00	0.33	7.08	0.25	0.33			1214.96	
		$us	31.29	1.33	975.31	7.65	1.33	9,020.20	198.05		0.13
	C1	Hr	0.00	0.33	5.33	2.00	0.33			765.76	
		$us	0.00	1.33	578.09	61.16	1.33	7,524.17	123.84		0.10
	H1	Hr	1.00	0.33	7.08	0.25	0.33			1405.09	
		$us	31.29	1.33	975.31	7.65	1.33	15,463.93	388.18		0.09
	H4	Hr	1.00	0.33	7.08	0.25	0.33			1501.95	
		$us	31.29	1.33	975.31	7.65	1.33	12,705.00	485.04		0.12
	C2	Hr	0.00	0.33	5.33	2.00	0.33			774.19	
		$us	0.00	1.33	578.09	61.16	1.33	7,748.74	132.27		0.10
	H3	Hr	1.00	0.33	7.08	0.25	0.33			1241.32	
		$us	31.29	1.33	975.31	7.65	1.33	20,548.75	224.41		0.06
	C3	Hr	0.00	0.33	5.33	2.00	0.33			791.68	
		$us	0.00	1.33	578.09	61.16	1.33	7,394.13	149.76		0.11

Table E.6. Cost Analysis for Amarillo District for 50,000 feet Crack Length

Type of Sealant	Days to Seal 50,000 ft	Days	Last Day	Total Cost $/day	Cost for Whole Days $	Cost for Last Day $	Total Cost 50,000 ft $	Unit Cost $/ft for 50,000 ft
C1	13.19	13	0.19	826.99	10750.92	286.91	11,037.83	0.22
C3	14.62	14	0.62	756.91	10596.75	464.30	11,061.05	0.22
H3	9.13	9	0.13	1123.55	10111.92	241.03	10,352.95	0.21
H4	9.04	9	0.04	1029.67	9267.00	171.94	9,438.94	0.19
H1	8.08	8	0.08	1117.16	8937.28	203.03	9,140.31	0.18

Table E.7. Cost Analysis for Atlanta District for 50,000 feet Crack Length

Type of Sealant	Days to Seal 50,000 ft	Days	Last Day	Total Cost $/day	Cost for Whole Days $	Cost for Last Day $	Total Cost 50,000 ft $	Unit Cost $/ft for 50,000 ft
H1	3.51	3	0.51	1077.92	3233.763	480.21	3,713.97	0.07
H2	2.92	2	0.92	1423.42	2846.835	802.48	3,649.32	0.07
C3	8.44	8	0.44	703.42	5627.331	268.52	5,895.86	0.12
C1	5.05	5	0.05	863.47	4317.329	102.32	4,419.65	0.09
C2	5.09	5	0.09	856.29	4281.44	119.55	4,400.99	0.09

Table E.8. Cost Analysis for Lufkin District for 50,000 feet Crack Length

Type of Sealant	Days to Seal 50,000 ft	Days	Last Day	Total Cost $/day	Cost for Whole Days $	Cost for Last Day $	Total Cost 50,000 ft $	Unit Cost $/ft for 50,000 ft
C3	7.21	7	0.21	852.11	5964.80	251.08	6,215.87	0.12
H4	3.65	3	0.65	1537.41	4612.23	713.17	5,325.40	0.11
C2	6.98	6	0.98	832.99	4997.94	690.86	5,688.80	0.11
H1	3.52	3	0.52	1358.43	4075.30	590.76	4,666.06	0.09

Table E.9. Cost Analysis for El Paso District for 50,000 feet Crack Length

Type of Sealant	Days to Seal 50,000 ft	Days	Last Day	Total Cost $/day	Cost for Whole Days $	Cost for Last Day $	Total Cost 50,000 ft $	Unit Cost $/ft for 50,000 ft
C2	11.50	11	0.5	794.70	8741.653	438.26	9,179.92	0.18
H3	4.33	4	0.33	1463.02	5852.088	423.93	6,276.01	0.13
C1	7.21	7	0.21	864.96	6054.755	262.83	6,317.58	0.13
H2	5.12	5	0.12	1242.78	6213.885	210.07	6,423.95	0.13

Table E.10. Cost Analysis for San Antonio District for 50,000 feet Crack Length

Type of Sealant	Days to Seal 50,000 ft	Days	Last Day	Total Cost $/day	Cost for Whole Days $	Cost for Last Day $	Total Cost 50,000 ft $	Unit Cost $/ft for 50,000 ft
H2	5.54	5	0.54	1214.96	6074.80	571.31	6,646.10	0.13
C1	6.65	6	0.65	765.76	4594.58	436.84	5,031.42	0.10
H1	3.23	3	0.23	1405.09	4215.28	269.17	4,484.45	0.09
H4	3.94	3	0.94	1501.95	4505.85	953.96	5,459.81	0.11
C2	6.45	6	0.45	774.19	4645.12	325.51	4,970.63	0.10
H3	2.43	2	0.43	1241.32	2482.65	464.14	2,946.79	0.06
C3	6.76	6	0.76	791.68	4750.08	504.40	5,254.48	0.11

Appendix F
Test Section Locations

Figure F.1. Not-Covered Test Sections in Amarillo District

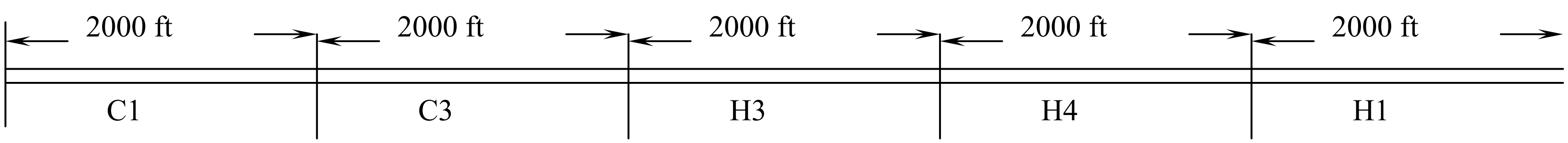
District: Amarillo
County: Randall

Sealing Dates: 2/19/01 and 2/20/01

Highway: FM 1151

Location: East Bound, Outside Lane
Highway Type: Two-lane, undivided

Construction Sequence for Sealants



CODES:

C1: Item 3127, Crack Seal ***Cold*** Pour

C3: DMS-6310, Class 9, Joint Seal ***Cold*** Pour
H3: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type I, Class A

H4: DMS-6310, Class 3, Joint Seal ***Hot*** Pour

H1: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type I, Class A

Figure F.2. Covered Test Sections in Amarillo District

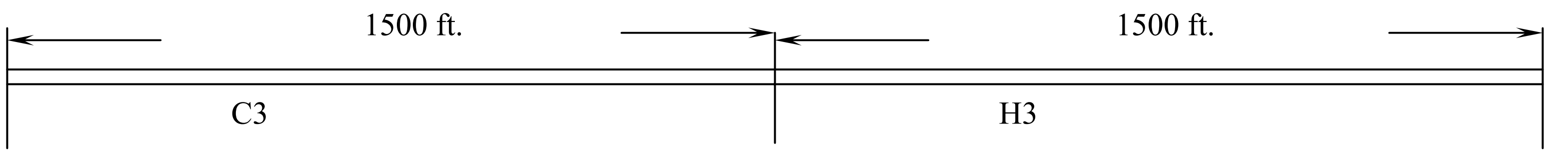
District: Amarillo
County: Randall

Sealing Date: 2/20/01

Highway: FM 1541

Location: South Bound, Outside Lane
Highway Type: Two-lane, undivided

<u>Construction Sequence for Sealants</u>



<u>CODES:</u>

C3: DMS-6310, Class 9, Joint Seal ***<u>Cold</u>*** Pour

H3: GSD 745-80-25, Crack Seal ***<u>Hot</u>*** Pour, Type I, Class A

NOTES:

Originally, C2 was scheduled for this road. However, no C2 was delivered to Amarillo. So, C3 was used instead.

During the visit of November 2000, each segment was considered to be 3000 feet long. However, because of the extension of cracking, each sgement length was reduced to 1500 feet.

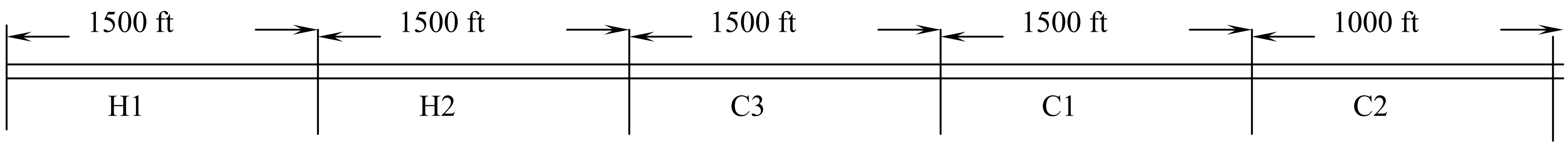
The road had bleeding in many areas on the wheel path at the time of sealing. This should be taken into consideration for analysis

Figure F.3. Not-Covered Test Sections in Atlanta District

District: Atlanta
County: Morris
Sealing Dates: 1/30/01 and 1/31/01

Highway: US 259
Location: South Bound, Outside Lane
Highway Type: Four-lane, undivided

Construction Sequence for Sealants



CODES:

H1: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type I, Class A

H2: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type III, Class B

C3: DMS-6310, Class 9, Joint Seal ***Cold*** Pour

C1: Item 3127, Crack Seal ***Cold*** Pour

C2: Item 3127, Crack Seal ***Cold*** Pour

Figure F.4. Covered Test Sections in Atlanta District

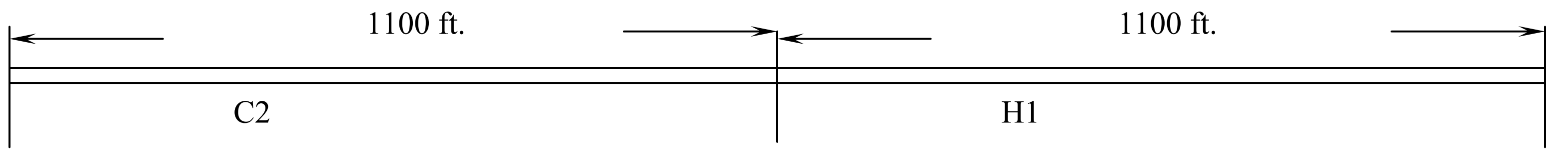
District: Atlanta
County: Harrison

Sealing Date: 1/31/01

Highway: Loop 281

Location: South Bound, Outside Lane
Highway Type: Four-lane, divided

Construction Sequence for Sealants



CODES:

C2: Item 3127, Crack Seal ***Cold*** Pour

H1: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type I, Class A

Figure F.5. Not-Covered Test Sections in El Paso District

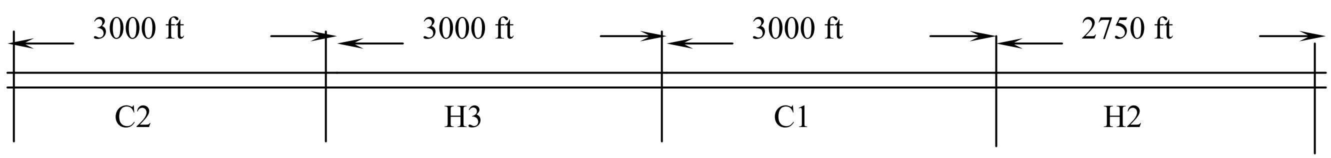
District: El Paso
County: El Paso

Sealing Dates: 3/5/01 and 3/6/01

Location: East Bound, Outside Lane

Highway: Loop 375 (Border Highway)
Highway Type: Four-lane, divided

Construction Sequence for Sealants



CODES:

C2: Item 3127, Crack Seal ***Cold*** Pour

H3: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type I, Class A

C1: Item 3127, Crack Seal ***Cold*** Pour

H2: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type III, Class B

Figure F.6. Not-Covered Test Sections in Lufkin District

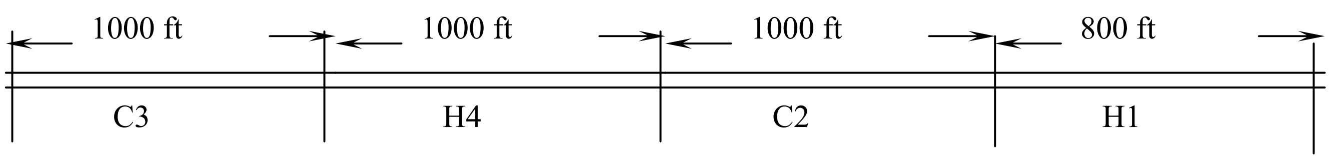
District: Lufkin
County: Polk

Sealing Dates: 2/6/01 and 2/7/01

Highway: US 59

Location: South Bound, Outside Lane
Highway Type: Four-lane, undivided

Construction Sequence for Sealants



CODES:

C3: DMS-6310, Class 9, Joint Seal ***Cold*** Pour

H4: DMS-6310, Class 3, Joint Seal ***Hot*** Pour

C2: Item 3127, Crack Seal ***Cold*** Pour

H1: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type I, Class A

Figure F.7. Covered Sections in Lufkin District

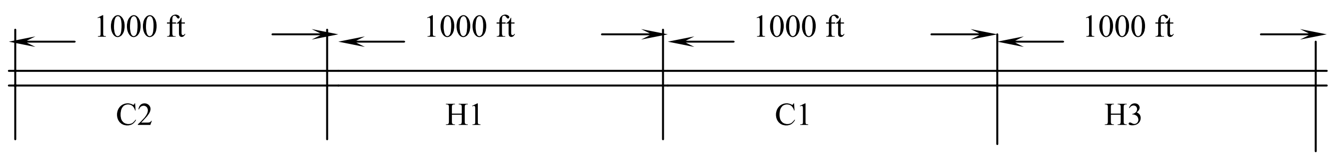
District: Lufkin
County: Polk

Sealing Dates: 2/7/01 and 2/8/01

Highway: US 190

Location: West Bound, Outside Lane
Highway Type: Two-lane, undivided

Construction Sequence for Sealants



CODES:

C2: Item 3127, Crack Seal ***Cold*** Pour
H1: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type I, Class A

C1: Item 3127, Crack Seal ***Cold*** Pour

H3: GSD 745-80-25, Crack Seal ***Hot*** Pour, Type I, Class A

Figure F.8 Not-Covered Test Sections in San Antonio District

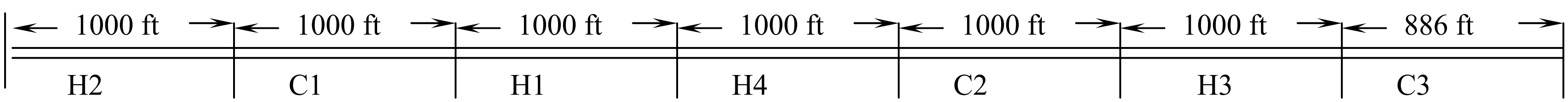
District: San Antonio
County: Bexar

Sealing Dates: 4/25, 4/26, and 4/27/2001

Highway: US 87

Location: South Bound, Outside Lane
Highway Type: Four-lane, undivided

<u>Construction Sequence for Sealants</u>



<u>CODES:</u>

C1: Item 3127, Crack Seal ***<u>Cold</u>*** Pour

H1: GSD 745-80-25, Crack Seal ***<u>Hot</u>*** Pour, Type I, Class A

C2: Item 3127, Crack Seal ***<u>Cold</u>*** Pour

H2: GSD 745-80-25, Crack Seal ***<u>Hot</u>*** Pour, Type III, Class B

C3: DMS-6310, Class 9, Joint Seal ***<u>Cold</u>*** Pour

H3: GSD 745-80-25, Crack Seal ***<u>Hot</u>*** Pour, Type I, Class A

H4: DMS-6310, Class 3, Joint Seal ***<u>Hot</u>*** Pour

Appendix G
Explanations of the Calculation

Explanation for Cost Calculations in Tables in Appendix D and Appendix E

The Tables in Appendix D and Appendix E present the initial cost calculations for the different sealants used in the test sections. Tables D.1-D.10 reflect data collected from test sections in the field. Tables E.1-E.10 utilize field data to calculate assorted costs. The costs in these tables were prepared using various, often complicated, calculations. All numbers were calculated in an Excel sheet using exact numbers with no rounding. The numbers as presented in the tables, however, are rounded. The results of example calculations come directly from the tables. In order to make the method of calculating these costs clear, two randomly selected sealants, one hot pour and one cold pour from the Atlanta district, will be used to illustrate the calculation of costs.

Calculations in Appendices D and E are based on certain assumptions that were verified in the field. First, the cone-hauling, dump and pickup trucks are assumed to have traveled 20 miles per day. Secondly, the time to pre-heat hot pour tank is assumed to be 1 hour. Curing times for hot pour and cold pour are assumed to be 15 minutes and 120 minutes, respectively. The unit costs presented in the tables and calculations for arrow board, cone-hauling trucks, dump trucks, pickup trucks, air compressor, hot pour tank and personnel were provided by TxDOT.

The Test Sections described in the Tables in Appendix D and Appendix E are located on different highway types. See figures F.1 thru F.8 to see the type of highway for each location.

Description of Terms Used in Cost Calculation

Arrow Board – Time elapsed from the beginning of traffic control setup to completion of removal of traffic control. Value displayed is per day.
Cone-hauling truck, dump truck, and pickup truck – Values are fixed at 20 miles for all sealants for each of these pieces of equipment for each day.
Air Compressor – Estimated value taken from the time the sealing started until it stopped. In order to account for the time the compressor was not in use, we use only 30% of the total sealing time. Final time is displayed on the per day basis.
Hot Pour Tank Pre-heating – Time is fixed at 1 hour, each morning, based on experience.
Hot Pour Tank and Equipment – Time taken from start of sealing until it stops.
Traffic Control Setup (# of people) – Traffic control setup duration time multiplied by the number of workers involved.
Traffic Control Removal – Time elapsed during traffic control removal, multiplied by number of workers.
Traffic Control – Sealing time. Traffic control value is later multiplied by number of workers to achieve control.
Crack Cleaning Crew – Same time as sealing time.
Sealing Crew – Sealing time.

Explanation for Tables D.1-D.5

Tables D.1-D.5 show the cost analysis data for materials used in the test sections. These tables reflect data in five areas:
1) Material Quantity
2) Cost per Unit
3) Total Cost
4) Crack Length
5) Material Cost per foot

Additionally, Ambient Temperature, Weather Conditions, and Time of reading for each product are shown.

In order to calculate the cost of the materials used for the test sections, there were a number of steps. First, the test sections were located and divided into equal sections for the different materials. Second, the crack lengths in each test section were measured, and third, the various sealants were applied. Then, the quantity of each sealing material used for each section was determined. The unit costs ($/gallon, $/lb.), including transportation cost (freight and material), for each product were based on shipment of a truckload of each product sent to San Antonio. Using the cost per unit value provided by TxDOT multiplied by the quantity used, the total cost of each material was determined. Finally, the total cost of the material was divided by the feet of crack seal to obtain the cost of the material per foot of cracks sealed. The calculation is presented below:

$$\text{Material Cost Per Foot} = \frac{\text{Unit Cost (\$) X Number of Units}}{\text{Feet of Crack Seal}}$$

For instance, Table D.2 shows the cost of materials for the Atlanta district. H1 is a hot pour material. The quantity of material used to seal the 4,200 feet of cracks in that part of the test section was 360 lbs. The per unit cost of the material was $0.18 per lb. Therefore, the total cost of the material for this section was $63.94. Then $63.94 was divided by the total number of feet that was sealed (4,200) to arrive at $0.02, the cost of the material per foot. The calculation is shown below:

<u>Cost of H1 in Atlanta district</u>
360 lbs X $0.18 / 4200 ft = **$.02** (Material Cost Per Foot)

C1 is a cold pour material. The quantity of material used to seal the 4,250 feet of cracks in that part of the test section was 52 gals. The per unit cost of the material was $2.89 per gal. Therefore, the total cost of the material for this section was $150.28. Then $150.28 was divided by the total number of feet that was sealed (4,250) to arrive at $0.04, the cost of the material per foot. The calculation is shown below:

<u>Cost of C1 in Atlanta district</u>
52 gals X $2.89 / 4250 ft = **$.04** (Material Cost Per Foot)

Explanation for Tables D.6-D.10

Tables D.6-D.10 contain information on the cost of the crack sealing operations. These tables are composed of 5 main parts:
1) Equipment for Traffic Control
2) Equipment for Sealing
3) Hot Pour Equipment (if applicable)
4) Personnel
5) Curing Times

Explanation of some terms

Traffic Setup (# of people) – Traffic control setup duration time.
Traffic Removal – Time elapsed during traffic control removal.
Sealing Crew – Sealing time for each sealant.

Personnel
Five elements were included as personnel for the sealing operations: Traffic Setup (# of people), Traffic Removal (# of people), Traffic Control (# of people), Crack Cleaning Crew (# of people), and the Sealing Crew (# of people). It is assumed that Traffic Setup and Traffic Removal are equal. For each sealant, Sealing Crew time was recorded and reported separately in the tables.

Explanation for Tables E1-E5

Tables E1-E5 contain information on the costs incurred for one workday of sealing wth each sealant. The data from the Atlanta district in Table E.2 can further illustrate the calculations of costs. These tables have the following information for each sealant used:
1) Equipment Preparation Time (time and cost)
2) Traffic Control Setup (time and cost)
3) Sealing Cracks (time and cost)
4) Cure Time (time and cost)
5) Traffic Control Removal (time and cost)
6) Length Sealed (feet per day)
7) Material Cost (cost per day)
8) Total Cost (cost per day)
9) Unit Cost (cost per foot)

Equipment Preparation Time
The amount of time for Equipment Preparation was fixed at 1 hour for Hot Pour materials based on experience. The cost of the equipment per hour was provided by TxDOT as $18.00. This cost was added to the cost of 1 worker at $13.29 per hour to arrive at a cost for the day of $31.29.

For H1 in the Atlanta district:

Cost of Equipment Preparation Time (Hot Pour)

= Equipment Cost + Personnel Cost (X # of people) X Preparation Time
= ($18.00 + $13.29) X 1hr
= **$31.29**

For all practical purposes, there is no preparation or equipment costs for cold pour equipment. Cold pour equipment does not require preparation, and, the purchase cost of cold pour equipment is low enough to be considered insignificant in calculations.

Traffic Control Setup
The time for Traffic Control Setup was measured in the field in each district, and is the same for both Cold Pour and Hot Pour materials. In the Atlanta district, the time was 46 min, which is 0.77 hr. The cost included the cost of one Arrow board and personnel to set up the traffic control.

For each hot pour and each cold pour product in the Atlanta district:

<u>Cost of Traffic Control Setup (Hot Pour and Cold Pour)</u>
= Time X Cost of (Arrow Board + Personnel)
= 46min / 60 X ($4.00 + $13.29 X 2 people)
= **$23.44**

Sealing Cracks
The time for Sealing Cracks was calculated by subtracting the times for Traffic Setup, Traffic Removal and Cure Time from an 8 hour working day for both Hot Pour and Cold Pour materials.

The cost for Hot Pour included the costs of the Arrow Board, Cone-hauling Truck, Dump Truck, Pickup Truck, Air Compressor, Dump Truck used for Sealing, Pickup Truck used for Sealing, Hot Pour Tank and Equipment, Traffic Control, Crack Cleaning, and Sealing Crew. The cone hauling truck, dump truck, and pickup truck are assumed to travel 20 miles for an 8 hour workday. Air compressor time is assumed to be 30% of sealing time.

For H1 in the Atlanta district:

<u>Cost of Sealing Cracks (Hot Pour)</u>

Sealing Time = 8 hrs – Traffic Setup – Traffic Removal – Cure Time
= 8 hrs – 0.77 hrs – 0.77 hrs – 0.25 hrs
= 6.22 hrs

Cost=
Arrow Board ($4.00 per hr) (6.22hrs) +
Cone-hauling Truck ($0.37 per mile) (20 miles) +
Dump Truck ($0.56 per mile) (20 miles) +
Pickup Truck ($0.33 per mile) (20 miles) +
Air Compressor ($11.00 per hr) (30%) (6.22 hrs) +
Dump Truck used for Sealing ($0.56 per mile) (20 miles) +

Pickup Truck used for Sealing ($0.33 per mile) (20 miles) +
Hot Pour Tank and Equipments ($18.00 per hour) (6.22 hrs) +
Traffic Control ($13.29 per hr) (1 person) (6.22 hrs) +
Crack Cleaning and Sealing ($13.29 per hr) (2 people) (6.22 hrs) +
Sealing Crew ($13.29 per hr) (4 people) (6.22 hrs)

Cost = **$778.62**

The cost for Cold Pour included the costs of the Arrow Board, Cone-hauling Truck, Dump Truck, Pickup Truck, Air Compressor, Dump Truck used for Sealing, Pickup Truck used for Sealing, Traffic Control, Crack Cleaning, and Sealing Crew.

For C1 in the Atlanta district:

Cost of Sealing Cracks (Cold Pour)
Sealing Time = 8 hrs – Traffic Setup – Traffic Removal – Cure Time
= 8 hrs – 0.77 hrs – 0.77 hrs – 2.00 hrs
= 4.47 hrs

Cost=
Arrow Board ($4.00 per hr) (4.47hrs) +
Cone-hauling Truck ($0.37 per mile) (20 miles) +
Dump Truck ($0.56 per mile) (20 miles) +
Pickup Truck ($0.33 per mile) (20 miles) +
Air Compressor ($11.00 per hr) (30%) (4.47 hrs) +
Dump Truck used for Sealing ($0.56 per mile) (20 miles) +
Pickup Truck used for Sealing ($0.33 per mile) (20 miles) +
Traffic Control ($13.29 per hr) (1 person) (4.47 hrs) +
Crack Cleaning ($13.29 per hr) (2 people) (4.47 hrs) +
Sealing Crew ($13.29 per hr) (3 people) (4.47 hrs)

Cost = **$431.78**

Cure Time
Cure Time was a measurement taken in the field. This duration represents the amount of time allowed for curing after completion of sealing until the road was opened to traffic. For the Atlanta district, it was 15 min for Hot Pour and 2 hours for Cold Pour. The cost was calculated by multiplying the Cure Time by the costs of the Arrow Board and Traffic Control.

For H1 in the Atlanta district:

Cost of Cure Time (Hot Pour)
= Cure Time X (Cost of Arrow Board + Cost of Traffic Control)
= 15min / 60 X ($4.00 + $13.29 X 1 person)
= **$4.32**

For C1 in the Atlanta District:

Cost of Cure Time (Cold Pour)
= Cure Time X (Cost of Arrow Board + Cost of Traffic Control)
= 120min / 60 X ($4.00 + $13.29 X 1 person)
= **$34.58**

Traffic Control Removal
The time for Traffic Control Removal was measured in the field in each district and was the same for both Cold Pour and Hot Pour materials. In the Atlanta district, the time was 46 min, which is 0.77 hr. The cost included the cost of 1 Arrow Board, and the personnel.

For H1 and C1 in the Atlanta district:

Cost of Traffic Control Removal (Hot Pour and Cold Pour)
= Time X Cost of (Arrow Board + Personnel)
= 46 / 60 X ($4.00 + $13.29 X 2 people)
= **$23.44**

Length Sealed per Day
The Length Sealed per hour is calculated by the length of the sealed cracks (see Table D.2) divided by the total sealing time (Table D.7) in each test section. This product is multiplied by the allowed sealing time (pages 103-104) of each sealant in an 8 hour workday.

For H1 in the Atlanta district:

Length Sealed per Day (Hot Pour)
= ft per hr X time
= (4,200 / 110) 60 X 6.22 hrs
= **14,241.82 ft per day**

For C1 in the Atlanta district:

Length Sealed per Day (Cold Pour)
= ft per hr X time
= (4,250 / 115) 60 X 4.47 hrs
= **9,904.35 ft per day**

Material Cost per Day
The cost of the material per day is calculated by multiplying the length sealed per day by the actual amount of material used in the test section (Table D.2) and dividing this

number by the length of cracks in the test section (see Table D.2) and multiplying this by the material cost per unit (see Table D.2).

For H1 in the Atlanta district:

<u>Material Cost per Day (Hot Pour)</u>
= (Length Sealed per day X Amount of Material / length of cracks) X Material Cost
= (14,241.82 X 360 / 4,200) X $0.18
= **$216.80** per day

For C1 in the Atlanta district:

<u>Material Cost per Day (Cold Pour)</u>
= (Length Sealed per day X Amount of Material / length of cracks) X Material Cost
= (9,904.35 X 52 / 4,250) X $2.89
= **$350.22** per day

Total Cost
The Total Cost per day is calculated by adding together the costs of the Equipment Preparation Time, Traffic Control Setup Time, Sealing Cracks Time, Cure Time, Traffic Control Removal Time, and Material Cost per day.

For H1 in the Atlanta district:

<u>Total Cost (Hot Pour)</u>
= Equipment Preparation Cost + Traffic Control Setup Cost + Sealing Cracks Cost + Cure Time Cost + Traffic Control Removal Cost + Material Cost
= $31.29 + $23.44 + $778.62+ $4.32 + $23.44 + $216.80
= **$1,077.92**

For C1 in the Atlanta district:

<u>Total Cost (Cold Pour)</u>
= Equipment Preparation Cost + Traffic Control Setup Cost + Sealing Cracks Cost + Cure Time Cost + Traffic Control Removal Cost + Material Cost
= $0 + $23.44 + $431.78+ $34.58 + $23.44 + $350.22
= **$863.47**

Unit Cost
The Unit Cost in dollars per foot is calculated by dividing the Total Cost per day by the length of sealing work.

For H1 in the Atlanta district:

Unit Cost (Hot Pour)
= Total Cost ($/day) / Length Sealed (ft/day)
= $1,077.92 / 14,241.82
= **$0.08 per foot**

For C1 in the Atlanta district:

Unit Cost (Cold Pour)
= Total Cost ($/day) / Length Sealed (ft/day)
= $863.47/ 9,904.35
= **$0.09 per foot**

Explanation for Tables E.6-E.10

Tables E.6-E.10 show the cost analysis data for an imaginary project of 50,000 ft crack length. The data from the Atlanta district in Table E.7 can further illustrate the calculations of costs. These tables have the following information for each sealant used:

1) Days to Seal 50,000 ft
2) Number of Whole Days
3) Last Day
4) Total Cost ($/day)
5) Cost for Last Day ($)
6) Cost of Whole Days ($)
7) Total Cost of 50,000 ft ($)
8) Unit Cost for 50,000 ft ($/ft)

Days to Seal 50,000 ft

The number of days to seal 50,000 ft was calculated by dividing 50,000 by the Length Sealed per day.

For H1 in the Atlanta district:

Days to Seal 50,000 ft (Hot Pour)
= 50,000 / Length Sealed per day
= 50,000 / 14,241.82
= **3.51 days**

For C1 in the Atlanta district:

Days to Seal 50,000 ft (Cold Pour)
= 50,000 / Length Sealed per day
= 50,000 / 9,904.35
= **5.05 days**

Number of Whole Days and Last Day
To make a cost analysis, the number of whole days was measured apart from the partial last day. For example, for H1 in the Atlanta district, the operation took 3 whole days and 0.51 of a day on the last day. Also, for C1 in the Atlanta district, the operation took 5 whole days and 0.05 of a day on the last day. The calculation of the costs for whole days versus partial days is different.

Total Cost per Day for Whole Days vs. Cost of the Last Day
The total cost for a whole day was determined using information from Table E.2. For H1 in the Atlanta district, the total cost for a whole day was $1077.92. For C1, the total cost for a whole day was $863.47.

The cost of the Last Day is calculated by subtracting the Length Sealed during the other whole days from 50,000 ft and dividing this amount by the speed of sealing. This amount is then multiplied by the cost of Sealing Cracks divided by the Hours per Day. Then this amount is added to the Equipment Preparation, Traffic Setup, Cure Time, and Traffic Removal Costs.

Cost of Last Day
(50,000 ft – Total Length Sealed during Whole Days / Speed of Sealing) X Cost of Sealing Cracks / Hours per Day) + Equipment Preparation Costs + Traffic Setup Cost + Cure Time Cost + Traffic Removal Cost

For H1 in the Atlanta district:

Total Length Sealed during Whole Days
= # of Whole Days X Length Sealed per Day
= 3 X 14,241.82 (see Table E.2)
= 42,725.46
Speed of Sealing = 2290.91 ft/hr (see Table E.2)
Cost of Sealing Cracks = $778.62 (see Table E.2)
Hours per Day = 6.22 (see Table E.2)
Equipment Preparation Costs = $31.29 (see Table E.2)
Traffic Setup Cost = $23.44
Cure Time Cost = $4.32
Traffic Control Removal Cost = $23.44

Cost of Last Day for H1 in Atlanta district (Hot Pour)
= ((50,000 ft – 42,725.46 ft) / 2290.91 ft/hr) X ($778.62 / 6.22 hrs/day) + $31.29 + $23.44 + $4.32 + $23.44

= 3.175 X $125.18 + $31.29 + $23.44 + $4.32 + $23.44
= **$480.21**

For C1 in the Atlanta district:

Total Length Sealed during Whole Days
= # of Whole Days X Length Sealed per Day
= 5 X 9,904.35 (see Table E.2)
= 49,521.75
Speed of Sealing = 2,217.39 ft/hr (see Table E.2)
Cost of Sealing Cracks = $431.78 (see Table E.2)
Hours per Day = 4.47 (see Table E.2)
Equipment Preparation Costs = $0 (see Table E.2)
Traffic Setup Cost = $23.44
Cure Time Cost = $34.58
Traffic Control Removal Cost = $23.44

<u>Cost of Last Day for C1 in Atlanta district (Cold Pour)</u>
= ((50,000 ft – 49,521.75 ft) / 2,217.39 ft/hr) X ($431.78 / 4.47 hrs/day) + $0 + $23.44 + $34.58 + $23.44

= 0.216 X 96.595 + $0 + $23.44+ $34.58 + $23.44
=$102.32

Total Cost of 50,000 ft and Unit Cost for 50,000 ft
The Total Cost of sealing 50,000 ft crack length is therefore the total cost of the whole days added to the cost of the last day.

For H1 in the Atlanta district:

<u>Total Cost of 50,000 ft (Hot Pour)</u>
= Total Cost of Whole Days + Cost of Last Day
= 3 days X $1,077.92 per day + $480.21
= $3,233.76 + $480.21
= **$3,713.97**

For C1 in the Atlanta district:

<u>Total Cost of 50,000 ft (Cold Pour)</u>
= Total Cost of Whole Days + Cost of Last Day
= 5 days X $863.47 per day + $102.32
= $4,317.33 + $102.32
= **$4,419.65**

The Unit Cost for 50,000 ft is then calculated by dividing the Total Cost by the number of feet, 50,000.

For H1 in the Atlanta district:

Unit Cost of 50,000 ft (Hot Pour)
= Total Cost of 50,000 ft / 50,000
= $3,713.97 / 50,000
= **$0.07**

For C1 in the Atlanta district:

Unit Cost of 50,000 ft (Cold Pour)
= Total Cost of 50,000 ft / 50,000
= $4,419.65 / 50,000
= **$0.09**