THE UNIVERSITY OF TEXAS AT AUSTIN ✦ COCKRELL SCHOOL OF ENGINEERING
TEXAS PAVEMENT PRESERVATION CENTER
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Current Status and Procedures of Crack Sealing

Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

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Past and Upcoming Events

Ongoing TPPC Courses

TPPC is currently collaborating with the TxDOT Training Department to develop training courses in topics that include crack sealing, fog sealsseal coats, thin asphalt overlays, hot and cold-in-place recycling, micro-surfacing, slurry seals, and how to plan a pavement preservation program. For more information contact TPPC Director, Dr. Yetkin Yildirim, at **yetkin@mail.utexas.edu**.

Courses for 2013

The TPPC continues their ongoing mission to educate industry practitioners about the most recent developments in pavement technology and knowhow with training courses which provide the latest crucial information and advancements in pavement technology to a wide audience of engineers, technicians and policy makers. In pursuit of this end, the TPPC will offer six different training courses in 2013.

TPPC Board of Directors

Crack Sealing

In an ever-expanding road and highway system, preventive and corrective maintenance procedures will always play a major role in efficiently increasing the service life of pavements. Cracking is possibly the most pervasive problem that flexible pavements face as they age. Sealing these cracks in a timely manner will greatly improve a pavement's service life without having to resort to costly reconstruction projects. In order to best understand crack sealing as a preventive maintenance procedure, it is first important to have a clear understanding of the types and causes of different roadway cracks.

Pavement cracking occurs in response to a variety of factors including: stress from vehicular loading, seasonal temperature fluctuations which causes expansion and contraction of the pavement, and moisture penetration to an underlying layer or to the base of a pavement. Small surface cracks generally develop in response to loading and temperature change. Heavy, fast-moving vehicles exert enormous stress on the riding surface of pavements causing them to compress over time. Such compression can easily result in surface cracks. Compression and expansion of the pavement from temperature changes, even fluctuations within a period of 24 hours, can also result in cracks similar to those caused by vehicular loading. Even more troubling, moisture penetration can quickly worsen these small cracks in a pavement. Water that seeps through surface cracks to the base can greatly weaken the roadway by washing away sub-surface materials. As a result, further cracks will form and become wider if not sealed.

Purpose of Crack Sealing

Crack sealing is a relatively inexpensive and cost effective routine maintenance treatment that significantly delays roadway deterioration. The sealing material should be applied directly into cracks before they are allowed to become too large or before the roadway is subjected to freezing conditions. Service life extension results from the reduction of incompressible debris retention in a pavement join/crack and minimizing the infiltration of water through a crack in the pavement. The primary function of any crack sealant material is to prevent moisture and surface water from penetrating and weakening the pavement structure. Moisture reduction helps maintain the pavement's structural capacity and limits future degradation. Crack sealing is designed to protect from the washing away of fines, thus maintaining a uniform and supportive base. Another purpose of crack sealants is that they can serve as a stress absorption system. It should be mentioned that crack sealing will not improve a pavement's ride quality. However, properly installed crack sealants may extend the service life of the pavement by several years and will greatly lower the maintenance costs over time.

Cracks are inevitable, and neglect will lead to a more rapid deterioration of the road surface. Maintenance activities can range from crack sealing and filling, to other, more involved surface treatments. Crack sealing and filling activities have been performed for quite some time. When performed properly, crack sealing and filling can extend the life of the pavement to the point where the cost of the activities is outweighed by the cost-benefit of the additional pavement life.

Common Cracks and their Characteristics

Fatigue Cracking

Fatigue Cracking is often called alligator cracking because the closely spaced crack pattern is similar to the pattern of alligator skin. Fatigue cracking is mainly caused by excessive loading on the pavement structure or from fatigue. The problem is often exaggerated by inadequate pavement drainage which adds to this distress by allowing the pavement layers to become saturated and lose strength. Water that penetrates through these cracks can easily weaken the base, thus allowing for more cracks to develop from future vehicle loads.

Fatigue/Alligator Cracking

Longitudinal Cracking

Longitudinal cracks are contiguous cracks that run parallel to the centerline of a roadway. Such longitudinal cracks, which often form between adjacent lanes, are typically the result of low temperatures. The material density is lowest at the joint between paving lanes, resulting in low tensile strength. As a result, a crack will often form in response to roadway contraction in cold weather.

Longitudinal Cracking

Transverse Cracking

Low temperatures can also cause transverse cracks. This type of cracking runs perpendicular to the roadway centerline. These transverse cracks normally occur when the temperature at the surface drops sufficiently causing thermally induced shrinkage stress in the HMA layer that exceeds the tensile strength of the asphalt mixture.

Transverse Cracking

Block Cracking

When the surface layer cracks both longitudinally and transversely in approximately square shapes, this is referred to as block cracking. Such cracks are usually caused by shrinkage of cemented layers. Mostly they develop on roadways with low traffic volume. Block cracking is more often seen in large paved areas, such as parking lots or airfield pavements than on roads or highways.

Block Cracking

Importance of Sealing and Filling

Sealing operations should be instituted when pavement cracks first develop, as timely treatment will help prevent further pavement deterioration. The effects of not sealing cracks include increased pavement deterioration, including raveling, tenting, and migrating of cracks, along with potholes and frost heave damage.

Crack sealing is a rigorous operation intended to prevent water from entering the pavement structure. It involves thorough crack preparation followed by the placement of a high-quality material in a specific configuration. Crack sealing is normally used on working cracks. Working cracks are defined as those that experience considerable horizontal and/or vertical movement as a result of temperature changes and/or traffic loading. Working cracks typically have horizontal and/or vertical crack movements of 2.5 mm or more.

Alligator and longitudinal cracks in the wheel paths are indicative of structural deficiency and require at least partial reconstruction for an effective solution. Proper pavement design and drainage can help control these types of cracks. Transverse and longitudinal cracking are most often caused by thermal changes and are related to cold temperature and age stiffening characteristics of the asphalt concrete, which in turn is directly related to the properties of the asphalt binder. This type of cracking should be treated soon after initiation to minimize the infiltration of water which will cause further deterioration.

Transverse and longitudinal thermal cracks can be treated through crack sealing and filling. The goal is to reduce or eliminate the infiltration of moisture into the pavement structure, and prevent incompressible materials from entering the crack. Water can lead to accelerated fatigue, stripping, pumping, and other pavement damage. It is commonly believed that sealing and filling are necessary in extending pavement life. The earlier these detrimental effects can be prevented, the better the chance that a pavement's life will be sufficiently extended.

Proper Crack Selection

The first step of any crack treatment operation is an evaluation of the pavement to assess the extent and type of cracking present and to determine the appropriate treatment(s). If a pavement is badly deteriorated, has large quantities of closely spaced or random cracking, or if other major deficiencies are present, crack filling or sealing may not be appropriate and another repair should be used. Good pavement condition data is essential for proper treatment selection.

Most highway agencies have developed policies and criteria that specify the type of maintenance to be performed on cracked pavements. These criteria are often based on an assessment of the overall pavement condition and crack characteristics. These policies also specify when cracks should first be filled or sealed.

Requirements exist at most highway agencies regarding air temperatures and the seasons when crack sealing operations should be conducted. Additionally, it is important that when performing a sealing operation, the crack is clean. Having a clean crack permits adhesion and provides for a better overall treatment.

Installation Procedures

Crack sealing operations consist of at least two and up to five steps, depending on the type of treatment. Given a situation where all five steps are necessary, the typical order is:

1. Crack cutting; 2. Crack cleaning and drying; 3. Material preparation; 4. Material placement; 5. Blotting

Crack Cutting

Crack cutting is performed in order to create a uniform, rectangular reservoir, centered as closely as possible over a particular crack, while inflicting as little damage as possible to the surrounding pavement. Crack cutting is done with either a diamond saw or rotary impact router. Widths and depths of the cut will vary depending on the configurations.

Studies show that there is almost a 40% greater chance of sealant success if cracks are routed prior to sealing. Cutting a reservoir also ensures that the proper amount of sealant penetrates the crack. An operator passes the pavement cutter or router over the crack and, through a series of star-shaped steel teeth, cuts a reservoir into the crack. Modern routers can follow even the most random pavement cracks. Once the rout is complete, simply use compressed air (hot or cold) to remove the dust created by the router. Engine-powered steel wire brushes can also be used to clean routed and non-routed cracks. (Note: Older-aged asphalt pavements and thin asphalt pavements may not be suitable for routing.)

Crack Cleaning and Drying

Crack cleaning and drying is done to provide a clean, dry crack channel and to remove any loose materials from the crack. A clean, dry crack is extremely important, as a large percentage of sealant failure is caused by adhesion failure with the crack wall. Crack cleaning can be done by hand tools, brushing or sweeping, airblasting, hot airblasting, or sandblasting. Airblasting with compressed air is an effective method of removing particles and dust. Hot airblasting with a hot compressed-air lance, or heat lance, is effective for both cleaning and drying a crack. The heat lance must be able to produce 1370°C (2500°F) and a blast velocity of 600 m/s (1970 ft/s). Sandblasting operations should be conducted during dry weather conditions and should be followed up by airblasting to remove the sand from the crack reservoir and roadway. Sandblasting not only removes dust and debris, but also strips away any loose particles. It is a specialized procedure that is usually more costly due to the equipment and materials needed.

Material Preparation

Proper material preparation is necessary for an effective seal. The specific material preparation requirements provided by the manufacturer should be followed. These include minimum placement temperature, material heating temperatures, prolonged heating guidelines, recommended pavement temperature and recommended moisture conditions. It is important that the specific recommendations from the material manufacturer are followed, as overheating of the material should be avoided. Overheating the material may alter the material's properties significantly. Under-heated material can also produce problems as the material may not flow correctly and it may not bond properly. This is another benefit of applying the material in the relatively mild weather of spring or fall, as maintaining material temperature in cold and hot weather is more difficult.

Material Placement

Flush Fill

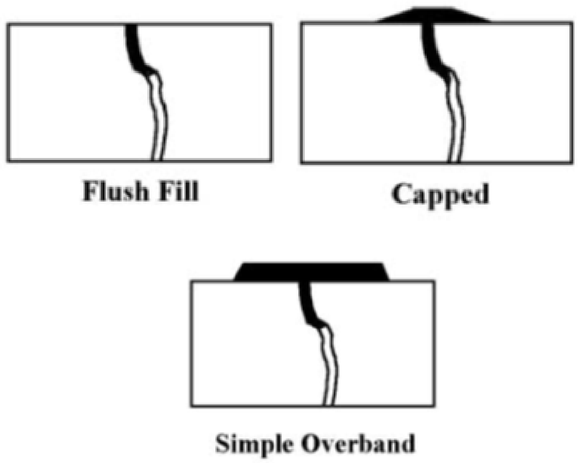
There are several configurations commonly used for the application of fillers and sealants. These configurations range from simply filling unprepared cracks, to cutting a specific size of reservoir for sealant placement. Reservoirs are generally associated with sealing operations, and simple overbands are usually used with filling operations, though this is not always the case. Once the filling or sealing operation commences, it is important that the entire operation moves at a steady pace. The application procedures for all crack sealing and filling materials are basically the same.

Sealing Configurations

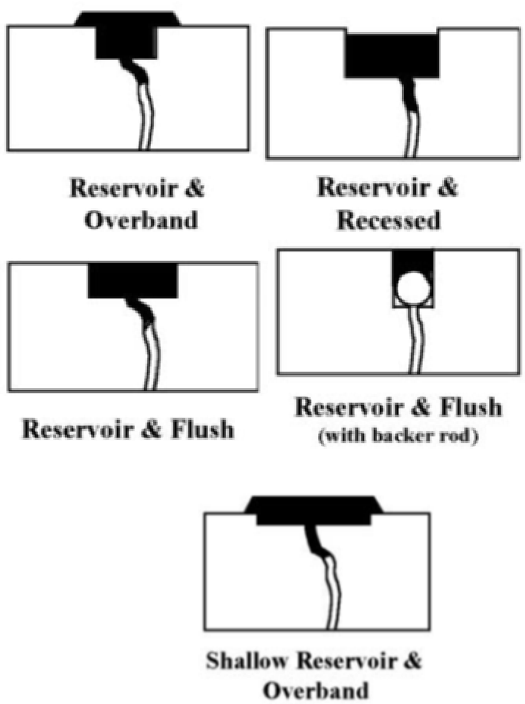
In a sealing operation, sealant is placed either flush with the surface or slightly recessed within a cut reservoir. The purpose of the reservoir is to create room for enough material to be applied, create a desirable sealant shape, and provide a uniform surface for the sealant to adhere to. Second, the sealant is not on top of the pavement surface, and therefore it is not directly exposed to abrasion by vehicle tires.

A combination reservoir over-band configuration exists in which the material is placed in a reservoir and also above the reservoir in an over-band. This configuration attempts to combine the advantages and eliminate some of the disadvantages of the reservoir and over-band configurations. A combined over-band and reservoir will limit cohesive failures and reinforce the edges of the reservoir.

Standard Crack Filling Configurations



Standard Crack Sealing Configurations



Blotting

Blotting protects the uncured crack treatment material from tracking under traffic. Blotting material is typically used in areas where traffic has to travel on the material before it has had time to cure. Toilet paper, talcum powder, lime, sand, and limestone chips are commonly used as blotting materials.

Equipment Used

Using the right equipment is an important part of any crack sealing program. There are two major areas of consideration: crack preparation and sealant application. In the same way that a dentist prepares a tooth before filling a cavity, crews must prepare cracks to receive sealants. The better the preparation, the better the chance that the sealant will last and perform. Cracks must be free of all dirt, dust and debris. The sealant must have a clean, dry bonding surface. Surface preparation can be accomplished with compressed air (100 PSI minimum) and a simple blowpipe. This technique works well when the dirt is dry and not packed hard. If the cracks are filled with wet dirt, the dirt needs to be removed and the crack must be completely dried. An air compressor or a hot-air lance generating temperatures in excess of 2,000º F is the best tool. In simple terms, a heat lance uses hot compressed air that blows cracks clean while drying them out.

Crack Preparation

Router

A router is used to create a sealant reservoir by enlarging meandering cracks to the desired depth and width. A vertical spindle router with a diamond bit is recommended to minimize damage to the asphalt pavement; however, an impact router may be used if it is equipped with carbide-tipped vertical-sided bits. Impact routers that are not equipped with carbide-tipped bits or those equipped with V-shaped bits should not be used because they tend to chip and damage the asphalt pavement.

When using a vertical spindle router, the router bit should be belt-driven to help prevent injury to the operator and damage to the pavement if the bit jams in the crack. If damage to the pavement is observed, work should be discontinued until corrective action is taken. Such corrective action may require replacing worn router bits, changing operators, or replacing the equipment completely.

Concrete saw

A concrete saw with a water-cooled diamond blade or abrasive disk can be used to widen straight cracks to the desired width and depth. Concrete saws may be used in place of a router if the blade has a diameter of 6 inches (150 millimeters) or less. The 6-inch diameter blade allows the saw to follow slightly meandering cracks; however, a saw blade does not follow the meandering crack as well as a router. If a saw is used to widen the crack, a high-pressure water stream can be used to remove the debris created by the saw.

Hot compressed-air (HCA) heat lance

The HCA heat lance is used to warm, dry, and clean the crack when the sealing operation must be conducted in less than desirable conditions. Such conditions occur following rain or when the pavement temperature is below 50 degrees Fahrenheit (10 degrees Celsius). The heat lance can also be used to remove small amounts of vegetation from cracks. Heat lances are capable of producing heated air at 3,000 degrees Fahrenheit (1,650 degrees Celsius) at velocities of up to 3,000 feet per second (915 meters per second); therefore, extreme care must be used by the operator.

The heat lance should not remain stationary over one spot but should be kept moving to ensure that the asphalt pavement is not overheated. Overheating will cause the pavement to become charred and brittle, resulting in premature sealant bond failure. Heating the cracks using direct flame methods should not be permitted. Direct flames harden the asphalt and leave a sooty residue that prevents adequate bonding of the sealant to the asphalt pavement.

Sandblasting equipment

Sandblasting equipment is used to remove residue left by the saw, loosened aggregate left by the router, vegetation, and other debris. If debris is left in the crack, the sealant will not bond adequately to the asphalt, causing premature failure. Equipment for sandblasting consists of an air compressor, hoses, and a venturi-type nozzle with an opening not to exceed 1/4 inch (6 millimeters). The air compressor should be equipped with traps that will keep the compressed air free of oil and moisture. The compressor should be capable of supplying air at 150 cubic feet per second (4 cubic meters per second) and maintaining a line pressure of 90 pounds per square inch (620 kilopascals). Caution should be exercised to prevent overblasting the crack. It is important to remove all debris from the crack, but overblasting could cause the pavement to ravel or create voids in the crack face.

Sand Blasting a Crack

Wire brushes

Wire brushes are helpful in removing debris and vegetation from shallow cracks, but they do not easily remove debris, such as saw residue, from the walls of the cracks. Debris on the crack faces will cause the sealant to lose adhesion with the pavement and prematurely fail. Worn brushes should not be used to clean the cracks because they will not effectively remove residual debris. Care should also be taken when wire brushes are used to clean cracks that have been sealed before. The brushes will have a tendency to smear the old sealant residue on the crack wall instead of removing it.

Hand tools
When approved by the Contracting Officer, hand tools may be used for repairing or cleaning cracks or removing old crack sealant. The tools should be examined to ensure that they will not damage the pavement in any manner when properly used.

Backer Rod
Installation of a backer rod should be performed on exceptionally wide cracks once a joint or crack channel has been cleaned. Installation of the backer rod into the channel is accomplished either by manual means or through the use of a specialized three-wheel tool. Two wheels ride on either side of the crack while the third rolls the backer rod into the crack channel.

Hot-Applied Sealant Equipment

At the present time, most asphalt pavement crack sealants are hot-applied. If a cold-applied sealant is used, the equipment requirements should be obtained from the sealant manufacturer. Some of the items of equipment used when sealing cracks with a hot-applied sealant are described below:

Hot-applied sealant applicator (melter)

The equipment used to heat and install the hot-applied sealant should consist of a double-boiler, agitator-type kettle. The heat transfer medium should be oil with a high flash point. The double-boiler helps eliminate hot spots in the heating kettle and the agitator provides mixing for uniform heating of the sealant. A direct heating kettle should never be allowed. The sealant should be transferred from the kettle to the crack by means of a direct-connected pressure-type extruding device (hose) with a nozzle that will insert into the crack. The equipment should be designed to allow the sealant to be circulated back into the inner kettle when sealing is not being performed. Positive temperature devices are used to control the temperature of the oil bath and measure the temperature of the sealant. Recording-type thermometers are useful for monitoring the temperature of the sealant in the kettle as work progresses. Recording-type thermometers are not normally installed on the equipment at the manufacturer, but can be installed by the Contractor. The thermometers should be positioned so that they are easily read.

Handtools

Due to the meandering nature of cracks, handtools are required to insert the backer rod materials in cracks that are deeper than 3/4 inch (19 millimeters). These tools should not twist, cut, or damage the backer rod material.

Sealant Applicators Not Recommended

Pouring pots or gravity-fed sealant applicators are not recommended for sealing cracks. These applicators have a tendency to trap air in the sealant as it is applied into the crack, creating voids in the sealant. When spot repairs are made to cracks that have been sealed, it may not be feasible to use the hot-applied sealant applicator as described above and pour pots may be used. The pour pot should be equipped with a nozzle that will fit inside the crack in the same manner as the nozzle of the hot-applied sealant applicator.

Finishing Procedures

Finishing techniques will vary depending on the application and type of material chosen. Flush finishes and over banding methods require the use of a squeegee. In some cases, a preformed plate on a hand lance assists in making the required flush result. All sealant left on the surface should be squeegeed to prevent a rough ride.

Blotter coats of clean sand are usually used with emulsion crack filling to prevent pick-up of an overband upon re-opening to traffic. To ensure a high quality blotter coat, only clean and dry sand should be used.

Poorly Finished Crack Seal

Opening to Traffic

Sealants and fillers undergo a curing cycle depending on the type of material used. Emulsions cure by water loss and reduce in volume. This process usually takes several days and creates a concave surface in the crack. Generally, cracks filled with these materials should not be overlaid for at least a year. Trafficking should not be allowed until after the emulsion has set sufficiently so that tires passing over the sealant/filler won't pick it up. It is common to blot with sand prior to opening to traffic.

Hot applied materials are thermoplastic; they set when they cool provided no diluents, such as solvents, are used in their formulation. These materials produce a non-tacky finish once the material reaches ambient temperature. A blotter coat can assist in this process. In addition, hot applied sealants require a three to four month cure time prior to being covered with a blanket or seal. Hot applied materials should not be placed over cold mix patches. This hot applied material will pick up, pulling the patch out.

Silicone, along with two-part systems (used in PCC pavements), cure by cross-linking either due to ambient moisture or a two-part chemical reaction. When using these materials the manufacturers' recommendations must be followed. Overbanding and capping must not be performed when using these materials and they should be applied such that they do not receive direct traffic. Sanding the fresh crack seal reduces safety concerns and improves the surface appearance. Excess sand must be swept away before opening the road to traffic.

Estimating Cost

A reliable estimate of the required materials can be the deciding factor in whether or not a certain section of road receives the appropriate maintenance activities. When calculating the quantities, the following factors need to be taken into account: Length of roadway to be treated; Length of sample segment inspected; Amount (length) of targeted crack in sample segment inspected; Amount (length) of targeted crack in the roadway. Sealing costs range from $3.94 to $8.20 per meter of crack, while filling costs range from $0.50 to $3.61 per meter of crack.

Recent Advancement in Crack Seal Technology

Crack sealing is considered to be a cost-effective routine maintenance procedure. However, selecting the wrong crack seal material, or installation on the wrong road can result in unnecessary costs since improper installation procedure can often result in premature failure of crack sealants. In order for the sealant to perform properly, it should fulfill some requirements which are given in the form of specifications from DOTs. Besides sealant's properties, improper installation might also result in premature failure which in return reduces the sealant's service life. Properties of the sealants which impact the installation process include viscosity, bulk stiffness, and adhesive bonding. Making proper project selection for crack sealing treatments has proven difficult due to the fact that laboratory testing has not been reliable in predicting field characteristics in determining proper candidates for crack seals.

ASTM, AASHTO, and several other standards describe testing procedures for crack sealants. Different DOTs around the country choose to use one of these standards, or develop their own, resulting in significant differences between the specifications. These differences create difficulties for crack sealant suppliers as many states have different installation criteria and specifications despite having similar environmental conditions. Recent developments in refining performance-based project and material selection guidelines, such as those described in "Development of Performance-Based Guidelines for selection of Bituminous-Based Hot-Poured Pavement Crack Sealant," "Perliminary Results of Repeatability and Sensitivity Study on Overlay Tester for Crack Sealants" (report 5457), and "Performance Comparison of Hot Rubber Crack Sealants to Emulsified Asphalt Crack Sealants" (report 4061), have done much in the way of improving DOT's ability to effectively choose the right sealant to use and indentify roadways that are in need of crack seal installation.

TxDOT Research Study on Using an Overlay Tester for Evaluating Crack Sealant

Although crack sealing has been one of the main pavement preservation strategies used by TxDOT, many sealants have exhibited a failure in adhesion within the first three years of their service life. There is currently on one adhesion test in use (ASTM D5329-04), but this test has limitations. First, the test takes several days to complete. Secondly, the test relies on subjective results obtained from visual observation. Finally, this test has proved to provide a very weak correlation with field adhesion failure data. TxDOT study 5457, "Evaluation of the Overlay Tester for

Adhesion Testing of Crack Sealants" develops a test and draft specification that can quickly and reliably test the adhesion properties of sealants in the laboratory.

Researchers developed their own adhesion testing device using an overlay tester. This device was used on multiple specimens. Each unique specimen had five copies in order to test each specimen at several testing temperatures. Specimens were prepared using thirteen unique crack sealants from a variety of vendors. Extensive studies were completed in order to determine the susceptibility of testing results to temperature. Testing revealed that the adhesion characteristics of the sealants were very sensitive to temperature conditions. These test results allowed researches to make recommendations on the best sealant material to be used on the different environmental zones of Texas. In addition to using established sealant materials, researchers also used new materials offered by the vendors and found that the newer sealant materials generally outperformed older materials when it came to adhesion testing.

This study produced two major findings: first, it was determined that the newly developed adhesion testing equipment provide a method of easily distinguishing between sealants with poor adhesion properties, and those with good adhesion properties. Second, researchers were able to propose a draft of crack sealant special specifications. Moving away from the current crumb-rubber based specification, the new specification is meant to be performance based – primarily based on the performance observed from this new adhesion testing device.

While this study represents significant advancement in laboratory evaluations of crack sealants, statewide evaluation should still be completed before fully integrating the new specification requirements. A proper next step for furthering and verifying this research will be to install and evaluate test sections so that field data can be compared to laboratory findings.

TxDOT Research Study on Hot and Cold Pour Sealants

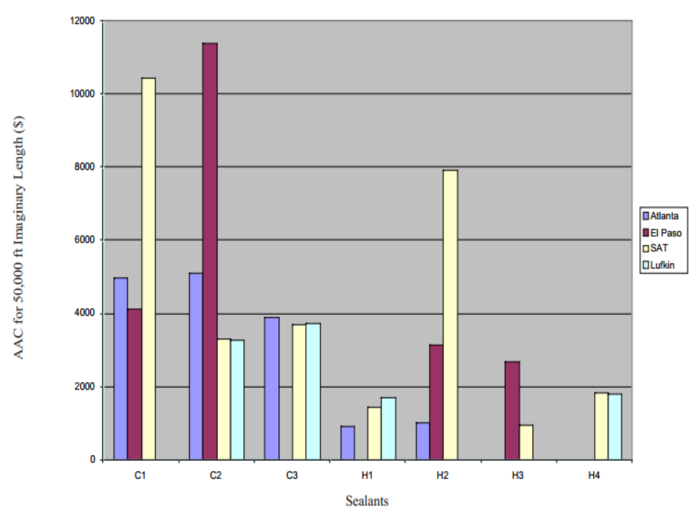
Hot pour sealant materials have always been and continue to be more popular that cold pour crack sealants. Despite this trend, very little information is available that compares the performance and life-cycle cost of hot vs. cold pour materials. TxDOT study 4061, "Comparison of Hot Poured Crack Sealant to Emulsified Asphalt Crack Sealant," compares the performance and cost of different hot and cold sealants so that more information will be available during the project and mixture selection process.

In order to complete this study, researchers first obtained responses to a survey on crack sealants from 21 different districts in Texas in addition to nine state departments of transportation. Next, a field comparison was completed involving seven different crack sealants – three cold pour (C1, C2, C3) and four hot pour (H1, H2, H3, H4). These sealants were applied on eights roads for a total of 33 test sections. These test sections were divided into two further groups by covering eight of them with a seal coat after crack sealing application, while thirty-three of the sections were left uncovered by a seal coat. The test sections were monitored for performance throughout the duration of the project. Initial evaluation was done three to four months after initial installation.

Responses to the survey revealed that every district used hot pour sealants, while only a third of the districts also used cold pour sealants. For the districts that used both, it was reported that better performance was observed from hot pour sealants, but neither type of sealant was given the designation of "poor performance."

Field performance results match with the responses received from the survey. Hot pour sealants were observed to outperform cold pour sealants in all test sections. Upon first inspection, both cold and hot pour sealants remained in good condition. However, as time went on, the sections using cold pour sealant deteriorated at a much higher rate than those using hot pour sealant. What's more, cold pour sealants were observed to perform exceptionally poorly in cold climates. Both types of sealant struggle in cold conditions, but cold pour sealants handle temperature fluctuation worse than hot pour alternatives.

While hot pour sealants outperformed cold pour sealants, this does not necessarily mean that hot pour sealants provide the most cost-effective option. Though they perform better, required installation temperature and condition guidelines result in the hot pour applications to be more expensive than cold pour alternatives. It is this high installation cost that likely encourages come districts to use cold pour sealants. However, installation cost is not that only fact that contributes to the cost-effectiveness of a material. In order to obtain a complete picture of each sealant, and life-cycle cost analysis was completed for each crack sealant material. When viewed in this light, it is revealed that hot pour sealants are generally a more cost-effective choice despite the fact that their installation cost is slightly higher. This is because the longer service life of hot pour sealants means that preservation or reconstruction projects will be delayed longer in cases where hot pour sealant is used. Cold pour sealants are cheaper to install, but more expensive to maintain.



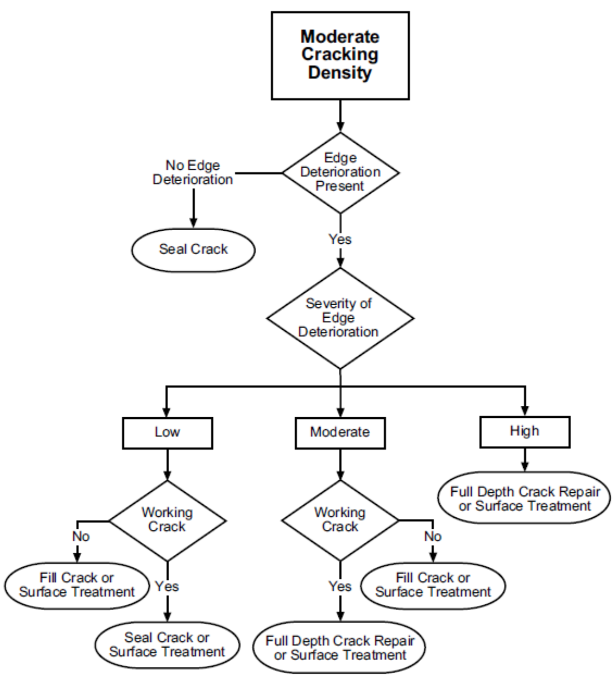
Average Annual Cost of Tested Crack Sealants

As a result of this study, researchers submitted suggestions for modification to TxDOT crack sealant specifications. These suggestions included characterizing sealants using bending beam rheometer (BBR) and dynamic shear rheometer tests as supplemental to the current testing standards. The BBR test is suggested due to the fact that most crack sealant failure were observed in cold climates and the BBR test examines sealant performance in cold temperatures. These tests can be used in evaluations of both hot and cold pour sealants.

Performance-Based Selection Guidelines

In their report, "Development of Performance-Based Guidelines for Selection of Bituminous-Based Hot-Poured Pavement Crack Sealant," released in January 2009, Dr. Al-Qadi, Jean-Francois Masson, Shih-Hsien Yang, Eli Fini, and Kevin McGhee, claim that most of the existing crack seal specifications are generally empirical and do not measure the sealant's fundamental properties. Subjective specification guidelines, which has been the norm, can be

seen in the diagram below. Also, if a look is given to today's sealant testing techniques, most of them are based on standard empirical tests such as flow, penetration, resilience, solubility, tensile adhesion or flexibility tests. These tests are used by most DOTs around the country in selecting their crack sealing materials, while, as mentioned above, selection guidelines and specification limits may vary from one state to another.



Example of Subjective, Non-Standardized Selection Guidelines for MDOT Crack Seal Installations

In the past few years researchers have reported that current specifications for selection of hot-poured crack sealants are based on tests whose results showed no correlation with field performance. Because of this, it has been common for crack sealing to be installed on roads that are too damaged for a crack seal, thus resulting in premature failure of the crack seal. Besides this fact, the invention of new and improved materials for crack sealing which exhibit complex behavior when compared to traditional ones makes it necessary for a new set of specifications to be developed.

Common Crack Sealant Failures and Concerns

Before researches are able to effectively improve crack sealant selection procedures, a complete understanding of the ways in which crack seals typically fail must be obtained. Al-Qadi et. al. collected data on common crack seal failures in order to know which properties of the sealant materials must be better understood. These failures were found to be the following:

During the sealant installation procedures, the viscosity of the sealant is often too high resulting in an inability for the material to properly fill the crack. As a result, interface bonding between the sealant and pavement substrate is inadequate. On the other hand, if viscosity is too low, the sealant may flow out from the cracks before proper adhesion or curing.

A second common problem is that of cohesive or adhesive failure. In order to accommodate pavement fluctuations due to ambient temperature, sealants extend in low temperatures and compress at high temperatures. However, with improper mix design, the sealant may pull out from the crack from tire passing during hot temperature conditions (adhesive failure), or at low temperatures, the crack may widen and pull away from the sealant, effectively leaving cracks in the surface (cohesive failure).

The third most common source of crack sealant failure is due to improper installation procedures. While failures that result from such a cause cannot be improved with better selection guidelines or mixture designs, it is clear that education of maintenance personnel must remain a high priority for DOTs around the country. Only through proper education will maintenance personnel be confident in proper installation procedures.

For these reasons, Dr. Al-Qadi et.al. have developed a new set of laboratory tests that measure bituminous-based crack sealants rheological properties which has lead to the development of performance-based guidelines for the selection of hot-poured crack sealants. Although field tests give a better understanding of the crack sealants performance, it is difficult to rely on these tests in order to develop general guidelines since differences in environmental conditions will affect the results. Because of this, researches needed to develop tests that could effectively measure the rheological properties of sealants in pursuit of developing reliable performance based guidelines for field selection of crack sealants. Thresholds for performance were set for each test that would live up to the rigors of field applications. Each test will be identified that is being used to ensure desirable sealant field performance and selection.

New Testing Procedures

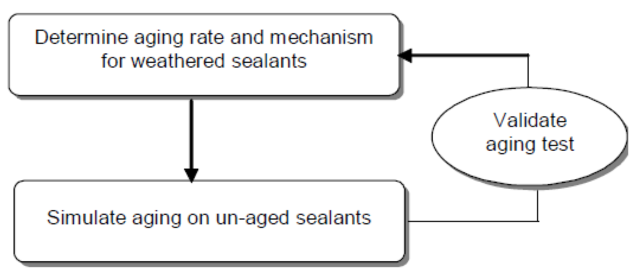
New testing procedures have been developed in order to obtain standardized performance-based guidelines for the selection of hot-poured crack sealants. These tests measure the following rheological properties of hot-poured crack sealants over a wide range of service temperatures:

Apparent Viscosity

The viscosity of the sealants is one of the main parameters affecting the initial bonding. Thus, the sealant should be applied when having the appropriate viscosity. In this case, improved testing techniques will result in better crack filling and will enhance interface bonding. Although standard tests to examine sealant consistency exist, these standard tests have not been proven to predict field performance.

Sealant Aging

Aging can be differently expressed as the rate at which the sealant oxidizes. Sealants with good performance tend to resist weathering for longer times, whereas sealants with poor performance will oxidize quickly. When performing experiments, waiting until the sealant oxidizes is impractical, thus different methods have been developed to mimic the effect of weathering on sealants. Some of them include: microwave aging, pressure aging, oven aging, and vacuum oven aging.



Schematic of Aging Procedure

3. Sealant Flow and Deformation

Bituminous sealants applied to cracked pavements sometimes fail due to deformation under the combined action of shear stresses and high service temperatures. Twenty-one different sealants were tested with a dynamic shear rheometer (DSR) in order to mimic the effects of various traffic levels and maximum temperatures found in the field.

4. Flexural Creep

A binder's stiffness at low temperatures is usually measured using the bending beam rheometer (BBR). In a newly developed approach, researchers use a new modified BBR test, a crack sealant bending beam rheometer (CSBBR) which allows for better understanding of how a crack seal material will behave at low temperatures.

5. Low Temperature Tensile Properties

Sealants can often become brittle depending on the composition and test temperature. Low-polymer and high-crumb-rubber-modified sealants behave as brittle plastic materials where the stress-strain curve is linear up to fracture. Such material is newly in use for laboratory tests in order to mimic the behavior of crack seals at low temperatures. So, the brittle-ductile failure that is observed in crack sealants can now be measured and accounted for during project selection.

6. Adhesive Properties at Low Temperature

ASTM D5329 is the most commonly used adhesion testing procedure. It is an empirical experiment which in return gives no security in correlating the laboratory testing to field performance. While still in use, improved testing procedures used in combinations with ASTM D5329 have resulted in more reliable performance-based selection guidelines.

Researchers have developed these new testing procedures based on the performance of sealants tested in the field and on the characterization of other sealants widely used in North America. The newly developed procedures examine fundamental sealant properties that include apparent viscosity at the recommended installation temperature, vacuum oven aging to simulate sealant weathering in the field, a DSR test to assess sealant's tracking resistance at high service temperatures, the CSBBR test to evaluate sealant's creep properties at low temperatures, the CSDTT to characterize sealant's low temperature extendibility, and low temperature adhesive (surface energy, direct adhesion, and blister) tests to evaluate the bonding between sealant and its substrate.

In order to perform these experiments, the equipment developed during the five-year Strategic Highway Research Program (SHRP) was adapted for use in measurement of binder rheological behavior. To develop performance-based guidelines for the selection of hot-poured crack sealants the research group made use of the SuperPave™ binder performance grading (PG) equipment.

Different modifications to the existing viscosity test, bending beam rheometer, and direct tension test devices, specimen size and preparation, and testing procedures were made to accommodate the testing of crack sealants. In addition, new tests for sealant aging and sealant evaluation at high service temperatures were introduced.

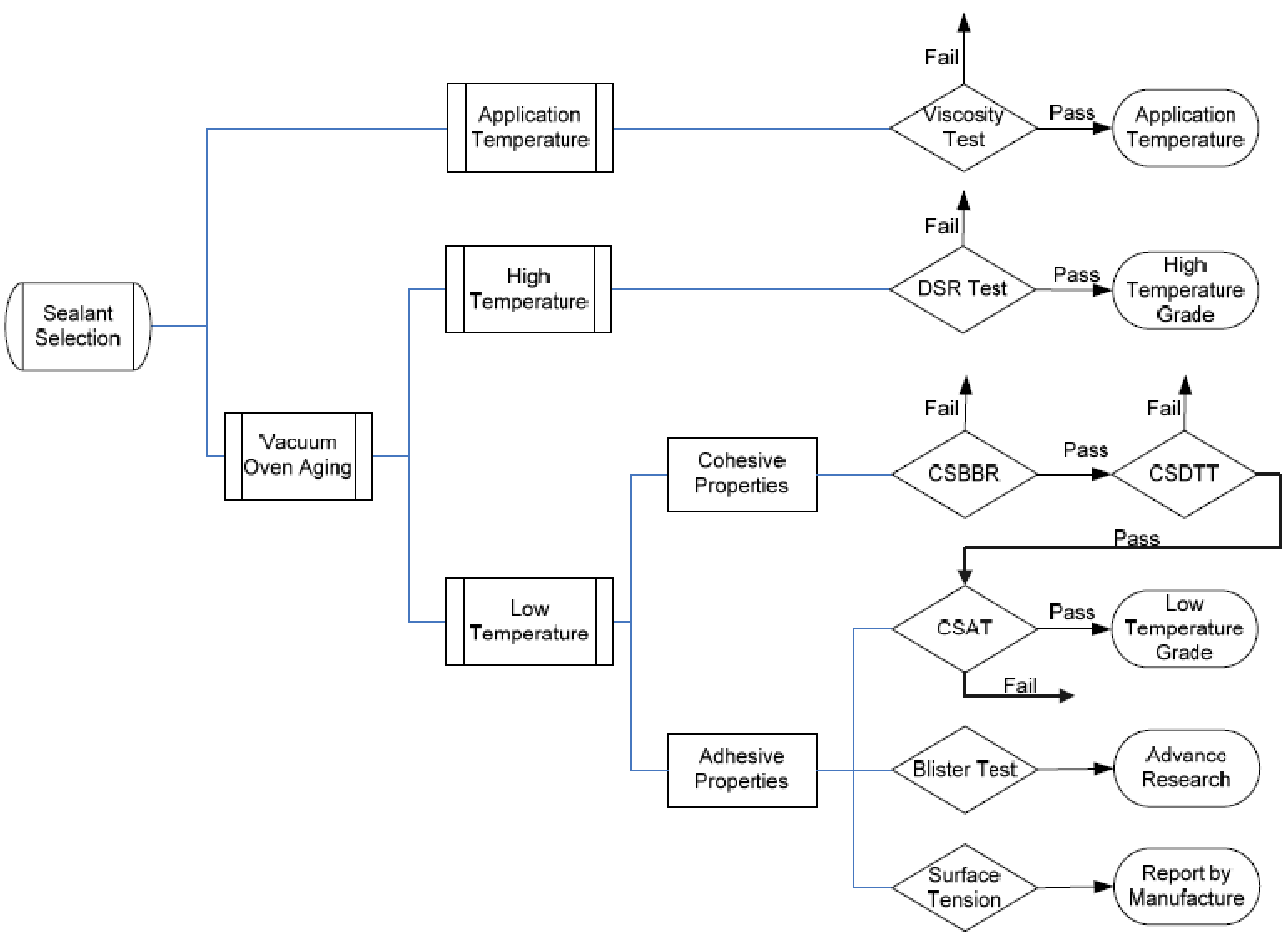
Road Too Damaged for Crack Seal

The Study's Findings and Recommendations

Dr. Al-Qadi et. al. compiled the results of these many laboratory tests and studies in order to make recommendations for the future of crack sealant performance-based selection guidelines. First, they found that an apparent viscosity at an installation temperature between 1 and 3.5 Pa.s provides for good crack filling without being excessively viscous. Second, resistance to tracking at high service temperatures can be best controlled through the use of a minimum flow coefficient of 4 kPa.s and a shear thinning exponent of 0.7 (determined with use of a dynamic shear rheometer). Third, using a modified BBR test, a maximum stiffness at 240 s of 24 MPa and a minimum average creep rate of 0.31 will promote good field performance of sealant materials which will be expected to withstand low-temperature field conditions. Fourth, measuring extendibility with the CSDTT is a good measure of a sealant's expected low-temperature field performance. Finally, of three used adhesion tests, the test best suited for development of performance-based selection guidelines was the direct adhesion test. In this test, a minimum load of 50 N at the testing temperature coincides with good performance for sealant adhesion.

Ongoing studies such as these continue to improve the reliability of performance-based selection guidelines for crack seal applications. As field and laboratory testing of roadways and maintenance materials become more reliable, appropriate maintenance decisions will become more standardized across all DOTs. With standardized performance-based selection guidelines, more cracks will be appropriately diagnosed for crack seal treatments and the appropriate sealant material will more often be selected. Currently there is still no universal standard for proper implementation of crack seal treatments. Because of this, many roads are allowed to degrade to the point of structural problems that cannot be fixed with crack seals. However, as selection guidelines continue to become more reliable and standardized, crack seal treatment selection is becoming more streamlined. With these improvements, more roads are receiving crack seal treatment at the right time, preventing the need for future, more expensive reconstruction projects.

As seen below, current trends in crack sealing have led to improved methods for sealant material selection when compared to previous selection guidelines above. For further information regarding sealant selection guidelines and the current state of crack sealing research, please refer to Dr. Qadi et. al.'s report titled “Development of Performance-Based Guidelines for Selection of Bituminous-Based Hot-Poured Pavement Crack Sealant.”



Process for Selection of Bituminous-Based Sealants