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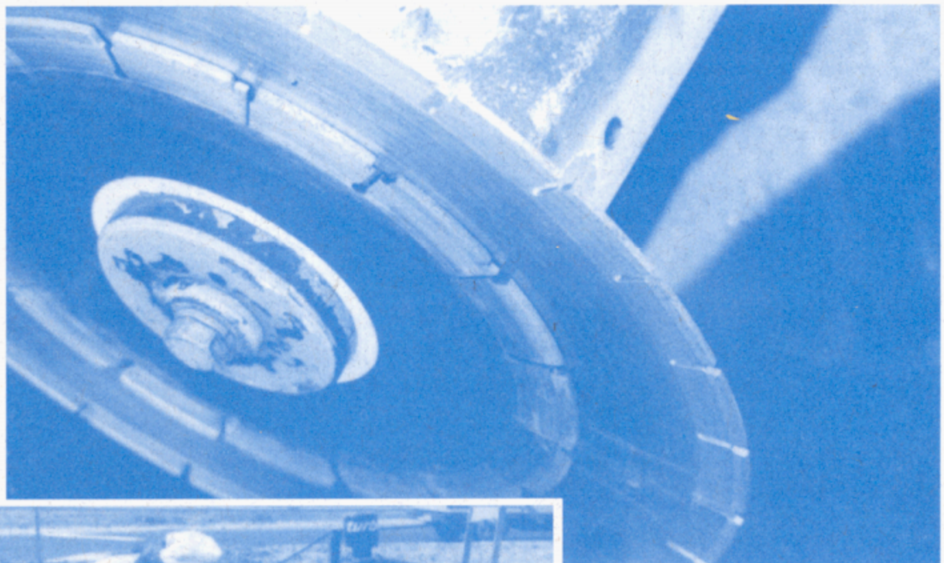

Sawing and Sealing Joints in Bituminous Pavements to Control Cracking

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The practice of sawing and sealing joints in pavements is not a new one. In fact, it is common practice in the construction of jointed Portland Cement Concrete (PCC) pavements. The idea of sawing and sealing joints in bituminous pavements is much less endorsed by those responsible for the construction and maintenance of hot mix asphalt (HMA) pavements. Minnesota began experimenting with sawing joints in HMA pavements in the late 1960's. Since then more than 50 test sections have been constructed throughout the State. Test sections include HMA overlays of Jointed Concrete Pavement, HMA overlays of HMA pavements and newly constructed HMA pavements. The results show that in over 76 percent of the test sections, the formation of cracking was controlled by the sawing of joints. The unsuccessful sections were those where a deep saw cut was not made, those where the existing joints were badly deteriorated and those where the underlying joints were poorly re-located. All of these factors can be minimized through proper project selection and good design.

This study involves a review of these test sections, identifying any problems associated with the saw and seal procedure and gives recommendations for its use in Minnesota.

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Sawing and Sealing Joints in Bituminous Pavements to Control Cracking

Final Report

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EXECUTIVE SUMMARY

The practice of sawing and sealing joints in pavements is not a new one. In fact, it is common practice in the construction of jointed Portland Cement Concrete (PCC) pavements. The idea of sawing and sealing joints in bituminous pavements is much less endorsed by those responsible for the construction and maintenance of hot mix asphalt (HMA) pavements. Minnesota began experimenting with sawing joints in HMA pavements in the late 1960's. Since then more than 50 test sections have been constructed throughout the State. This study involves a review of these test sections, identifying any problems associated with the saw and seal procedure and gives recommendations for its use in Minnesota. The findings of this study can be generalized according to the following pavement types:

Bituminous Overlays of Jointed Concrete Pavement

Saw and seal can be extremely effective in eliminating maintenance costs associated with transverse reflective cracks. Candidate projects should have sound or well-patched joints and a limited amount of midpanel cracks. Relocating the underlying joint is critical for success. Studies have shown that the saw cuts in the overlay must be within 25 mm (1 in.) of the joints in the underlying concrete pavement in order for the cracks to develop at the saw cuts.

New Hot Mix Asphalt Pavements

In new HMA pavements, transverse temperature cracks can be controlled by sawing joints every 9 to 12 m (30 to 40 ft). Effectiveness decreases at longer joint spacing. Problems have developed on sections when a silicone sealant, no sealant or preformed neoprene pressure seals were used. The optimum joint spacing, depth and width need to be investigated further.

Bituminous Overlays of Bituminous Pavements

The only section that looks encouraging is the test section where the saw cuts in the overlay were made directly above the existing transverse cracks in the underlying pavement. After five years, this section is in excellent condition. In the other sections, joints were sawed at a uniform spacing no matter where the cracks were located in the existing pavement. This practice did not control the formation of reflective cracks in the overlay.

INTRODUCTION

Background

The term "saw and seal" refers to the practice of sawing joints in a pavement and sealing the joints with a sealant, usually consisting of rubberized or polymer modified asphalt. While a standard practice for Portland Cement Concrete (PCC) pavements, sawing and sealing joints in Hot Mix Asphalt (HMA) surfaced pavements is not a great deal. It is more common to wait until cracks develop in the overlay or new surface and then maintain them. The Minnesota Department of Transportation (Mn/DOT) began experimenting with sawing and sealing bituminous pavements in 1969 and has constructed more than 20 separate projects, with more than 50 test sections, under various conditions with several joint and sealant types. This report summarizes the saw and seal procedure and makes recommendations for its use in Minnesota.

History of Saw and Seal in the U.S.

The idea of saw and seal was first recommended in 1954 [1]. Most early experimentation with saw and seal was in the eastern U.S. The states of Connecticut, Maine, Massachusetts, New York, Ohio and Pennsylvania were all experimenting with some form of saw and seal in the 1950's and 1960's. The literature suggests that this research was conducted on HMA overlays of PCC pavements with the intent being to control reflective cracking that occurs at the joints.

Based on work done in the 1980's, the State of New York currently saws and seals transverse joints on many HMA overlays on Jointed Concrete Pavements (JCP). The New York procedure has received much publicity and has been tried in several other States. As a result, the procedure of sawing and sealing joints in HMA overlays on JCP is often called "New York Saw and Seal."

Mn/DOT's Experience

Nationally, most experimentation with saw and seal has been on HMA overlays of JCP. However, Minnesota's first experience with saw and seal was to control cracking in a *new* HMA pavement. Special Study 315, "Sawing Joints to Control Cracking in Flexible Pavements" was conducted from the late 1960's through the mid 1970's [2]. Three test sections, 150 m (500 ft) long, and two control sections, 215 m (700 ft) long, were created in a new HMA pavement in the southbound lane of I-35 near Stacy, Minnesota. The study hypothesized that uniformly spaced sawed joints could be sealed and maintained more efficiently than random, crooked cracks that form by themselves.

To learn if this hypothesis is correct, joints were sawed in a 305 mm (12 in.) thick, deep-strength HMA pavement built in 1969. The study focused on two main factors, the spacing between these sawed joints and the sealant material. Joint spacings of 12, 18 and 30 m (40, 60 and 100 ft) were used. Both hot-pour rubber asphalt sealant and preformed neoprene seals were used. All joints sealed with the hot-pour sealant were 6.4 mm (0.25 in.) wide by 76 mm (3 in.) deep. The joints sealed with the preformed neoprene seals were 11 mm (7/16 in.) wide by 76 mm (3 in.) deep.

Although the study documented a major problem with adhesion of the sealants (95-100 percent failure), it did report that all three sections with sawed joints had less cracking than the control sections. The sections with 12 and 18 m (40 and 60 ft) joint spacing had less than 2 percent of the cracking the control sections had after five years.

Other subsequent Mn/DOT studies also attempted to reduce crack occurrence/reflectance but they focused on other techniques such as using softer asphalt binders, aggregate interlayers, thicker overlays, fabrics, Stress Absorbing Membranes (SAMs) and Stress Absorbing Membrane Interlayers (SAMIs). Since 1985, Mn/DOT has constructed more than 50 test sections on over a dozen projects using the saw and seal technique. The impetuous for this came from the New York State work done in the 1980's. While most of these projects have been HMA overlays of JCP, many are new HMA pavements and some are HMA overlays of existing HMA pavements.

The City of Minneapolis' Experience

The City of Minneapolis has been sawing and sealing joints in new HMA pavements since 1976. They began looking at the saw and seal procedure for controlling cracking that occurs around manholes and intersections of City streets, particularly where concrete curb and gutter are used. The dimensions of the sawed joints are 6.4 mm wide (0.25 in.) and one-third the total bituminous thickness deep. Their procedure involves wet sawing, cleaning with a water blast (until the water runs clear) and drying with compressed air. The joints are then sealed with material meeting Mn/DOT Specification 3723 [3] (similar to ASTM D-3405). Joints are randomly spaced 9 to 15 m (30 to 50 ft) apart so that they line up with a joint in the curb & gutter section. In addition, the intersections are treated by sawing an "X" pattern from adjacent radii. Many of these sections were reviewed in 1994 by Mn/DOT personnel. The amount of random and transverse temperature cracking on these sections is very small, even after many years of service. Today, saw and seal is used on all of the City's new bituminous pavement.

Mn/ROAD Parking Lot

Another practical use of saw and seal is to control random cracks that develop in parking lots. The parking lot at the Mn/ROAD pavement test facility was paved in 1990 and sawed into 15 m (50 ft) square blocks. The saw cuts were sealed with a material meeting the Mn/DOT 3723 Specification. After five years of service, only one crack exists in the entire parking lot. This crack occurs along a longitudinal paving joint.

Minnesota Airports

Several airports in Minnesota have also tried saw and seal on runways and taxiways. Municipal airports in Hutchinson, Hibbing/Chisholm, International Falls and Silver Bay have all used saw and seal successfully.

Pavement Types

In Minnesota, saw and seal has been used on many different types of pavement including conventional HMA construction (NEW), bituminous overlays on jointed concrete pavement (BOC) and bituminous overlays on bituminous pavements (BOB). Other projects include overlays of previously overlaid jointed concrete pavements. Sometimes, the old overlay was completely milled off exposing the concrete. In other cases, only part of the old overlay was milled off. There are also BOC sections over cracked & seated concrete pavements, over rubblized concrete pavements, "sandwich" sections consisting of HMA on granular material over a concrete pavement and sections with cold in-place recycle (CIR) material under the HMA surface. Rather than try to put these pavements into many different groups for analysis, with a limited number in each, the data is grouped into three broad categories:

- New Bituminous Pavements (NEW)
- Bituminous Overlays on Jointed Concrete Pavement (BOC)
- Bituminous Overlays on Bituminous Pavement (BOB)

The BOC category includes any pavement that has an existing concrete pavement somewhere in its layer configuration, cracked or uncracked, including "sandwich" sections. NEW construction includes deep-strength and aggregate base construction and pavements with CIR material as a base.

HOW SAW AND SEAL WORKS

The most common type of crack found in bituminous pavements in Minnesota is the transverse thermal crack. As documented by Mn/DOT's Pavement Management Section, more than 95 percent of all the trunk highway mileage in Minnesota has at least some transverse thermal cracks. In addition, when a bituminous or concrete pavement is overlaid, the existing thermal cracks, midpanel cracks and joints reflect through the overlay to the surface. These cracks are called "reflective cracks." This section will discuss how saw and seal can be used to mitigate these two types of cracks.

Transverse Thermal Cracks in New Bituminous Pavements

When a new bituminous pavement is subjected to cold temperatures, it contracts according to its coefficient of thermal contraction. This contraction causes tensile stresses to develop in the pavement. As the temperature decreases, these tensile stresses increase. If the thermal tensile stress exceeds the tensile strength of the bituminous material, a crack will form. During cold weather, the temperature is lower at the pavement surface than it is at the bottom where the aggregate base or subgrade serves as an insulating layer. Since the temperature is lower at the pavement surface, the tensile stresses that develop are higher at the surface. As a result, transverse thermal cracks develop at the pavement surface and propagate downward.

This phenomenon was verified at the Sainte Anne Test Road [5]. The report entitled "St. Anne Test Road Revisited Twenty Years Later" states *"The fact that the transverse cracking initiated at the pavement surface and propagated downward was verified in several different ways. The automatic recorders indicated that the crack detection tape embedded in the upper portion of the pavement was broken shortly before the tape in the lower part of the pavement. Secondly, in composite pavements which comprised 'non-cracking' asphalt-type binder courses overlaid with 'crack-susceptible' type wearing courses, cracking was found to occur in the 'crack-susceptible' wearing course only."*

The frequency of these thermal cracks primarily depends on the asphalt stiffness but is also influenced by the subgrade soil type, pavement thickness, traffic loadings and friction properties at the interface between the bituminous and the underlying aggregate base or subgrade. Generally, pavements on granular subgrades will have closer spaced thermal cracks than pavements on plastic soils. This is likely due to the increased friction between the granular material and the bituminous layer. Since the bituminous layer cannot slide as easily when contracting, the stresses that develop are greater and cracking is more prevalent. As observed at the control sections near Mn/DOT's saw and seal projects, the frequency of thermal cracking increases each year until some optimum spacing is achieved. This spacing is the distance at which tensile stresses that develop between successive cracks is below the tensile strength of the bituminous. It appears that most HMA pavements in Minnesota will experience thermal cracking until an effective spacing of 9 to 15 m (30 to 50 ft) is achieved.

A saw cut in a bituminous pavement produces a weakened plane, due to the pavement's reduced cross section. When thermal stresses develop, the pavement will crack at the sawed joint because this weakened plane cannot withstand the same stresses as the unsawed portion of the pavement without cracking.

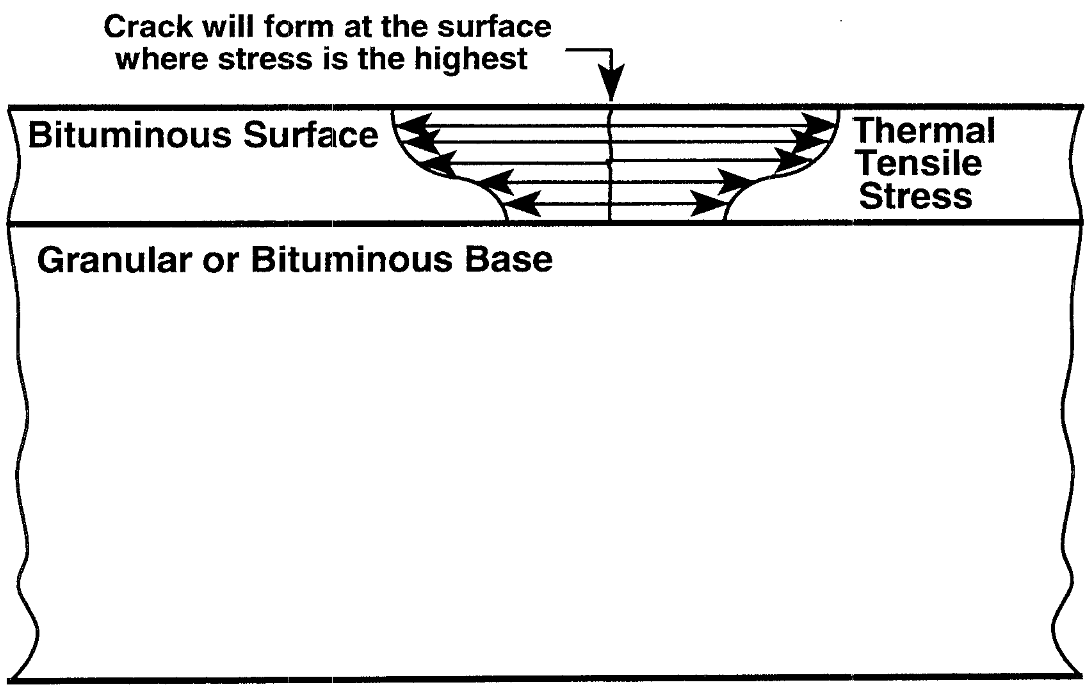

Figure 1. Thermal tensile stress in a bituminous surface producing a crack (Source: FHWA-RD-89-143)

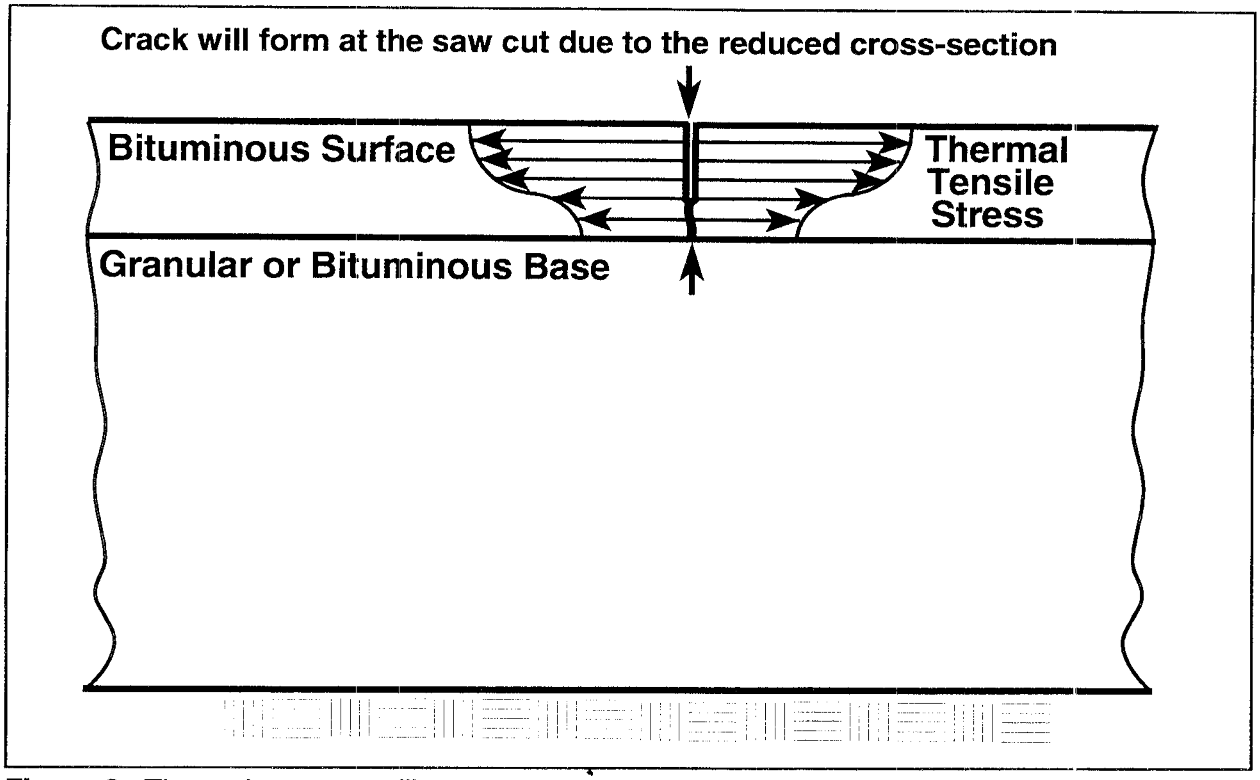

Figure 2. Thermal stresses will cause pavement to crack at the sawed joint.

To be effective, the saw cuts need to be:

1. Deep enough to ensure that the crack will occur at the sawed joint.

   If the saw cuts are not deep enough in NEW bituminous pavements to produce a sufficiently weak plane, weaker than the surrounding pavement, the cracks will not form at the joints.

2. Close enough together to ensure that tensile stresses that develop between them are not high enough to cause other thermal cracks to occur.

   If the saw cuts are too far apart, the tensile stresses that develop between successive sawed joints will exceed the tensile strength of the bituminous layer and a crack will form. This was seen on Mn/DOT's original saw and seal test sections. The sections with 30 m (100 ft) joint spacing had 14 times as much cracking as the sections with 12 and 18 m (40 and 60 ft) joint spacing. Typically, joints should be spaced approximately 9 to 12 m (30 to 40 ft) apart for NEW bituminous pavements. Results from the most recent saw and seal test sections suggest joint spacings greater than 15 m (50 ft) result in thermal cracks occurring between the sawed joints. This is due to the magnitude of the tensile stresses exceeding the tensile strength of the bituminous material. Conversely, most new pavements will not develop thermal cracks more frequent than about 9 m (30 ft) if left to crack by themselves. Thus, sawing joints less than 9 m (30 ft) apart may needlessly add to the expense of the project but not add to the performance. The spacing depends on the asphalt stiffness, pavement thickness, subgrade soil type and traffic loading.

Recently, the Strategic Highway Research Program (SHRP) has attempted to reduce transverse thermal cracking in HMA pavements with its SuperPave design procedure. This new HMA mix design procedure conducts laboratory tests that determine the properties the asphalt must have to prevent thermal cracking. The result is a recommended Performance Graded (PG) asphalt. This technique will be studied over the next several years to determine its cost effectiveness compared with the saw and seal procedure.

Reflective Cracks in Overlaid Pavements

Reflective cracks can be broken into two different types:

1) Those caused by underlying joints
2) Those caused by underlying cracks

Reflective cracks caused by underlying cracks are found in both BOC and BOB pavements. They are the result of horizontal and/or vertical movement of the pavement at the underlying cracks. Reflective cracks are also caused by underlying joints in BOC pavements. These cracks are caused by the movements that occur as the slab undergoes temperature cycling.

Unlike thermal cracks in HMA pavements, which begin at the pavement surface and propagate downward, reflective cracks begin at the bottom of the HMA layer and progress upward toward surface.

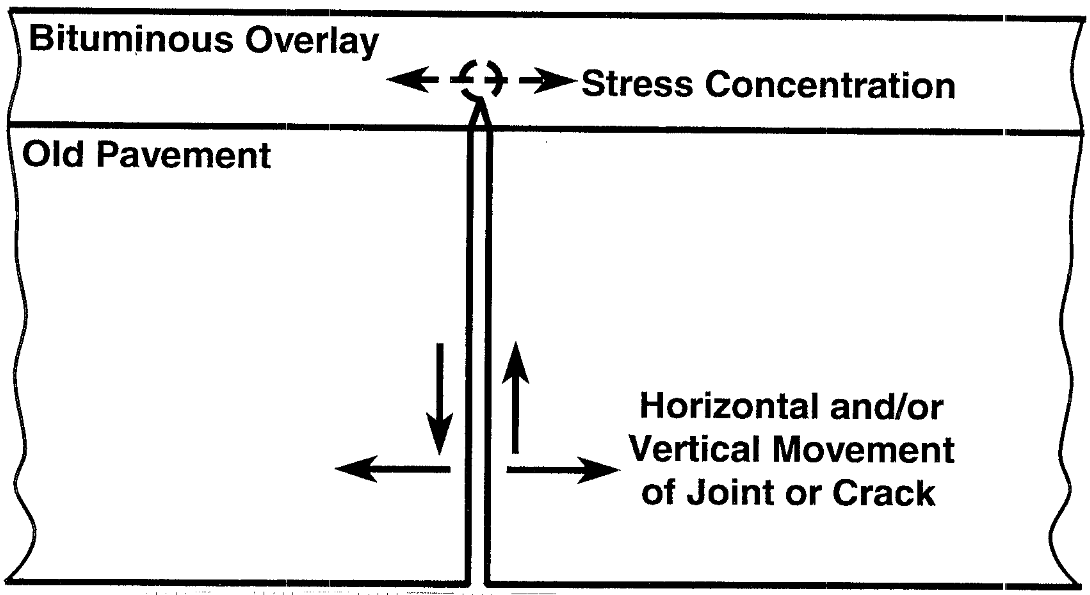

Figure 3. Stress concentrations in AC overlay resulting from thermally induced movements of PCC slab. (Source: FHWA-RD-89-143)

Bituminous Over Concrete Pavements (BOC)

The saw cuts must be made within one inch longitudinally of the underlying joints in BOC pavements or the cracks will form near, but not at, the sawed joint in the overlay. On sections with short joint spacing, say 4.5 m (15 ft), many sawed joints are not "working joints." Since discerning which joints in the PCC pavement will produce working cracks is impossible, saw cuts should be made above every joint.

A particular problem with BOC pavements occurs when the existing PCC pavement is already overlaid with HMA and only part of the overlay will be milled off before placing the new surface. Normally, the saw cuts will be made directly over the cracks in the milled HMA because they are assumed to be directly above the joints in the underlying PCC pavement. The likelihood of these cracks being directly above the joints is good if most of the old overlay is milled off. However, if a substantial thickness of the old overlay remains, there is an increased possibility that the cracks are propagating upward at some angle rather than vertically. If this is the case, then the new saw cut will not be centered over the underlying joint. This may lead to the problem shown in Figure 4.

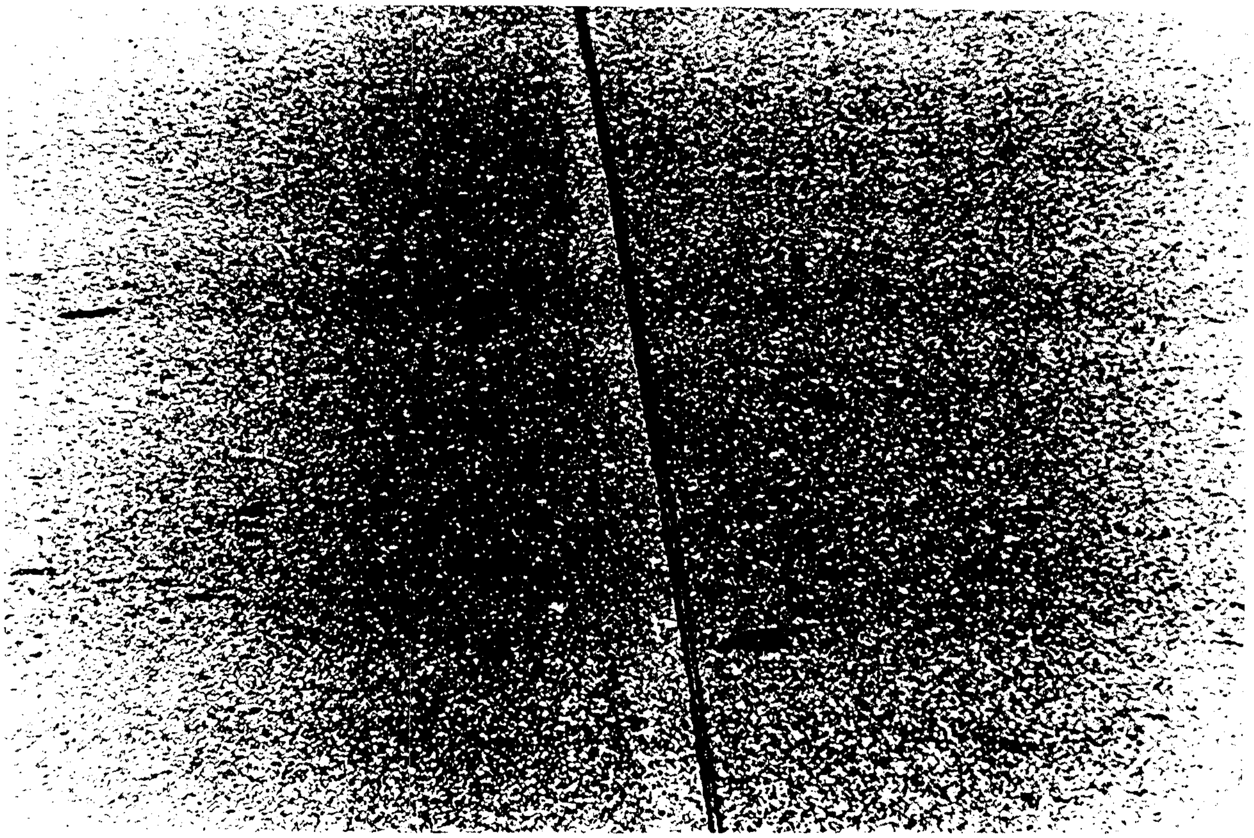

Figure 4. The result of incorrectly re-locating the underlying joint.

Bituminous Over Bituminous Pavements (BOB)

Saw and seal should only be considered for this type of pavement if the transverse cracks are extremely straight. Meandering cracks will generally reflect to the surface in their existing meandering pattern. Placing a straight saw cut in the new surface above a meandering crack will not result in a straight crack reflecting to the surface. Instead, the straight saw cut will be in the middle of the meandering reflective crack and spalling along the joint edge is likely to occur.

DETERMINING THE SUCCESS OF SAW AND SEAL

The success of saw and seal is determined primarily by *how well the process controls the formation of cracks in the pavement,* not by how well the sealant sticks to the edge of the sawed joints. While having the joints sealed is desirable, the main goal is to control the amount of cracks by forcing them to occur at the sawed joints. Exactly how successful the saw and seal procedure has been on a project can be calculated by first counting the number or measuring the length of transverse thermal cracks, reflective cracks and sawed joints in the test section. The number or length of the sawed joints is then divided by this value. For example, a test section that has 50 sawed joints and no transverse cracks is 100 percent successful at controlling the cracking (50 ÷ 50 = 1). A section with 50 sawed joints and 50 transverse cracks is 50 percent successful (50 ÷ (50+50) = 0.50). Figure 5 provides an example of this notion.

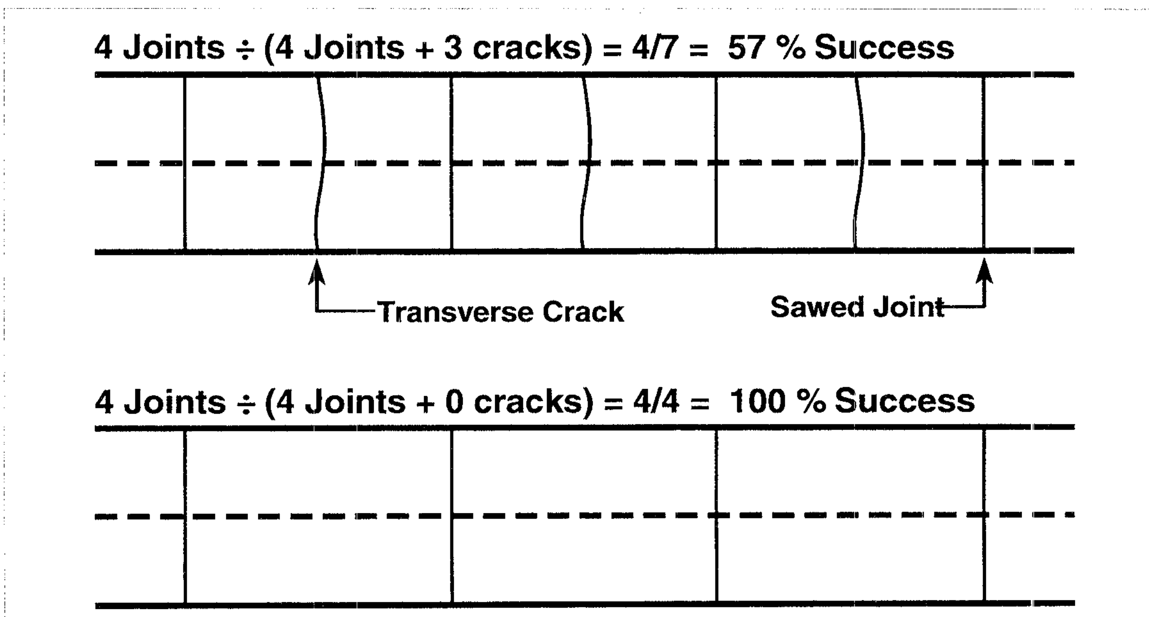

Figure 5. How to Determine Saw and Seal Success Rate.

The 50 test sections reviewed in this study have a saw and seal success rate ranging from 47 to 100 percent. More than 75 percent of the test sections have a success rate above 85 percent. Eighty-five percent success has been established as the level at which a project is considered successful or not. This was decided after consultation with members of Mn/DOT's saw and seal advisory committee. Figure 6 and 7 show the success rate of all of the test sections from this study.

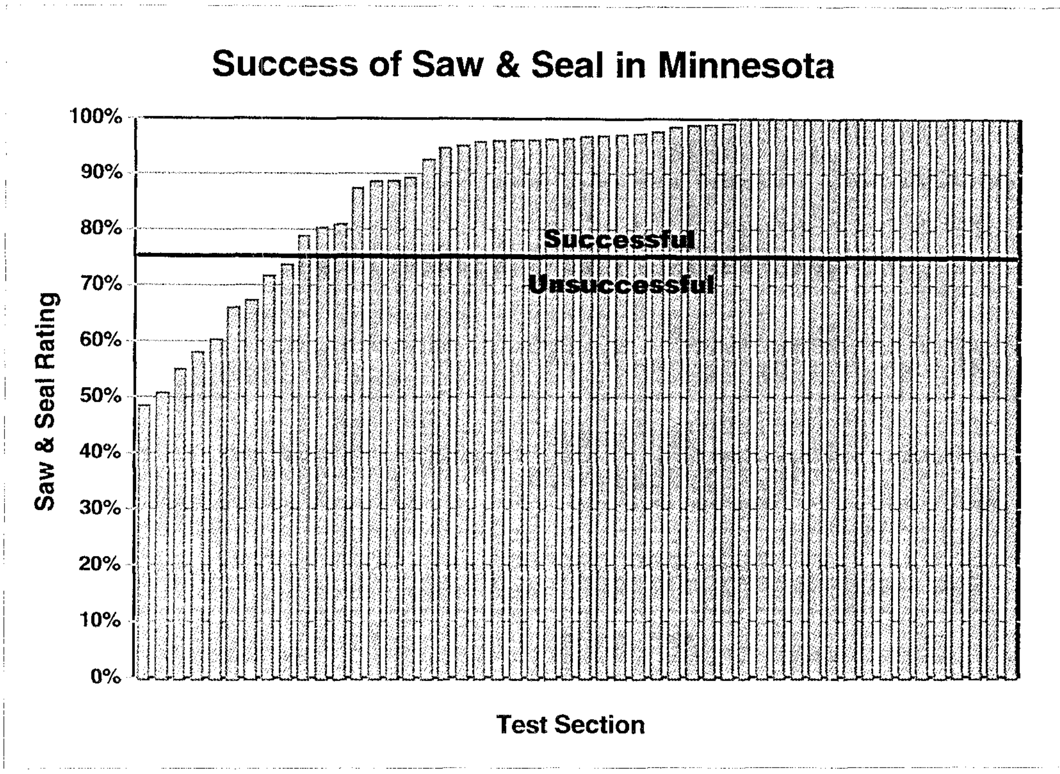

Figure 6. Success of saw & seal in Minnesota, all pavement types

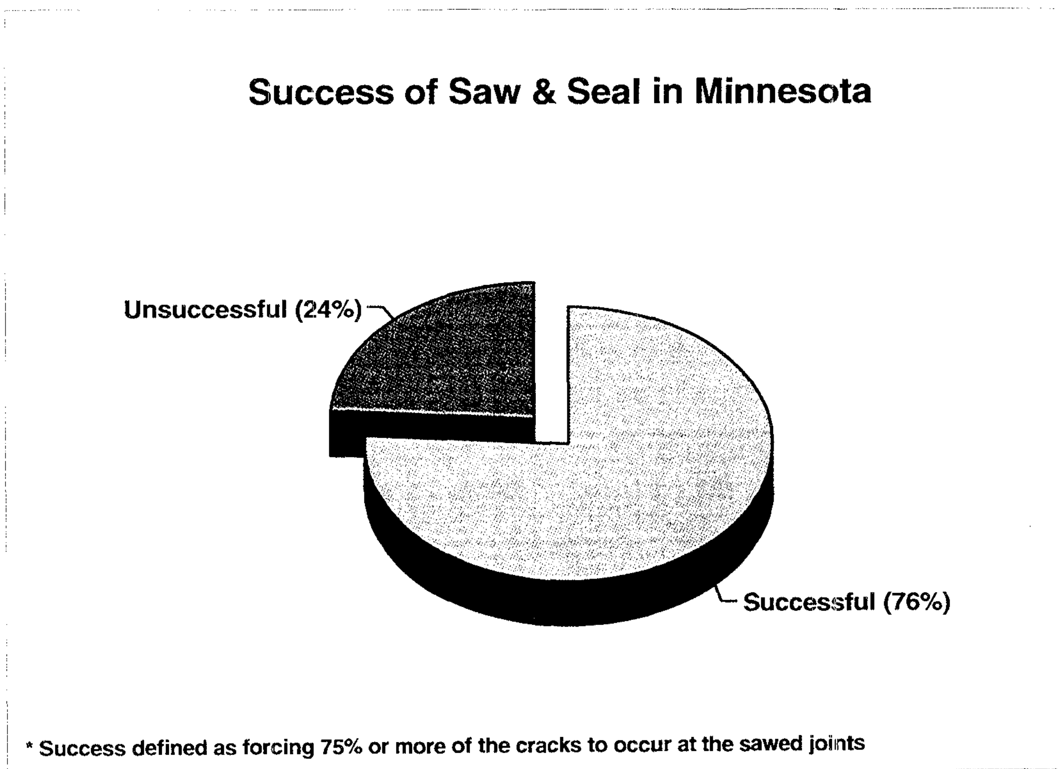

Figure 7. Success of saw & seal in Minnesota, all pavement types.

SUCCESS OF SAW AND SEAL IN MINNESOTA

For various reasons, the success of saw and seal varies by pavement type. As shown in Figure 8, the most successful saw and seal projects have been on NEW pavements followed by BOC pavements. Saw and Seal on BOB pavements has not been very successful. For all pavement types, nearly all of the unsuccessful sections can be explained and changes made to reduce or eliminate their number in the future.

The NEW sections that were unsuccessful all used reservoir-only configurations, ie. no deep saw cut. The reduced pavement cross section at the saw cuts was apparently not weak enough to force the cracks to occur at the saw cut, i.e. the necessary weakened plane was not established or developed.

The unsuccessful BOC sections were generally sections with many mid-panel cracks, badly deteriorated joints or the result of misalignment of the underlying joints.

All but one BOB section did not attempt to align the saw cuts over the cracks in the existing pavement. As a result, nearly all of the old cracks reflected through the new overlay resulting in a pavement with both cracks and sawed joints. However, the one section on I-94 where the existing cracks were straight and the saw cuts made directly over these cracks has a 100 percent success rating after five years of service.

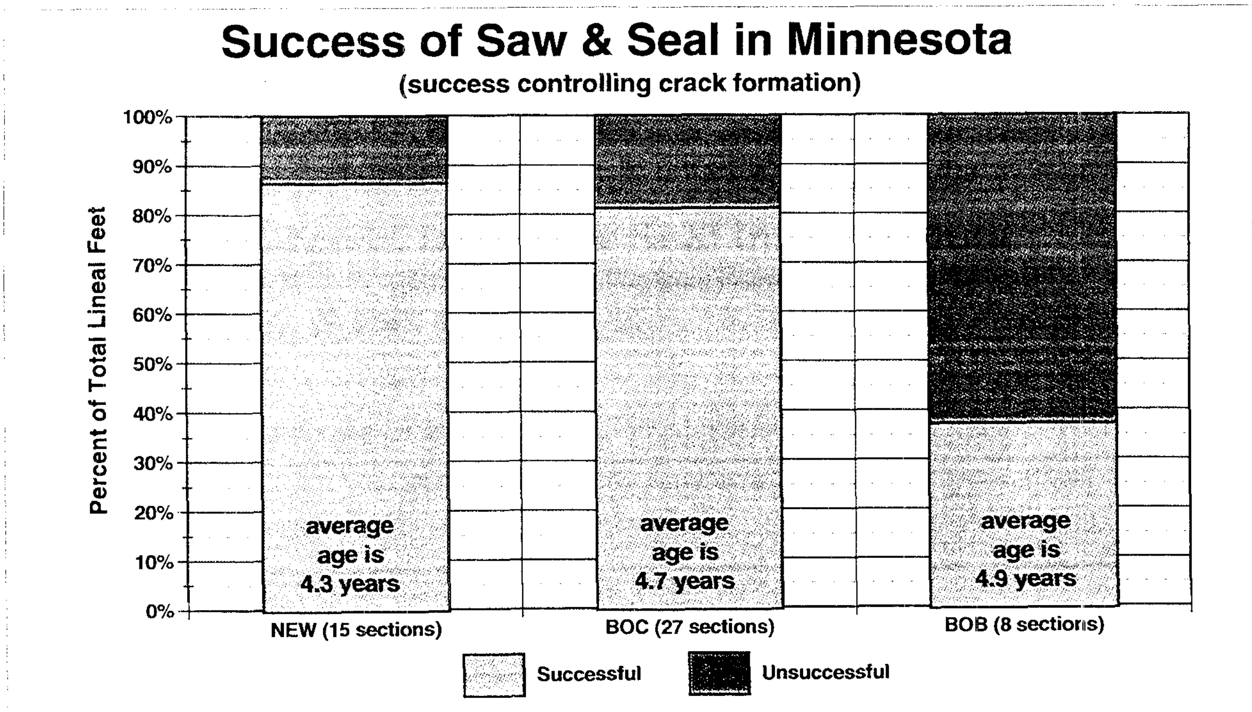

Figure 8. Success of saw and seal test sections in Minnesota at controlling crack formation.

Performance of Joints

As mentioned previously, the success of saw and seal is determined by how well the process controls the formation of cracks, not by how well the sealant performs. However, having the joints remain sealed is more desirable. To find out how well the joints are remaining sealed, condition surveys were done on each of the 50 test sections over the past few years. Many sections had multiple surveys done. The rating concentrated on the following three areas:

1. Adhesion to the joint side walls.
2. Pavement damage along the edge of the joint.
3. Damaged or missing sealant.

The amount of each of these three conditions was determined, on a lineal footage basis, for each sawed joint in the test sections. In addition, the presence of any additional cracking was recorded. The total number of lineal feet of each of the three failure criteria was calculated.

Adhesion Failure

The most common problem with the joints themselves was a loss of adhesion between the sealant and the joint sidewall(s). This could be caused by any number of factors, alone or in combination. Factors such as physical properties of the sealant, insufficient cleaning and/or drying of the joint before sealing, the joint dimensions or shape factor, and poor construction all can lead to adhesion loss.

Physical Properties of the Sealant

If the physical properties of the sealant do not meet the demands imposed by the pavement as it contracts, the stresses that build up in the sealant will exceed the material's ability to stick to the edge of the joint. An attempt is made in the laboratory to simulate this condition. This is done by running the bond test. The bond test consists of pouring a square of sealant, 12.5 mm (0.5 in) thick and 50 mm (2 in) square, between two cement mortar blocks. These blocks are then placed in a freezer and subjected to repeated cycles of stretching and relaxation. For Minnesota specification 3723, "Concrete Joint and Crack Sealer (Hot-Poured Elastic Type)" the bond test is run at -18 degrees C (0 degrees F). The specimen must undergo five cycles of 100 percent elongation without separating from the joint (adhesion failure) or splitting (cohesion failure) to pass.

The American Society for Testing and Materials (ASTM) standard D-3405 "Standard Specification for Joint Sealants, Hot-Poured, for Concrete and Asphalt Pavements" is one of the most often used joint sealant specifications nationally. It is very similar to Mn/DOT 3723. However, D-3405 allows the bond test to be run at either -18 or -29 degrees C (0 or -20 degrees F). Since experiencing -29 degrees C (-20 degrees F) is common for pavements in Minnesota, recent specifications using Mn/DOT 3723 have included the following modifications:

Crack Sealant

The Contractor will provide certification that the sealant meets the requirements of Mn/DOT Standard Specification 3723 (Hot-Poured Elastic Type Sealant) with the following modifications:

1.) The bond strength test will be run at -20 degrees F rather than the current 0 degrees F.

2.) The material will be flexible at -30 degrees F (capable of being bent over a mandrel without cracking).

3.) Only sealant material proven successful in the field in Minnesota during the last two (2) years will be acceptable.

Mn/DOT is also currently experimenting with the South Dakota DOT asphalt crack sealing specification. This specification requires the sealant to undergo three cycles of 200 percent elongation at -29 degrees C (-20 degrees F) rather than 100 percent elongation required by Mn/DOT and ASTM D-3405. This requirement will result in a softer sealant that can stretch farther without developing high stresses that cause it to lose adhesion. Mn/DOT has recently inserted this specification into all saw and seal projects. While is too early to detect how well this material works in Minnesota, the South Dakota experience suggests improved performance is likely.

An unexpected problem has been observed when using a silicone sealant to seal the sawed joints. It appears that some type of chemical reaction takes place between the silicone and the aggregate and/or asphalt in the mix. Nearly every test section that used silicone sealant has a high rate of pavement damage beside the edge of the joint. The type of damage is similar to raveling and gives the appearance that the bituminous is being eroded by the sealant.

Consequently, *silicone sealants are not recommended for sealing sawed joints in HMA pavements.*

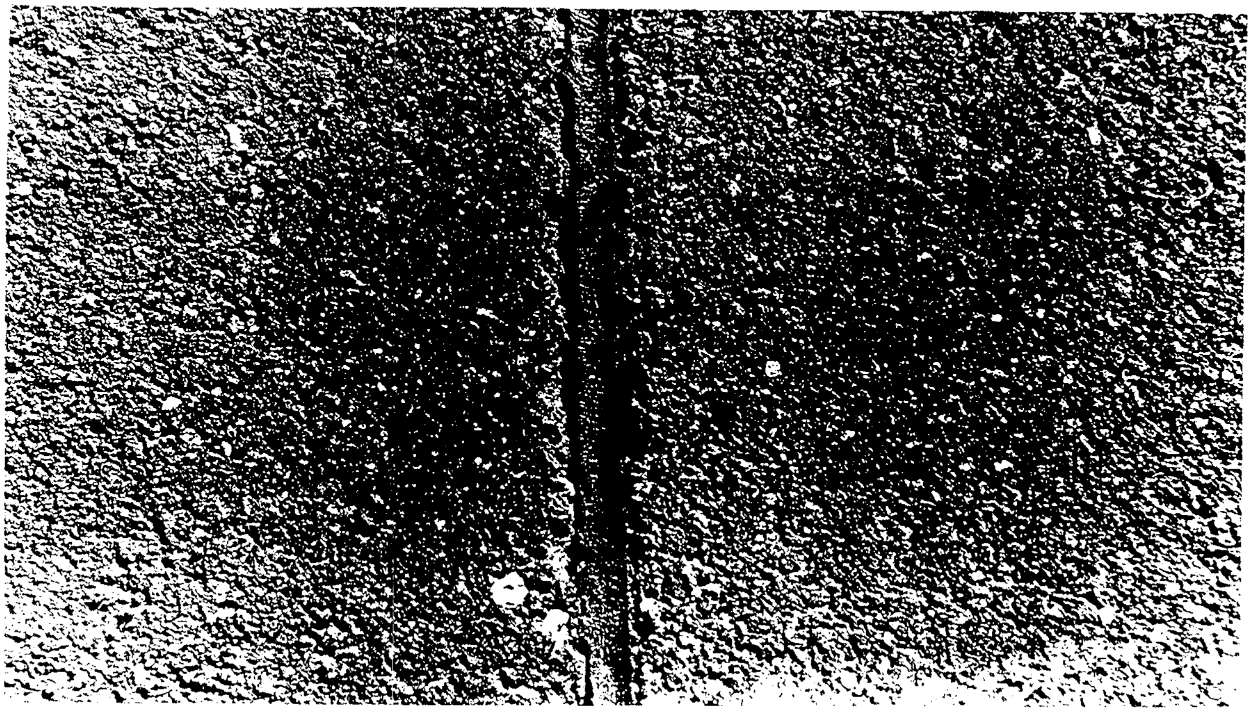

Figure 9. Pavement deterioration associated with silicone sealant

Cleaning and/or Drying the Joint

Perhaps the most overlooked part of sealing a joint is the preparation itself. Since most saw and seal is done with a wet saw cut, attention must be paid to how well the joint is cleaned and dried. If the saw cut is not properly cleaned and dried, the sealant will not develop a good bond with the joint sidewalls, despite its physical properties.

The procedure that has shown to result in the best performance when wet sawing is the following:

1. Flush the sawed joint with high pressure water until the water runs clear.

2. Clean and dry the joint with compressed air.

3. Heat the joint with a hot-air lance immediately before sealing.

The procedure that has shown to result in the best performance when dry sawing is the following:

1. Dry the joint with compressed air.

2. Heat the joint with a hot-air lance immediately before sealing.

Inspection becomes particularly important in this part of the saw and seal process. Attention must be paid to the cleanliness or limited performance will result. Besides the joint being clean, it must also be dry. Joints that are not properly dried will exhibit small air bubbles, when the joint is filled, caused by the hot sealant material producing steam as it contacts the water in the joint. These air bubbles by themselves may not affect the joint performance but are an indication that adhesion failure may occur.

Joint Dimensions (Shape Factor)

In order for the sealant to be able to stretch and not lose its bond with the joint reservoir sidewalls it must have the correct shape factor. The shape factor is the ratio of the joint width to depth. For example, a joint with a shape factor of 2.0 means the width of the reservoir is twice the depth. Stiffer sealants need larger shape factors than soft sealants so that the stress that develops along the reservoir sidewall does not exceed the material's ability to adhere as the joint opens in cold weather. The New York saw and seal procedure for HMA overlays on PCC pavements recommends the following dimensions based on the existing slab length.

Table 1. Reservoir dimensions used by New York DOT.

Slab Length	Width	Depth	Shape Factor
15 m or less (50 ft)	13 mm (½ in)	16 mm (5/8 in)	0.80
15 - 19 m (51-62 ft)	16 mm (5/8 in)	16 mm (5/8 in)	1.00
19 - 23 m (63-75 ft)	19 mm (3/4 in)	16 mm (5/8 in)	1.20
23 - 27 m (76-87 ft)	22 mm (7/8 in)	19 mm (3/4 in)	1.16
27 - 30 m (87-100 ft)	25 mm (1 in)	22 mm (7/8 in)	1.14

Since none of the BOC pavements in Minnesota have slab lengths more than 15 m (50 ft), the 13 mm (1/2 in) wide by 16 mm (5/8 in) deep dimension has been used exclusively. The first saw and seal project in Minnesota reported problems with adhesion failure and attributed the problem to the shape factor of the joints. This project used deep and narrow joints with shape factors of 0.08 and 0.29. Sealants in joints with these small shape factors are exposed to extremely high levels of stress as they stretch. The result is usually a loss of adhesion along the joint sidewalls.

Construction

As with any type of pavement construction or maintenance, construction plays an important role in the success of the project. All of the work spent preparing good specifications, performing lab tests, and designing the project can be negated by poor construction. Improper filling of the joint, with either too much or not enough sealant, too high of an overband, not following the sealant manufacturers recommendations as far as temperature and handling, improper cleaning and drying of the reservoir and not recirculating the sealant material through the applicator wand will all shorten the expected life of the sealant.

Current Condition of Sealant Performance

Based on the three criteria used for determining the sealant performance described previously, the following figures show the performance of the 38 projects considered "successful" at controlling crack formation, as defined earlier.

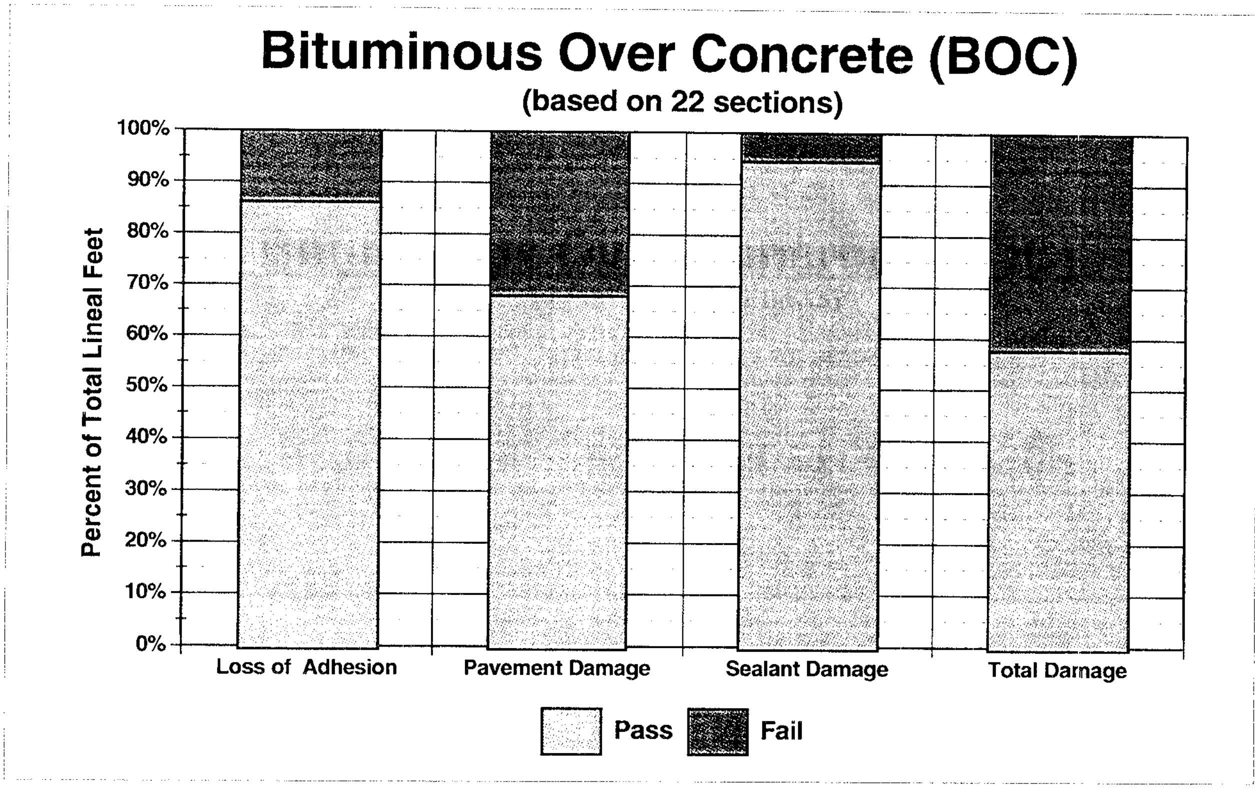

Figure 10. Performance of Sawed & Sealed Joints on BOC Pavements

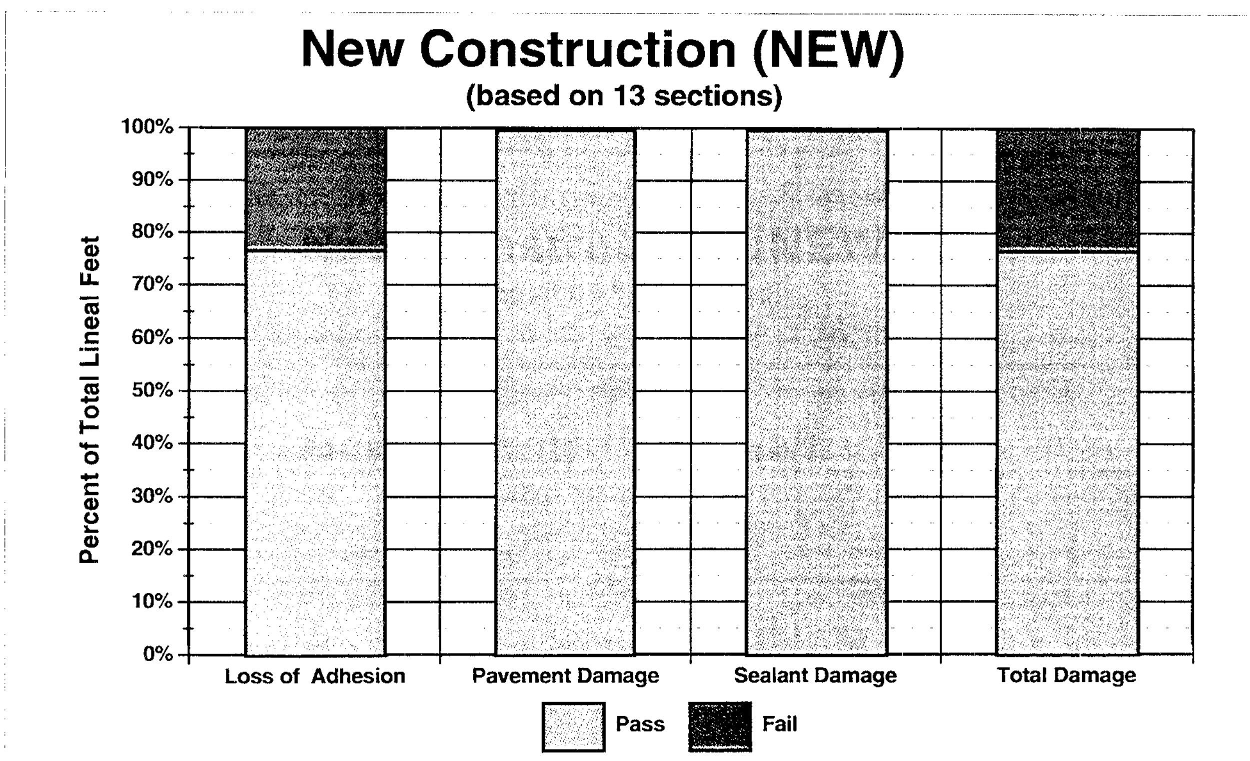

Figure 11. Performance of Sawed & Sealed Joints on NEW Pavements

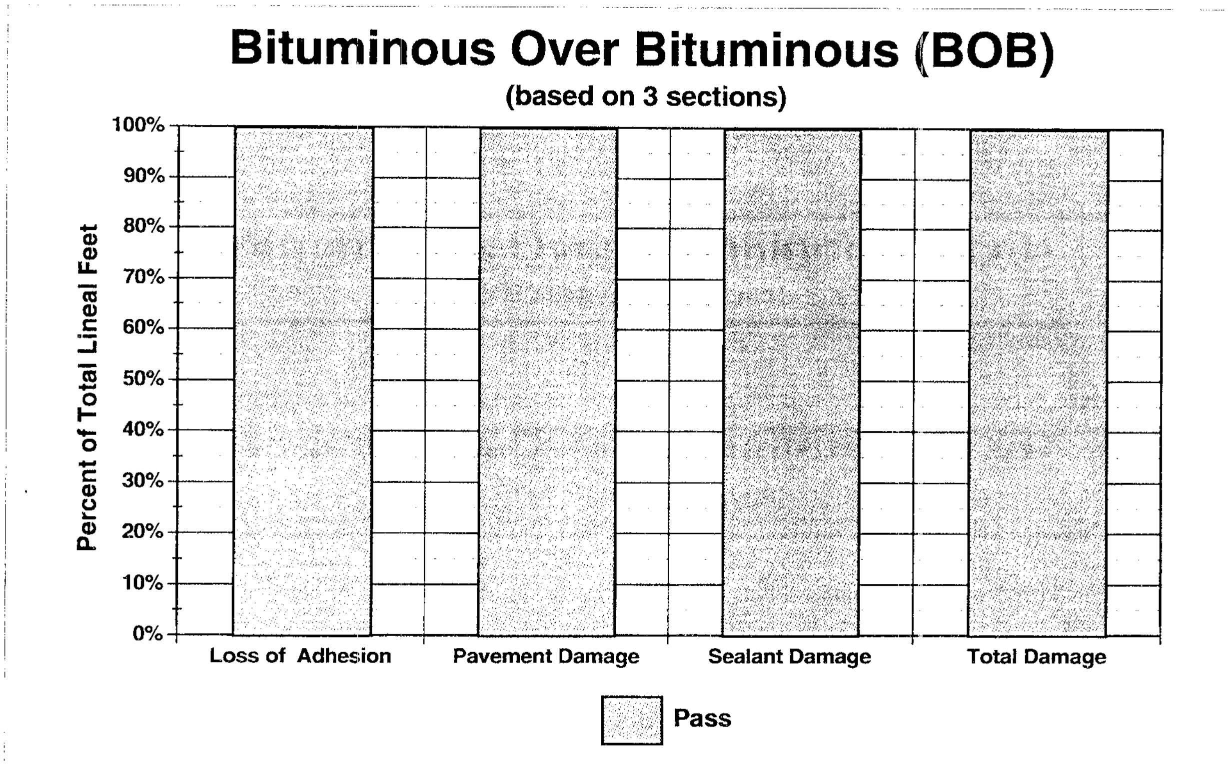

Figure 12. Performance of Sawed & Sealed Joints on BOB Pavements

The oldest saw and seal section still in service (not overlaid) is TH 371 near Brainerd, Minnesota. This project was constructed in 1986 and consists of 7 test sections spread out over three miles. The existing 9-7-9 doweled concrete pavement, paved in 1956, was overlaid with 133 mm (5.25 in) of HMA placed in three lifts. Saw cuts were made directly above the existing joints. The test sections are as follows:

1. Concrete was rubblized, overlaid and sawed & sealed @ existing joints, 6 m apart (20 ft).
2. Concrete was overlaid and sawed and sealed @ existing joints, 6 m apart (20 ft).
3. Concrete was rubblized with a Wirten device and overlaid.
4. Concrete was rubblized a PB4 resonant breaker and overlaid.
5. Concrete was cracked into 1 m (3 ft) slabs, seated and overlaid.
6. Concrete was cracked into 1.5 m (5 ft) slabs, seated and overlaid.
7. Concrete was overlaid, this was the control section.

After 10 years there are no cracks in test section 1 and only a few short diagonal cracks in test section 2. As shown in Figure 13, the two saw and seal sections have the highest Mn/DOT

Surface Rating (SR) of any of the test sections. An SR of 2.8 is generally considered to be the level where rehabilitation is considered warranted.

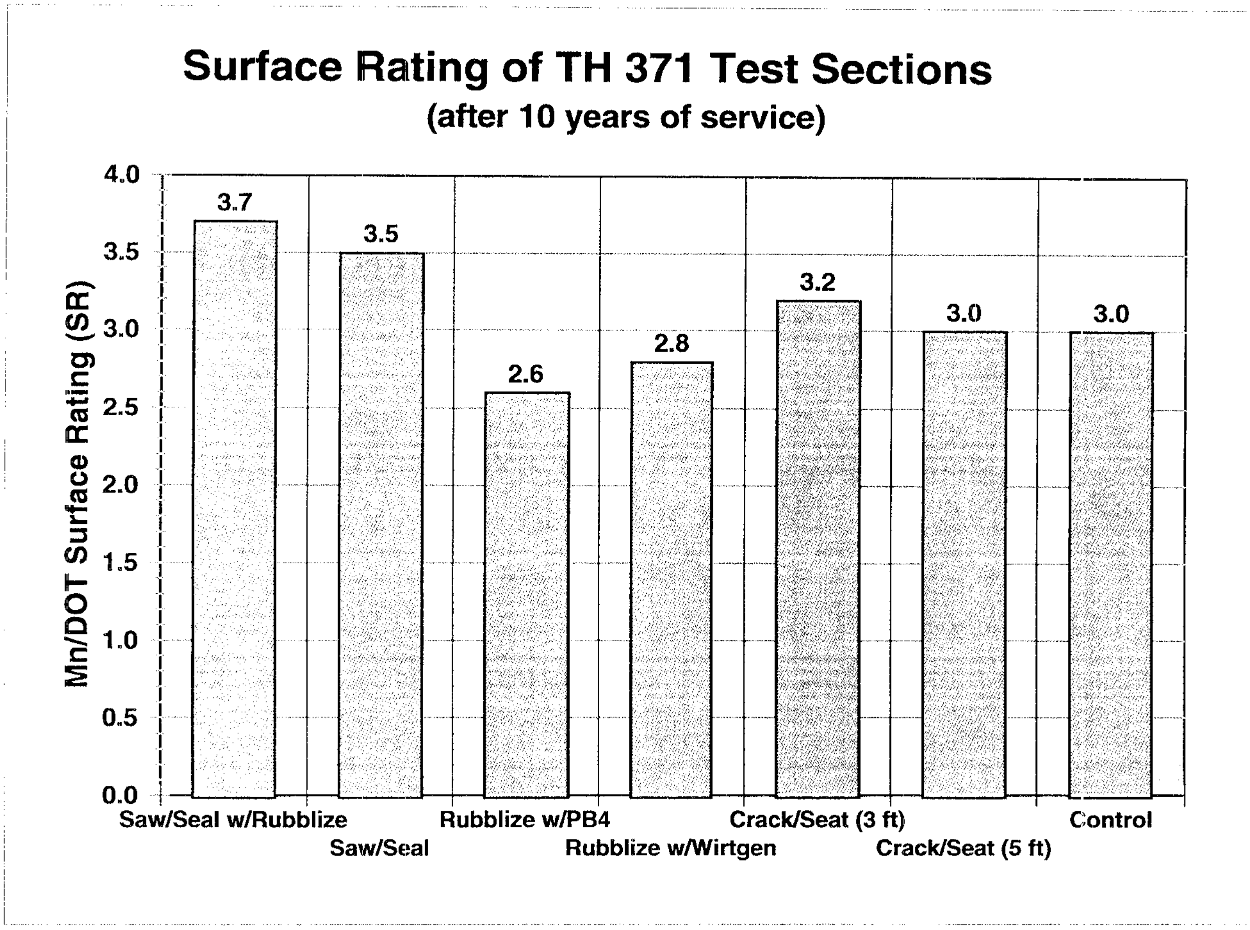

Figure 13. Comparison of T.H. 371 Test Sections after 10 years of Service.

PROJECT SELECTION

As with any other preventive maintenance technique, project selection is critical to the success of saw and seal. The recommended use of saw and seal on each of the three pavement types is as follows:

NEW Pavements

Saw and seal should be considered as an option on all new HMA pavements including deep-strength design, aggregate base design and pavements rehabilitated using HMA overlays with cold in-place recycling. In particular, areas with pavements that have historically cracked at frequent intervals due to soil type or extreme temperatures are good candidates for saw and seal.

BOC Pavements

Overall, saw and seal is effective in controlling both thermal and reflective cracking on BOC pavements. However, this does not mean that saw and seal should always be used on this type of pavement. Most of the BOC sections where saw and seal did not work had one of the following:

- A high frequency of midpanel cracks.
- Badly deteriorated joints and/or lots of patching at or near the joints.
- Badly deteriorated or stripped cracks at the depth of milling.

Midpanel cracks will quickly reflect through an HMA overlay unless the overlay is very thick. Consideration should be given to sawing a joint over the midpanel cracks if they are straight, not badly deteriorated and do not meander across the pavement surface.

Pavements with badly deteriorated joints or lots of patching should *not* be considered for saw and seal. This type of pavement has large areas of distress reflect through the overlay rather than a defined crack. As a result, the sawed joint is in the middle of a larger distressed area as shown in Figure 14.

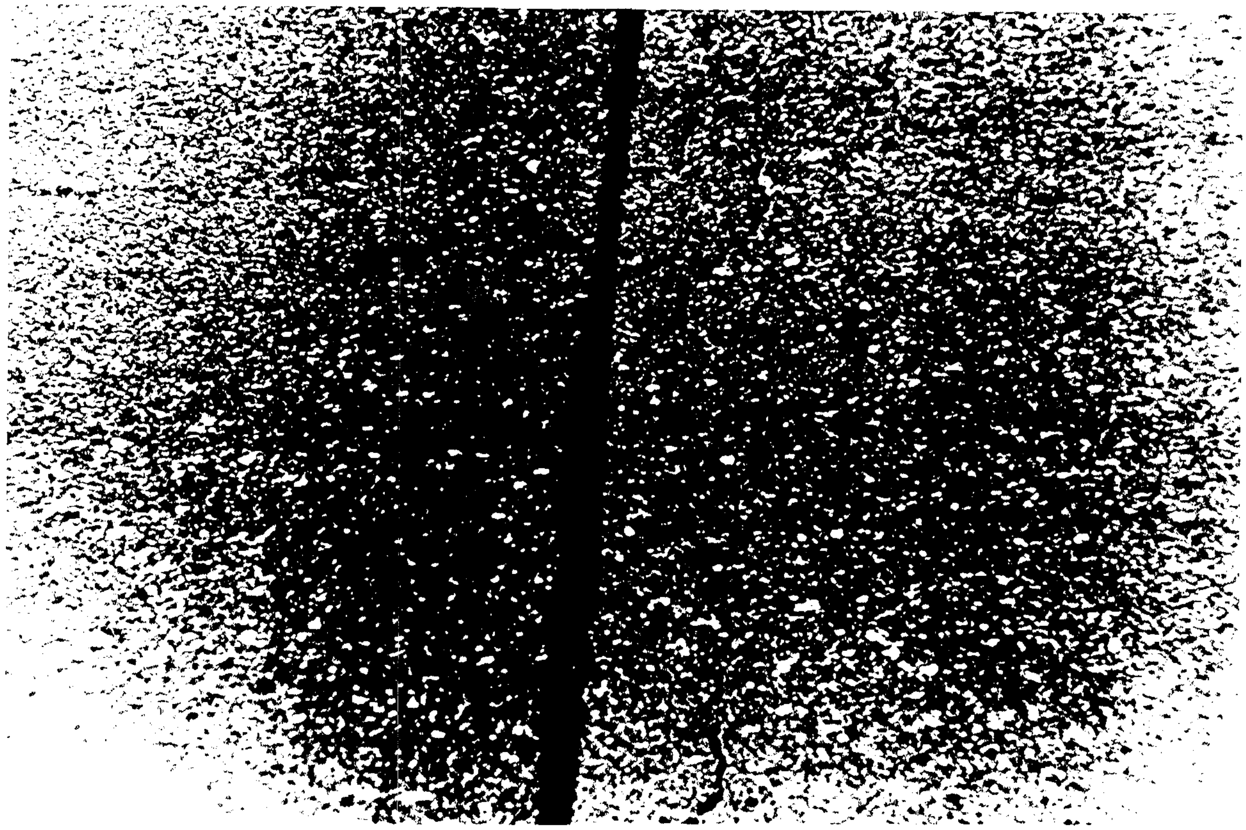

Figure 14. Pavement Distress Due to Poor Condition of Underlying Joint in a Concrete Pavement.

BOC pavements with an existing HMA overlay that will only be partially milled off need some preliminary investigation before their selection as a good candidate for saw and seal. Cores should be taken at several locations throughout the job at the cracks in the HMA surface. The cores should be deep enough to reach the concrete surface. Two things can be learned from these cores. First, if the joint in the old concrete is not centered in the core, this suggests that the cracks are not progressing vertically through to the surface. Secondly, the condition of the cores at the proposed depth of milling should be determined. If the condition of the core at this depth reveals badly deteriorated, and/or stripped pavement, consideration should be given to milling off the entire bituminous thickness.

BOB Pavements

Saw and seal is only recommend for BOB pavements on a limited basis. The cracks must be in good condition (either at the surface or at the depth of proposed milling) and straight across the pavement . The joints should then be sawed directly over these underlying cracks. Sawing joints at some uniform spacing, which do not line up with these cracks, is not recommended.

Meandering cracks will reflect through the HMA overlay in the same meandering pattern. Centering a sawed joint above these cracks will not cause this crack to reflect through in a straight pattern.

TYPICAL COSTS

Saw and seal is normally bid as one pay item. This includes sawing, cleaning and sealing of the joint. Normally, Mn/DOT personnel locate or re-locate any underlying joints or cracks. Typical contractor bid prices for saw and seal range from $4.92 to $6.56 per lineal meter ($1.50 to $2.00 per lineal foot). The bid prices from the two most recent Mn/DOT projects were $5.31 and $5.74 per lineal meter ($1.62 and $1.75 per lineal foot).

Based on the most common spacing of 12 m (40 ft), this results in a cost of $3,280 to $4,371 per km ($5,150 to $6,900 per mile) to saw and seal a mile of 7.5 m (24 feet) wide pavement. This includes extending the saw cuts 300 mm (12 inches) into the shoulder on both sides.

CONSTRUCTION DETAILS

Saw Cut Spacing

NEW Bituminous Pavements

The goal in saw and seal on NEW pavements is to saw the joints close enough together so that no cracks will form between them yet far enough apart to maximize the cost effectiveness. The data suggests that joints sawed in new bituminous pavements at 9 to 15 m (30 to 50 ft) intervals can control both thermal and random cracking. Sawing the joints closer than this will result in many joints being static. This adds needlessly to the cost of the project. The test sections where joints are sawed 18 m (60 ft) apart have cracks between nearly every sawed joint. This is due to the magnitude of the thermally induced tensile stresses exceeding the tensile strength of the HMA.

BOC Pavements

The saw cuts should be made directly above the existing joints in the concrete pavement. In order for saw and seal to be successful, the saw cut must be within one inch of the joint (1). In addition, special attention needs to be paid to pavements with HMA overlays only partially milled off before placing the new surface. If the cracks have propagated upward at angles rather than vertically from the joint, the likelihood of the crack growing up through the sawed joint decreases.

If the existing slab length exceeds 15 m (50 ft), consideration should be given to sawing joints between the existing joints to prevent thermal cracks in the new overlay from forming between them.

BOB Pavements

Saw and seal *is not recommended* for BOB pavements unless the saw cuts are made directly over the existing cracks. The cracks must be straight and in good condition.

Joint Reservoir Configuration

All Pavement Types

The New York recommended standard of 13 mm (½ in) wide by 16 mm (5/8 in) deep, for slab lengths less than 15 m (50 ft), sealed with material meeting Mn/DOT specification 3723 is performing fairly well. However, further study is recommended to learn if another reservoir shape and/or sealant will give improved performance, such as the South Dakota sealant specification.

It is recommended that a slight overband be used with saw and seal to protect the bond at the joint edges. Surveys of the saw and seal test sections reveal that those sections that have a very slight overband have less adhesion failure than those that were flush filled. This has also been the case on Mn/DOT route and seal projects.

Depth of Cut

NEW Pavements

More study is needed to learn how deep the saw cut must be to ensure the thermal and reflective cracks will occur at the sawed joints. For NEW pavements, this will occur if the saw cut is deep enough to cause the pavement to be much weaker at the saw cut than the surrounding pavement. However, making the saw cut too deep adds needlessly to the cost. Minneapolis saws to a depth of one-third the total bituminous thickness. Mn/DOT has used depths from 16 to 115 mm (5/8 to 4.5 in). Most literature suggests a depth of one-third the total bituminous thickness or 64 mm (2.5 inches), whichever is greater.

BOC Pavements

The FHWA-RD-89-142 publication states that several agencies require a saw cut depth of 50 mm (2 in) or one-third the overlay thickness, whichever is greater, whenever the overlay thickness is greater than 102 mm (4 in). Pavements with overlay thicknesses less than 102 mm (4 in) do not require a deep saw cut. These pavements use a reservoir only. Some debate remains about whether the deep saw cut should ever be eliminated. All five of the Mn/DOT sections where only reservoirs were created, due to the overlay being less than 102 mm (4 in) thick, have resulted in the failure of saw and seal to control crack formation. The cracks that formed did not occur at the sawed joints with any regularity.

BOB Pavements

The thicker the overlay, the more likely it is that the crack will wander away from the crack as it progresses toward the pavement surface. As a result, thicker overlays should have deeper saw cuts to ensure the cracks will connect with the saw cuts. The Minneapolis depth of cut on NEW pavements, equal to T/3 (where T is equal to the thickness of the bituminous layers) should be investigated further.

Saw Cutting Operation

One of the more critical operations involved in the saw and seal procedure is the saw cutting operation. In Minnesota, both wet and dry sawing has been done with wet cutting comprising the vast majority of projects. The saw cuts must be made with minimal damage to the adjacent pavement. Dull saw blades, which can cause spalling of the HMA, will lead to adhesion failure of the sealant.

Timing of Saw Cut

In 1990, problems with adhesion failure were experienced on two of the saw and seal projects, T.H. 52 near Hampton and I-35W in Richfield. Both projects were sawed less than 24 hours after the mix was placed. It is believed that the saw blade did not "cut" through the aggregate particles in the fresh mix but "plowed" through them instead. This resulted in spalling along the edge of the joint and led to adhesion failure. The special provisions were changed to require 72 hours between the time the HMA is placed and when it can be sawed. This has been reduced to 48 hours for more recent projects.

Mn/DOT has also experimented with putting seasonal saw cuts into the binder course on projects where the wear course is not placed in the same year. This came about as the result of a project where this occurred. Due to the timing of the project, the wear course could not be placed the same year as the binder. During the first winter, many cracks developed in the binder. Due to the spacing and orientation of these cracks, saw and seal was not performed in the subsequent wear course.

The idea of the seasonal cut is to put a narrow, unsealed saw cut into the binder course so that if the pavement cracks during the first winter it will crack at the saw cut locations only. The following year the wear course is placed and saw cuts and reservoirs are made directly above the seasonal cuts, similar to when saw and seal is used on overlay projects. Further research is needed to determine the need and benefit of using these seasonal cuts.

Direction of Saw Cut

The T.H. 52 project was the first, and only project, where the contractor used a riding "up-cutting" saw on one lane and a conventional walk behind "down-cutting" saw on the other. The up-cut saw severely tore the joint edges as it cut through the HMA. Up-cut saws have not been allowed on any subsequent Mn/DOT saw and seal projects.

One Versus Two Pass Cutting

One pass saw cutting is preferred over two pass cutting. In one pass cutting, several blades are mounted side by side (normally two smaller diameter blades on each side of a larger blade). With this setup, the proper joint configuration, both deep saw cut and reservoir, is obtained in one pass of the saw. One common complaint about using this procedure is an increase in blade wear.

Two pass cutting involves using a single 3 mm (1/8 in) wide saw blade to make the initial deep saw cut. This is followed by using several blades, with spacers between them to create the wider reservoir. While this procedure can produce good results, the following problems have occurred:

1. The second saw cut jumps to one side of the narrow first cut rather than remaining centered over it.

2. The second saw cut leaves small "fins" of bituminous material in the reservoir. These fins are caused by the spacers between saw blades used to create the desired reservoir configuration.

In 1996, Mn/DOT will be experimenting with using a router, rather than a saw, to create the reservoir shape. Since router teeth are much cheaper than saw blades, this has the potential of greatly reducing the cost of saw and seal projects. One concern is that the router teeth may damage the edge of the reservoir in the fresh bituminous mat.

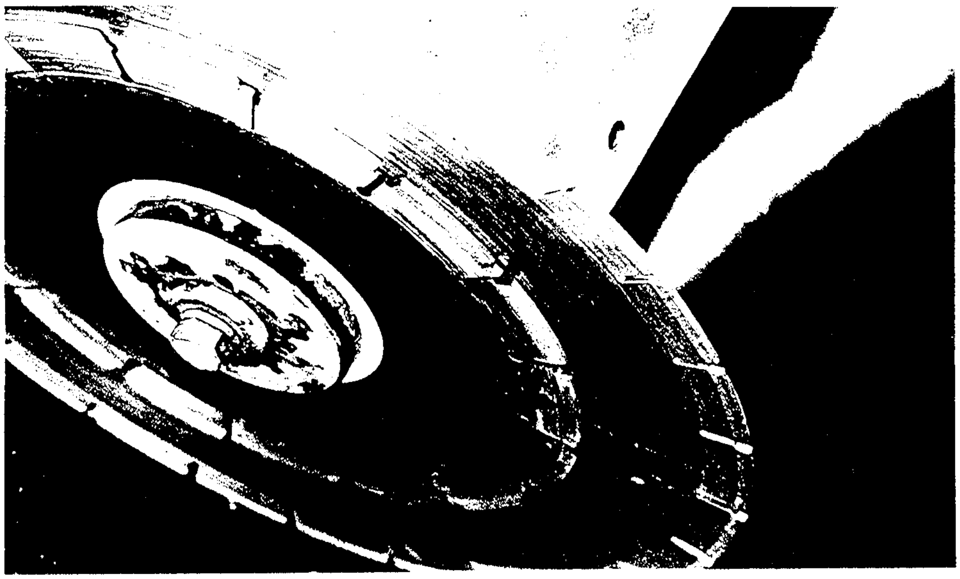

Figure 15. Example of saw blade configuration for one pass cutting.

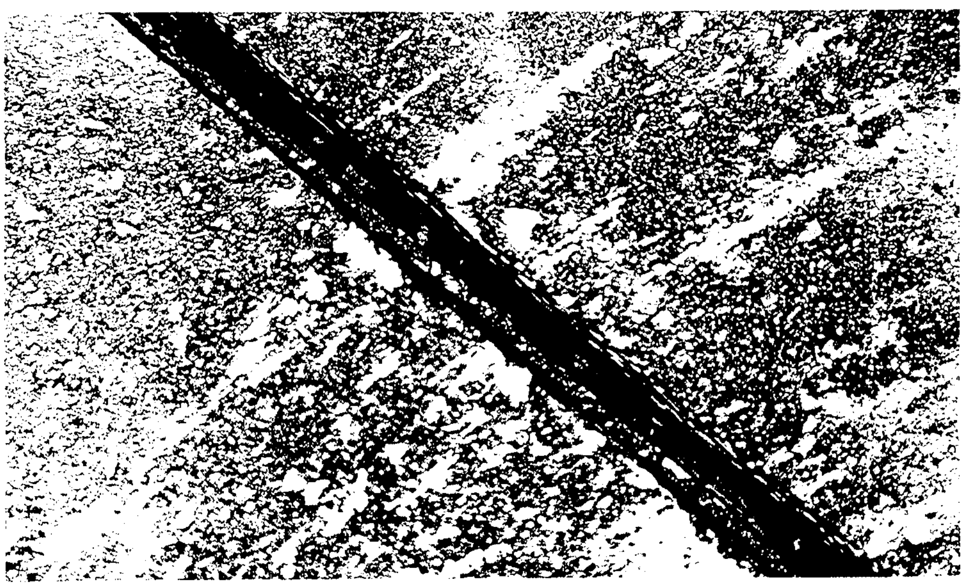

Figure 16. Problem with two pass cutting (notice "fin" of bituminous).

Extending the Saw Cut into the Shoulder

On pavements with bituminous shoulders, the saw cuts are normally extended 300 mm (1 ft) beyond the driving lane into the shoulder. This decision is primarily one of economics and the desire to focus efforts on the main line pavement. Experience has shown that sawing 300 mm

(1 foot) into the shoulder will produce cracks extending from the end of the sawed joint to the outer edge of the shoulder. Thus, sawing the entire shoulder seems unnecessary. In addition, this is a good way to tell if the joint is "working" or "static." A static joint will not have a crack extending beyond the saw cut whereas a working joint will.

Saw and Seal in Urban Sections

When using saw and seal in an urban setting where curb and gutter is present the saw cuts should line up with the joints in the gutter sections whenever possible. Failure to do this may result in cracks developing in the gutter or secondary cracks in the pavement near the gutter section. The City of Minneapolis uses this practice as have most Mn/DOT sections that are in urban areas.

Backer Tape

Backer tape has been required on nearly every saw and seal job in Minnesota. However, in reality it is often not used in the field. One project that attempted to learn if backer tape is needed is U.S. 12 near Willmar. Several joints were sawed and sealed, some with and some without backer tape. No discernable difference in the performance of these joints has been detected after six years. However, the use of backer tape provides some insurance that the reservoir will be filled to the correct level since the sealant cannot flow down into the deep saw cut. The need and benefit of using backer tape is an area in need of further research.

Relocating Existing Joints and Cracks

Several methods have been used to relocate the existing joints and cracks under the new bituminous overlay. The most common method is to extend a string line over the joint/crack and place stakes, steel pins, etc. where they will not be disturbed during paving. After paving is complete, a chalk line can be snapped between these two references. Other methods include the use of surveying equipment and steel pins w/metal detectors to relocate the joints/cracks.

Relocation of the existing cracks and joints is critical. Most literature states that the sawed joint must be *within one inch* of the underlying crack or joint for saw and seal to be successful. If not, the crack may occur near, but not at, the sawed joint. It is recommended that cores be taken at several cracks when overlays are placed on previously overlaid pavements if only part of the old overlay is milled off. This will verify whether the cracks are occurring directly above the underlying cracks and joints. If not, a deeper saw cut, possibly full depth, is recommended to ensure the crack will propagate upward at the sawed joint location.

CONCLUSIONS

The following conclusions are felt to be appropriate at this time concerning the saw and seal procedure on all pavement types:

- Saw and seal has controlled the location of transverse thermal and reflective cracking on over seventy-five percent of the test sections. In addition, the amount of random cracking is reduced in these sections compared to the control sections.

- The sections with saw and seal are in better condition than the control sections as measured by the Mn/DOT Surface Rating (SR) procedure.

- The average price for saw and seal in Minnesota has been $5.42 per lineal meter ($1.65 per lineal foot). This is equal to $3,613 for a 7 m wide lane km ($5,662 for a twenty-four foot wide lane mile), including extending the saw cut 300 mm (12 inches) into the shoulder on each side.

- Two pass cutting has resulted in less than desirable results in some cases due to misalignment of successive passes of the saw.

- Silicone sealant has not worked well for sealing bituminous pavements.

- The test sections that used a reservoir only, ie. did not use a deep saw cut, did not control the formation of cracking.

- Although not extensive, adhesion failure is the main problem encountered in trying to keep the joints sealed. The overall adhesion failure rate, for projects that controlled crack formation, is 15.8 percent. It is felt that this can be reduced by using softer sealants and paying closer attention to the sawing and cleaning operation.

- Backer tape has been used on most jobs but has not been shown to be critical to a successful saw and seal project.

RECOMMENDATIONS

Based on the results of the many test sections constructed by Mn/DOT and others, the following recommendations are given:

Project Selection

- Saw and seal should be considered as an option for controlling cracking on all new bituminous pavements, overlays of JCP pavements and selected overlays of bituminous pavements. As with any other preventive maintenance technique, project selection is critical to the success of saw and seal. Therefore, saw and seal should not be used on the following:

  - Overlays on Jointed Concrete Pavements with a high frequency of midpanel cracks (> 20%) or badly deteriorated cracks.

  - Overlays on Jointed Concrete Pavements with badly deteriorated joints and/or lots of patching at or near the joints.

  - Overlays on bituminous pavements with meandering transverse cracks.

  - Overlays on previously overlaid concrete pavements where the cracks at the depth to be milled are badly deteriorated or stripped.

  - Overlays on bituminous pavements with severe load related distress such as alligator cracking, potholes or severe stripping related distress.

Joint Spacing/Location

NEW Bituminous Pavements

- Saw cuts should be spaced 12 m (40 ft) apart. Pavements on granular soils may benefit from having the joints spaced at 9 m (30 ft) apart. Further research is needed in this area to determine what joint spacing will work best for a given pavement.

BOC Pavements

- The saw cut must be directly above the existing joint in the concrete pavement. In order for saw and seal to be successful, the saw cut must be within 25 mm (1 in) of the joint.

- Consideration should be given to making saw cuts at midpanel cracks provided they are small in number and straight and not meandering.

- If the existing slab length exceeds 15 m (50 ft), consideration should be given to making additional saw cuts in the overlay between the concrete joints. This may prevent thermal cracks in the new overlay from forming between them.

BOB Pavements

- Saw and seal *is not recommended* for BOB pavements unless the saw cuts are made directly over the existing working transverse cracks. The cracks must be straight, in good condition and not too closely spaced.

Joint Configuration

- The recommended reservoir shape is 13 mm (½ in) wide by 16 mm (5/8 in) deep sealed with material meeting Mn/DOT specification 3723. Further study should be done to learn if another reservoir shape and/or sealant will give improved performance, such as the South Dakota sealant specification.

- It is recommended that a very slight overband be used with saw and seal to protect the bond at the joint edges. Surveys of the saw and seal test sections reveal that those sections that have a slight over banding tend to have less adhesion failure than those that were flush filled. This has also been the case on Mn/DOT route and seal projects.

Depth of Cut

- More study is needed to learn how deep the saw cut must be made to ensure that the thermal and reflective cracks will occur at the sawed joints. Meanwhile, it is recommended that the saw cut be 64 mm (2.5 in.) or T/3 (where T is equal to the thickness of the bituminous layers), whichever is greater.

Timing of Saw Cuts

- The sawing operation should not be done within 48 hours of placing the wearing course. Sawing fresh bituminous pavements can cause damage at the joint edges leading to poor sealant adhesion and joint spalling.

One Versus Two Pass Cutting

- One pass saw cutting is recommended over two pass cutting. While two pass cutting can produce good results, problems have occurred.

Extending the Saw Cut into the Shoulder

- It is recommended that the saw cuts extend 300 mm (1 ft) beyond the driving lane into the shoulder on pavements with bituminous shoulders. Sawing the entire shoulder adds to the cost of the project and seems unnecessary.

Saw and Seal in Urban Sections

- When using saw and seal in an urban setting where curb and gutter is present the saw cuts should line up with the joints in the gutter sections whenever possible. Failure to do this may result in cracks developing in the middle of gutter sections rather than at the joints between them.

Backer Tape

- Further research is needed to determine how valuable the practice of using a backer tape is to the saw and seal operation

Relocating Existing Joints and Cracks

- Relocation of the existing cracks and joints is critical. Most literature states that the sawed joint must be *within 25 mm (1 in)* of the underlying crack or joint for saw and seal to be successful. If not, the crack may occur near, but not at, the sawed joint.

- It is recommended that cores be taken at several cracks when overlays are placed on previously overlaid concrete pavements if only part of the old overlay is milled off. This will verify whether the cracks are occurring directly above the existing joint. If not, a deeper saw cut, possibly full depth, is recommended to ensure the crack will propagate upward at the sawed joint location.

Future Work

- Further research is recommended in the following areas:

    1. New and improved methods for relocating existing joints and cracks after an overlay is placed.

    2. Sawing joints in overlays only at the "working" joints and cracks.

    3. Using a router to create the joint reservoir rather than a saw.

- A follow-up report should be prepared identifying the location and condition of the test sections. Conditions should include Surface Ratings, Ride Measurements and Present Serviceability Rating (PSR).

REFERENCES

1. Kilareski, Walter P. and Bionda, Richard A., FHWA-RD-89-142, “Structural Overlay Strategies for Jointed Concrete Pavements - Volume 1: Sawing and Sealing Joints in AC Overlays of Concrete Pavements,” Federal Highway Administration, June 1990.

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3. “Standard Specifications for Construction,” Minnesota Department of Transportation, 1988 Edition.

4. “1994 Annual Book of ASTM Standards, Volume 4.03, Road and Paving Materials; Paving Management Technologies,” American Society of Testing and Materials, 1994.

5. Deme, I.J. and Young, F.D. “Ste. Anne Test Road Revisited Twenty Years Later”, 32nd Annual Meeting of the Canadian Technical Asphalt Association, November 16-18, 1987.

APPENDIX A

Mn/DOT SPECIAL PROVISIONS
FOR
BITUMINOUS JOINT SAWING AND SEALING
April 1996

DESCRIPTION

This work shall consist of saw cutting, cleaning, drying and sealing transverse joints in new bituminous surfaces according to the plans, Mn/DOT specifications and as directed by the Engineer.

A MATERIALS

A1 Joint Sealant Material

The Contractor shall provide certification that the sealant meets the requirements of ASTM D-3405 with the following modifications:

Penetration at 25 deg. C..90 - 150
Bond at -29 deg. C, Std. Specimen, 3 cycles, 200% extension....................................Passes
The sealant material shall weigh not less than 1.08 nor more than 1.12 kg/l.

The crack sealant compounds shall be packaged in sealed containers. Each container shall be clearly marked with the name of the manufacturer, the trade name of the sealant, the manufacturer's batch and lot number, the pouring temperature, and the safe heating temperature.

A copy of the manufacturer's recommendations concerning the heating and application of the joint sealant material shall be submitted to the Engineer before the commencement of the work. These recommendations shall be followed by the Contractor. The temperature of the sealer in the field application equipment shall never exceed the safe heating temperature recommended by the manufacturer. Any given quantity of material shall not be heated at the pouring temperature for more than six hours and shall never be reheated. Material shall not be placed if the material's temperature is below the manufacturer's recommended minimum application temperature.

Mixing of different manufacturers' brands or different types of sealants shall be prohibited.

A2 Bond Breaker Tape

Bond breaker tape shall consist of regular masking tape or other suitable bond beaker tape designed for use with hot pour sealants. The width of the tape may be equal to but not more than 3 mm narrower than the width of the saw cut.

B WEATHER LIMITATIONS

Sealant materials may be placed during a period of rising temperature after the air temperature in the shade and away from artificial heat sources has reached 4 degrees C and indications are for a continued rise in temperature. During a period of falling temperature, placement of the sealant material shall be suspended until the above conditions are met.

Sealants shall not be placed when, in the opinion of the Engineer, the weather or roadbed conditions are unfavorable. Sawing and sealing shall be permitted only during daylight hours.

C EQUIPMENT REQUIREMENTS

The melting kettle shall be double jacketed boiler type, equipped with both agitation and recirculation systems capable of melting and applying the sealant through a pressure-fed hose and wand. The melter shall be capable of starting at ambient temperature and bringing the sealing material to application temperature in one hour or less, while continuously agitating and recirculating the sealant. The melter shall be equipped with automatic thermostatic controls and temperature gages to monitor the sealant temperature in the applicator lines and temperature of heat transfer oil in the kettle jacket.

A self-propelled power saw capable of providing a straight cut of uniform depth and width shall be used. Diamond saw blades with either single or gang blade arrangement shall be used. The saw blade or blades shall be of such size and configuration such that the desired joint reservoir shape and deep saw cut are achieved in one pass of the saw. Two pass cutting will not be allowed. No spacers between blades shall be allowed unless the Contractor can show that the desired reservoir and saw cut can be obtained with them. Either wet or dry sawing will be permitted provided the above conditions are met.

The air compressor shall be capable of producing a continuous stream of clean, dry air through the nozzle at 600 kPa and 3.5 m^3/m minimum. The compressed air unit shall be equipped with water and oil traps and must produce sufficient air volume and pressure to remove all debris from the sawed joint and all adjacent road surfaces in a safe manner such that the debris will not re-enter the joint prior to the sealing operation.

The heat lance shall operate with propane and compressed air in combination and be capable of achieving a temperature of heated air at the exit orifice of 1000 degrees C and a discharge velocity of 1000 m/s.

D CONSTRUCTION DETAILS

C1 General

The Contractor shall conduct the operation so that saw cutting of transverse joints, cleaning, and sealing are a continuous operation. Traffic shall not be allowed to knead together or damage the sawed joints. Sawed joints not sealed before traffic is allowed on the pavement shall be re-sawed, if necessary, when sawing and sealing operations resume at no additional cost to the State. Saw cutting, cleaning and sealing shall not be done within 48 hours of placement of the wear course.

C2 Saw cutting of Transverse Joints

The transverse saw cut joints shall normally extend the full width of the pavement and shall extend into the asphalt shoulder a distance 300 mm beyond the edge of the mainline pavement, unless otherwise detailed on the plans, in the proposal or directed by the Engineer.

C3 Cleaning Operation

Dry sawed joints shall be thoroughly cleaned with an air compressor meeting the requirements previously outlined. Cleaning shall continue until the joint is dry and all dirt, dust or deleterious matter is removed from the joint and adjacent pavement to the satisfaction of the Engineer.

Wet sawed joints and adjacent pavement shall be thoroughly cleaned with a water blast (345 kPa minimum) immediately after sawing to remove any sawing slurry, dirt or deleterious matter adhering to the joint walls or remaining in the joint cavity. The joints shall then be dried with an air compressor. Cleaning shall continue until the joint is dry and all dirt, dust or deleterious matter is removed to the satisfaction of the Engineer. If the air compressor produces dirt or other residue from the joint cavity, the Contractor may be required to re-clean the joint with a water blast.

Following cleaning, the sawed joints shall be dried and warmed with a hot air lance. The Contractor shall be careful not to burn the pavement surface. After the hot air lance has been used to warm and dry the joint, the backer tape shall be place into the bottom of the joint reservoir. Under no circumstances shall more than two (2) minutes elapse between the time the hot air lance is used and the sealant is placed.

The Contractor shall be required to provide protective screening, subject to approval of the Engineer, if his cleaning operations could cause damage to or interference with traffic in adjacent lanes.

C4 Sealing Operation

The joints shall be sealed when the sealant material is at the pouring temperature recommended by the manufacturer. The Contractor shall fill the joint such that after cooling, the sealant is flush with the adjacent pavement along the edges and the center does not sag more than 3 mm below the pavement or shoulder surface. Care shall be taken in the sealing of the joints so that the joints are not overfilled and the final appearance shall present a neat fine line. The applicator wand shall be returned to the machine and the joint sealant material recirculated immediately upon completion of each joint sealing. The Engineer may require the Contractor to use a squeegee to force the sealant material into narrow joint shapes if in the opinion of the Engineer the sealant material is not flowing into the joint properly. Sand shall not be spread on the sealed joints to allow for opening to traffic. The sealant shall be tack free before opening to traffic. A given quantity of sealant material shall never be heated at the pouring temperature for more than six (6) hours and shall never be reheated.

C5 Acceptance Sampling

The Contractor shall record the temperature of the kettle and the temperature of the sealant once every hour during the actual working operations. This information is to be recorded on the forms provided by the Engineer. At the end of each days' production, the completed forms shall be presented to the Engineer, and they shall be placed in a permanent file by the Engineer. The Engineer shall continuously review the sealant temperatures. Temperatures measured more than 5°C above the manufacturer's specified safe heating temperature shall result in the rejection of the material in use and the Contractor shall dispose of the overheated material, at his expense, in an acceptable manner.

C6 Seasonal Saw Cut

If the wear course is to be placed the year after the binder/leveling course, due to seasonal paving limitations, all exposed courses shall receive a 13 mm deep by 3 mm wide saw cut to control thermal and/or reflective cracking and to provide a means of properly referencing the saw cut to eventually be made in the top course. These saw cuts shall be made in all exposed courses. The seasonal saw cuts shall be made before any evidence of reflective cracking has developed.

After placement of the top wearing course the following spring, the Contractor shall be responsible for locating the underlying seasonal saw cuts in a manner approved by the Engineer. Once the wear course is placed and the underlying joints are located, the appropriate saw cut shall be made and the joint sealed according to the plans. It is critical that the saw cuts not be offset more than 13 mm from the underlying seasonal saw cuts.

Seasonal saw cutting shall be paid for per lineal meter under a separate pay item for such work and shall include the cost of all material, labor (including joint relocation) and equipment necessary to complete the work specified.

D WORKMANSHIP

Sealed joints shall be rejected if there is evidence of poor workmanship or obvious defects, such as, but not limited to the following:

a) Sawed joint not filled completely
b) Lack of bond to the sides of the joint
c) Excessive debris or moisture in the joint
d) Contamination of the sealant
e) Sawed joint not filled flush

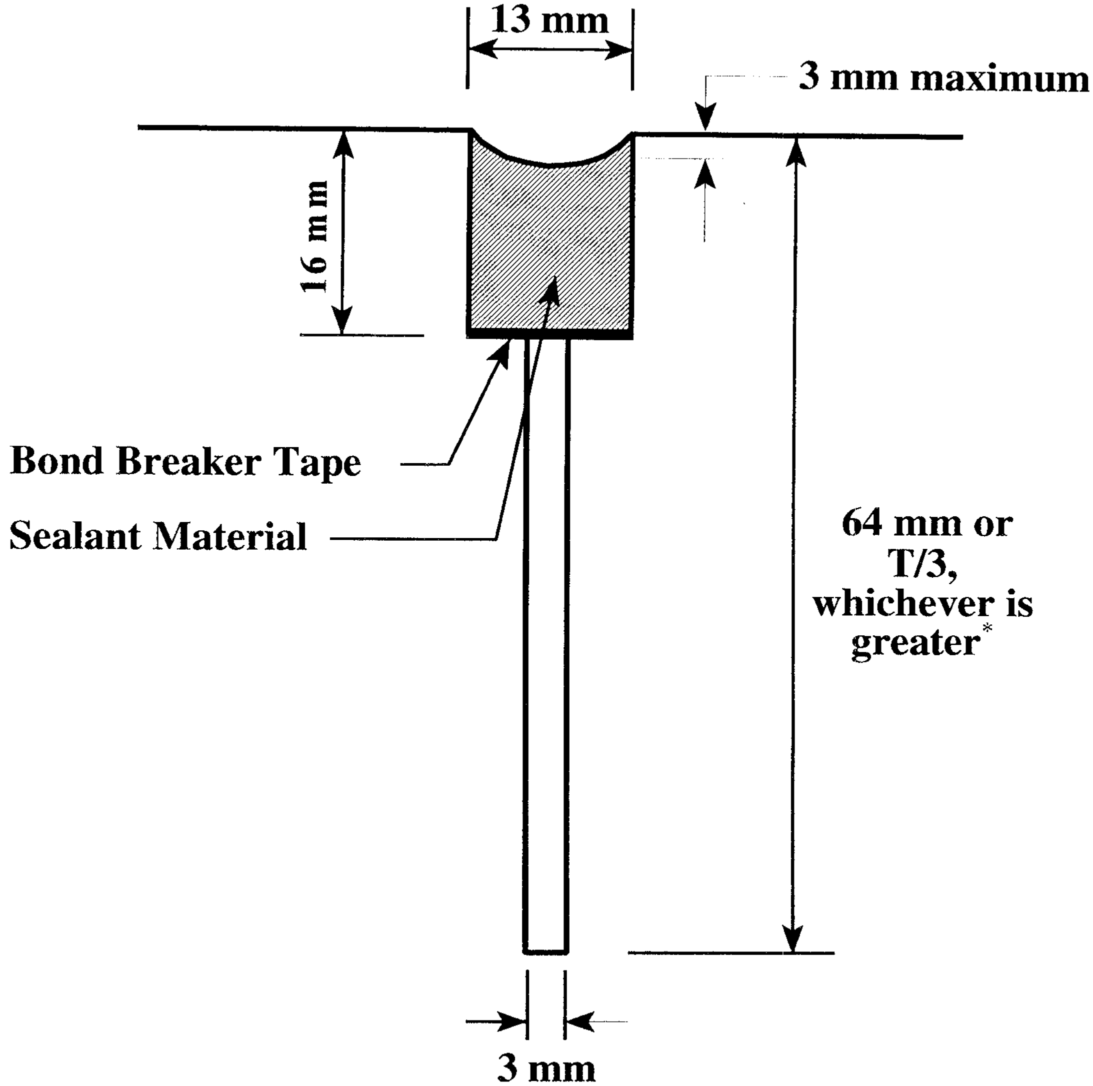
Rejected sealed joints shall be repaired, the sealant removed and disposed of in an appropriate manner and the joints resealed as necessary, to the Engineer's satisfaction and at no further cost to the State.

E PAYMENT

Payment shall be made under separate items for each joint type at the Contract bid price per lineal foot, which shall include the cost of all labor, equipment and materials necessary to complete the work as specified.

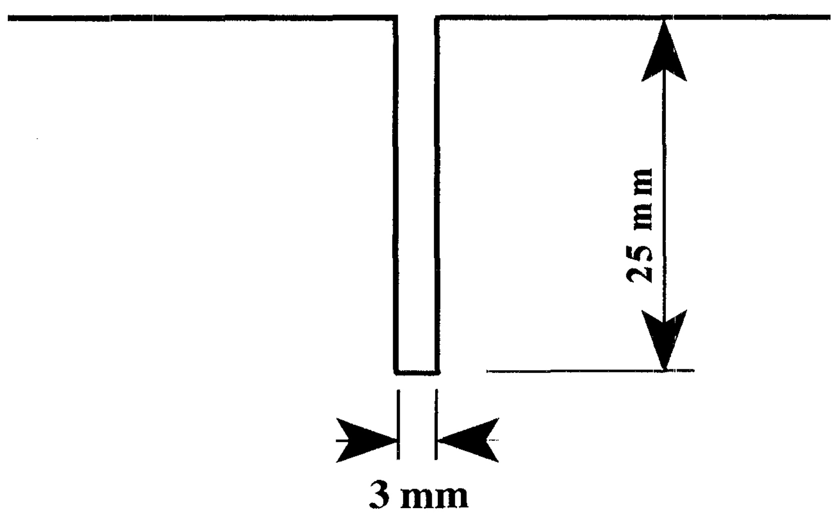
Item No.	Item	Unit
0331.603	Sawed/Sealed Joint	Lineal Meter
0331.604	Seasonal Saw Cut	Lineal Meter

Typical Joint Section



*Where T = total thickness of the overlay or new bituminous surface.

Seasonal Saw Cut



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