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16. Abstract

This is the second report from the Center for Transportation Research on the Project 4061. It presents the results, findings, conclusions, and recommendations based on the field surveys of the test sections for the second year of a 3-year study. This study comes as an attempt to determine the feasibility of using both hot pour and cold pour sealants. This will be achieved by comparing the long-term performance of both hot and cold pour sealing materials. For the purpose of the study, seven sealing materials were selected; four hot pour sealants designated as H1, H2, H3, and H4 and three cold pour sealants designated as C1, C2, and C3. These materials were applied on eight pavement maintenance sections for testing purposes in five districts in Texas. The investigation on test sections was based on AASHTO P20-94 "Standard Practice for Evaluating the Performance of Crack Sealing Treatment on Asphalt Surfaced Pavements". Three investigation visits were conducted; the first one about three months after the construction (Summer 2001), the second one about one year after the construction (Winter 2002), and the third one which was completed approximately 18 months after the construction (Summer 2002.) The visits indicated relatively excellent performance for the hot pour sealants in the majority of the test sections. On the other hand, cold pour sealants showed drastic decline in their performance with time.

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Performance Evaluation of Hot and Cold Pour Crack Sealing Treatments on Asphalt Surfaced Pavements

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Research Report 4061-2

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Comparison of Hot Poured Crack Sealant to Emulsified Asphalt Crack Sealant

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Preface

This is the second report from the Center for Transportation Research on the Project 4061. It presents the results, findings, conclusions, and recommendations based on the field surveys of the test sections for the second year of a 3-year study. The investigation on test sections was based on AASHTO P20-94 "Standard Practice for Evaluating the Performance of Crack Sealing Treatment on Asphalt Surfaced Pavements."

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Disclaimers

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1. Introduction

1.1 Summary

With the interstate highway in place and due to expensive costs of building new pavements, preserving existing pavement structures has become the focus of transportation agencies. Preventive maintenance is one of the main techniques in preserving pavement structures, and crack sealing is one of the most important procedures of preventive maintenance. A lot of different materials are used today for crack sealing purposes. Hot rubber asphalt is a very commonly used material for sealing purposes. However, this material can be hazardous due to high operating temperatures. This can put construction crews or the public at risk when a hose carrying very hot sealing material bursts. Also, hot rubber asphalt may stick to vehicles' tires due to lack of adherence to the pavement. Thus, alternative sealing materials, such as cold pour sealants, have often been the subject of research studies. This study comes as an attempt to determine the feasibility of using hot pour and cold pour sealants. This will be achieved by comparing the long-term performance of both hot and cold pour sealing materials. For the purpose of the study, seven sealing materials were selected: four hot pour sealants designated as H1, H2, H3, and H4 and three cold pour sealants designated as C1, C2, and C3. These materials were applied on eight pavement maintenance sections for testing purposes in five districts in Texas. These districts are Atlanta, El Paso, Amarillo, San Antonio, and Lufkin. A total of thirty-three test sections were constructed between January and April 2001. The main criteria in determining the best sealing material will be the cost-effectiveness. Hence, a cost analysis will be done in two stages for this study. The first one is an initial cost analysis, which was already performed at this point of the research study. This analysis was prepared using the initial costs required in constructing each procedure treatment. The second cost analysis, which is the life-cycle cost analysis, will be performed at the end of the monitoring period of the study. In this analysis, cost of the treatment procedures with regard to their service life will be compared. So far, the initial cost analysis has been completed using two different approaches; both approaches showed that treatments using hot pour sealants cost less than those using cold pour sealants. To evaluate the performance of different sealing materials, the test sections were visited and the treatment jobs were evaluated according to American Association of State Highway and Transportation Officials (AASHTO) procedures (Ref 1). Three investigation visits were conducted: the first one about three months after the construction (Summer 2001), the second one about one year after the construction (Winter 2002), and the third one approximately 18 months after the construction (Summer 2002.) The visits indicated relatively excellent performance for the hot pour sealants in the majority of the test sections. On the other hand, cold pour sealants showed drastic decline in their performance with time.

1.2 Background

State transportation agencies utilize crack sealing as one of the most common procedures of preventive maintenance. The main purpose behind crack sealing is to create a watertight barrier that hinders moisture from reaching the under-layers of the pavement structure. Pavement cracks can be either longitudinal or transverse, and sealing such cracks would have a remarkable effect on prolonging the service life of the pavement. In general, rubberized materials are used as crack sealing agents due to their ductile properties.

In the Texas Department of Transportation (TxDOT), as is the case in many other transportation agencies, hot rubber asphalt has been the most commonly used material for sealing purposes. It is relatively inexpensive and has been proven to perform well after years of usage in pavement preventive maintenance. However, hot rubber asphalt requires being heated at elevated temperatures during the application process. Hot rubber asphalt creates a big hazard for the workers and the public at these very high temperatures. Furthermore, the heating process takes time and this causes a considerable amount of loss of time.

Due to the negative attributes of hot pour sealants, cold pour sealants have come into consideration. The most commonly used cold pour sealants are asphalt emulsions. As opposed to hot pour sealants, cold pour sealants do not need to be heated prior to application. They can be used directly in the ambient temperature. Therefore, they are considered to be safer and more time efficient. Also due to their relatively low viscosity, cold pour sealants can penetrate and fill cracks more effectively. However, they require more time to cure and set, which adds to the time needed to complete the sealing job. Cold pour sealant application is more susceptible to environmental conditions. Therefore, curing time for the cold pour sealants may vary remarkably due to different environmental conditions.

Another difference between the cold and hot pour sealants is the format in which they are commercially stocked and provided. Usually, cold pour sealants are supplied in gallons and hot pour sealants are, on the other hand, supplied in solid blocks. This difference was considered during the initial cost analysis.

1.3 Past Research Experience

It is well understood that applying appropriate preventive maintenance treatments at the right time extends the service life of pavements. Lin et al. (Ref 2) stated that each dollar invested in preventive maintenance at the appropriate time in the life of a pavement might save \$3 to \$4 in future rehabilitation costs. However, the cost-effectiveness of preventive maintenance is usually derived from observational experience. Even if it is based on observational experience, transportation agencies can still apply the knowledge and take advantage of the cost-effectiveness of preventive maintenance. In FY2001, TxDOT allocated at least \$324 million to preventive maintenance treatments. Because of these huge amounts of investment, TxDOT has a great interest in the effectiveness of preventive maintenance treatments. In their study, in which TxDOT participated, the researchers investigated 14 test sites that were subjected to four different preventive treatment procedures (thin overlay, slurry seal, crack seal, and chip seal). TxDOT's distress score concept was adopted to evaluate the effectiveness of preventive maintenance treatments on these sections. The investigated section is given a score from 1 to 100 (very good to very poor). The distress score is a product of what are so-called utility factors, which reflect the contribution of different kinds of pavement stresses including: rutting, patching, and different kinds of cracking. It is seen that although crack seal treatment improved pavement performance, the distress score remained almost the same as computed in this study. There was no improvement in the distress score after the crack seal treatment. This is due to the current TxDOT distress evaluation system making no distinction between a sealed and an unsealed crack. Lin et al. (Ref 2) concluded that when the initial cost was considered, crack seal treatment provides the best alternative for a low traffic route with sound underlying pavement structure.

The emphasis of the Interstate Highway program is shifting from capital investment to maintenance and operation. Senior executives, legislators, and the public believe that maintenance is the key not only to protecting the multibillion dollar highway infrastructure but also continuing to provide a safe and efficient transportation system. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 placed major emphasis on preservation of the system and environment. ISTEA established the Interstate Maintenance Program, which called on states to implement pavement, bridge, and other management systems to extend their life and maximize their efficiency. One of the major methods in pavement preservation is crack sealing. Like any other engineering procedure, crack sealing faces challenges. These challenges can be financial or technical. Because crack sealing is a tedious and labor intensive operation, most of the cost is due to labor expenses. Sims (Ref 3) reported that the associated costs are approximately $1800 per mile with 66% attributed to labor, 22% to equipment, and 12% to materials. However, the procedure of crack sealing is not standardized in practice yet. Hence, construction procedures that minimize road closure and increase laborers' safety must be adopted, and training for better skills and material selection must be improved regularly. It is the role of research to determine the proper procedure for repairing cracks and improving field performance of the sealants.

Smith et al (Ref 4) developed a checklist with the desirable properties of sealing material. Some examples are the ability to be easily placed over the crack, adequate adhesion to remain bonded with the crack faces, resistance to weathering, and resistance to abrasion. Sealing and filling materials are categorized as thermoplastic materials (hot applied and cold applied) and thermosetting chemically cured materials. In this study, both types of thermoplastic sealing materials will be used. Hot applied thermoplastic materials are those that are heated and harden when cooled, usually without chemical change. They possess temperature dependent properties and experience hardening with age. They are the most commonly used crack sealing materials. To enhance their performance, modifiers such as polymers, rubber, or fibers are usually added to hot applied materials. On the other hand, cold applied materials are those that set by releasing of solvents or breaking of emulsions. Emulsified and cutback asphalt are typical cold applied thermoplastics. Cold applied materials are usually modified as well. According to Smith et al.'s questionnaire survey, asphalt rubber as a hot applied material is mainly used in dry climates. They stated that the life expectancy of rubber asphalt is 4.3 years in warm conditions and 2.2 years in cold conditions. Thirty-one agencies that used hot asphalt rubber rated its average effectiveness as good to very good. Emulsified asphalt (cold applied thermoplastic) had a mean life expectancy of 2.3 years in warm dry conditions. However, for wet conditions slightly over one year average life expectancy is found for emulsified asphalt. An average effectiveness rating of fair was determined from a response of 20 agencies that used this material.

In a study to compare performance of various materials and procedures in treating cracks in asphalt concrete pavements, Smith and Romine (Ref 5) conducted research on a total of four transverse crack seal sites and one longitudinal crack fill site. These treatments were installed in locations in the US and Canada in 1991. At each site several experimental treatments were applied. Each treatment consisted of a material, a placement configuration, and a crack preparation procedure. Comparison was basically based on the percentage of failure that occurred on the treatment after installation. Failure in this study was signified by distresses like full-depth pullouts and full-depth adhesion and cohesion loss. The percentage of failure was calculated as the ratio between the length of failed section and the original length of the treatment. In the study, all materials used, except for proprietary emulsion and fiberized asphalt, showed percentage of failure less than 10%. In addition, simple band-aid sealant configuration experienced between four and twenty times more failure than the reservoir-and-flush and the recessed band-aid sealant configurations.

Masson et al (Ref 6) states that hot pour crack sealants are generally composed of four basic ingredients, which are bitumen, oil, polymer, and filler (usually recycled rubber). They conducted a study to investigate and quantify the proportions of these ingredients in four typical sealant samples in a performance-based four-year study. After physico-chemical analysis of the four sealant samples, they tried to examine the correlation between the composition of the sealant and its performance in low and medium temperatures. To determine the composition and properties of the sealants, a series of physico-chemical test methods were performed on each sealant. These methods were viscometry, fluorescence microscopy, infrared spectroscopy, thermogravimetry, and modulated differential scanning calorimetry (MDSC). In addition to that, low temperature tensile testing was performed on the sealant samples. It was found that the physico-chemical properties of crack sealants were related to crack sealant performance. Viscosity and filler content affect adhesion, which controls short-term performance. In other words, low viscosity and low filler contents enhance the bonding of sealant to asphalt concrete (AC), whereas high viscosity and high filler contents introduce interfacial defects that can become failure at the sealant-AC interface. Furthermore, the short-term performance predicted from viscometry and filler content as obtained from microscopy correlated well with the 1-year field performance of the sealants in a wet-freeze climate. A reasonable correlation was also found between the outcome MDSC test and 4-year performance in wet-freeze climate.

1.4 Objectives of this Study

This study is a continuation of an ongoing process of monitoring performance of treatment procedures using two types of crack sealants. The main objective of the analysis in this report is to compare the long-term performance of hot pour sealants to that of cold pour sealants. For the purpose of this comparison four types of materials are used. These materials are: hot pour crack sealant, hot pour joint seal, cold pour crack sealant, and cold pour joint seal. Hot pour crack sealant is basically composed of rubber asphalt and cold pour sealant is composed of different asphalt emulsions.

Crack sealant refers to the sealing materials that are used to seal the cracks generated in asphalt pavements, while joint seals are used to seal the joints of concrete pavements. Joint sealants were included in this study because they must pass a bonding test, and it was thought that the bonding test might be useful for crack sealant specification requirements.

2. First Year Summary

2.1 Introduction

In this ongoing research, hot pour sealants and cold pour sealants were compared in terms of performance, ease and safety of installation, and cost effectiveness. The project will be completed in three years.

During the first year, surveys on crack sealing techniques and materials have been completed. Nine states and twenty-five districts in Texas have participated in the survey. Also, thirty-three test sections were constructed on eight roads in five districts in Texas. Both hot and cold pour sealants were applied on the cracks in the test sections. Construction cost analysis was determined after the construction work was completed. This analysis did not take long-term performance of the pavement into consideration, which may influence the cost effectiveness. More comprehensive cost analysis would be the life-cycle cost analysis. At this stage of the project, life-cycle cost analysis could not be performed, because the service life of the treatment procedures is required to calculate the life cycle cost. Test sections have been inspected regularly during the first year of the project. During the first year, every test section was investigated twice.

2.2 Survey Results

Surveys were conducted in twenty-five districts in Texas, and in nine states in the USA. Twenty-one out of twenty-five districts in Texas responded to the survey. Hot pour sealants were commonly used sealing materials in all districts, while cold pour sealants were used only by some of the districts. The survey included ten questions; each was answered in the form of a ranking such as: poor, fair, good, and excellent. Overall performance of hot pour sealants seemed to be better than that of cold pour sealants, while resistance of hot pour sealants to flushing and bleeding appeared to be poor. Effective life of hot pour sealants also was much higher than effective life of cold pour sealants.

Nine other states also responded to the survey. All of the states used hot pour sealants, and five of them also used cold pour sealants. Ten questions that are the same ones used in the Texas districts were utilized in the states' surveys. According to the states' survey, hot pour sealants perform well except for resistance to flushing and bleeding, while cold pour sealant was ranked poor in most of the cases. Effective service life of cold pour sealants was never higher than three years, while effective service life of hot pour sealants went up to five years. Both districts' and states' survey results clearly showed that hot pour sealants performed better than cold pour sealants.

2.3 Material Properties of Sealants

Of each type, hot pour and cold pour, both crack sealants and joint sealants were used in this study. Crack sealants are used to fill the pavement cracks, whereas joint sealants are generally used to seal concrete pavements' joints. Two different cold pour crack sealants and one cold pour joint sealant were applied. Cold pour crack sealants were designated as C1 and C2, and they met TxDOT requirements for Item 3127 specifications. Cold pour joint seal designated as C3 satisfied TxDOT requirements of DMS-6310, Class 9 specifications. Three hot pour crack sealants (H1, H2, and H3), and one hot pour joint sealant were used. H1 and H3 satisfy TxDOT's GSD Spec. 745-80-25, Class A, and H2 satisfies GSD Spec. 745-80-25, Class B requirements. Joint sealant H4 met DMS-6310, Class 3 specification requirements. Laboratory test results of the sealing materials used in this study are depicted in Appendix A. Specifications for GSD 745-80-25, Item 3127 and DMS-6310 are located in Appendix B.

Eight of thirty-three test sections were overlaid with a chip seal layer during the following summer in order to observe the tendency of sealants to bleed. The bleeding problem was basically expected to occur in sections treated with hot pour sealants since it was recorded earlier in the surveys.

2.4 Initial Cost Analysis

Cost analysis for construction was done for the non-covered test sections. Sealing materials, equipment for traffic control, sealing equipment, hot pour equipment, and crew labor cost were taken into consideration when calculating costs. Cost analyses were done in two ways. The first method was to determine the total amount spent to seal a crack; then, this amount was divided by the total length of the treatment to determine the cost per foot. It was found that the longer the crack, the lower the cost, because some costs are constant regardless of length of crack. Therefore, sealants applied on long sections may seem to be cheaper. The second method provides more reliable comparison. A 50,000 ft crack length was assumed for all sealants. The production rate (feet per hour) from the test sections was used to determine the time required to seal a 50,000 ft crack. The cost for sealing 50,000 ft was calculated and the other costs such as equipment preparation, traffic control, etc. were added to calculate the total cost. Cost analyses show that using the same volume of sealants, cold pour sealants can seal more cracks than hot pour sealants. A 115 ft crack can be sealed using one gallon of cold pour sealant, while only a 75 ft crack can be sealed with one gallon of hot pour sealant. On the other hand, per gallon cost of cold pour sealant is almost twice that of hot pour sealant. However, construction cost is not the sole factor in cost effectiveness. Performance of a sealant is also another significant factor. Also, field performance allows for determining lifetime cost. However, life-cycle cost analysis can only be done when all the treatments reach failure point.

2.5 Evaluation Technique

2.5.1 Non-Covered Sections

Determining short-term and long-term performance of sealants on non-covered and covered test sections is one of the primary objectives of this project. Short-term performance of 25 non-covered sections was determined at the end of 4 months after the construction. Sections were also visited for visual observation once in the winter and once in the summer to gather information for long-term performance. Test sections were visually monitored for the following types of failure:

- Open previously sealed cracks
- Adhesion loss
- Cohesion loss
- Loss of seal in previously sealed cracks
- Settlement and bleeding of sealants
- Pullout of material
- Spalls or secondary cracks in or near the sealed crack
- Other distresses

A pointed tool was used to determine the strength of bonding between the sealant and pavement. Pullout tests were conducted by two individuals to eliminate bias in observation. They ranked the easiness of pulling sealant as “Easy,” “Medium,” or “Difficult.” This ranking determines adhesion and cohesion loss of the material. Settlement and bleeding of sealants were also measured. Since settlement is common for cold pour sealants, water may accumulate in the settled areas and penetrate into the crack which leads to loss in adhesive and cohesive forces. Height of the hot poured sealant is critically important in terms of ride quality. All other failures were inspected visually and recorded.

Treatment effectiveness can be calculated using percent failure. Percent failure is calculated by dividing failed length of sealed cracks by total length of sealed cracks.

Percent Failure = 100 * (Failed length/Total length)

Percent Treatment Effectiveness = 100 – Percent Failure

After that, a treatment effectiveness versus time graph is plotted. This graph will be helpful in predicting the life of treatment if the effectiveness trend can be somehow extrapolated.

2.5.2 Covered Sections

Bleeding is the main problem when a pavement is overlaid or chip-sealed after crack treatment. If excessive crack sealant is placed, sealing material fills the voids and tends to penetrate through the chip seal surface creating a shiny, glass-like, reflecting surface. Strategic Highway Research Program (SHRP) identifies three levels for bleeding:

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 SHRP Manual recommends measuring the area of bleeding surface, but in this project only length of the bleeding sections was measured.

The eight overlaid or seal-coated test sections were observed for sealant bleeding through the subsequent seal coat or overlay. These sections were designated as “Covered” sections. Sections were observed at the end of three months after construction for short-term performance. Roads will be monitored once in winter and once in summer every year to determine long-term performance. These sections were visually inspected and the rate of bleeding for each sealant type was recorded. Bleeding amount and rate were used to determine the rate of failures, which determines the treatment effectiveness.

2.6 Performance Results for Non-Covered Sections Four Months after Crack Seal Construction

2.6.1 Atlanta

In Atlanta, no newly developed cracks were observed on sections where H1 and H2 sealants were applied. Cohesion and adhesion of these sealants were ranked as “Difficult,” and there was no sealant loss. Cold pour sealants C1, C2, and C3 on this section did not have any newly developed cracks as well. C1 and C2 showed adhesive and cohesive failures. C3 sealant had pullout problems in some parts of the treatment. C1 was ranked as “Medium” and C2 and C3 were ranked as “Easy” to pullout.

2.6.2 El Paso

Similar results were obtained in El Paso, where heavy border traffic is taking place. Failures were observed on wheel paths. All the failures were observed on cold pour sealant treated sections.

2.6.3 Amarillo

In Amarillo, failure had a scattered pattern. Failed sections of the treatment were not confined to certain parts of the pavement. This is possibly due to weather conditions in Amarillo, where freeze/thaw cycles are likely to occur. The C1 sealant section showed excessive failure, while the other sections H1, H3, and H4 exhibited very good performances.

2.6.4 San Antonio

Failures were observed in cold pour sealed sections in San Antonio. Sections sealed with C1 exhibited newly developed thin cracks. Depression of cold pour sealants was more severe in the test section in this district.

2.6.5 Lufkin

All sealants showed very good performance in Lufkin. No failure signs were observed in these test sections. As was the case in other districts, cold pour sealants were softer than hot pour sealants.

2.7 Performance Results for Covered Sections

Covered test sections in Atlanta and Amarillo were constructed. Both cold and hot pour sealants were used in these test sections. After sealing, treated test sections were covered with chip seal. The chip seal applied was AC-15-5TR binder, which consisted of a minimum of 5% ground tire mixed with grade 4 aggregate.

Sections in Atlanta and Amarillo were visited two months after the chip seal was constructed. In Atlanta, C2 and H1 sealants were applied. Sections treated with H1 showed a low level of bleeding, while no bleeding was observed on the section sealed with C2. In Amarillo two sealants, C1 and H3, were applied. None of the sections showed bleeding. The chip seal proposed for Lufkin was not constructed during the first year.

3. Performance Evaluation Process

In the evaluation process, American Association of State Highway and Transportation Officials (AASHTO) procedure was adopted to calculate percentage of effectiveness. The main types of failure considered were opening of sealed cracks, full depth adhesion or cohesion loss, and spalls.

AASHTO procedure provides a standard practice for evaluating the performance of crack sealing treatment (Ref 1). This practice can be used for several types of crack sealants such as: cold applied sealants, hot applied sealants, and chemically cured sealants. It also can be used for the selection of crack sealant filler materials, placement configurations, and finishing operations. The projected life of the treatment can be determined by extrapolation of the function of treatment effectiveness versus time.

As shown in Figure 3.1, the main product of this evaluation procedure is a chart depicting effectiveness (in percentage) with respect to time of measurement. A minimum of one evaluation measurement each year is needed to provide an estimation of the performance of the crack treatment. For the most effective evaluation, measurements should be conducted during the mid-winter period when the crack is subjected to maximum opening. It is suggested that the first inspection be made during the first winter, while another can be done after winter to assess winter damage. Along with the traffic control devices, the basic apparatus needed is a distance measurement device like a measuring wheel.

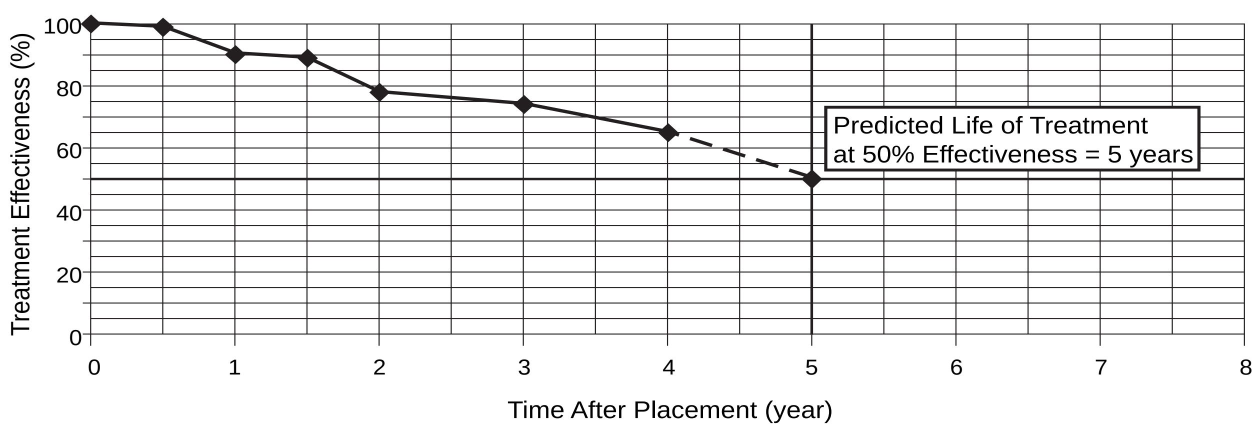

Figure 3.1 Example graph of treatment effectiveness versus time

An unbiased sample of the pavement treated section is used for testing. The sample length must not be less than 150 m (492 ft) in length. Generally, pavement sections are grouped according to the type of treatment, sealant, or sealing procedure. When a pavement sample has been previously evaluated, it is best to use the same section for re-evaluation in the succeeding evaluation procedures. Otherwise, a minimum of 5 different pavement samples are selected each year.

To determine the effectiveness, first the length of cracks is measured and recorded to the nearest 300 mm (12 inches). Qualitative evaluation is performed by visual examination of cracks, and the type of failure is recorded. Failure can be in the form of full-depth adhesion or cohesion loss, complete pullout, spalls and secondary cracks, potholes, etc. Length of failure of all cracks is measured and recorded. The treatment effectiveness is the ratio between the length of remaining sealed crack and the length of the original treatment in percentage.

4. Field Evaluation Results

4.1 Non-Covered Test Sections

For the purpose of evaluating the long-term performance of the non-covered sections, two successive investigations were conducted after the first one. Regardless of which district the treatment was applied, the performance of hot pour sealants was better than that of cold pour sealants in general.

4.1.1 Atlanta

Five types of sealants were used in this district, two hot pour sealants (H1 and H2) and three cold pour sealants (C1, C2, and C3). C3 and H4 are joint sealants. The treatment procedures were installed on January 31, 2001 on US 290 in Morris County in the southbound, outside lane. The first investigation test for short-term performance evaluation was made on May 24, 2001. Two other investigations were conducted on February 13 and August 7 of 2002.

The pavement structure of this section was an AC overlay on Jointed Concrete Pavement (JCP), where most of the cracks were reflection cracks over the joints. These cracks were transversely spaced at 15 ft (4.5 m). The main source of the cracks was probably the heavy truck traffic that caused movements of joints, which could be seen by the naked eye in some cases.

Hot pour sealants exhibited excellent performance compared to cold pour sealants. During the winter 2002, both hot pour sealants designated as H1 and H2 scored effectiveness greater than 89%. At the summer 2002 investigation the two hot pour sealants scored an effectiveness of more than 98%.

Cold pour sealants, on the other hand, showed average effectiveness of slightly less than 70% about one year after construction when the winter 2002 investigation was conducted. By the time the third investigation was conducted in August, 2002, cold pour sealants scored an average of 66%. In contrast to C1 and C3, performance of C2 seems to continue to decrease even after the second investigation. Figure 4.1 depicts performance trends for the sections in Atlanta district.

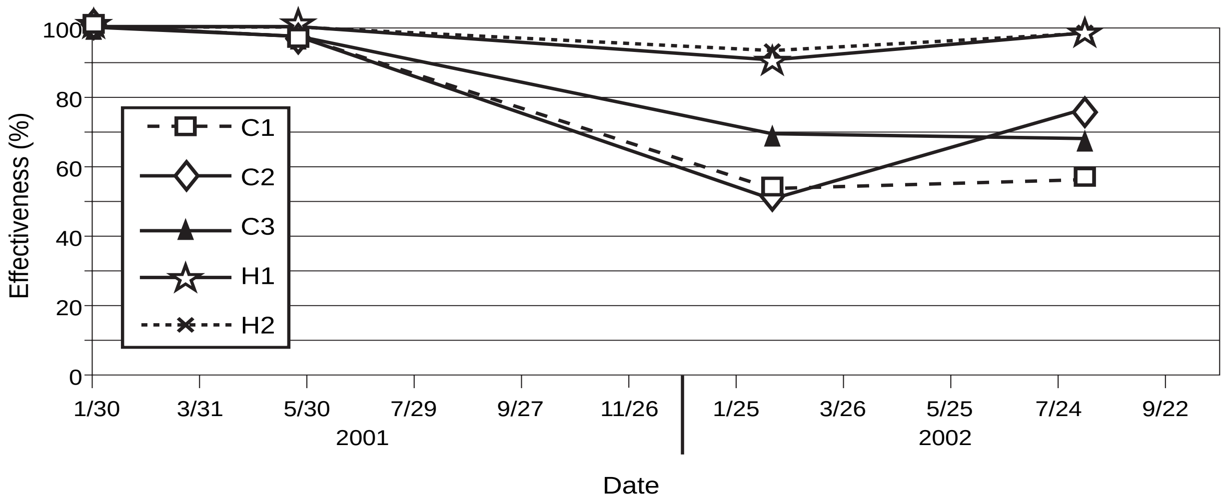

Figure 4.1 Performance trends for the sections in Atlanta district

4.1.2 El Paso

Four types of sealants were used in this district, two hot pour sealants (H2 and H3) and two cold pour sealants (C1 and C2). The treatment procedures were constructed on May 5, 2001 on Loop 375 in El Paso County on the Border Highway in the eastbound, outside lane. The first investigation test was made on June 19, 2001 for short-term performance evaluation. The second and third investigations were made on April 10, 2002 and August 22, 2002, respectively. These test sections are located in a heavy-truck traffic area by the US-Mexico border. Therefore, most of the failures occurred on the wheel path.

The performance of hot pour sealants surpasses that of cold pour in this district as well. However, the effectiveness of the hot pour sealants used in this district (H2 and H3) dropped to slightly below 80% at the winter 2002 investigation. At the summer 2002 investigation, hot pour sealants scored an average effectiveness of 92.4%.

The performance of cold pour sealants was in general lower than that of hot pour sealants. Unlike the other sealants, the performance trend of C2 continued to drop even after the winter 2002 investigation visit, where it reached 8.4%. The performance trends of the sealing materials used in El Paso are shown in Figure 4.2.

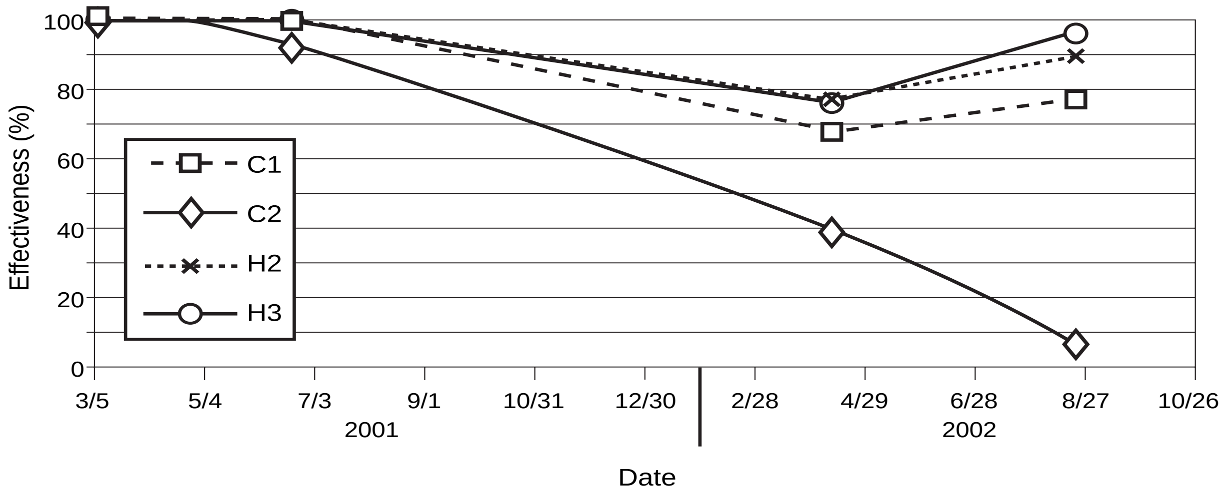

Figure 4.2 Performance trends for the sections in El Paso district

4.1.3 Amarillo

In the Amarillo district, three hot pour sealants (H1, H3, and H4) and two cold pour (C1 and C3) were used. The treatment procedures were constructed on February 19, 2001 on FM 1151 in Randall County in the eastbound, outside lane. Then, three investigation visits were made on June 21, 2001, March 31, 2002, and August 15, 2002, respectively.

Except for H3, hot pour sealants showed excellent performance with an effectiveness greater than 90% even after about 13 months of installation. Hot pour sealant H3 attained only 65.8% effectiveness after the same period. However, during the summer of 2002, H3 attained an effectiveness of 85.2%.

In this district at the winter 2001 investigation, performance of cold pour sealants showed very low values. Nonetheless, at the summer 2002 investigation, the performances of C1 and C3 drastically climbed up to 84.3% and 90.8% respectively. Figure 4.3 depicts performance trends of the sealants used in test sections in Amarillo district.

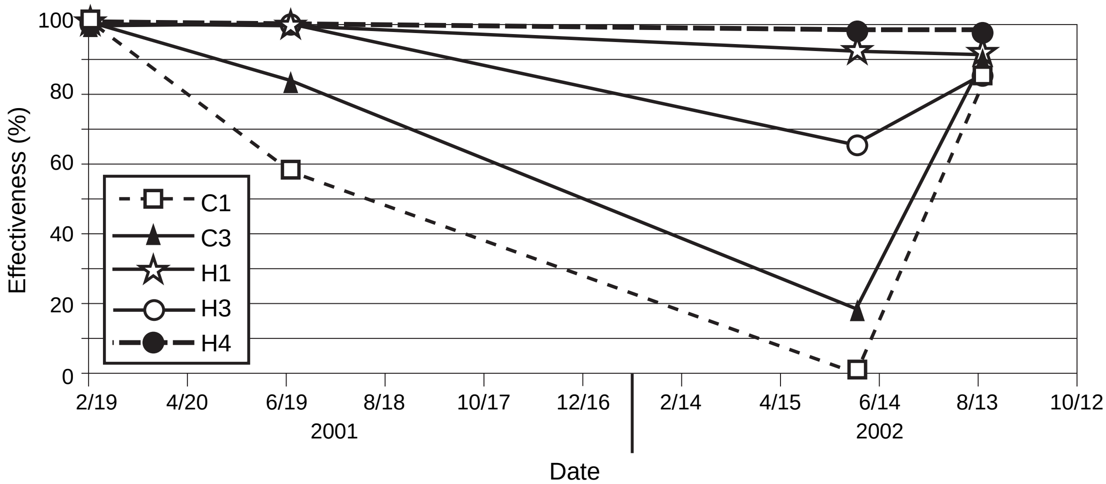

Figure 4.3 Performance trends for the sections in Amarillo district

4.1.4 San Antonio

All the types of sealing materials were used in treatment procedures in this district. Treatment construction started on April 25, 2001 on US 87 in Bexar in the southbound, outside lane. An investigation visit was conducted on July 18, 2001. The next two investigation visits were made on March 8, 2002 and September 14, 2002.

Despite the decreasing performance of H2 at the winter 2002 investigation, which dropped to a score of only 58%, the other hot pour sealants attained an effectiveness level greater than 91%. At the summer 2002 investigation, H1, H3, and H4 reached an effectiveness level close to 100%. Similarly, the effectiveness of H2 increased approximately to 92%.

Sealant C1 failed totally at the winter 2002 visit. Unlike the other two cold pour sealants, the performance trend of C1 did not increase after the winter 2002 evaluation; whereas sealants C2 and C3 maintained effectiveness of 95% and 85% respectively. Figure 4.4 depicts the performance trends of the sealants used in test sections in San Antonio district.

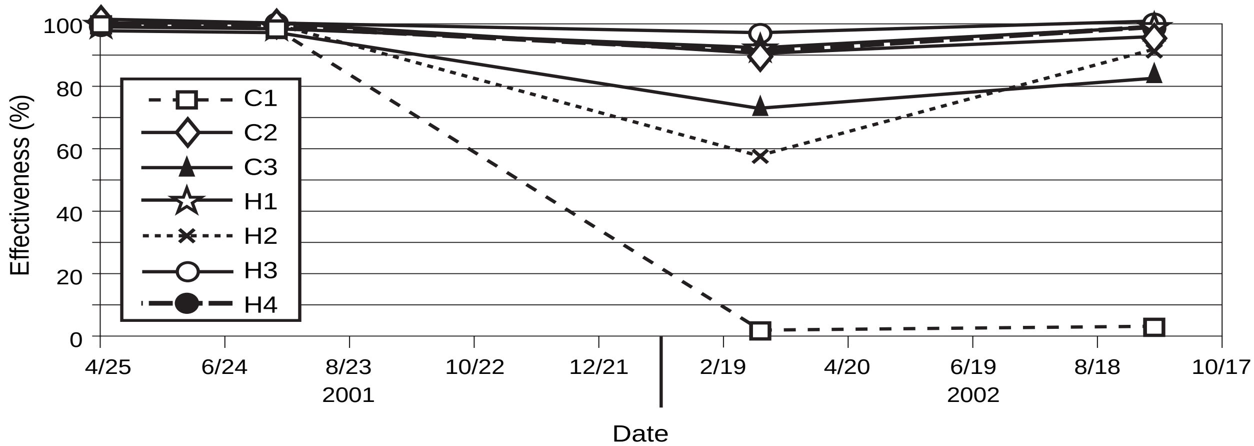

Figure 4.4 Performance trends for the sections in San Antonio district

4.1.5 Lufkin

In Lufkin district two cold pour sealants (C2 and C3) and two hot pour sealants (H1 and H4) were installed on February 6, 2001 on US 59 in Polk County in the southbound, outside lane. Then, evaluation tests were conducted three times: on May 7, 2001, February 22, 2002, and August 22, 2002.

As was the case in most of the other districts, hot pour sealants attained effectiveness greater than that of cold pour sealants, scoring an average of 97% after the first investigation. The performance of H4 stayed the same. H1 exhibited an increase in effectiveness from 91% to 97% after the winter 2002 evaluation. The performances of both C2 and C3 declined after the first evaluation. At the summer 2002 evaluation, cold pour sealant C2 scored an effectiveness greater than 95%. The performance of C3 could not be measured at the summer 2002 investigation; because this test section had deteriorated significantly, it had been milled and given a new overlay. Figure 4.5 illustrates the performance trends of the sealants used in the sections in Lufkin district.

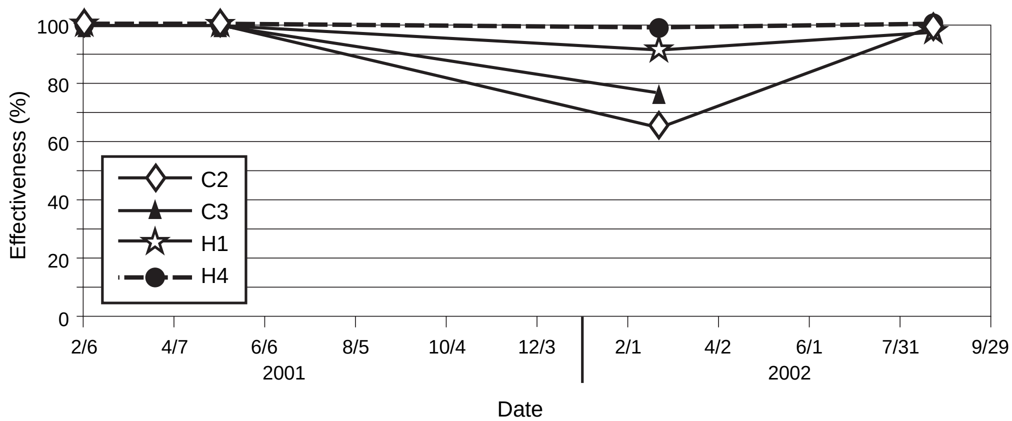

Figure 4.5 Performance trends for the sections in Lufkin district

4.2 Covered Test Sections

As mentioned before, these test sections were installed to evaluate the tendency of the sealing materials to bleed through a chip seal or overlay. These test sections were constructed in Atlanta, Amarillo, and Lufkin districts. Results for the length of bleeding sections on covered test sections based on each visit and district are located in Table 4.1.

4.2.1 Atlanta

In Atlanta, crack seal was applied on January 31, 2001, and chip seal was applied on June 20, 2001, to Loop 281 in Harrison County in the southbound, outside lane. An evaluation was made after two months and the results are mentioned in Chapter 2. This section was evaluated again on August 8, 2002.

Before applying chip seal, the test sections were treated using hot pour sealant H1 and cold pour sealant C2. Sections treated with H1 showed bleeding signs of low severity level. The length of the bleeding portions was 407 ft (124 m). Figure 4.6 shows a part of the section that is treated with H1, which developed bleeding. Sections treated with C2 showed no bleeding problem. Figure 4.7 shows the C2-covered test section in Atlanta during the August 8, 2002 investigation visit.

Table 4.1 Length of Bleeding Sections on Covered Sections Based on District and Visit

District	Sealant	First Visit Summer 2001	Second Visit Summer 2002
Atlanta	C2	-	-
	H1	700	407
Amarillo	C1	-	-
	H3	-	-
Lufkin	C1	-	-
	C2	-	-
	H1	-	214
	H3	-	150

Figure 4.6 Atlanta, H1-covered test section during the August 8, 2002 investigation visit

Figure 4.7 Atlanta, C2-covered test section during the August 8, 2002 investigation visit

4.2.2 Amarillo

This test section, located in Randall County on FM 1541 in the Southbound, Outside Lane, was crack sealed on February 20, 2001 and was chip sealed and visited for evaluation two months after the chip seal. Cold pour sealant C1 and hot pour sealant H3 were used for crack treatment before the chip seal was applied on August 17, 2001. Then, the test sections were investigated again on August 15, 2002. Once more, the hot pour sealant seemed to engender a bleeding problem. However, the severity of the bleeding was very low. Figure 4.8 shows the H3-covered section in Amarillo during the August 15, 2002 investigation visit. On the other hand, the test section that was treated with C1 did not show any bleeding problems. Figure 4.9 shows the C1-covered section in Amarillo during the August 15, 2002 investigation visit.

Figure 4.8 Amarillo, H3-covered test section during the August 15, 2002 investigation visit

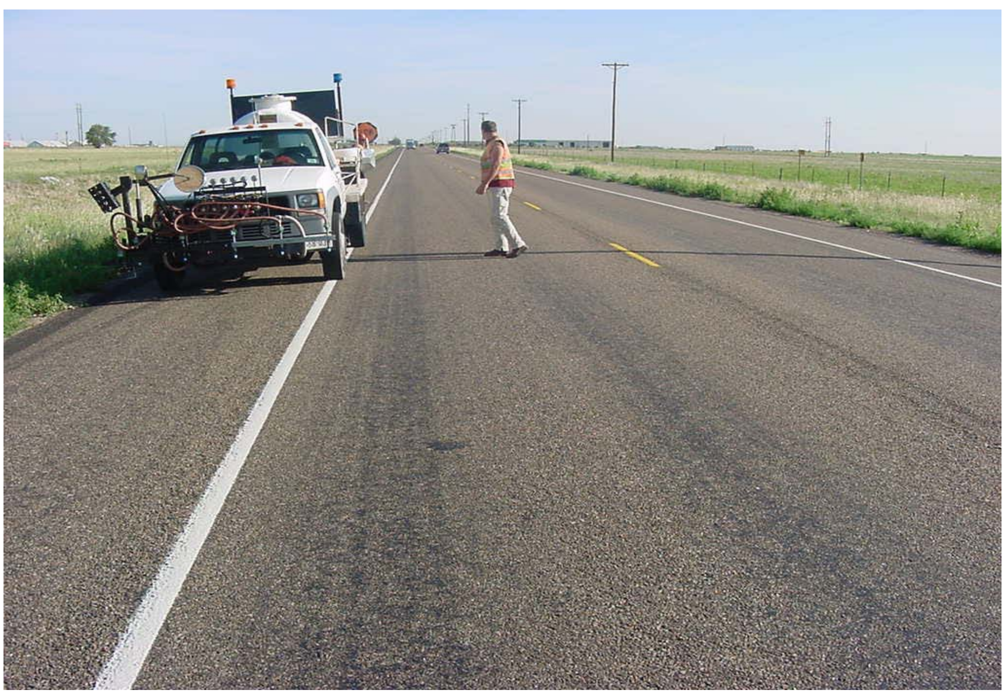

Figure 4.9 Amarillo, C1-covered test section during the August 15, 2002 investigation visit

4.2.3 Lufkin

This test section, located in Polk county on US 190 in the Westbound, Outside lan, was chip sealed on June 25, 2002, and then crack seal was applied on February 7 and 8, 2001. It was investigated once only on August 20, 2002. Two cold pour sealants (C1 and C2) and two hot pour sealants (H1 and H3) were used for crack treatment of this test section. As expected, bleeding was observed during the investigation of hot pour treated sections. However, its severity was very low. Bleeding portion lengths were 214 ft (65.2 m) and 150 ft (45.7 m) for H1 and H3 respectively. In the case of cold pour sealants, no signs of bleeding were observed. Figures 4.10 through 4.13 show the covered sections in Lufkin that are treated with C1, C3, H1, and H3 respectively.

Figure 4.10 Lufkin, C1-covered test section during the August 20, 2002 investigation visit

Figure 4.11 Lufkin, C2-covered test section during the August 20, 2002 investigation visit

Figure 4.12 Lufkin, H1-covered test section during the August 20, 2002 investigation visit

Figure 4.13 Lufkin, H3-covered test section during the August 20, 2002 investigation visit

5. Discussion of the Results

The findings of this study were obtained in two stages. The results of each stage will be discussed in order to understand the performance trend of the sealing materials. The first stage refers to the short-term performance evaluation, which was done within 3–4 months after crack sealants were placed. The overall summary of the findings of this stage is shown in Table 5.1.

Table 5.1 Effectiveness Evaluation Results for the Short-Term Performance after the First Investigation (3-4 months after crack sealing)

	Effectiveness (%)					
	1st visit (3–4 months after installation)					
Sealant Material	***Atlanta***	***El Paso***	***Amarillo***	***San Antonio***	***Lufkin***	**AVG.**
C1	95.1	98.9	57.7	99.1	N/A	87.7
C2	97	93.4	N/A	98.6	100	97.3
C3	96.6	N/A	84.2	98.6	100	94.9
H1	100	N/A	99.8	99.8	100	99.9
H2	100	100	N/A	99.8	N/A	100
H3	N/A	100	99.2	99.9	N/A	99.7
H4	N/A	N/A	99.4	100	100	99.8
Date of investigation	5/24/2001	6/19/2001	6/21/2001	7/18/2001	5/7/2001	
AVG. for Cold Pour	96.2	96.2	71.0	98.8	100	92.4
AVG. for Hot Pour	100	100	99.5	99.9	100	99.9
Overall AVG.	97.7	98.1	88.1	99.4	100	96.7

The first investigation was made shortly after the construction was done. It was found that the overall performance of hot pour sealants was slightly better than that of cold pour sealants. Regardless of the district, all hot pour sealants gave the best results, scoring an effectiveness level of approximately 100%. C1 performed the worst with 87.7% effectiveness. Except Amarillo, all the districts exhibited an overall effectiveness greater than 97%.

The second stage or the long-term performance evaluation is a long process in which several more investigations will be conducted in the following years. This stage began with the second investigation of the test sections in the winter of 2002. The overall summary of the second visit is shown in Table 5.2.

Table 5.2 Effectiveness Evaluation Results for the Long-Term Performance after the Second Investigation (Winter 2002)

	Effectiveness (%)					
	2nd visit (Winter 2002)					
Sealant Material	***Atlanta***	***El Paso***	***Amarillo***	***San Antonio***	***Lufkin***	**AVG.**
C1	53.8	66.9	0	0.3	N/A	30.3
C2	50.7	40.4	N/A	88.9	65.4	61.4
C3	69	N/A	18.6	74.1	77.3	59.8
H1	89.9	N/A	91.9	91	91	91.0
H2	92.7	77.8	N/A	57.6	N/A	76
H3	N/A	76.1	65.8	96.8	N/A	79.6
H4	N/A	N/A	98	92.1	99.3	96.5
Date of investigation	2/13/2002	4/10/2002	5/31/2002	3/8/2002	2/22/2002	
AVG. for Cold Pour	57.8	53.7	9.3	54.4	71.4	49.3
AVG. for Hot Pour	91.3	77.0	85.2	84.4	95.2	86.6
Overall AVG.	71.2	65.3	54.9	71.5	83.3	69.2

The second investigation was conducted about one year after the construction. It was found that the performance of hot pour sealants was still better than that of cold pour sealants in every district. Hot pour sealant H4 seems to have the optimum performance among other sealants. Cold pour sealant C1 has the least resistance to traffic and environmental influences with an effectiveness level of 30.3% after one year from installation. The results show a general trend of decrease in effectiveness level for all the sealants. However, the decrease is much steeper for cold pour sealants.

The third investigation was conducted about 18 months after the construction during the summer of 2002. The results of this investigation are shown in Table 5.3.

Table 5.3 Effectiveness Evaluation Results for the Long-Term Performance after the Third Investigation (Summer 2002)

	Effectiveness (%)					
	3rd visit (Summer 2002)					
Sealant Material	***Atlanta***	***El Paso***	***Amarillo***	***San Antonio***	***Lufkin***	**AVG.**
C1	56.12	75.86	84.3	1.26	N/A	54.4
C2	75.4	8.4	N/A	94.53	65.4	69.2
C3	67.4	N/A	90.8	85	N/A	81.1
H1	98	N/A	91.1	99.1	97.1	96.3
H2	98.6	89.53	N/A	91.75	N/A	93
H3	N/A	95.23	85.2	99.82	N/A	93.4
H4	N/A	N/A	97.4	99.8	99.9	99.0
Date of investigation	8/7/2002	8/22/2002	8/15/2002	9/14/2002	8/22/2002	
AVG. for Cold Pour	66.3	42.1	87.6	60.3	98.4	68.2
AVG. for Hot Pour	98.3	92.4	91.2	97.6	98.5	95.5
Overall AVG.	79.1	67.3	89.8	81.6	98.5	83.8

An increase in the performance of the sealants was observed during the third investigation as opposed to an expected decrease in performance with time. This can be attributed to the fact that cracks close during summer months. As is seen in Table 5.3, the investigation was made during the summer period when the temperature is expected to be at its highest. Also, at high temperatures, the viscosity of the sealing material decreases, which may cause re-filling of the generated cracks. In the case of hot pour sealants, the sealant originally plugs mainly the top part of the crack and does not penetrate all the way down to the crack root. Hence, it is more likely that the failed sections treated with hot pour sealants will recover in high temperatures due to the decrease in viscosity. Since excessive amounts of hot pour sealant are usually accumulated near the surface, when the viscosity drops, enough material will be available to seal the failed sections. On the other hand, cold pour sealants have lower viscosity than hot pour sealants. Therefore, when they are applied for the first time, they tend to penetrate the cracks more thoroughly. This leaves less surplus material and subsequently less recovery in the failed sections when the viscosity drops due to high temperatures. Figure 5.1 shows the configuration of hot and cold pour sealants after being applied in the crack.

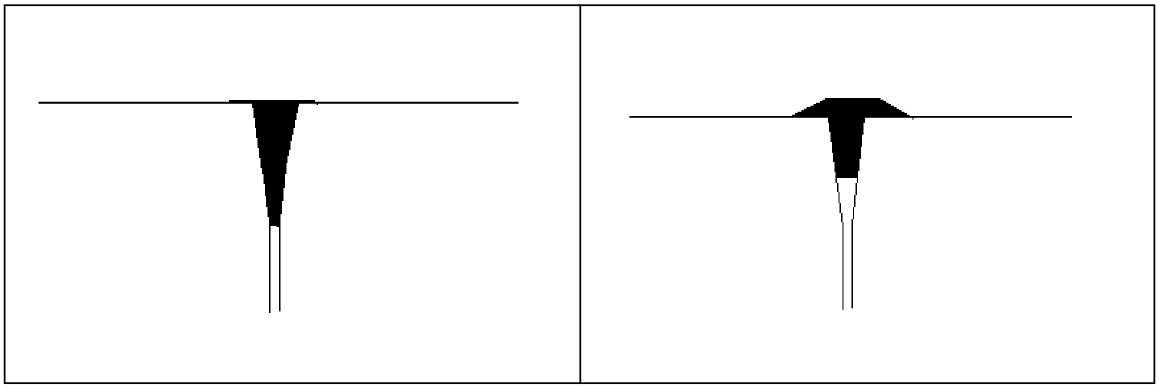

Figure 5.1 Sealing material configurations in the crack

The proportionality among the sealants' effectiveness, however, remained very similar to that in the winter 2002 investigation. Again, H4 achieved the best overall effectiveness whereas C1 achieved the lowest overall effectiveness.

Since both traffic and environmental conditions vary from district to district, a comparison of sealants' performance in each district is necessary. This kind of a comparison will provide more information about the performance of the sealants and its correlation to prevailing factors where it was installed. Weather records were extracted from www.weather.com in order to achieve a better understanding of the performance trends of sealing procedures in different districts (Ref 8). Table 5.4 includes average annual extremes, average mean temperatures, and average annual precipitation in the five districts.

Table 5.4 Weather Annual Averages for the Districts

	Atlanta	***El Paso***	***Amarillo***	***San Antonio***	***Lufkin***
Max Temp. °F	93	96	91	95	93
Min Temp. °F	30	29	21	37	36
Range °F	63	67	70	58	57
Mean °F	63	63	56	68	66
Sum Precipitation (in)	35.4	8.9	19.6	30.9	42.4

For a better understanding of the behavior of the sealing materials, they must be categorized according to their types. The first category is the hot pour sealants with H1, H2, and

H3 as crack sealants and H4 as joint sealant. The second category is the cold pour sealants with C1 and C2 as crack sealants and C3 as joint sealant.

Crack sealant H1 and joint sealant H4 performed very well, scoring approximately over 90% at the winter 2002 investigation and over 96% at the summer 2002 investigation in all the districts. Joint sealant H4 exhibited the highest performance among all other sealing materials. It showed highest values of penetration at 39.2° F and 77° F. Also, it had the maximum resilience value as is shown in Appendix A. The second best performance was attained by crack sealant H1. Although it had better performance than the other two hot pour crack sealants (H2 and H3), no significant difference in material properties could be found between H1 and the other two.

Cold pour sealants C2 and C3 showed relatively similar performance, while C1 showed the lowest performance, having an average performance of 30.3% after the winter 2002 investigation and 54.4% after the summer 2002 investigation. No significant correlation could be established between the laboratory test results and the field performance of cold pour sealants. Furthermore, annual temperature range seems to have an effect on the performance of different sealing materials. This is expected since the temperature range controls thermal movements of the cracks. This effect can be seen in the performance trends of H3 and to some extent C2 and C3. Figures 5.2 and 5.3 show performance trends of hot and cold pour sealants with respect to annual rainfall and temperature range after the winter 2002 investigation. It appears that as the temperature range decreases, the sealant effectiveness increases.

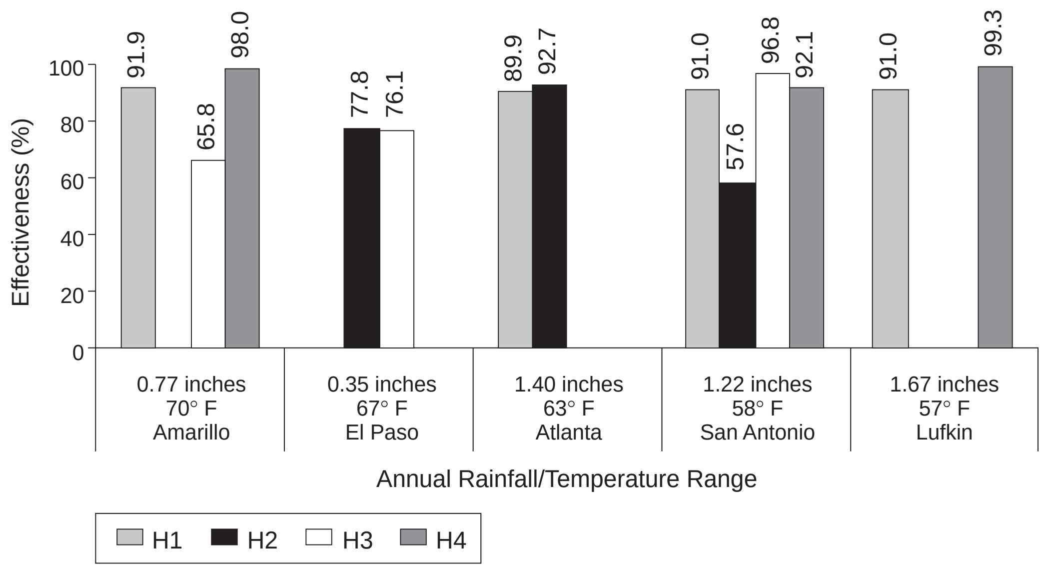

Figure 5.2 Performance trends of hot pour sealants with respect to temperature range after the winter 2002 investigation

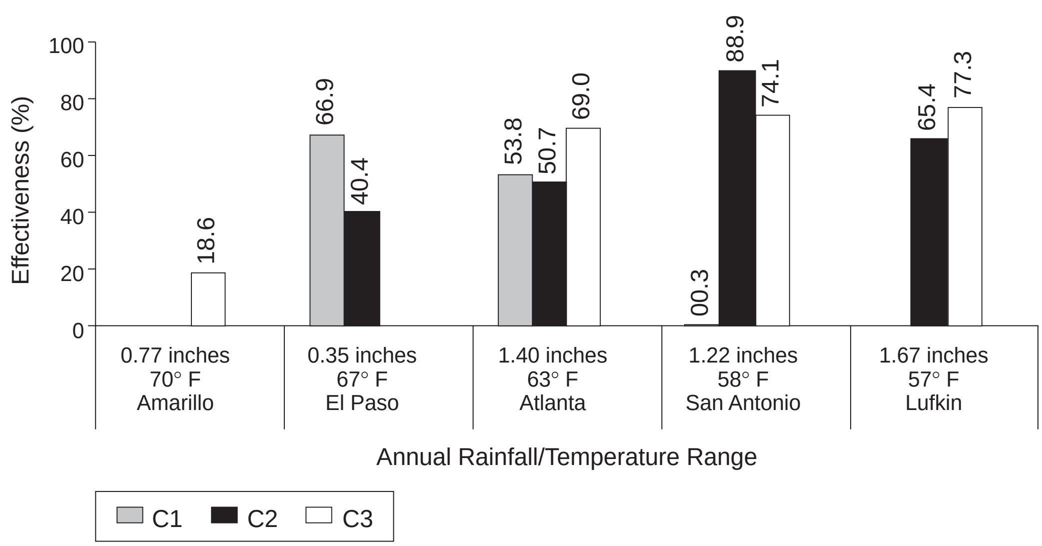

Figure 5.3 Performance trends of cold pour sealants with respect to temperature range after the winter 2002 investigation

Similarly, performance trends of both hot and cold pour sealants with respect to environmental factors after the summer 2002 investigation are shown in Figures 5.4 and 5.5 respectively.

For the hot pour sealants, there is a pattern of increase in performance with the decrease of annual temperature range. This pattern can be clearly seen in the performance trend of H3 and H4 where their performance continues to increase as we go from Amarillo to Lufkin. This trend also occurs generally in the performance of H1 and H2.

For the cold pour sealants, on the other hand, two different patterns can be extracted. The first pattern is that of C1 (highest softening point, 202° F, among the cold pour sealants) where the effectiveness exhibits a continuous drop with the decrease of annual temperature range. The opposite pattern is exhibited by C2 (lowest softening point, 158° F among the cold pour sealants) in which the effectiveness increases with the decrease of annual temperature range.

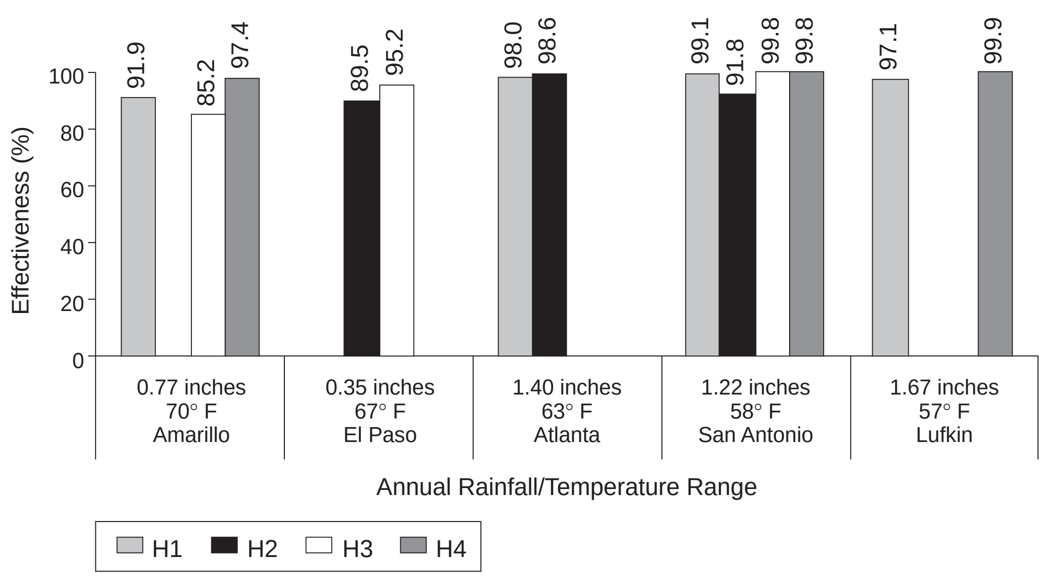

Figure 5.4 Performance trends of hot pour sealants with respect to temperature range after the summer 2002 investigation

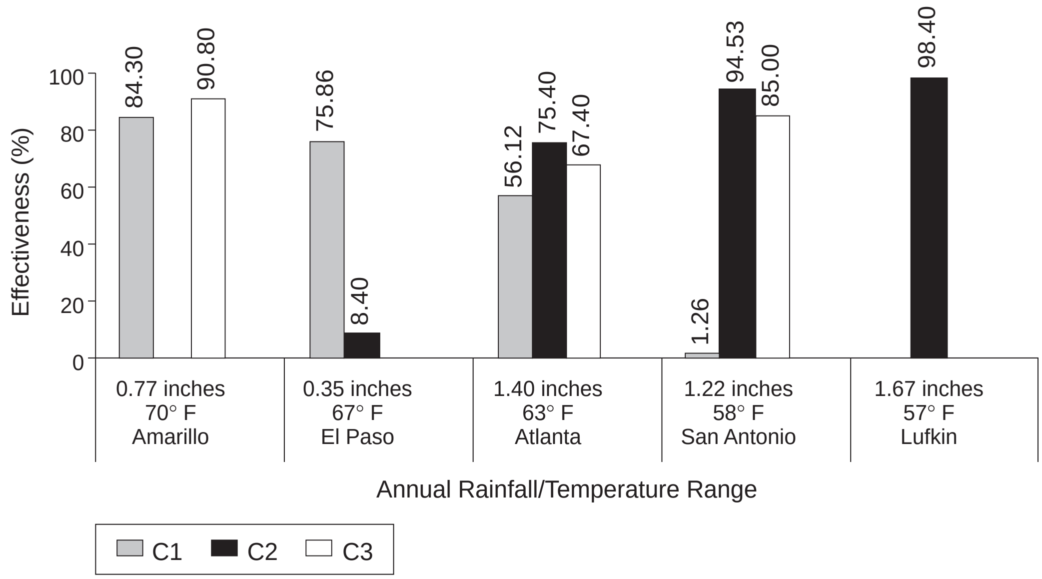

Figure 5.5 Performance trends of cold pour sealants with respect to temperature range after the summer 2002 investigation

The increase in the percent effectiveness in the summer seems to have a correlation with the maximum annual temperature. This phenomenon is largely based on the temperature range and the natural process of cracks opening in the winter and closing in the summer, plus other pavement, soil, and rain conditions. This was expected given the configuration of the hot pour sealing material in the crack. The recovery of hot pour sealants at different districts is shown in Figure 5.6.

The recovery rate for the cold pour sealants seems to respond contrarily. Higher rates of recovery were exhibited in districts with lower annual maximum temperatures, such as Amarillo. Figure 5.7 shows the cold pour sealants' recovery rate in different districts.

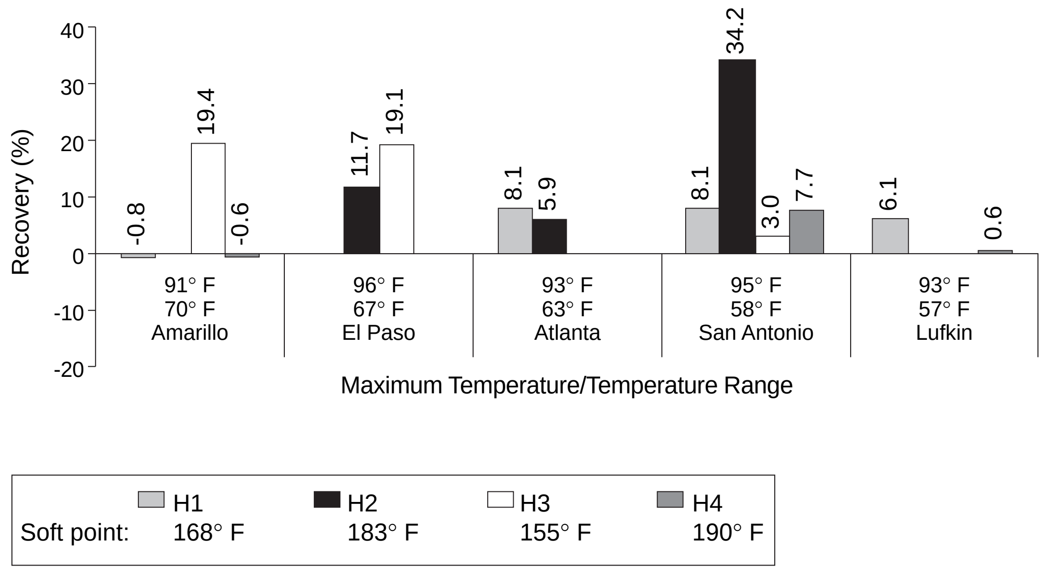

Figure 5.6 Recovery rate of hot pour sealants in different districts

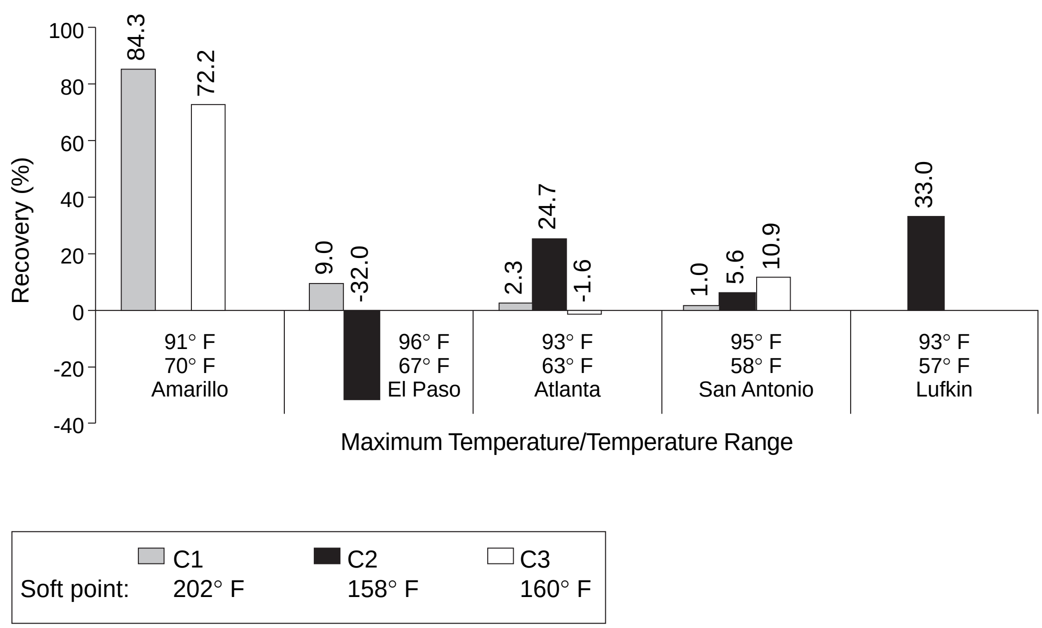

Figure 5.7 Recovery rate of cold pour sealants in different districts

6. Conclusions

This report comes as a follow-up study after the second year of a three-year research project. The main objective of the study is to compare long-term performance of hot pour sealants to cold pour sealants. Three investigation visits have been made to the test sections to date. The results of these investigations were used to plot the chart of effectiveness versus time for all the sealing materials in the different districts.

Initial cost analysis, in which the construction cost of the different crack sealants were considered, was done using two approaches. When the initial costs were compared, hot pour sealants proved to cost less than cold pour sealants in all cases. The life-cycle cost of the crack sealing treatments would be a crucial factor in determining which type of sealants are more feasible. However, for this kind of an analysis, we need to know the length of time period in which the treatment comes to a failure point. Since this information is not available for all the sealants to date, the life-cycle cost analysis will be done later when this information is gathered.

The main conclusion that could be drawn at this stage of the project is that in the field, hot pour sealants perform better than cold pour sealants. It was also learned that joint sealants when used as crack sealants could perform better than crack sealants. In fact, they are among the sealing treatments which exhibited the best performances.

The performance results show that some sealing materials tend to perform well in environments with narrow annual temperature ranges. The findings of the study also demonstrated that sealing materials with higher softening points perform better in higher temperature ranges.

During the summer, high temperatures may cause previously failed sections to "recover." This is due to the drop in the viscosity of the sealant and the fact that cracks close in the summer. This might reflect as an increase in the effectiveness level. Recovery rate might have a correlation with the maximum annual temperature.

To explain the behavior and performance patterns of the different sealants, material properties from laboratory results and the environmental conditions such as rainfall and temperature ranges at each district were used. For both cold pour and hot pour crack sealants, there seems to be a correlation between the softening point of the sealant and its performance in areas with certain temperature ranges. This can only be verified with further research and larger sample sizes.

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8. www.weather.com

Appendix A:

Material Properties

Table A.1 Laboratory Test Results for Sealants Used in Test Sections

Properties	C1 (Crack Sealant)	C2 (Crack Sealant)	C3 (Joint Sealant)	H1 (Crack Sealant)	H2 (Crack Sealant)	H3 (Crack Sealant)	H4 (Joint Sealant)
BrkF Viscosity at 77˚F (Centipoise)	12900	13600	32560	N/A	N/A	N/A	N/A
Granulated Vulcanized Rubber Content (%)	0	0	0	25.8	14.6	24.6	0
Evaporation Residue (%)	67.8	65	67	N/A	N/A	N/A	N/A
Penetration at 39.2˚F	12	12	14	13	21	11	48
Penetration at 77˚F	42	45	60	34	47	33	82
Resilience at 77˚F (%)	15	23	20	59	69	54	72
Ductility at 39.2˚F (cm)	100+	100+	100+	7.5	16	8	49
Bond Test	Failed	Failed	Pass	Failed	Pass	Failed	Pass
Flow at 77˚F (mm)	5+ (Fail)	5+	5+	5+	5+	5+	Pass
Flash Point (˚F)	455	540	580	400	540	410	415
Softening Point (˚F)	202	158	160	168	183	155	190

Appendix B:

Specifications for Crack Sealing and Joint Sealing Materials

SPECIFICATION GSD 745-80-25

Rubber Asphalt Crack Sealing Compound

PART I
GENERAL CLAUSES AND CONDITIONS

1. It is the intent of TxDOT to purchase goods, equipment and services having the least adverse environmental impact, within the constraints of statutory purchasing requirements, TxDOT need, availability, and sound economical considerations. Suggested changes and environmental enhancements for possible inclusion in future revisions of this specification are encouraged.

2. TxDOT is committed to procuring quality goods and equipment. We encourage manufacturers to adopt the International Organization for Standardization (ISO) 9001-9003 standards, technically equivalent to the American National Standards Institute/American Society for Quality Control (ANSI/ASQC Q91-93 1987), and obtain certification. Adopting and implementing these standards is considered beneficial to the manufacturer, TxDOT, and the environment. It is TxDOT's position that the total quality management concepts contained within these standards can result in reduced production costs, higher quality products, and more efficient use of energy and natural resources. Manufacturers should note that future revisions to this specification may require ISO certification.

3. Measurement will be given in both the English and metric system. Where any conflict between the two stated measurements may occur, the measurements provided in the English system shall supersede those provided in the metric system.

PART II
SPECIFICATIONS

1. SCOPE: This specification describes rubber asphalt crack sealing compound suitable for sealing 1/8 inch (3.20 mm) or larger width cracks in asphaltic concrete pavement. This material shall be a blend of asphalt and granulated vulcanized rubber (Class A Sealer) or a blend of asphalt, granulated vulcanized rubber, virgin rubber, fillers and plasticizers (Class B Sealer). It shall be capable of being melted and applied by a suitable oil jacketed kettle equipped with pressure pumps, hose and nozzle, at a temperature of 400 degrees F (20 degrees C) or less. It shall contain no water or highly volatile matter and shall not track by traffic once cooled to road temperature.

2. PROPERTIES OF THE RUBBER: The rubber shall be one of the following types:

   2.1. Type I – Ground tire rubber. For use in Class A sealer.

   2.2. Type II – Mixture of ground tire rubber and high natural reclaimed scrap rubber. The natural rubber content, determined by ASTM D297, shall be a minimum of 25 percent. For use in Class A sealer.

   2.3. Type III – Ground tire rubber. For use in Class B sealer. NOTE: Bidder shall indicate class and type sealer to be supplied on the Invitation for Bids.

   2.4. The ground rubber shall be any crumb rubber, derived from processing whole scrap tires or shredded tire materials taken from automobiles, trucks or other equipment owned and operated in the United States. The processing shall not produce, as a waste, casing, or other round tire material that can hold water when stored or disposed above ground. Rubber tire buffing produced by the retreading process qualify as a source of crumb rubber.

2.5. The ground rubber shall comply with the following gradation requirements when tested by Test Method TEX-200-F, Part I:

PERCENT RETAINED

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

2.6. The ground rubber shall be free from fabric, wire, cord or other contaminating materials.

3. PROPERTIES OF THE SEALING COMPOUND

3.1. RUBBER CONTENT

	Class A Sealer	Class B Sealer
Granulated vulcanized rubber, percent by weight:	22 minimum 26 maximum	13 minimum 17 maximum
Virgin rubber polymer, percent by weight:		2 minimum

3.1.1. Rubber Content Determination Procedure

3.1.1.1. Core the sample as received from top to bottom with 1-1/4 to 1-1/2 inch (31.75 to 38.10 mm) core drill.

3.1.1.2. Place cored material in a 1000-ml metal beaker or 1 quart (.95 L) can. Container should be at least half full when crack sealer is melted. It may be necessary to take more than one core.

3.1.1.3. In an oven maintained at 375 degrees F (190 degrees C), heat sample to 350 degrees F (177 degrees C).

3.1.1.4. Stir sample thoroughly and immediately pour 50 (+5) grams into a 600-ml beaker.

3.1.1.5. Add 300 ml of 1,1,1-trichloroethylene. Cover container and let stand for a minimum of 4 hours at room temperature.

3.1.1.6. When there appears to be complete separation between asphalt and rubber, pour onto a No. 140 (106 μm) sieve and wash with solvent until wash stream is the color of light straw.

3.1.1.7. Let sieve remain in well-ventilated area for a minimum of 30 minutes.

3.1.1.8. Place in a forced draft oven maintained at 140 degrees F (60 degrees C) for 30 minutes.

3.1.1.9. Let cool for 15-20 minutes, weigh to nearest 0.1 gram.

3.1.1.10. Repeat heating and cooling procedure until weight varies not more than 0.1 gram from previous weighing.

Calculations

$$\text{Percent rubber} = \frac{\text{Weight of rubber}}{\text{Weight of sample}} \times 100$$

3.2. FLASH POINT, MODIFIED CLEVELAND OPEN CUP: Minimum 400 degrees F (204 degrees C).

3.2.1. The equipment and procedure shall be as specified in ASTM D92, Test for Flash and Fire Points of Petroleum Materials by Cleveland Open Cup, with the following modification:

3.2.1.1. Prior to passing the test flame over the cup, agitate the sealing compound with a 3/8 to 1/2 inch (9.50 to 12.70 mm) wide square-end metal spatula in a manner so as to bring the material on the bottom of the cup to the surface, i.e., turn the material over. This shall be done, starting at one side of the thermometer, moving around to the other, then returning to the starting point, using eight to ten rapid circular strokes. The agitation shall be accomplished in three to four seconds. The test flame shall be passed over the cup immediately after the stirring is completed.

3.2.2. This procedure shall be repeated at each successive 10 degrees F (5.0 degrees C) interval until the flash point is reached.

3.3. CONSISTENCY

	Minimum	Maximum
3.3.1. Penetration at 77 degrees F (25 degrees C), 150 g, 5 sec	30	50
3.3.2. Penetration at 32 degrees F (0 degrees C), 200 g, 60 sec	12	

3.3.3. The penetration shall be determined by ASTM D5 except that the cone specified in ASTM D217 shall be substituted for the penetration needle.

3.4. SOFTENING POINT: Ring and Ball Minimum – 170 degrees F (76.7 degrees C) (Applies to Class B Sealer only).

3.5. BOND: 3 cycles at 20 degrees F (-6.7 degrees C), Test Method TEX-525-C. (Applies to Class B Sealer only). There shall be no crack in the joint sealing material or break in the bond between the sealer and the mortar blocks over 1/4 inch (6.35 mm) deep for any of the specimens after completion of the test.

4. PACKAGING: The material shall be packaged in boxes having a maximum weight of 65 pounds (30 kg) per box. The material in each box shall be divided into a minimum of two blocks, which shall be individually packaged in a liner made of polyethylene. Individual blocks shall not exceed 35 pounds (16 kg). The boxes shall be placed on pallets. The total weight of pallet and containers shall be approximately 2100 pounds (952 kg).

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	-	

Tests on Residue from Evaporation			
Penetration, 77F 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

SPECIFICATION DMS-6310, Joint Sealants and Seals

Class 3 (Hot-Poured Rubber for Portland Cement Concrete Pavement Joints and Joints between Concrete and Asphalt Pavement)

This sealer shall be a rubber asphalt compound which, when heated to the manufacturer 's recommended safe heating temperature, shall melt to the proper consistency for pouring and shall solidify on cooling at ambient temperatures.

The sealer must be compatible with asphaltic concrete.

Class 3 Specifications	
Property	**Requirement**
Penetration, 25 C (77 F) 150 g, 5 s, 0.1 mm (in.), maximum	90
Flow (5 h, 60 C [140 F], 75 degree incline), maximum	3 mm (1/8 in.)
Resilience: 25 C (77 F), original material, minimum	60 %
Bond (3 cycles at -29 C [-20 F])	There shall be no crack in the joint sealing material or break in the bond between the sealer and the mortar blocks over 6 mm (1/4 in.) deep for any of the specimens after completion of the test.

Class 9 (Polymer Modified Asphalt Emulsion Joint Seal)

This shall be a single component, polymer modified emulsion composed principally of a semi-solid asphalt base, water and an emulsifying agent suitable for sealing joints at ambient temperatures of 10 C (50 F).

In addition, the emulsion sealer shall comply with the following requirements:

Class 9 Specifications		
Properties	**Requirements**	**Test Procedure**
Viscosity, Brookfield, 25 C (77 F) Pa*s	30.0 minimum 70.0 maximum	ASTM D 2196, Method A
Evaporation Residue (%)	65 minimum	Residue evaporation procedure*
Tests on Residue from Evaporation:	-	-
Penetration, 25C (77F), 100 g, 5 seconds, (0.01mm)	35 minimum 75 maximum	AASHTO T 49
Softening Point, F&B, C (F)	70 (160)	AASHTO T 53
Bond, 3 cycles at -32C (0F), 50% extension	Pass**	Test Method “Tex-525-C, Tests for Asphalts and Concrete Sealers”

*The Residue may be obtained by the following evaporation procedure:

> Weigh 200 grams (seven [7] ounces) of sealant into a tared 1000 milliliter beaker or a 0.95 liter (one [1] quart) can and place in a heating mantle designed for a 1000 milliliter beaker. (Tare should include any stirring instrument and thermometer).
>
> Apply heat with the mantle to evaporate the water from the sealant within one hour. During the evaporation the sealant should be stirred frequently to prevent foam over or local overheating. The temperature shall be maintained between 125 and 150 C (260 and 300 F) for 2 to 5 minutes after the material is water free.
>
> Weigh the beaker and calculate the amount of residue by difference, then pour the required specimens.

**There shall be no crack in the joint sealing material or break in the bond between the sealer and mortar block over 6 millimeters (1/4 inches) deep for any of the specimens after completion of the test.

Appendix C:

Test Sections Matrix

Table C.1 Test Sections Matrix

District	**Sealant**													
	Non-Covered							Covered						
	C1	C2	C3	H1	H2	H3	H4	C1	C2	C3	H1	H2	H3	H4
Atlanta	1	1	1	1	1				1		1			
El Paso	1	1			1	1								
Amarillo	1		1	1		1	1	1					1	
San Antonio	1	1	1	1	1	1	1							
Lufkin		1	1	1			1							
Total	4	4	4	4	3	3	3	2	2	0	2	0	2	0

Appendix D:

Weather Records in the Districts

Table D.1 Weather Records in Atlanta

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	52°F	57°F	66°F	75°F	82°F	89°F	93°F	92°F	86°F	76°F	65°F	55°F
Avg. Low	30°F	34°F	43°F	52°F	59°F	67°F	70°F	69°F	62°F	50°F	42°F	34°F
Mean	41°F	46°F	55°F	64°F	71°F	78°F	82°F	81°F	74°F	64°F	54°F	45°F
Avg. Precip.(in)	3.20	3.60	4.60	4.20	4.60	4.10	3.20	2.70	3.60	3.60	4.70	4.70
Record High	82°F	88°F	90°F	93°F	95°F	103°F	107°F	107°F	106°F	93°F	86°F	84°F
	Y1997	*Y1996*	*Y1995*	*Y1987*	*Y1998*	*Y1988*	*Y1998*	*Y1999*	*Y1998*	*Y1998*	*Y1983*	*Y1988*
Record Low	4°F	5°F	14°F	28°F	40°F	52°F	56°F	51°F	40°F	30°F	19°F	-1°F
	Y1982	*Y1996*	*Y1996*	*Y1996*	*Y1992*	*Y1993*	*Y1987*	*Y1986*	*Y1999*	*Y1993*	*Y1992*	*Y1989*

Table D.2 Weather Records in El Paso

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	56°F	62°F	69°F	78°F	87°F	96°F	96°F	93°F	87°F	78°F	66°F	57°F
Avg. Low	29°F	33°F	40°F	48°F	56°F	64°F	68°F	66°F	61°F	49°F	38°F	30°F
Mean	43°F	48°F	55°F	63°F	72°F	80°F	82°F	80°F	74°F	64°F	52°F	44°F
Avg. Precip.(in)	0.40	0.40	0.30	0.20	0.30	0.70	1.50	1.60	1.70	0.80	0.40	0.60
Record High	80°F	83°F	89°F	98°F	104°F	114°F	112°F	108°F	104°F	96°F	87°F	80°F
	Y1970	*Y1986*	*Y1989*	*Y1989*	*Y1951*	*Y1994*	*Y1979*	*Y1980*	*Y1982*	*Y1994*	*Y1983*	*Y1973*
Record Low	-8°F	8°F	14°F	23°F	31°F	46°F	57°F	56°F	42°F	25°F	1°F	5°F
	Y1962	*Y1985*	*Y1971*	*Y1983*	*Y1967*	*Y1988*	*Y1988*	*Y1973*	*Y1975*	*Y1970*	*Y1976*	*Y1953*

Table D.3 Weather Records in Amarillo

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	49°F	52°F	61°F	71°F	79°F	87°F	91°F	89°F	81°F	72°F	59°F	50°F
Avg. Low	21°F	25°F	32°F	42°F	51°F	60°F	65°F	63°F	56°F	44°F	32°F	23°F
Mean	35°F	39°F	47°F	57°F	65°F	74°F	79°F	77°F	69°F	59°F	46°F	37°F
Avg. Precip.(in)	0.50	0.60	1.00	1.00	2.50	3.70	2.60	3.20	2.00	1.40	0.70	0.40
Record High	81°F	88°F	94°F	98°F	103°F	108°F	105°F	104°F	103°F	95°F	87°F	81°F
	Y1950	*Y1963*	*Y1971*	*Y1965*	*Y1996*	*Y1998*	*Y1994*	*Y1994*	*Y1995*	*Y1954*	*Y1980*	*Y1955*
Record Low	-11°F	-14°F	-3°F	17°F	28°F	42°F	51°F	49°F	30°F	12°F	0°F	-8°F
	Y1984	*Y1951*	*Y1948*	*Y1997*	*Y1954*	*Y1955*	*Y1990*	*Y1956*	*Y1984*	*Y1993*	*Y1976*	*Y1989*

Table D.4 Weather Records in San Antonio

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	60°F	65°F	73°F	80°F	85°F	91°F	95°F	95°F	89°F	81°F	71°F	63°F
Avg. Low	37°F	41°F	49°F	58°F	65°F	72°F	75°F	74°F	69°F	58°F	48°F	40°F
Mean	49°F	54°F	62°F	69°F	76°F	82°F	85°F	85°F	79°F	70°F	60°F	52°F
Avg. Precip.(in)	1.70	1.80	1.50	2.50	4.20	3.80	2.20	2.50	3.40	3.20	2.60	1.50
Record High	89°F	100°F	100°F	101°F	103°F	105°F	106°F	108°F	103°F	99°F	94°F	90°F
	Y1971	*Y1996*	*Y1991*	*Y1996*	*Y1989*	*Y1998*	*Y1989*	*Y1986*	*Y1985*	*Y1991*	*Y1988*	*Y1955*
Record Low	0°F	6°F	19°F	31°F	43°F	53°F	62°F	61°F	46°F	27°F	21°F	6°F
	Y1949	*Y1951*	*Y1980*	*Y1987*	*Y1984*	*Y1964*	*Y1967*	*Y1992*	*Y1983*	*Y1993*	*Y1976*	*Y1989*

Table D.5 Weather Records in Lufkin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	58°F	63°F	71°F	78°F	84°F	90°F	93°F	93°F	88°F	80°F	70°F	61°F
Avg. Low	36°F	39°F	47°F	55°F	63°F	69°F	72°F	71°F	66°F	54°F	46°F	38°F
Mean	48°F	52°F	60°F	67°F	74°F	80°F	83°F	83°F	77°F	68°F	58°F	50°F
Avg. Precip.(in)	3.70	2.80	3.20	3.30	4.90	4.20	2.60	2.40	4.00	3.30	3.90	4.10
Record High	86°F	92°F	97°F	98°F	99°F	106°F	108°F	110°F	106°F	100°F	90°F	89°F
	Y1911	*Y1996*	*Y1946*	*Y1936*	*Y1996*	*Y1936*	*Y1934*	*Y1909*	*Y1907*	*Y1938*	*Y1917*	*Y1910*
Record Low	-2°F	-2°F	16°F	30°F	39°F	50°F	56°F	52°F	36°F	25°F	15°F	2°F
	Y1930	*Y1951*	*Y1943*	*Y1987*	*Y1909*	*Y1984*	*Y1907*	*Y1920*	*Y1920*	*Y1993*	*Y1911*	*Y1989*

Appendix E:

Detailed Field Results on Non-Covered Test Sections

Results of the investigation done on the test sections 3 months after crack seal installation are located in Research Report 4061-1.

ATLANTA

Table E.1 Performance Evaluation During Winter 2002 in Atlanta

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
H1	1,500	4,200	0	426	10.1	89.9	+0.5 to 1.0
H2	1,500	4,125	0	302	7.3	92.7	+0.5 to 1.0
C3	1,500	4,200	0	1303	31.0	69	-0.5
C1	1,500	4,250	0	2005	47.2	52.8	-0.5
C2	1,500	2,750	0	1355	49.3	50.7	-0.5

Table E.2 Performance Evaluation During Summer 2002 in Atlanta

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
H1	1,500	4,200	0	84	2.0	98.0	0
H2	1,500	4,125	0	60	1.5	98.5	0 to +1.0
C3	1,500	4,200	0	1,369	32.6	67.4	+0.5
C1	1,500	4,250	0	1,865	43.9	56.1	0
C2	1,500	2,750	0	6,78	24.7	75.3	0

EL PASO

Table E.3 Performance Evaluation During Winter 2002 in El Paso

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
C2	3,000	2,750	49	1638	59.6	40.4	0 to -0.5
H3	3,000	2,138	51	511	23.9	76.1	0 to +0.5
C1	3,000	2,518	45	833	33.1	66.9	0 to -0.5
H2	3,000	2,750	50	610	22.2	77.8	0 to +0.5

Table E.4 Performance Evaluation During Summer 2002 in El Paso

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
C2	3,000	2,750	517	2,519	91.6	8.4	0
H3	3,000	2,138	312	102	4.8	95.2	0
C1	3,000	2,518	317	608	24.1	75.9	0 to -1.0
H2	3,000	2,750	384	288	10.5	89.5	0

AMARILLO

Table E.5 Performance Evaluation During Winter 2002 in Amarillo

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
C1	2,000	350	42	390	100.0	0.0	- 1.5
C3	2,000	500	68	407	81.4	18.6	- 1.0
H3	2,000	480	24	164	34.2	65.8	0
H4	2,000	500	33	10	2.0	98.0	0
H1	2,000	1,000	17	81	8.1	91.9	0

Table E.6 Performance Evaluation During Summer 2002 in Amarillo

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
C1	2,000	350	45	55	15.7	84.3	-1.5
C3	2,000	500	72	46	9.2	90.8	-1.0
H3	2,000	480	20	71	14.8	85.2	0
H4	2,000	500	50	13	2.6	97.4	0
H1	2,000	1,000	20	81	8.1	91.9	0

SAN ANTONIO

Table E.7 Performance Evaluation During Winter 2002 in San Antonio

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
H2	1,000	2,653	171	1125	42.4	57.6	0
C1	1,000	2,704	206	2696	99.7	0.3	- 0.5
H1	1,000	2,547	135	228	9.0	91.0	0
H4	1,000	2,541	107	202	7.9	92.1	0
C2	1,000	3,269	134	363	11.1	88.9	-1.5
H3	1,000	3,868	143	122	3.2	96.8	0
C3	886	1,733	122	449	25.9	74.1	-1.0

Table E.8 Performance Evaluation During Summer 2002 in San Antonio

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
H2	1,000	2,653	343	219	8.3	91.7	0 to +0.5
C1	1,000	2,704	274	2,670	98.7	1.3	- 1.5
H1	1,000	2,547	357	23	0.9	99.1	0 to +0.5
H4	1,000	2,541	290	6	0.2	99.8	0 to +0.5
C2	1,000	3,269	325	179	5.5	94.5	-1.5
H3	1,000	3,868	384	7	0.2	99.8	+0.5
C3	886	1,733	312	260	15.0	85.0	-1.0

LUFKIN

Table E.9 Performance Evaluation During Winter 2002 in Lufkin

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
C3	3,000	3,020	33	684	22.7	77.3	-1.0 to –2.0
H4	3,000	2,421	17	18	0.7	99.3	0
C2	3,000	2,251	27	779	34.6	65.4	-0.5
H1	3,000	1,475	27	132	9.0	91.0	0

Table E.10 Performance Evaluation During Summer 2002 in Lufkin

Sealant	Length of The Section (ft)	Sealed Crack Length (ft)	Length of Newly Develop. 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)
C3	1,000	3,020	N/A	N/A	N/A	N/A	N/A
H4	630	1,634	36	3	0.2	99.8	0
C2	1,000	829	35	36	4.3	95.7	0 to -1.0
H1	1,000	1,475	95	42	2.8	97.2	0