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16. Abstract

The placement of an asphalt seal coat under an asphalt concrete overlay has been used to provide an impervious membrane to stop the intrusion of surface or subsurface moisture. It is also specified to enhance the bond of subsequent applications asphalt concrete pavement. However, underseals have contributed to premature cracking, rutting, stripping, and flushing or bleeding.

The objective of this study was to develop the criteria needed to determine when and where to place an underseal. Researchers reviewed the literature, surveyed and interviewed engineers in Texas Department of Transportation (TxDOT) districts to determine the current practice, experiences, and problems around the state regarding the use of underseals.

Case studies of forensic investigations of pavements where underseals or lack of underseals have contributed to pavement failures are presented. A decision tree and criteria were developed and evaluated to determine when and where to place an underseal. Guidelines and training materials were developed on the use of underseals as a moisture barrier.

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GUIDELINES ON THE USE OF UNDERSEALS AS A PAVEMENT MOISTURE BARRIER

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation. The researcher in charge of the project was Cindy Estakhri, P.E. (77583).

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Chapter 1 Introduction

Background

Placement of an asphalt seal coat between layers of asphalt mixtures is considered beneficial and necessary. Pavement designs may call for application of a seal prior to overlaying the pavement (commonly called an underseal) to provide an impervious membrane to stop the intrusion of surface or subsurface moisture. The designer may also specify the seal to enhance bonding with subsequent layers. However, at the onset of this study, many engineers felt that premature cracking, rutting, stripping, and flushing or bleeding have occurred on highway pavements because the seal was installed. Microsurfacing and cape seals have also been associated with premature failures.

There is a need to understand the mechanisms that make a seal beneficial but also when they may lead to a premature failure of the pavement layers above or below.

Objective

The objective of this research study was to develop the criteria needed to determine when and where to place an underseal.

Research Approach

Researchers reviewed the literature and found that there was very little research which has been performed on underseals as used here in Texas. However, there was a great deal of information which was documented regarding the movement of moisture through pavement structures.

Researchers also surveyed the districts to determine the current practice regarding the use of underseals, district successes or failures, and remedies and new approaches which have been adopted as a result of successes or failures.

Pavement failures which were associated with the use or lack of an underseal were identified and documentation was collected as to the cause associated with that failure.

Based on the results from the literature, district survey, and forensic documentation, researchers developed decision making criteria, guidelines and instructional materials. This was then followed up with pavement evaluations and test sections aimed at supporting the criteria and guidelines.

Chapter 2 Literature Review

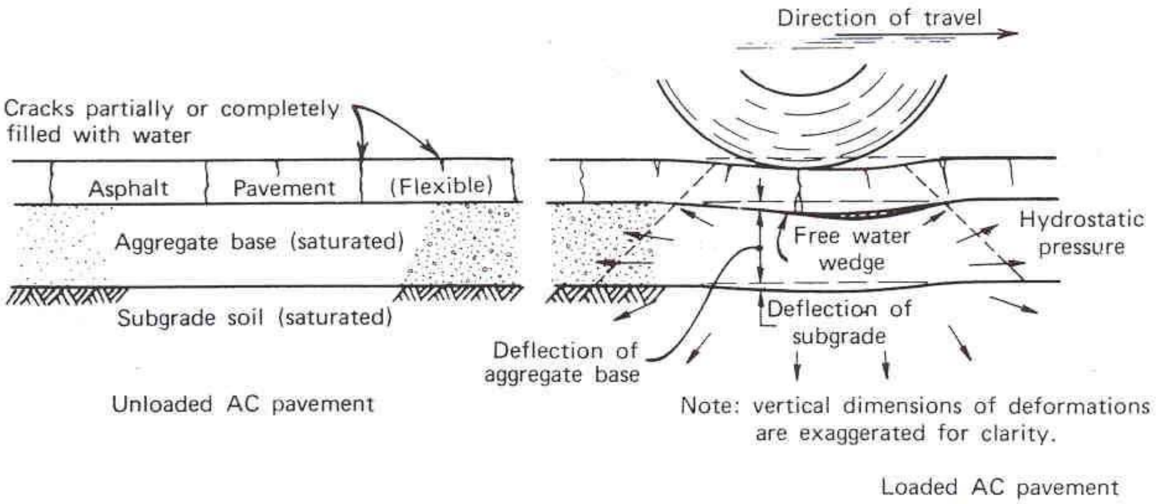
General

Pavements in Texas are generally not designed for rapid elimination of water, and pervious surface layers provide a built-in a mechanism of self-destruction. When free water infiltrates the boundaries between structural layers, the multi-layered systems act like diaphragm pumps under the pounding of heavy wheel loads. Cedergren (1987) points out that each heavy-load impact causes water to move about at the interface between a wearing course and its base, eroding material and ejecting it through cracks and joints, producing channels and cavities that undermine the pavement; the result is damage that eventually leads to total failure of the pavement. Most design methods assume that the controlling factors are stress and strain, deformation, volume change, and fatigue under repeated loadings; however, these design methods largely ignore the dynamic effects of excess water, which can completely overshadow the factors that *are* considered. Thus, erosion between a primary pavement layer and its base can occur regardless of the thickness or rigidity of the base if conditions conducive to erosion exist at their interface. Cedergren (1987), a proponent of free-draining bases, states that "erosion and the damaging actions of pore pressures cannot occur in the absence of free water, hence there is reason to believe that well-designed, well-drained pavements should carry their design loads almost indefinitely with only normal, routine maintenance, whereas their undrained counterparts may require large amounts of costly repairs long before their design age is reached."

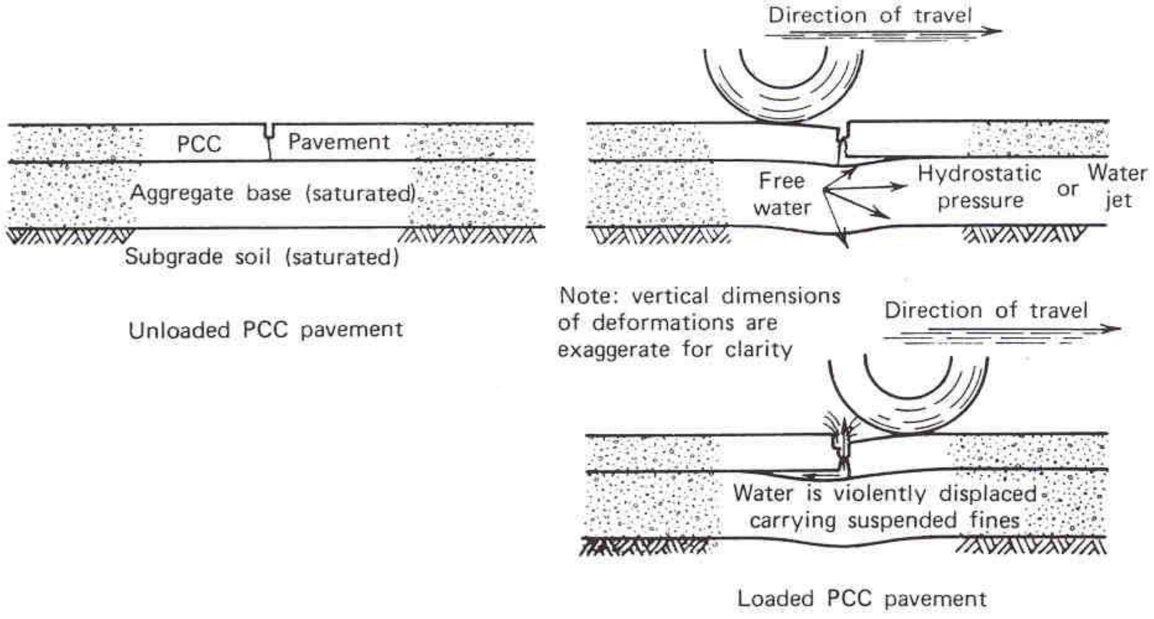
Most dense-graded base materials in Texas are easy to handle and place, are strong and durable, and transfer load well when they are not in a saturated moisture condition; however, they are not designed to transmit water or drain. This characteristic makes protection from surface water intrusion very important for these types of bases.

Several experimental road tests (Western Association of State Highway Officials [WASHO] road test, American Association of State Highway Officials [AASHO] road test, and University of Illinois circular test track) have documentation indicating that during periods when pavements contain large amounts of free water the rates of pavement deterioration range from 10 or 20 up to hundreds and thousands of times greater than during times when they contain little or no free water. Figure 1 illustrates some of the possible ways that heavy wheel impacts on saturated pavements can damage both asphalt concrete (AC) and portland cement concrete (PCC) pavements. One of the most dramatic demonstrations of the effect of pulsating hydrostatic forces is the pumping of material under rigid PCC pavements (Figure 1).

Pumping also occurs under flexible AC pavements, but it is not as dramatic because the asphalt concrete normally fails by cracking before it develops the high elastic slab deflection that allows it to act like a pump diaphragm. When high pore pressures develop in a base or subbase material, its load transfer properties are altered considerably so that stresses applied to the subgrade are not reduced to their expected level (Ridgeway 1982).



a Action of free water in AC pavement structural sections under dynamic loading



b Pumping phenomena under PCC pavements

Figure 1. Ways That Traffic Impacts Can Damage Saturated Pavements (Both Rigid and Flexible).

Moisture control has not generally been a focus of pavement design or maintenance. There are two general ways to control moisture in pavement structures: by the use of subsurface drainage or by sealing the pavement to reduce infiltration through the pavement (Marienfeld and Baker 1999). The latter is the focus of this report, which examines the use of seal coats as an underseal or pavement moisture barrier.

Sources of Water in the Pavement Structure

Many sources of water have the potential to reach the pavement structure and its immediate vicinity. To evaluate the various sources, the pavement designer should consider the entire profile and cross section of the highway. The pavement structural designer, who may not be directly involved with the other aspects of the facility, cannot predict the possible sources and amounts of water without knowledge of the surface and subsurface drainage geometry (Ridgeway 1982).

Free water can enter the pavement structure from several potential sources, as shown in Figure 2 (Ridgeway 1982):

- cracks in the pavement surface,
- a permeable pavement surface,
- infiltration through the shoulders,
- infiltration from side ditches,
- free water from the pavement base,
- high groundwater table, and
- condensation of water vapor (small amounts).

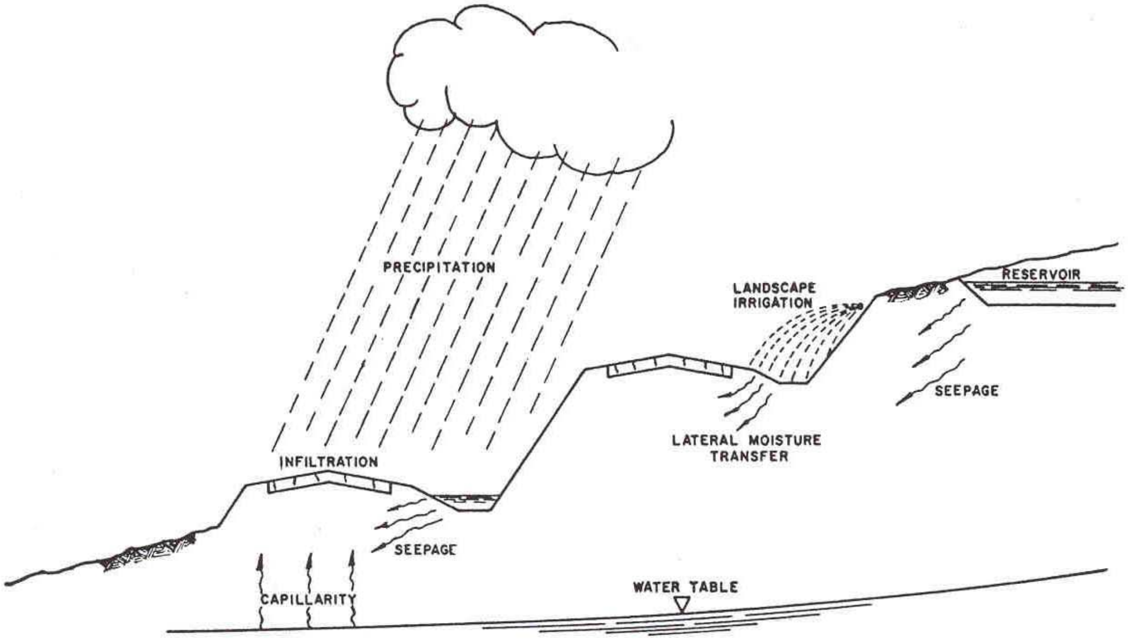


Figure 2. Potential Sources of Water in Pavement Structure. (Cedergren et al. 1973)

Severe groundwater or seepage conditions usually appear during construction or are revealed by advance drilling and groundwater observations. These sources often create wet, boggy conditions that must be controlled to make construction possible. Surface water infiltration occurs after a pavement is completed and put in service. Cedergren (1987), a renowned expert in the subject area of highway drainage, states that "although groundwater inflows certainly need to be controlled, it is unlikely that more than about *5* percent of the total pavements in the United States need this kind of protection. On the other hand, at least *90 to 95 percent* of the pavements in this country are in areas where rainfall rates are greater than subgrade drainage capabilities….."

Infiltration of Water through Pavement Surface

The amount of surface water that can enter the pavement structure is controlled by: (a) the amount of water allowed by the effective permeability of the wearing course or (b) the amount of supply available. The "global" permeability or "macroscopic" permeability of a pavement section depends on the age and condition of that pavement and the width and spacing of cracks and/or joints, as well as the permeability of the pavement material.

Permeabilities associated with asphalt concrete pavements depend on the mixture type and the density of that mix. Izzo and Button (1997) discovered that coarse matrix high binder (CMHB) mixtures are more permeable than dense-graded mixtures made using similar materials at similar air void levels. They also found that the permeability of newly constructed CMHB pavements was relatively high, whereas after 1 year of traffic, permeabilities were more similar to those of dense-graded mixtures.

Estakhri et al. (2001) compared permeabilities of the longitudinal construction joint to those in the center of the mat on newly constructed pavements. They performed these tests on cores of pavements which were constructed prior to the implementation of a longitudinal joint density specification. Permeability as a function of density for dense-graded Types D and C pavement cores is shown in Figure 3 and for CMHB mixtures in Figure 4.

Based on the data shown in Figures 3 and 4, the permeability of newly constructed dense-graded asphalt pavements in Texas can range from about 0.00002 cm/sec (or 0.03 in./hr and 0.1 ft/day) to about 0.0005 cm/sec (or 0.7 in./hr and 1.4 ft/day). The permeability of new CMHB pavements can range from about 0.0001 cm/sec (or 0.06 in./hr and 0.3 ft/day) to about 0.0005 cm/sec (or 0.7 in./hr and 1.4 ft/day). The permeability of these mixes will likely decrease with further densification by traffic, but probably not in the areas between the wheel paths. When cracks begin to appear in the surface, the global permeability of the pavement will increase significantly.

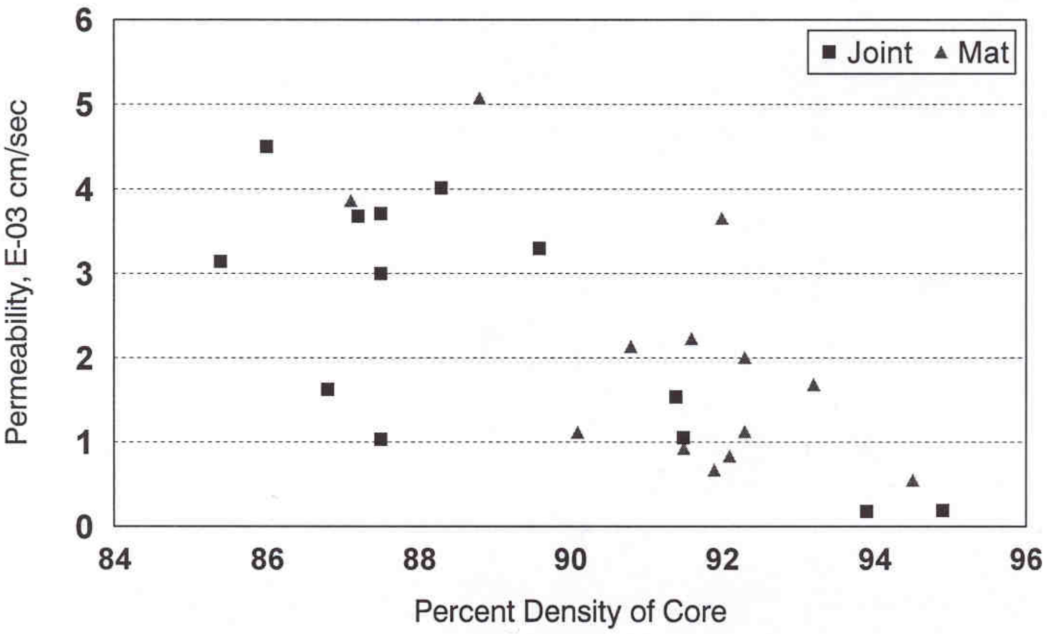


Figure 3. Permeability Data for TxDOT Hot Mix Asphalt Type C and Type D Pavement Cores. (Estakhri et al. 2001)

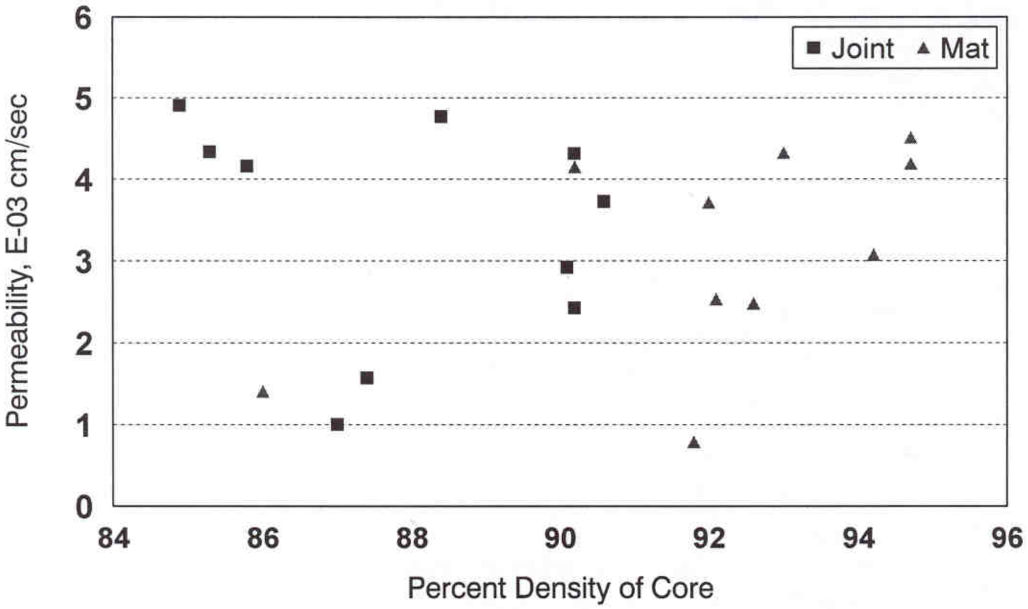


Figure 4. Permeability Data for TxDOT Hot Mix Asphalt Coarse Matrix High Binder Pavement Cores. (Estakhri et al. 2001)

Table 1 illustrates inflow rates obtained by University of Maryland research. In these tests, PCC pavements with cracks of various widths were placed on a range of surface slopes. Precipitation was applied at a rate of 2 in/hr in each test, and measurements were made of the percentage of the runoff that entered the cracks. These rates of inflow apply to cracks with no obstructions at the bottom. The rates of flow would be less when the cracks and cavities become filled with water and backpressure or head builds up.

Table 1. Percent Runoff into Surface Cracks of PCC Pavements. (Cedergren 1987)
(Precipitation Intensity: 2 in./hr)

Crack Width, In.	Pavement Slope, %	Percent of Runoff Entering Crack
0.035	1.25	70
0.035	2.50	76
0.035	2.75	79
0.050	2.50	89
0.050	3.75	87
0.125	2.50	97
0.125	3.75	95

Research by University of Maryland (Laboratory Tests).

Cedergren (1987) reports that numerous investigators have obtained coefficients of permeability ranging from a high of several hundred feet per day for unsealed asphalt mixes to virtually zero for well-sealed pavements. Permeability obviously depends on mixture type, density, and degree of cracking. Surface openings and imperfections can make both AC and PCC pavements much more permeable than the bases upon which they are constructed.

The Federal Highway Administration *Guidelines* (FHWA 1973) recommend using the 1 hour 1 year frequency precipitation rate as a design precipitation rate. This rate is the maximum rainfall in 1 hour that can be expected to occur on the average of one time each year. Figure 5 shows contours of the 1 hour 1 year frequency precipitation rates for Texas. These precipitation rates are recommended for use in the design of drainable bases. When considering the potential rainfall that can enter a base material which is *not* designed to drain, a more critical precipitation rate is one that occurs over a longer period of time, which is shown in Figure 6. If the permeability of a mix is 0.7 in./hr and a 6 hour rainfall of 3 inches (or 0.5 in./hr) occurs, the potential exists for all of this rainfall to enter the pavement structure. FHWA *Guidelines* suggest that for design purposes, assume that the infiltration rate for PCC pavements is between 50 and 67 percent (of the 1 hour 1 year frequency rate) and from 33 to 50 percent for AC pavements.

Figure 5. The 1 Hour 1 Year Frequency Precipitation Rates. (National Oceanic and Atmospheric Administration)

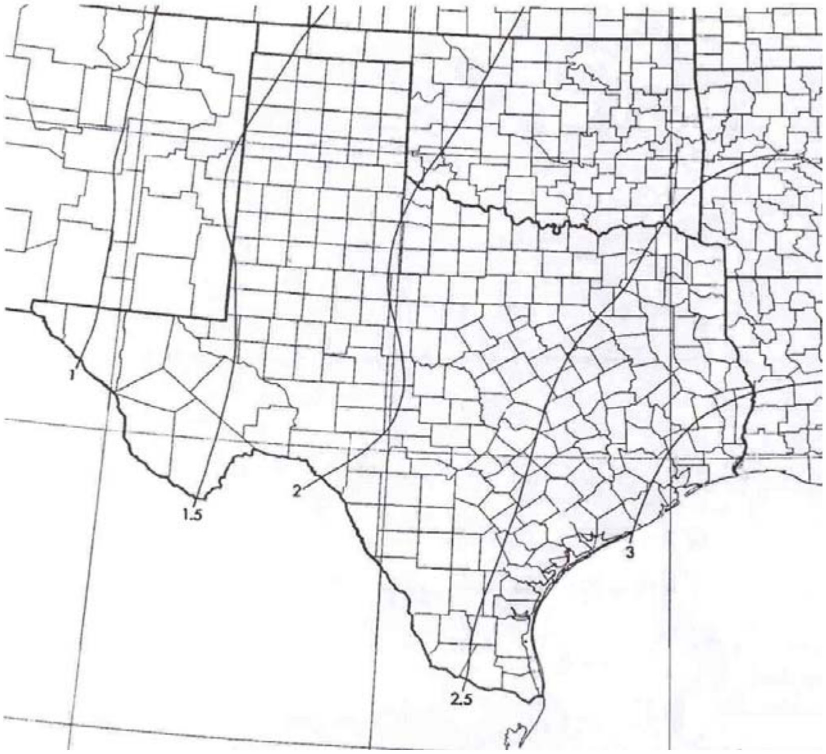


Figure 6. The 6 Hour 1 Year Frequency Precipitation Rates. (National Oceanic and Atmospheric Administration)

Groundwater Inflow

Once bases with more than about 5 to 10 percent fines (which are most of the flex base materials in Texas) become saturated, they will not drain freely due to capillary forces. This characteristic makes it very important to keep surface moisture from entering the base layer.

As mentioned previously, severe groundwater or seepage conditions usually show up during construction or are revealed by advance drilling and groundwater observations. It is unlikely that more than about 5 percent of the total pavements in the United States need protection from groundwater inflow.

Some engineers express concern regarding the use of underseals in applications where it may "trap" groundwater in underlying pavement layers. In areas with high groundwater levels, excessive sidehill seepage, or spring inflows, there are several ways to minimize the quantities of water that can reach the structural sections. This type of seepage should be handled by drainage methods rather than not sealing the pavement. Please refer to the textbook, *Seepage, Drainage, and Flow Nets* (Cedergren 1977) for more design guidance in this area. Some of the guidance from this text is described briefly below.

Field investigations should be made to establish the locations where springs and other groundwater inflows can be expected and should be continued into the wettest times of the year, since construction usually occurs in the driest periods of the year when it may be easy to overlook critical locations needing to be drained. Cedergren (1977) presents some of the types of subsurface drains that are used for control of groundwater and sidehill seepage in the following illustrations and discussion.

Figure 7 shows longitudinal drains for several types of roadbed conditions and groundwater levels needing control. In Figure 7a, a longitudinal drain along the left edge of the structural section provides control of sidehill seepage. In Figure 7b, a narrow road below the elevation of the normal water table requires fairly deep longitudinal drains along both sides to ensure adequate groundwater control. In Figure 7c, a wide pavement needs three lines of longitudinal drains to prevent groundwater from rising into the structural section.

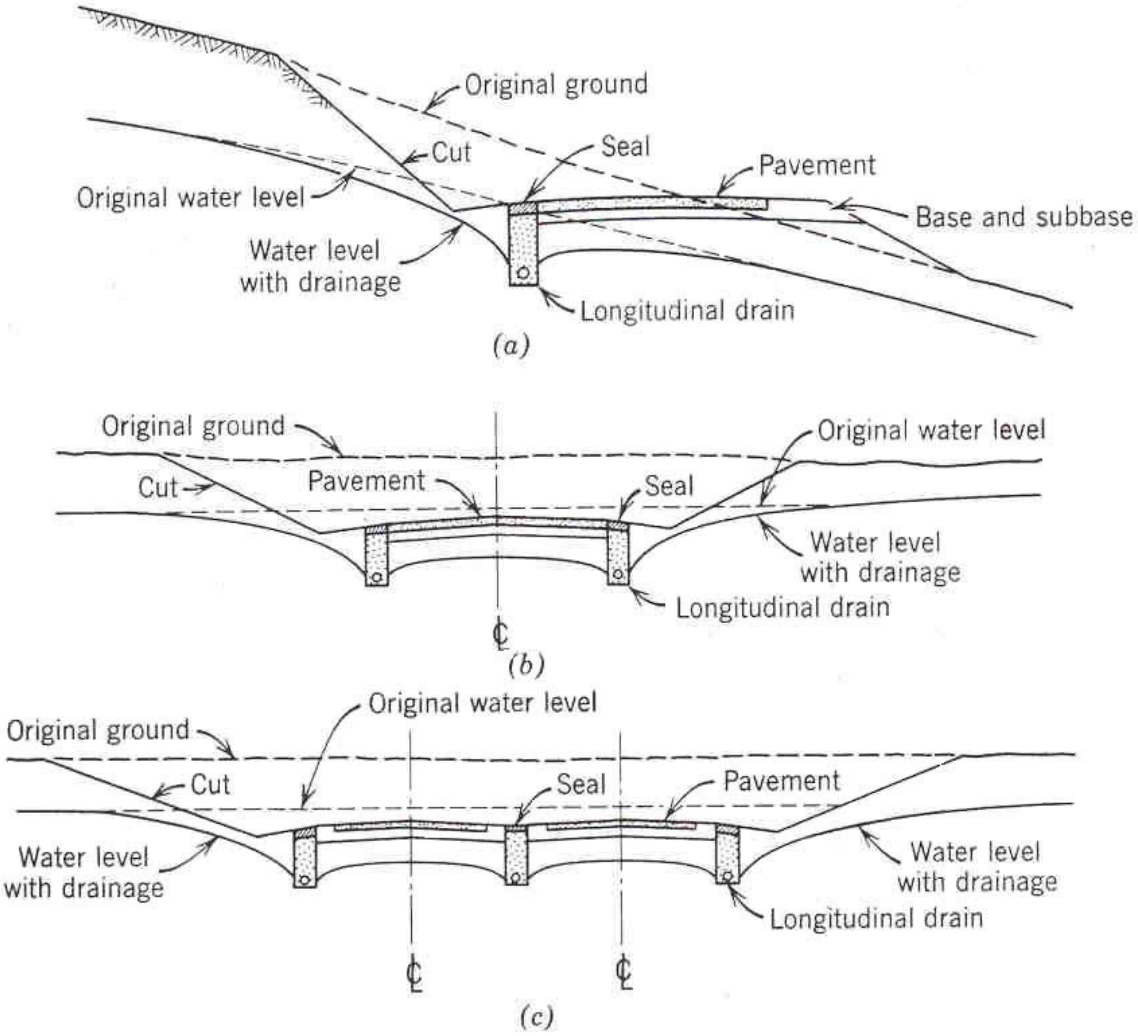


Figure 7. Longitudinal Highway Drains. (a) Side Hill Construction. (b) Narrow Road Terrain. (c) Wide Road in Flat Terrain. (Cedergren 1977)

Figure 8 shows a portion of a long, sustained grade of a highway in hilly terrain. Here cross drains placed at intervals prevent seepage and surface water infiltration from accumulating in larger quantities than can be accommodated by the base drainage layer.

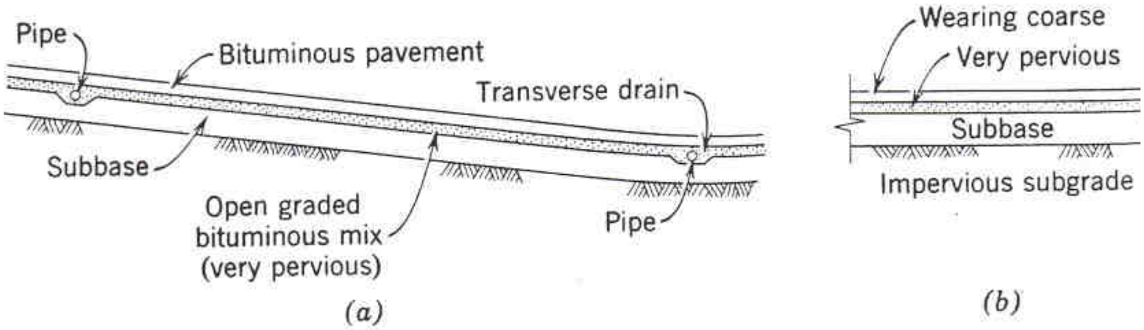


Figure 8. Pavement Design Providing Permeable Shallow Layer for Drainage of Surface Water (Primarily on Long, Sustained Grade). (a) Profile. (b) Section. (Cedergren 1977)

Figure 9 depicts a transverse interceptor drain located at the lower end of a cut having groundwater inflows. This drain prevents seepage that enters the structural section from flowing out on the fill.

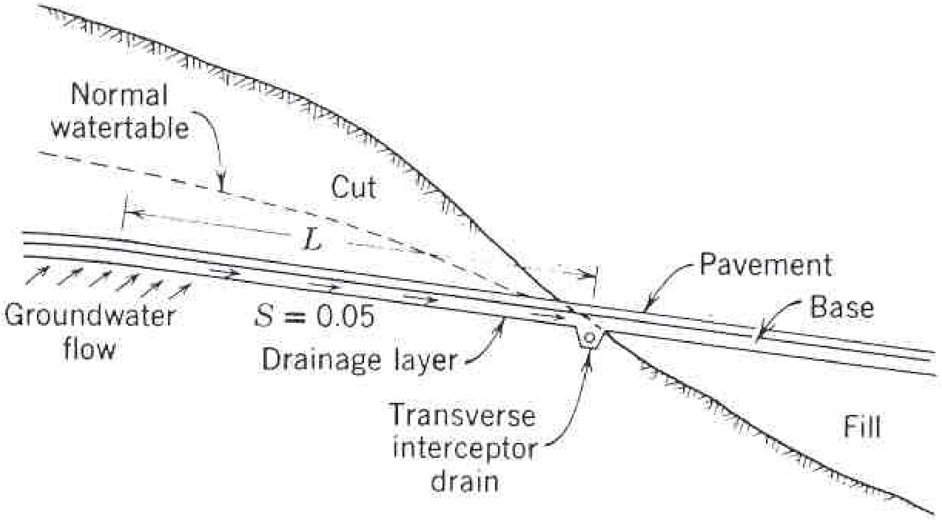


Figure 9. Transverse Interceptor Drain. (Cedergren 1977)

Summary

Several factors presented in this chapter support the need for underseals used as moisture barriers:

- Records of experimental road tests document that during periods when pavements contain large amounts of free water the rates of deterioration range from 10 or 20 up to hundreds and thousands of times greater than during times when they contain little or no free water. The effects of excess water in a pavement structure can overshadow many of the other pavement design factors such as stress and strain, deformation, volume change, and fatigue.
- When base materials which contain more than 5 to 10 percent fines (which are most of the flex base materials in Texas) become saturated, they will not drain freely due to capillary forces. If base materials are not designed to drain freely, they should be protected from the intrusion of surface water.
- In most cases, water which enters a pavement's structure comes through the pavement surface. In those few cases where groundwater seepage enters the pavement structure, drainage provisions should be made to intercept this type of water.
- The infiltration of water through the pavement surfaces depends on the global permeability, which is affected by the mixture type, density, and degree of cracking for AC pavements. For PCC pavements, the global permeability is affected by the condition of the cracks and/or joints. An FHWA study of numerous pavement sections found that 33 to 50 percent of the precipitation water falling on an AC pavement and 50 to 67 percent for PCC pavement could infiltrate through the pavement surface to the road base.

Chapter 3 Current Practice on the Use of Underseals in Texas

General

Researchers sent a questionnaire to each TxDOT district to determine the current practice, experiences, and problems around the state regarding the use of underseals. Responses were received from 20 of the 25 districts. These responses were compiled and analyzed to obtain specific information about underseals. The results are presented according to specific questions asked in the survey. Detailed responses from each district are also presented in Appendix A.

Location of Underseal in Pavement Structure

Researchers presented four cases in which an underseal might be used in a pavement structure. The definition of an underseal provided for the questionnaire was: a seal coat or microsurfacing placed on an asphalt layer, flexible base layer, or PCC layer and topped with an asphalt surface layer. Figure 10 shows the graphical representation of four different types of underseal situations. The underseal in each case is represented as the seal coat.

Figure 11 shows the extent of use for each case. Several of the districts report using all four cases, either routinely, based on money available, or depending on other criteria, as will be discussed further. Case 3 (using an underseal on top of an old asphalt concrete pavement [ACP] in a flexible pavement structure) is the most common application.

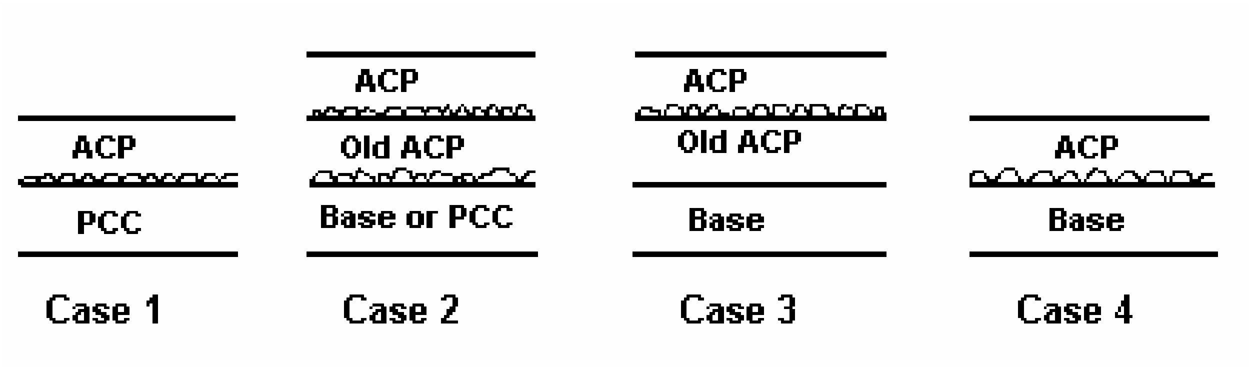


Figure 10. Four Different Possible Types of Underseal Situations.

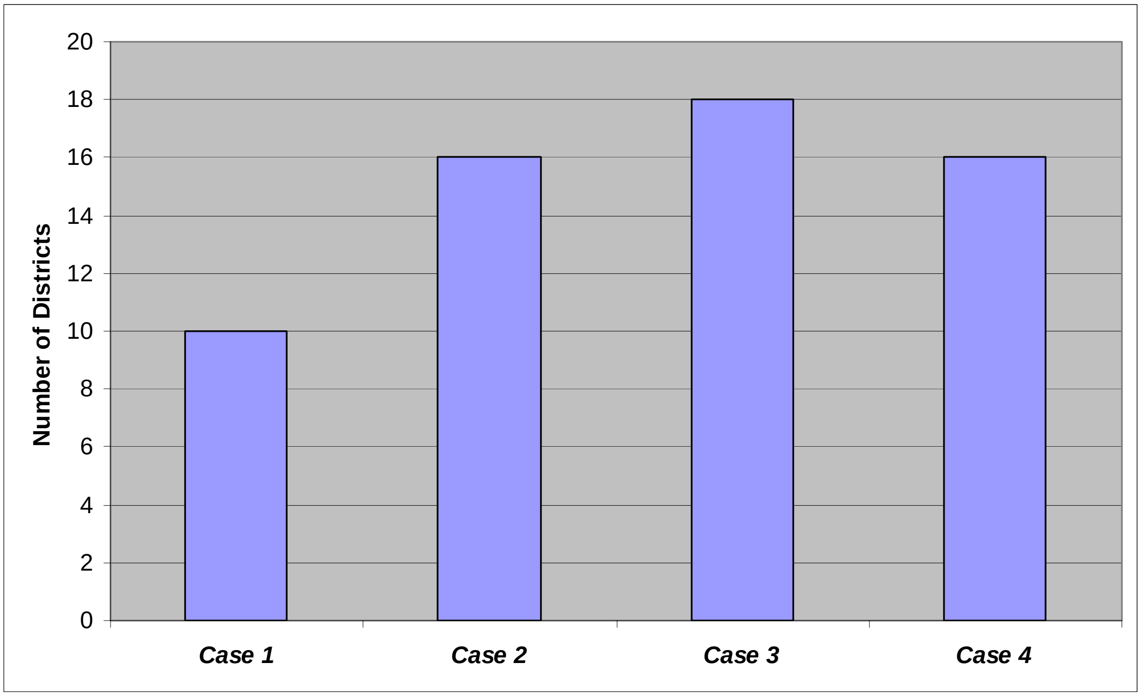


Figure 11. Underseal Situations Used by Districts in TxDOT (Refer to Figure 10).

Function of Underseal

Districts were asked to identify how they viewed the function(s) of the underseal as used in their district. Their responses are shown in Figure 12. Overwhelmingly, the districts responded that the primary function of an underseal was as a moisture barrier to prevent the intrusion of surface water into underlying layers. A few of the districts believe that the underseal may possibly prevent the movement of subsurface moisture into the surface layer.

Quite a few districts also consider the underseal very important in terms of enhancing the bond with the subsequent pavement layer. This may be even more important when the final overlay surface is thin. Definitions of “thin” vary according to respondents: thin may be considered anything less than 3 inches or may be as thin as 1 inch. The seal coat is believed to bond better to the existing pavement than a hot mix asphalt (HMA) layer. One respondent described that when a seal coat is rolled, it is rolled vertically into the existing pavement with little lateral movement. Hot mix, on the other hand, when rolled tends to have some lateral movement and the underseal is believed to help provide a better bond between the two layers.

One respondent believes that a seal coat (or underseal) when used on an old ACP can serve to somewhat bond together cracks that may not yet be visible. Evidence cited for this was regarding a roadway which had a great deal of visible alligator cracking in the wheel paths. Maintenance forces sealed the pavement and had essentially no failures for 2 years.

The underseal also may serve as a temporary wearing course to accommodate construction phasing prior to placing the final surface. The underseal allows the designer to move traffic into the desired patterns so that the ACP longitudinal joints are at the lane lines. Longitudinal joints are one of the weakest areas of a hot mix asphalt concrete (HMAC) pavement and should never be allowed to occur in a wheel path.

None of the districts responded that the underseal was used specifically as a stress absorbing membrane to delay reflective cracking. However, a few believe that it may provide a secondary benefit in this area. When used on an existing cracked ACP, the underseal seals those cracks to prevent surface water intrusion. The underseal is viewed as more effective at sealing cracks than a crack sealing operation.

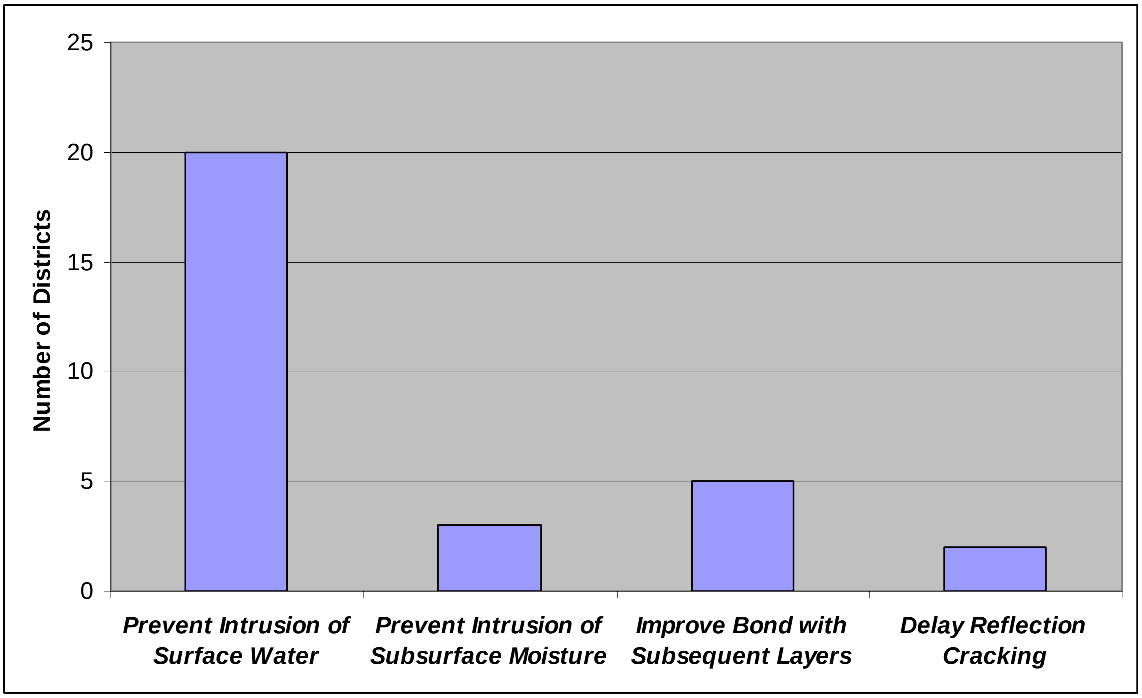


Figure 12. Functions of Underseals as Cited by TxDOT Districts.

Description of Underseals

The project statement for this research identified underseals as either seal coats (or surface treatments) or microsurfacing. In Texas, a seal coat refers to a layer of asphalt binder and aggregate applied to an existing paved surface. When applied to an aggregate base, it is called a surface treatment. In this report, we generally use the term seal coat whether it is applied to an aggregate base or a paved surface.

Results of the survey indicated that seal coats are almost exclusively the only type of underseal that is used in Texas. Microsurfacing may end up as an underlying pavement layer but is generally not designed or placed as a "moisture barrier." Geotextiles were outside the scope of this research project; however, three districts mentioned their limited use as a moisture barrier. The Dallas District routinely uses geotextile fabric strips applied directly over PCC cracks, then applies a seal coat prior to overlay. If the underseal is applied to a flex base, it is quite common for it to be a two-course surface treatment.

The binder types used for underseals are shown in Figure 13.

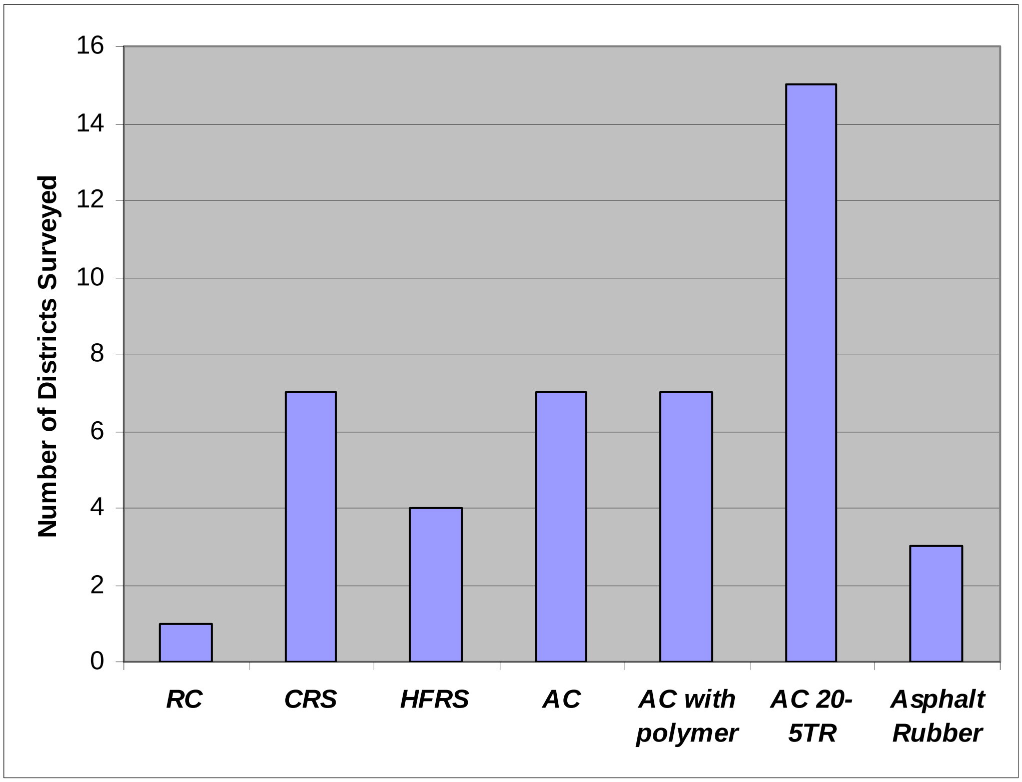


Figure 13. Types of Binders Used in Underseal Applications.

Some of the specific criteria districts use for binder selection are shown below. Refer to Appendix A for more detailed descriptions for each district.

- The Abilene District uses CRS-1P (Cationic Rapid Set) in winter, and in summer either AC-20-5TR, AC-5 or 10 with latex, or CRS-2.
- The Atlanta District uses hot AC or CRS-2 when long-term traffic on the seal is not a concern. Otherwise, they use a modified asphalt such as CRS-2P or AC-20-5TR.

- The Brownwood District uses an asphalt rubber seal coat with a Grade 3 precoated aggregate when placing an overlay over PCC. On ACP, they use AC-20-TR with Grade 4.
- During warm weather, the Bryan District uses AC-20-5TR or AC-15p with either precoated Grade 3 or 4. During cold weather, they use HFRS-1p (High Float Rapid Set) or CRS-1P with uncoated Grade 3 or 4.
- The Childress District uses AC-5 or 10 for low volume roadways and AC-20-5TR for high volume.
- If the underseal is on a treated or untreated flex base, the Corpus Christi District uses AC-5 or 10, CRS-2, or HFRS-2. If on an existing asphalt surface, then AC-15P, CRS-2P, or HFRS-2P is used.
- For high traffic applications, the Waco District uses AC-20-5TR or AC-15P. For low traffic applications, they use AC-15P, CRS-2P, or HFRS-2P.

The aggregate gradations which are used for underseals are shown in Figure 14, with Grade 4 being the most common. Districts use both lightweight and natural aggregates for underseals.

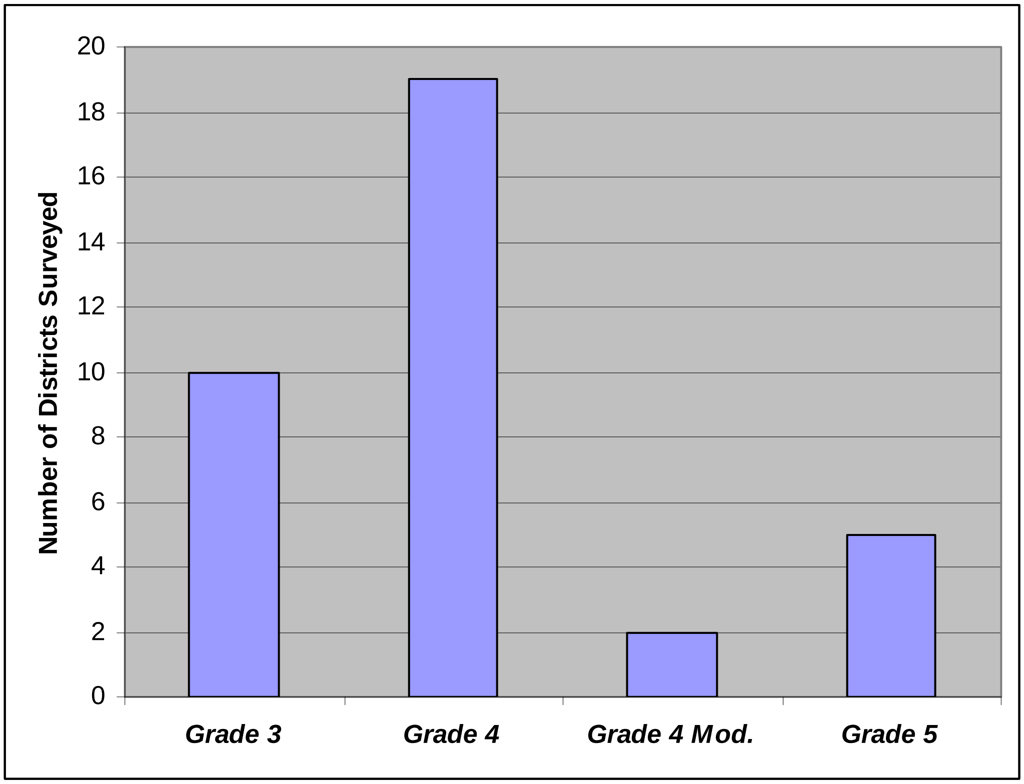


Figure 14. Aggregate Grades Used in Underseal Applications.

Conditions Which Warrant the Use of an Underseal

In the survey, researchers asked districts to define the conditions under which they would "definitely" use an underseal. Responses to this question included the following:

- Always use between a base and HMA overlay.
- Always use on top of PCC.
- Anytime the HMA overlay is less than 3 inches.
- Use on all HMA overlay projects.
- Always use if the existing pavement is cracked.
- Use on all U.S. highways.
- Use on all milled surfaces.

Several respondents considered underseals important enough that they thought they should be placed under all HMAC overlays if the money was available. A summary of these responses is presented in Figure 15. These responses represent specific opinions from the districts on when an underseal is more of a necessity as opposed to a desired pavement treatment (provided there is money available).

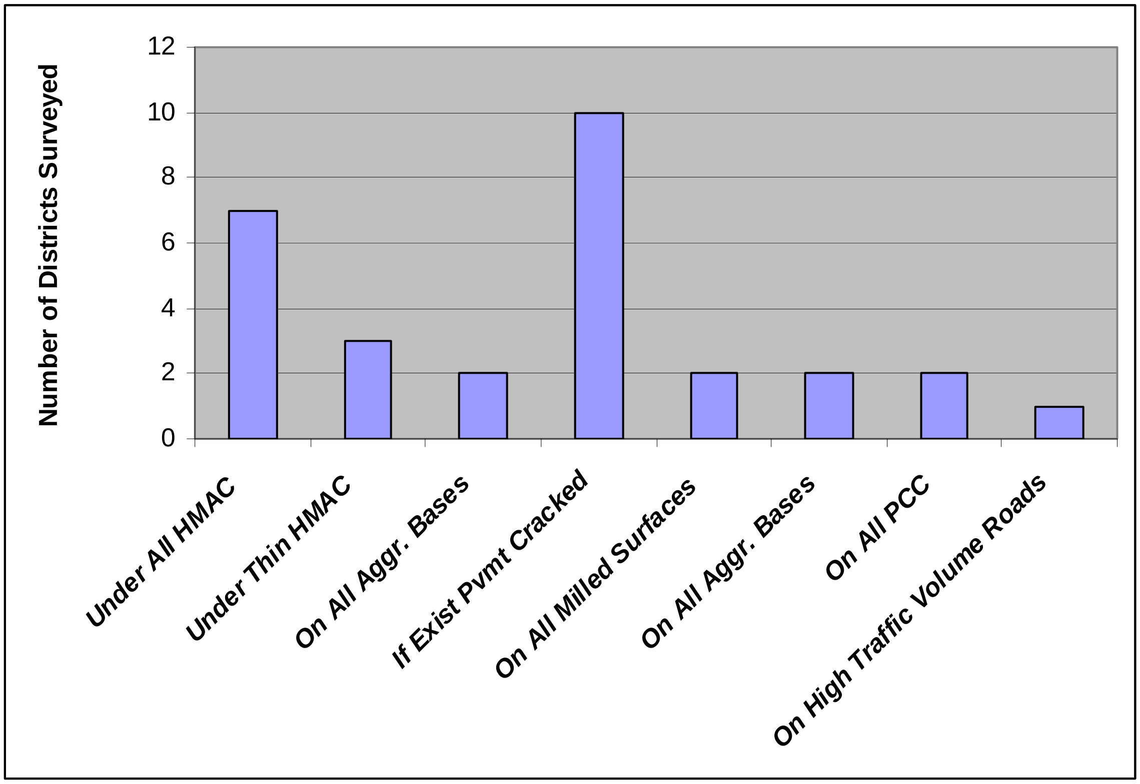


Figure 15. District Responses on Applications in Which Underseal is Definitely Needed.

Respondents were also asked under what specific conditions they would *not* use an underseal. Not all responded to this question but for those who did (Figure 16), the following was noted:

- Would not use for new, full-depth pavement construction.
- Would not use for thick asphalt layer construction (i.e., 2 inch Type D over 4 inch Type B).
- Would not use if pavement already has relatively new seal coat.
- Would not use on reasonably new ACP with no cracking.
- Would not use prior to level-up (should be after level-up).
- Would not use if underlying pavement is prone to stripping.

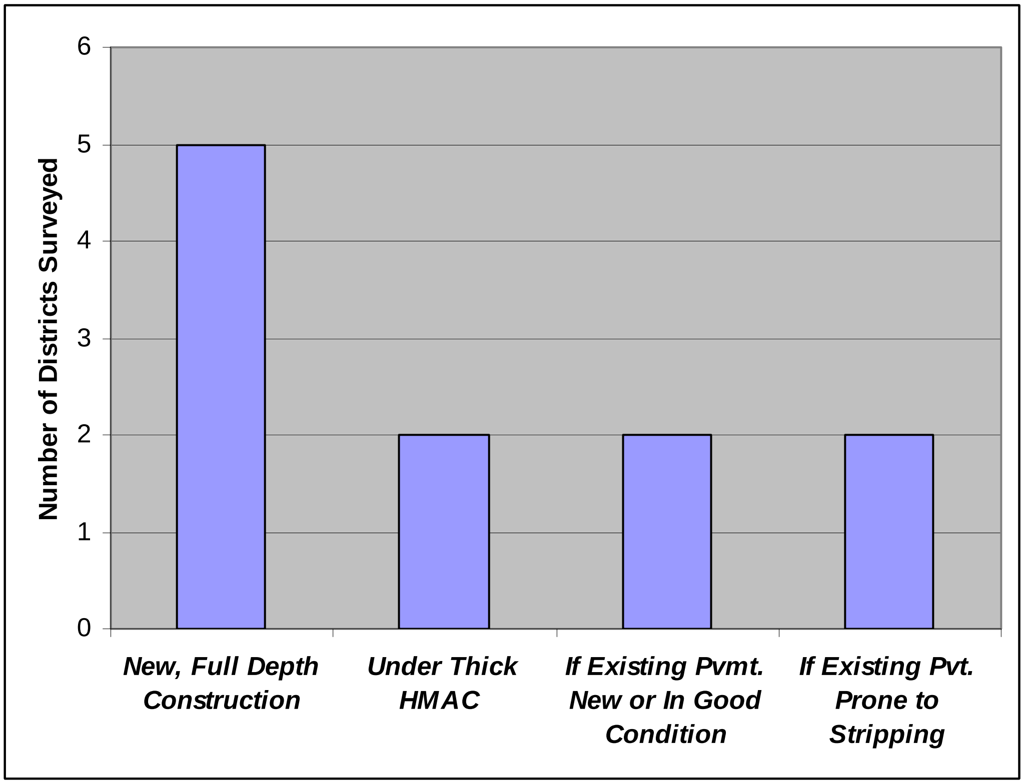


Figure 16. District Responses for Conditions in Which an Underseal Would Specifically *Not* Be Used.

Testing Prior to Underseal Application

Researchers queried districts on whether any testing was performed prior to placing an underseal on an existing paved surface. Some perform no tests but for those who do, the following types of responses were given:

- We have cut cores and applied the “Gene Rudd” screwdriver test in the field (to evaluate integrity of mix). (HMAC which is stripping-susceptible when subjected to the action of water and the coring operation will often disintegrate due to the coring operation. This is often evident visually.) We have collected falling-weight deflectometer (FWD) data on flexible pavement structures.
- We perform visual evaluation and history review.
- We perform core sampling in distressed areas to determine if distressed layer should be milled.
- No testing, but if asphalt layer is badly cracked, we mill it off prior to underseal.
- We perform coring and FWD to determine structural adequacy.
- FWD, cores, ground-penetrating radar (GPR), and profiler (for ride quality) are conducted.
- We check Pavement Management Information System (PMIS) scores and do a visual inspection to see if the existing surface needs to be milled.
- We evaluate traffic data.
- If we are doing a significant amount of hot mix work, we core pavement and do a visual evaluation to determine if there are any signs of stripping. If so, we mill the old surface.

Some of the actions listed above are not necessarily because an underseal is being considered but are simply part of the routine process for the planning of any HMAC overlay operation.

Types of Surfaces Used on Top of Underseal

Districts were also asked what type of hot mix was typically placed on top of the underseal. These responses are shown in Figure 17. This figure is really more of a representation of the types of hot mix surfaces routinely used by districts regardless of the presence of underseals. The mixture type does not seem to be a factor for deciding whether or not to use an underseal.

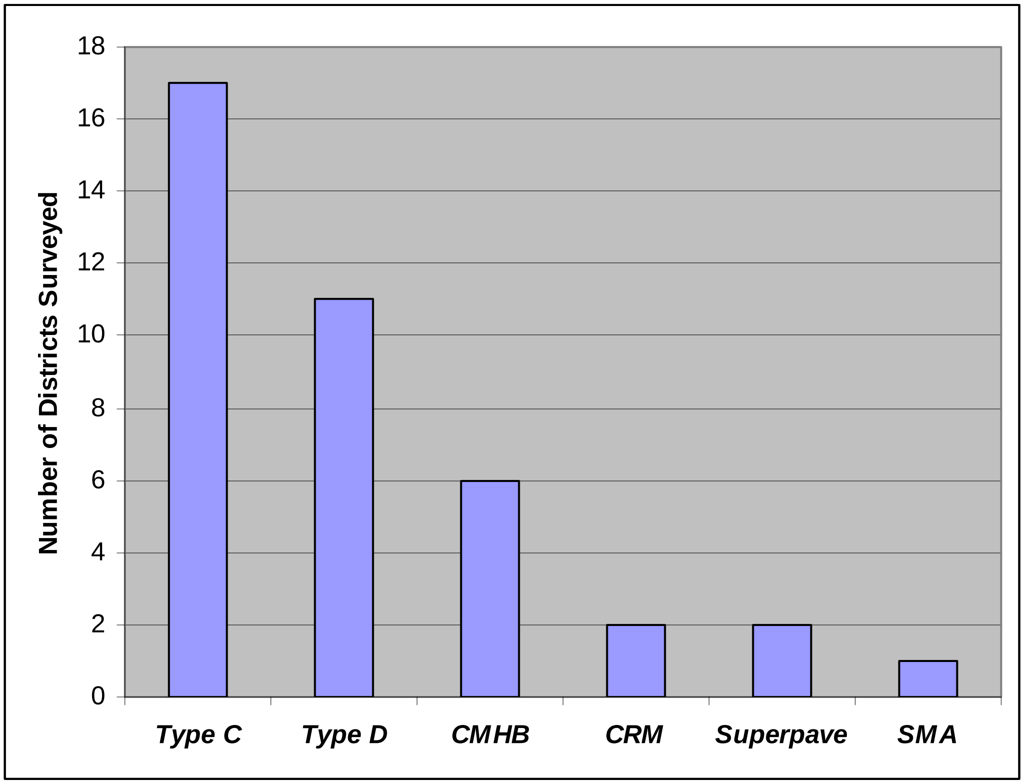


Figure 17. Types of HMAC Used over Underseals.

Variable Rate Nozzles

It has become common practice in some districts to use variable rate nozzles for seal coat construction. The purpose of these nozzles is to vary the asphalt rate transversely across the pavement so that more binder is placed between the wheel paths (or less in the wheel paths) in an attempt to improve aggregate retention between wheel paths and reduce propensity for flushing in the wheel paths. Respondents were asked if the practice of variable rate nozzles was used for underseal applications. Though some use it for their seal coat program, they generally report that it is not used for underseals. These responses are shown in Figure 18.

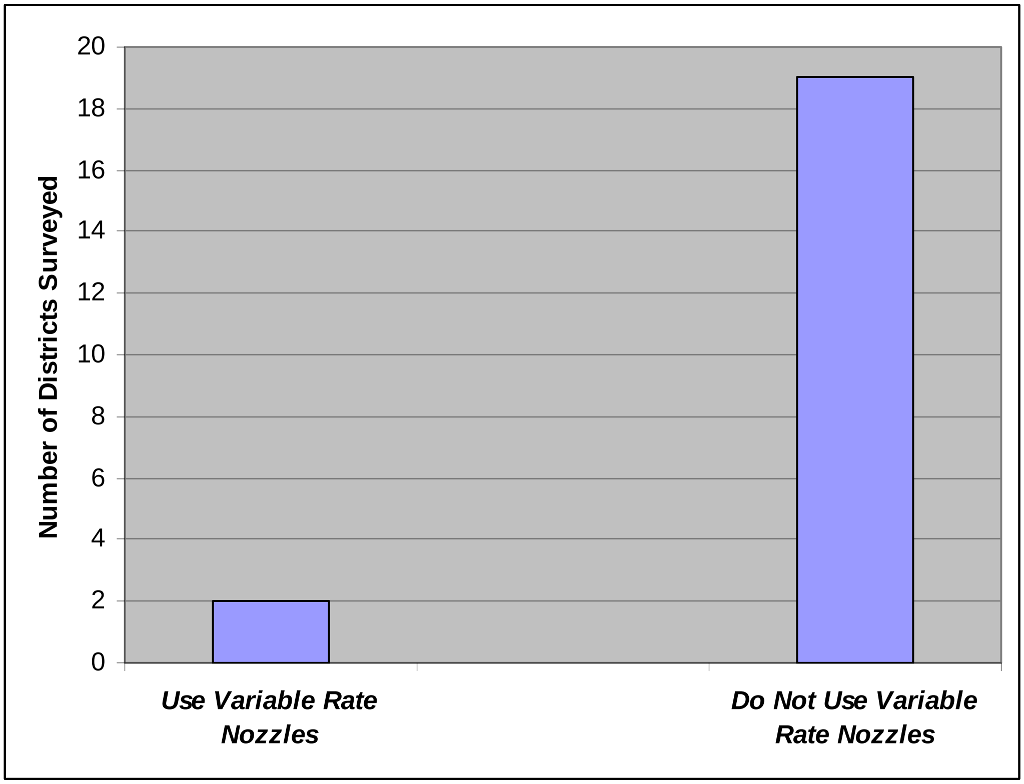


Figure 18. Number of Districts Using Variable Rate Nozzles for Underseal Applications.

Problems or Failures Associated with Underseals

One of the most common problems or failures associated with underseals is caused when the asphalt binder from the underseal bleeds or flushes through to the surface. This has been reported by several districts and is generally associated with the application of too much asphalt for the underseal. The Beaumont District noticed that sometimes after several layers of level-up/underseals, the pavement section flushes, becomes weak, and ruts. The Waco District points out that it is the policy of the Bridge Division to utilize a two-course surface treatment when placing an overlay on a bridge. This treatment prevents salts from penetrating the bridge deck but often causes bleeding through to the surface due to the high rate of asphalt application.

To alleviate the problem of the underseal "bleeding through," some districts have reduced the asphalt application rate and/or used a larger aggregate. Others are considering the use of variable rate nozzles to reduce the rate applied in the wheel paths.

Another relatively common problem with underseals occurs when the seal is placed on an aggregate base. The seal is sometimes damaged by traffic or construction operations prior to placement of the overlay. Water eventually leaks into the base course in the areas where the underseal was damaged, causing premature pavement failure.

The Abilene District had a problem in the past with the laydown machine pulling up the underseal. This problem occurred when a latex modified asphalt was used in the underseal. They have alleviated the problem since discontinuing the use of latex modified asphalt for underseal applications. The Odessa District noticed a similar problem with the underseal picking up underneath the laydown machine when then underseal was placed on top of an aggregate base. Experienced seal coat inspectors noticed that when loaded dump trucks are parked too long on a “fresh” seal, the truck wheels “pick up” the seal coat. Inspectors should be aware of this potential problem and take action to correct it should it occur. Researchers viewed several hot mix paving operations throughout the course of this research and were unable to witness this type of underseal “pick up.”

Districts noticed some problems surrounding the use of microsurfacing or instances where water trapped in lower layers is unable to escape. The Yoakum District reports two instances where continuously reinforced concrete pavement (CRCP) was sealed with hot rubber before an asphalt concrete overlay. Some years later, another seal or a microsurfacing was placed as a corrective measure. Then when rutting or ride became a problem, another overlay was placed. The second overlay had a short life and caused the district to remove everything above the concrete. The Yoakum District speculates that the failure is caused by moisture trapped in the lower ACP layer, causing it to strip. District personnel state, “How it got there was a mystery, but apparently there is too much material on top to allow proper evaporation.” They question that the microsurfacing, which is allowed to stay as an interlayer, may act as a “one-way valve” allowing water in the pavement structure but not allowing it to evaporate. The Wichita Falls District also expressed concern that when asphalt rubber is used as an underseal, it seals so well that it may trap water underneath. The Corpus Christi District had some failures in the past associated with not placing an underseal. But they also had a project where a microsurfacing layer trapped moisture below, causing a failure.

The Austin District had problems on IH 35 where an underseal (with HFRS binder) was used under microsurfacing. The roadway experienced rutting and bleeding under very high traffic. The Austin District attributes this problem to a lot of asphalt binder in a very thin surface. Also, the contractor had poor quality control.

The Waco District reports that when a microsurface was placed over an existing microsurface on IH 35, there was a bonding problem between the two treatments, causing the microsurface to delaminate. They now recommend using an underseal (seal coat) under microsurface when placed on an existing microsurface, though they also have had some problems with the underseal bleeding through.

Almost all of the pavements in the Dallas District are originally PCC. They remove the overlay down to the PCC, rout and clean the cracks, apply fabric strips over the cracks, and then apply a seal coat prior to overlay. They report that this type of underseal is usually successful. The biggest problem occurs when the seal coat is left under traffic too long (usually due to weather) and begins to debond in the area where fabric is located. They recommend that when the underseal is placed that the temperature be above 50°F and the pavement be totally dry. If bad weather is imminent, try to pave over it immediately; otherwise, the seal can be left under traffic for about a week.

Summary

- One hundred percent of the districts surveyed consider the primary function of an underseal to be to serve as a moisture barrier to prevent intrusion of surface water into underlying layers. Another function considered important is that it enhances the bond with the subsequent pavement layer. A few districts mentioned that they believed there was a secondary benefit associated with delayed reflection cracking and preventing the movement of subsurface moisture into the surface layer.
- Districts use underseals on all types of surfaces: existing HMAC, PCC, and aggregate bases. The most common use is to apply an underseal to seal off cracks in an existing pavement (PCC or ACP) prior to overlay. However, several districts (about one-third of those surveyed) routinely use an underseal any time a hot mix overlay is placed.
- The most common type of binder used for seal coats applied as underseals is AC-15-5TR, and the most common aggregate grade is Grade 4. Some districts select binder based on specific criteria (such as weather and traffic). Districts use both lightweight and natural aggregates for underseal construction.
- Testing and evaluation performed by some districts prior to underseal and overlay include coring (and visual evaluation of cores for signs of stripping), FWD, GPR, ride quality, check PMIS scores, and perform visual evaluation to determine if milling is required.
- Dense graded types C and D mixes are the most common surfaces applied over underseals.
- The main problems or failures experienced with underseals include: (1) asphalt binder from the underseal bleeds through to the surface of the overlay; (2) underseals (on aggregate bases) sometimes get damaged by traffic or construction operations prior to overlay, allowing water to leak into the base; and (3) underseal traps moisture in a moisture susceptible layer causing it to fail.

Chapter 4 Case History Performance of Underseals

General

Locating failures associated with the performance of underseals throughout this research study proved to be difficult; however, researchers were able to gather information from TxDOT personnel around the state to provide documentation for this effort. The following is a description of a number of case studies where underseals or the lack of an underseal may have contributed to a pavement failure.

Case History 1 – Underseal Bleeding

One of the common problems associated with underseals concerns the asphalt binder from the underseal (seal coat) bleeding or flushing to the surface of the HMAC overlay. TTI was involved in a research project several years ago to evaluate the performance of asphalt-rubber interlayers (Shuler et al. 1985). Test sections were constructed in 3 locations around the state The test sections constructed in Brownsville are of interest to this research study because multiple sections were constructed with different underseal binder application rates (both one and two course), and different binder viscosities (asphalt rubber, asphalt cement, and polymer modified asphalt cement). Some of these test sections exhibited severe flushing through the overlay.

The test sections were constructed to evaluate the effectiveness of asphalt-rubber as a stress-absorbing membrane interlayer (SAMI) to prevent or delay reflective cracking. At the time of construction, some were speculating that perhaps the reason asphalt-rubber was effective as a SAMI was because asphalt-rubber seal coats were constructed at higher binder application rates than conventional asphalt seal coats. Therefore, in terms of the interlayer absorbing stress from moving cracks underneath, is more binder better? The Brownsville test road was designed to evaluate field performance of two aggregate grades in single and double asphalt-rubber applications as interlayers. Control sections were constructed of interlayers with polymer modified binders and conventional asphalt cement. Though called “interlayers” since they were used to address reflection cracking, they could also be termed “underseals”.

The existing pavement structure prior to rehabilitation was a curb and gutter and consisted of 4 inches of asphalt concrete placed over 8 inches of crushed stone base. The asphalt rubber binder was produced just as AR binders are currently produced. One week after they were placed, 1 ½ inches of Type D HMAC was applied.

A total of 18 test sections were constructed as described in Table 2. The asphalt rubber test sections were each 1500 feet and the controls were 500 feet long. Only 9 sections are shown in this table, but each combination had two replicates.

Because the original study was concerned with reflection cracking, only cracking data was documented in published information. However, TTI researchers still had the pavement evaluation information and were able to identify which sections exhibited flushing distress.

Table 2. Types of Interlayers (Underseals) Constructed at Brownsville Test Road.

Interlayer Type	Binder Type	Aggregate Grade in Top Course of Seal	Aggregate Grade in Bottom Course of Seal
One Course	Asphalt-Rubber	3	None
One Course	Asphalt-Rubber	4	None
One Course*	Asphalt-Rubber	4	4
Two Course	Asphalt-Rubber	3	3
Two Course	Asphalt-Rubber	4	3
Two Course	Asphalt-Rubber	4	4
Two Course	AC-10	4	3
Two Course	HFRS-2P	4	4
None	None	None	None

*In this section, two courses of Grade 4 aggregate was applied to a single application of binder.

During construction, researchers documented the actual binder application rates for the seal coat construction as shown in Table 3. Binder application rates were excessive for many of the test sections and exceeded the design rate in almost all. In fact, many sections were exhibiting flushing prior to application of the overlay. The underseals were exposed to traffic for one week prior to overlay.

Many of the test sections exhibited flushing in the surface of the overlay. This flushing was clearly a result of the excessive binder application rates in the underseal. In fact, tire rubber particles (from the asphalt rubber) were visible in the surface of the overlay. The last column in Table 3 presents the condition of the section (in terms of flushing) five years after construction. A layout of the test sections is shown in Figure 19. It also appears that the traffic may also have been a contributing factor with some of the inside lanes exhibiting less flushing.

Examples of the flushing distress seen on the test sections are shown Figures 20 and 21.

Table 3. Brownsville Test Road Underseal Application Rates and Degree of Flushing After Five Years.

Underseal (or Interlayer Type)	Binder	Aggregate Size (Bottom/Top)	Measured Binder Application Rate, gal/yd^2, Bottom/Top	Flushing Distress
One Course	AR	3	Section 2: 0.78 Section 6: 0.76	Moderate Severe
One Course	AR	4	Section 10: 0.58 Section 15: 0.56	Severe Severe
One Course*	AR	4 / 4*	Section 11: 0.65 Section 16: 0.66	None None
Two Course	AR	3 / 3	Section 5: 0.77 / 0.85 Section 2: 0.67 / 0.65	Moderate Severe
Two Course	AR	3 / 4	Section 3: 0.48 / 0.71 Section 7: 0.59 / 0.71	Severe Severe
Two Course	AR	4 / 4	Section 9: 0.49 / 0.51 Section 14: 0.56 / 0.52	Severe Severe
Two Course	AC-10	3 / 4	Section 4: 0.60 total Section 8: 0.45 / 0.58	None Severe
Two Course	HFRS-2P	4 / 4	Section 13: 0.48 total Section 18: 0.53 total	None None
None	None	None	Section 12: None Section 17: None	None None

*In this section, two courses of Grade 4 aggregate were applied to a single application of binder.
** Indicates data not available.

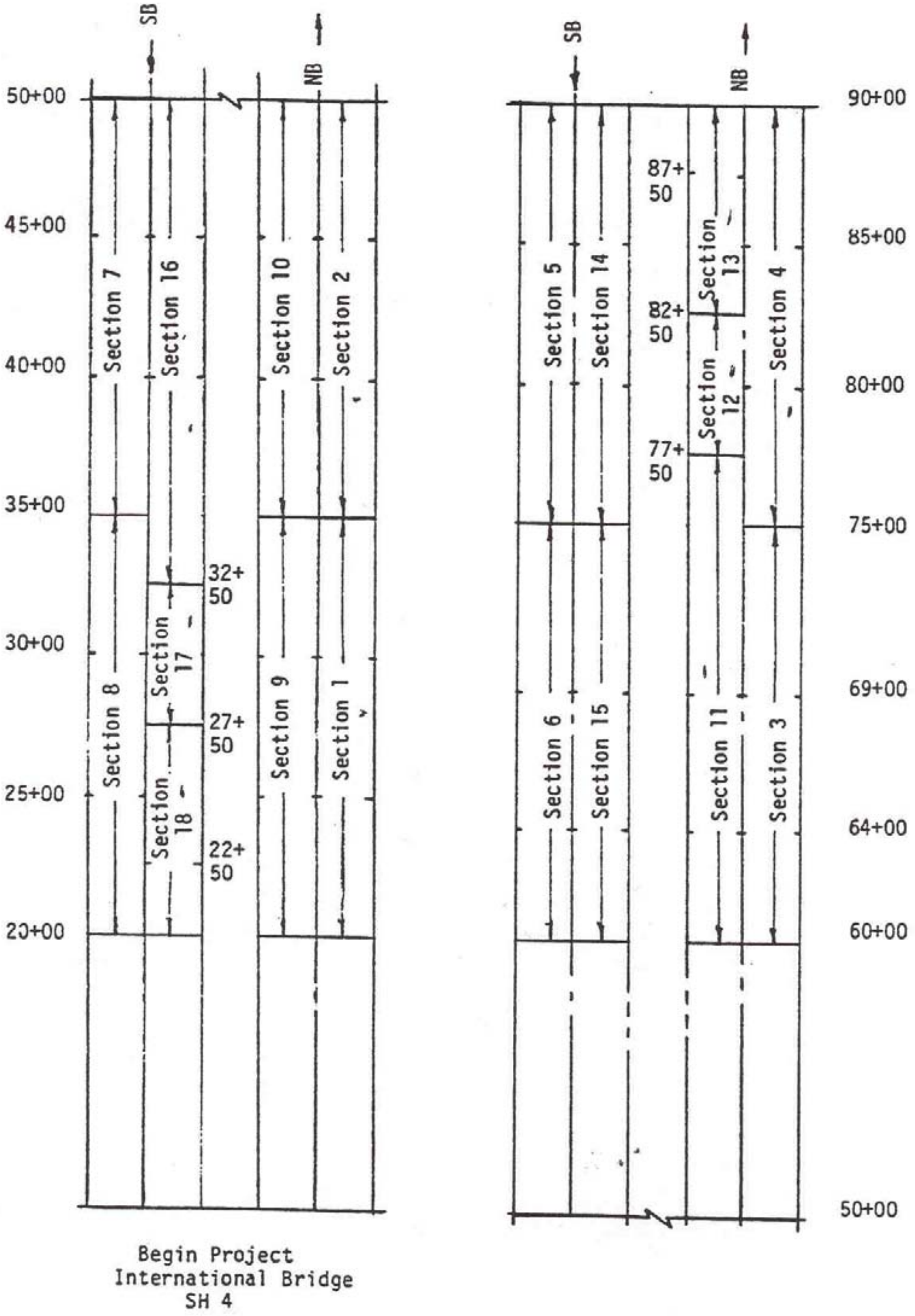


Figure 19. Brownsville Test Road – Test Section Layout.

Figure 20. Underseal Test Section Bleeding Through to Surface.

Figure 21. Inside Lane Test Sections Flushing Less Than Outside Lanes.

Figure 22. Severe Flushing From Underseal.

Case History 2 – Flushing of Underseal

Figures 23 and 24 show other examples of an underseal flushing through to the pavement surface. The case in Figure 23 represents one in which the underseal binder was field changed prior to placement to use a softer asphalt since construction was during colder months. Therefore, it was believed that the softer binder contributed to flushing.

Figure 23. Underseal Flushing on SH 6.

Figure 24. No Paper Joint Used In Underseal Construction.

Case History 3 – Damaged/Missing Underseal

The Bryan District performed an investigation of a premature pavement failure on SH 7 in Limestone County as shown in Figure 25. The pavement cross-section consisted of a Type C HMAC over a surface treatment over a stabilized base.

The District analyzed the existing roadway with the falling weight deflectometer (FWD), ground penetrating radar (GPR) and sampled the existing material at one location with a backhoe (Personal communication from Darlene Goehl, Bryan District Pavement Engineer to Tom Parker, Area Engineer Robertson County, 2001). The FWD data indicated that the existing stabilized base was strong (tested both lanes). The GPR indicated irregularities in the area just below the hot mix and there appeared to be problems with the seal coat. Based on conversations with the area office and maintenance personnel, there were problems with the seal coat during construction. Maintenance patched areas of the seal coat just ahead of the hot mix laydown machine. The Pavement Engineer also reviewed the pay sheets for the stabilization and seal coat items and found inconsistencies (gaps in the seal coat areas) in the pay sheets for the seal coat material, indicating that the full width may not have been sealed before the overlay. There was also a change order to use AC-3 or AC-5 instead of AC15-5TR for the second course of the surface treatment.

Recommendations were to repair the failed hot mix areas and place a seal coat full width.

Figure 25 displays the distresses along the edgeline in the hot mix pavement (this is one of the worst locations). Testing was performed just north of this location and the stabilized base was found to be solid.

Figure 25. Distressed Area on SH 7.

Figure 26 displays the material in the shoulder. The shoulder consists of approximately 2 in. of hot mix, seal coat, 4 in. of unstabilized flexible base, seal coat, etc.(did not test below the 2nd seal coat). The shoulder material extends out towards the lane under the edgeline.

Figure 26. Cross Section of Shoulder Materials.

Case History 4 – Water Trapped in Moisture Susceptible Layer

The Atlanta District investigated a failure on IH 30 which involved PCC overlayed with hot mix. The cross section of the pavement was as shown below in Figure 27.

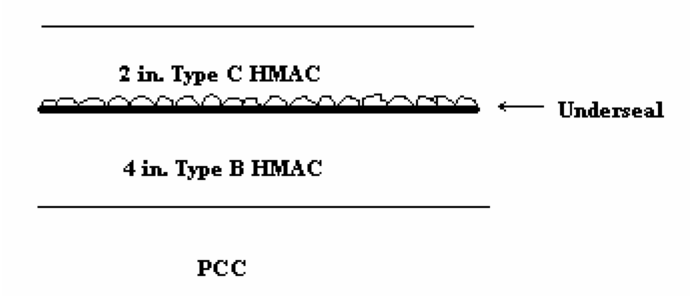


Figure 27. Cross Section of Pavement on I 30.

This pavement had six areas of bowl-shaped depressions in the pavement surface (in the east bound outside lane – EBOL). The Type C surface was constructed with a sandstone aggregate and a PG 76-22 binder. The Type B mix was also constructed with sandstone, RAP and a PG 64-22 binder. The underseal consisted of a Grade 4 lightweight and AC-20-5TR.

The district took at least 18 cores from the project in an attempt to identify the cause of distress, sources of moisture, and extent of potential problems. The surface mix (Type C) of all the cores appeared in good condition. However, the Type B was soft and visibly stripped. It appeared that moisture was trapped in the Type B layer between the seal coat and the CRCP. Though the distressed areas were within the outside lane, the moisture damage viewed from the cores was also present in the inside wheel path and as far back (up-hill) as 1000 ft from one of the "bowled" areas. The contractor made repairs to some areas, and shortly thereafter, another failure would show up immediately upstream.

This pavement had edge drains in place and researchers noted from the field coring log at two coring locations that at the crest of a hill, the Type B layer was in good condition. At the sag, the Type B layer was severely stripped, yet the edge drains were dry.

The District contacted the Construction Division to perform GPR to determine the limits of the trapped moisture and how the moisture is entering the layer. A portion of this analysis is described below (Personal communication from Joe Leidy, TxDOT Construction Division to Miles Garrison, Atlanta District Pavement Engineer, 2000):

> *My understanding is that there is a lightweight aggregate seal coat between the upper and lower HMAC layers. Typically, this would show up as a continuous faint blue line between the HMAC layers. This was not the case in this evaluation. To eliminate possible influence of this layer in the upper displays, the lower voltage button was pushed well below the level where any influence from the lightweight aggregate should be visible. The areas of suspected stripping are fairly extensive – perhaps too extensive to be caused by artesian spring action. Also, the lower displays do not show extensive areas of moisture below the slab. However, this problem may be masked to some extent (perhaps a large extent) as a result of most of the energy being reflected in the upper layers by the time the radar signal finally makes it to the bottom of the slab.*

The conclusion was that although not evident on the surface, the stripping was pretty extensive throughout the mix. There was no definitive conclusion on how the water was entering the Type B layer. It was either coming from underneath the PCC or through the surface. If coming through the surface, it would have to penetrate through the Grade 4 underseal or enter at the longitudinal joints (shoulders not PCC). A note on the coring log indicated that the underseal was left open to traffic for some time before overlaying and may have been damaged.

Repairs were made to the failed areas by milling down to the PCC, placing a seal on top of the PCC followed by the Type B and Type C. Also, a different type of edge drain was placed in these areas and seems to be functioning well. District practice is to now seal PCC concrete prior to overlaying with a Type B base and not to seal the layer between the Type B and Type C (to avoid trapping water in the Type B layer).

Case History 5 – Debonding of Underseal

In 1997, the Brownwood District experienced some pavement failures on US 190 in San Saba County. This pavement exhibited half-moon shaped tears in the top 1 inch of the pavement surface, primarily in the inside wheel paths. See Figures 28 and 29.

Figure 28. US 190 Pavement Failure.

Figure 29. Close-Up of US 190 Pavement Failure.

This pavement consisted of about 1 inch of HMAC over a lightweight seal coat, about 3 inches of HMAC, and flex base (Figure 30). The seal coat binder was probably a CRS-2. The seal coat was not placed as an underseal but had been in service for many years prior to the HMAC overlay and had performed well. After the seal was overlayed, these types of failure started to occur. The failure was occurring at the bottom of the seal coat (i.e. the seal coat debonded). As can be seen in Figure 29, no binder from the seal coat is visible on the underlying HMAC surface.

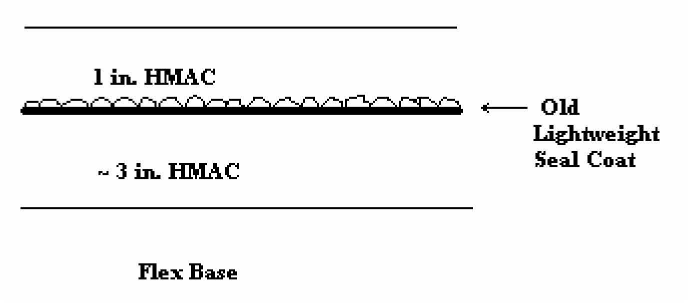


Figure 30. US 190 Pavement Cross Section.

There were no obvious mitigating factors as to the cause of failure. Some of the failures occurred going up hills, some going down hills, and some in flat areas. The lightweight aggregate left grooves in the underlying pavement where the upper pavement slid across it.

The district performed an investigation consisting of coring the asphalt layers (Figure 31), sampling the base and subgrade and also removing slabs of the pavement (Figure 32). Field personnel noticed that the "slid areas" appeared to be asphalt rich.

Samples of the base and the subgrade were tested for gradation, moisture content and Atterberg Limits. The PIs of the base materials ranged from 12 to 23 and the moisture content ranged from 9.7% to 11.8%. Based on all the laboratory tests, the district concluded that neither the base nor subgrade was a major contributing factor to the failures.

The District removed and replaced the debonded surface mix. There was no definitive conclusion as to the cause of the pavement failure. District staff speculated that possibly water was coming through cracks of the underlying pavement causing the asphalt from the seal coat to strip from the surface. Another speculation was that there may have been contaminants on the roadway prior to the seal being placed.

Figure 31. Pavement Cores Showing Debonded Overlay.

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Figure 32. Pavement Slabs Cut From US 190.

Case History 6 – Water Trapped in Moisture Susceptible Layer without Underseal

Concern has been expressed regarding placing an underseal which could trap water in a layer which is moisture susceptible. Here is a case where apparently a moisture susceptible layer was overlayed *without* placing an underseal first. The new ACP layer as well as the underlying layer failed, both due to stripping. Rutting and stripping were present in the pavement surface.

The surface mix (on this portion of I 10) was a gravel mix, and the underlying layer consisted of 2, 2-inch layers of limestone ACP. The Construction Division sampled and tested in both distressed and nondistressed areas.

In-place density was determined for the longitudinal joint, left wheel path and between the wheel paths for the surface layer. These densities averaged 94.9 for the wheel paths and 90.7 at the longitudinal joint (Table 4).

Table 4. In-Place Density for Top Layer.

Location	Longitudinal Joint	Wheel Path	Between Wheel Path
1 – Rutting	90.5	94.2	93.2
2 – Rutting	90.8	95.6	93.7
3 – No Distress	N/A	95.2	N/A
4 – No Distress	N/A	94.4	N/A
5 – No Distress	N/A	95.0	N/A

In-place density for the underlying limestone layers (taken in wheel paths only) ranged from 93.5 to 95.2 percent. The in-place density between the wheel path shows that the contractor achieved passing density during placement. However, specifications at the time did not allow measurement of density near the joint. The low joint density provided a means for water to enter the pavement. The in-place density results show the limestone layer to have adequate density.

Tensile strength was evaluated using the indirect tension test. Two sets of cores were used for each of the locations. The first set was subjected to vacuum saturation for 30 minutes then soaked in a water bath at 77°F for 24 hours, and the second set was kept dry. Tables 5, 6, and 7 show the results for the tensile strength tests.

Table 5. Tensile Strength of Dry and Wet Cores for the Top ACP Layer.

Location	Tensile Strength of Dry Cores (psi)	Tensile Strength of Wet Cores (psi)	Tensile Strength Ratio (TSR)
1 – Rutted Area	93.9	64.4	69
4 – Good Condition	107.4	74.1	69
5 – Good Condition	116.2	66.2	57

Table 6. Tensile Strength of Dry and Wet Cores for Middle Limestone Layer.

Location	Tensile Strength of Dry Cores (psi)	Tensile Strength of Wet Cores (psi)	Tensile Strength Ratio (TSR)
4 – No Distress	107.9	74.2	69
5 – No Distress	127.7	60.4	47

Table 7. Tensile Strength of Dry and Wet Cores for Bottom Limestone Layer.

Location	Tensile Strength of Dry Cores (psi)	Tensile Strength of Wet Cores (psi)	Tensile Strength Ratio (TSR)
4 – No Distress	141.4	74.2	69
5 – No Distress	127.7	60.4	47

Visual examinations of the broken cores showed that the cores subjected to moisture conditioning had stripped. The Tensile Strength Ratios for all of the values were very low and show that there is evidence of stripping in the surface ACP as well as the limestone in the middle and bottom layers. The bottom layer of limestone is in the worst condition overall.

The forensic investigation indicated the following (personal communication from Maghsoud Tahmoressi, TxDOT Construction Division to Wayne Ramert, Yoakum District Engineer, 1999):

1. *The gravel ACP surface layer experienced mild to severe stripping. Stripping is evident in both inside and outside lanes.*
2. *The limestone ACP layer under the surface has disintegrated. The extent of disintegration of this layer was variable throughout the length of the project. In general, in areas with the worst rutting, the limestone ACP was in the worst condition.*
3. *The low in-place density at the longitudinal joint is the likely reason for intrusion of water into the pavement. The density between the wheel paths indicate that proper in-place density was achieved during construction.*

TxDOT engineers recommended that due to the stripping of the gravel ACP layer, this layer should be removed from the project. Also, about 4 inches of the limestone ACP under the surface layer was in various stages of disintegration and stripping. The layer appeared to be sound in the inside lane. However, there was about a 1-inch thick weak layer at the bottom of the limestone ACP in both the inside and outside lanes. If left in place, it was felt the ACP would have a tendency to cause failure, and therefore it was recommended that the limestone ACP layer be removed as well.

Case History 7 – Missing or Damaged Underseal

The Atlanta District constructed six test roads using fly ash bases. Some of these pavements experienced problems with the surface treatment. Five of the pavements were scheduled to receive a one-course surface treatment as the final riding surface. However, soon after placement, the surface treatment began to delaminate from the underlying fly-ash base (Figure 33). This required the placement of HMAC over the surface treatment on some of the more heavily trafficked roadways.

Figure 33. Delamination of One-Course Surface Treatment (Loop 390).

After four years of surface, Loop 390 in Marshall began exhibit alligator cracking-type distress in isolated areas as shown in Figure 34. It also appeared that the base material was pumping through to the surface. A Grade 4 seal coat was placed on the HMAC surface to seal the pavement from water intrusion.

TTI researchers and TxDOT staff collected FWD data as shown in the analysis in Figure 35. The base material did appear to be somewhat weaker in the area where the alligator cracking is observed as noted on Figure 35. However DCP tests performed in the area showed that the base had good integrity and resisted penetration. Cores removed from the area (Figure 36) also showed no significant problems with the base.

Perhaps sealing the surface helped arrest the problem with the alligator cracking because it subsided and the pavement performed well for several years afterward.

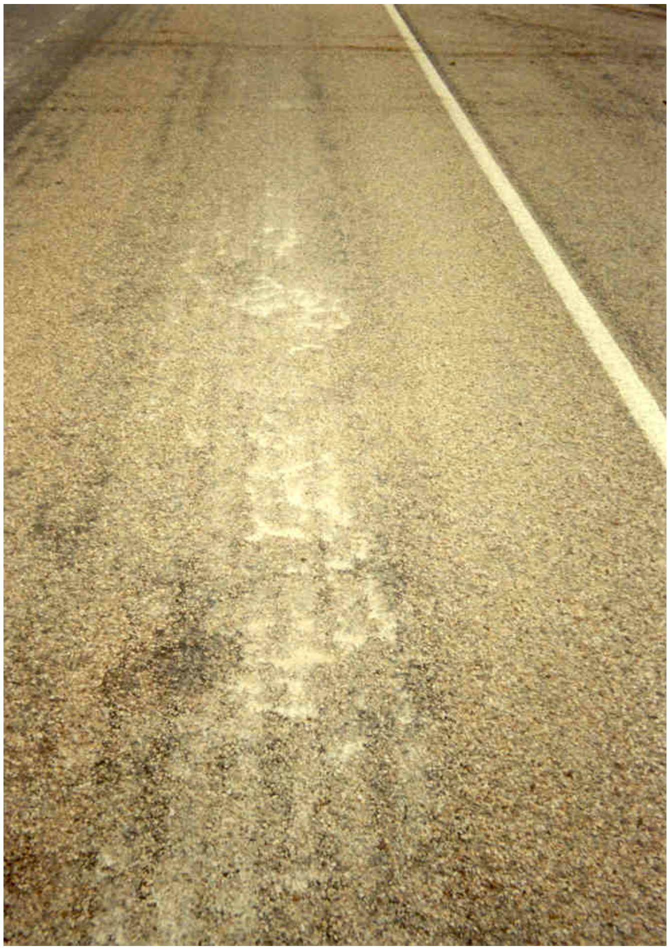


Figure 34. Alligator Cracking Distress on Loop 390 in Atlanta.

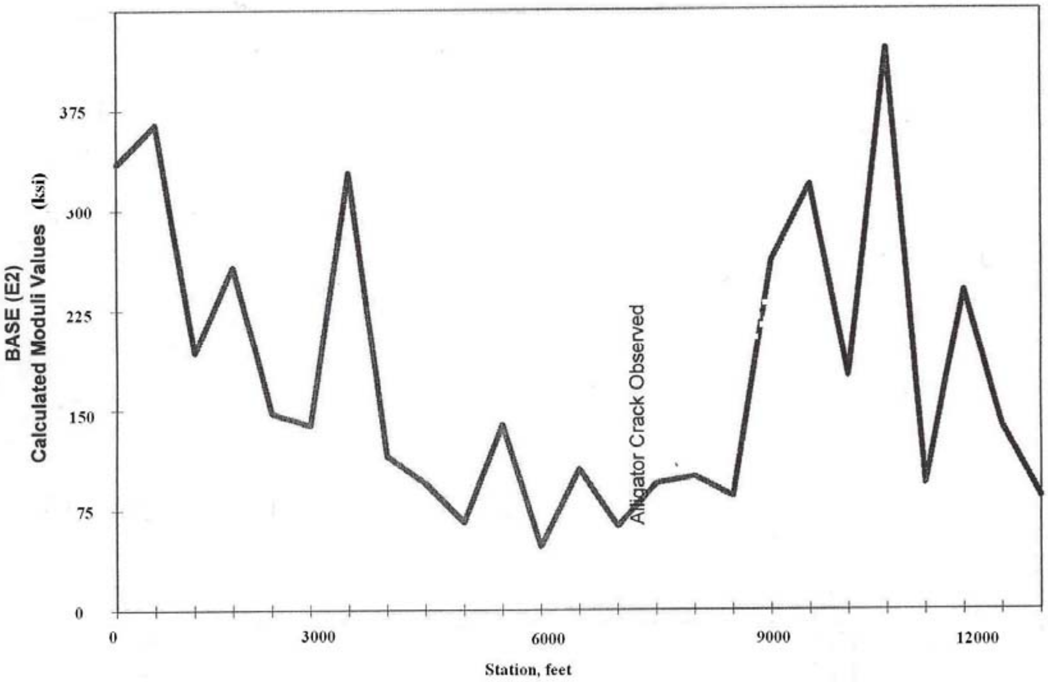


Figure 35. FWD Data Analysis on Loop 390.

Figure 36. Core of Stabilized Base on Loop 390.

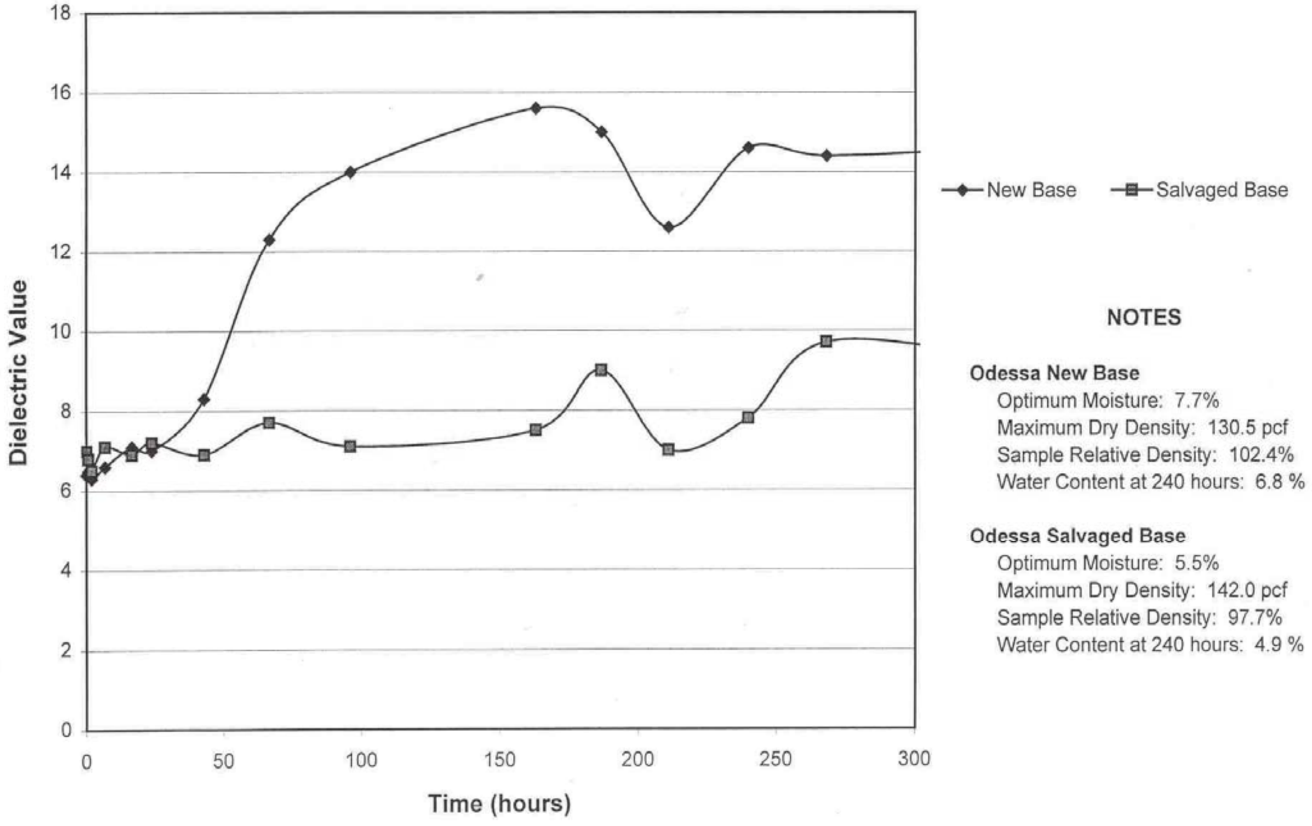
Case History 8 – Damaged or Missing Underseal with Moisture-Susceptible Base

A section of IH 20 near Pecos exhibited premature distress consisting primarily of alligator cracking as shown in Figure 37. This pavement was newly constructed with a flexible base, surface treatment and HMAC surface course.

Figure 37. Cracking Distress on IH 20 Near Pecos.

TTI conducted an investigation into the cause of failure (Personal communication from Tom Scullion, TTI Research Engineer, to Steve Smith, Odessa District Construction Engineer, 1999). GPR data were collected as well as samples of the base and HMAC.

Figure 38 shows the results of the Tube Suction Test (as described in Appendix C). In this test, samples are compacted to optimum moisture content and allowed to dry back at 40°C for four days and then placed in a shallow water bath. The moisture content at the top of the sample is measured with a special dielectric probe. The dielectric is an indication of both the amount of water and also the state of bonding of the moisture within the sample.



NOTES

Odessa New Base
Optimum Moisture: 7.7%
Maximum Dry Density: 130.5 pcf
Sample Relative Density: 102.4%
Water Content at 240 hours: 6.8 %

Odessa Salvaged Base
Optimum Moisture: 5.5%
Maximum Dry Density: 142.0 pcf
Sample Relative Density: 97.7%
Water Content at 240 hours: 4.9 %

Figure 38. Laboratory Tube Suction Test Results on Odessa Bases. (Personal communication from Tom Scullion, TTI Research Engineer to Steve Smith, Odessa District Construction Engineer, 1999)

For Class 1 materials the dielectric should not rise above 10 after a ten-day soak. For very moisture-susceptible materials the dielectric value will be more than 16. The new base material is much more moisture susceptible than the old salvaged base. Because of the high suction value in the new base material, it is possible to predict that *if* moisture is available, it will be attracted to this layer.

Cores were taken in the center of the mat, near the joint and over the joint to assess the density. The air void contents were found to be as follows:

In Lane	10.0%
Near Joint	13.2%
Over Joint	16.6%.

The permeabilities on the cores were also very high. This was demonstrated in the laboratory where it was possible to visually observe water flowing directly through the cores. A small amount of moisture was placed on the surface. This immediately soaked into the sample and within a few seconds appeared at the bottom of the core. Permeability was similar for all the cores and the overall average was 1.5 x 10^{-3} cm/sec.

Scullion concluded that since all of the problems occurred shortly after a significant rainfall or snow melt indicates that a moisture susceptible base and a leaking HMAC/surface seal were to blame. The seal was possibly damaged where vehicles ran directly over it prior to overlaying. “It is my idea that it is those places where the seal is damaged that the failures are occurring.” He recommended that a seal coat be placed over the entire structure as soon as possible to preserve what was still in good condition and to then follow up with the base repair work.

Case History 9 – Effect of Underseals on Hot Mix in Northeast Texas

A task group was formed in late 1997 to evaluate the performance of crushed gravel asphaltic surfacings in northeast Texas. In 1998, this task group selected and evaluated the performance of 35 pavements constructed using a wide variety of materials. Pavement performance evaluations included a visual distress survey, ground-penetrating radar analysis, pavement management information system data, testing and visual evaluation of pavement cores. When the 1998 evaluation was performed, many of the pavements were of a relatively young age. Therefore, the task force recommended evaluation of the performance after an additional three years.

In the spring of 2001, a follow-up study was conducted on the initial 35 pavements previously evaluated in 1998. The findings of this evaluation concluded that the utilization of hydrated lime as an anti-stripping additive appears to have a positive influence on performance of the mixtures containing crushed siliceous river gravel (Tahmoressi and Scullion, 2002). Types of screenings used (siliceous or limestone) did not appear to influence performance and the use of liquid anti-stripping additives was found to improve the performance of limestone mixtures.

Of the 35 pavements which were evaluated, 6 pavements in the Atlanta District included the use of an underseal. The benefit of placing seal coats beneath an overlay was of substantial interest to the Atlanta district engineers. The rationale was that the seal would protect the lower HMA layer from moisture entering from the surface. Any surface moisture would be held in the upper asphalt layer and hopefully evaporate quickly.

GPR has the capability of defining the presence of moisture on top of the seal or moisture under the seal. Using GPR, Table 8 illustrates the predominant interface condition from sections which had an underseal beneath the overlay, which also have a lower HMA layer, and which were tested one day after a heavy rainfall.

Table 8. Interface Condition on Atlanta Pavement Sections (TxDOT 1998).

Section ID Number – Highway	Interface Condition
4 – IH 30	Moisture on Top of Seal
5 – FM 881	Moisture Under Seal
12 – SH 155	Moisture Under Seal
14 – SH 43	Moisture Under Seal
15 – US 271	Moisture on Top of Seal
18 – US 59	Moisture on Top of Seal

The district selected the pavement layer of interest for further evaluation (in terms of moisture susceptibility). This was the top HMAC layer in sections 4, 5, 12, 14, and 15. In Section 18, the layer of interest was the second layer (beneath the underseal). Project locations, types of aggregates used in the hot mix, and pavement age at the time of evaluation is shown in Table 9.

Table 9. Pavement Sections with Underseals.

District – Project ID (Layer of Interest)	**Highway**	**Aggregate Mineralogy**		**Antistripping Agent Type**	**Age, years**
		Coarse	Screenings		
Atlanta – 4	IH 30	Siliceous Gravel	Siliceous Gravel	Lime	6
Atlanta – 5	FM 881	Limestone	Limestone	Liquid	5
Atlanta – 12	SH 155	Siliceous Gravel	Limestone	Lime	4
Atlanta – 14	SH 43	Siliceous Gravel	Siliceous Gravel	Lime	4
Atlanta – 15	US 271	Sandstone	Sandstone	Liquid	4
Atlanta – 18 (2)	US 59	Siliceous Gravel & RAP	Siliceous Gravel	Liquid	5

Table 10 shows the visual condition survey results for each pavement. All of the pavements were in excellent condition, except project 18 which had a field performance rating of 70 due to a slight amount of rutting.

Table 10. Visual Condition Survey Results

District – Project ID (Layer of Interest)	Visual Condition Survey Results	Field Performance Rating
Atlanta – 4	No distress, excellent condition	100
Atlanta – 5	No distress, excellent condition	100
Atlanta – 12	Slight reflective cracking, no rutting with many logging trucks	95
Atlanta – 14	Longitudinal cracks, no rutting	95
Atlanta – 15	No distress, excellent condition	100
Atlanta – 18 (2)	Microsurfaced due to rutting, has slight rutting	70

Indirect tensile strength tests were conducted before and after moisture conditioning according to Texas Test Method Tex-226-F on cores. The tensile strength ratio shown in Table 11 represents the ratio of the wet strength to that of the dry strength.

Table 11. Comparison of Tensile Strength Ratio (TSR) and Core Air Voids.

Project	Layer	1998 Cores		2001 Cores			
		Air Voids, %	TSR, %	Air Voids, %	Indirect Tensile Strength, 77°F, psi		TSR, %
					Dry	Wet	
Atlanta – 4	1	4.2	99	4.4	111	95	86
Atlanta – 5	1	6.5	80	7.3	190	170	89
Atlanta – 12	1	4.9	106	3.0	194	244	126
Atlanta – 14	1	10.5	58	7.9	238	178	75
Atlanta – 15	1	1.7	88	0.6	154	139	90
Atlanta – 18	2	4.3	119	4.2	174	143	83

The Hamburg Wheel Tracking test was performed on pavement cores in accordance with Test Method Tex-242-F. In this test, the specimen is subjected to repeated wheel tracking for 20,000 cycles or until the sample experiences 12.5 mm of rutting. The Hamburg Wheel Track test was conducted at 122°F. These results are shown in Table 12.

Table 12. Hamburg Results.

Project	Layer	Hamburg Test Results, Rut Depth at 20,000 cycles, mm	Hamburg Visual Rating
Atlanta – 4	1	0.6	4.3
Atlanta – 5	1	8.9	3.3
Atlanta – 12	1	2.5	3.9
Atlanta – 14	1	1.3	3.5
Atlanta – 15	1	3.0	4.2
Atlanta – 18	2	11.2	3.5

Visual ratings:
5 – no evidence of stripping observed.
1 – completely stripped.

The laboratory tests performed on the pavement cores from the Atlanta test sections indicate that some of the mixes are more moisture susceptible than others though none would fail the current criteria. In terms of TSR, Section 14 is the most moisture susceptible, yet had excellent pavement performance after 4 years in service.

In Section 18, the layer beneath the underseal was tested and was the most moisture susceptible in terms of Hamburg results. This pavement exhibited a slight amount of rutting.

All six test sections were tested with GPR one day after a rain. Three of the sections showed moisture beneath the underseal and three showed moisture on top of the underseal.

Summary

- Excessive binder application rates for underseals can cause the binder to bleed through to the surface of the HMAC overlay. This is true for both very high viscosity asphalt binders, such as asphalt rubber, as well as low viscosity binders. There is some evidence to suggest that low viscosity binders (even when applied at appropriate application rates) have a propensity for bleeding.
- Poor construction and quality control practices on the underseal can reflect through to the performance of the HMAC overlay.
- Underseals can be very effective in protecting base materials from the intrusion of surface water. This is evidenced from failures which occurred in areas where the underseal was damaged prior to overlay. This has been a problem in regions of the state with low rainfall as well as high rainfall rates. The need for an underseal may be more a function of the moisture susceptibility of the base material than the region in which it is used.
- Base materials should be adequately cured prior to prime and surface treatment. This helps to ensure a good bond of the surface treatment and prevent highway traffic or construction traffic from damaging the surface treatment prior to overlay. Any damaged areas should be repaired. Even small and isolated areas associated with a damaged underseal have lead to failure of the underlying base and HMAC overlay.
- While concern has been speculated over underseals trapping moisture in underlying layers which eventually leads to pavement failures, researchers could find no evidence to document this. On the other hand, there is evidence to show that any moisture susceptible ACP layer which is overlayed (even without an underseal) has the potential to strip.
- Concern has also been expressed that when a seal is placed under an HMAC overlay, water penetrates the HMAC and collects on top of the underseal where it remains until evaporation. There is a fear that the action of traffic in these conditions will accelerate damage to the mix. In pavements where GPR data were collected one day after a heavy rain and showed this situation to exist, these pavement have performed very well.
- Because of the permeability associated with most of asphalt concrete pavements or their longitudinal construction joints, rainfall will penetrate through most overlays. Without an underseal, this water will proceed to the underlying layers.
- GPR data collected one day after a heavy rainfall showed that moisture seems to be penetrating the underseal on some pavements. This could be due to cracking in the underlying layer, damage which occurred to the underseal prior to overlay, or that in some cases the underseal may be completely impermeable.

Chapter 5 Criteria for Determining When and Where to Place Underseal

General

Based on the information presented in the previous chapters, criteria were developed for determining when and where to place an underseal. These criteria are presented as follows. Guidelines were also developed and are presented in Appendix B.

Determining When to Apply an Underseal to an Existing Pavement Surface

1. Evaluate Existing Pavement Surface

A. Identify predominant distresses.

Predominant Distress Type	***Should an Underseal be Used?***	
	Yes	No
Cracking	✔	
Rutting	*	*
Raveling	✔	
Bleeding		✔

* Cause of rutting should be determined. If it is due to stripping, layer should be removed.

B. Determine if pavement is potentially moisture susceptible.

If a pavement layer is moisture susceptible, it should not be undersealed. Application of an impermeable seal can trap moisture and accelerate stripping and, thus, pavement failure. If it is suspected that a pavement layer is moisture susceptible, it should be cored and tested to identify moisture susceptibility as described in the guidelines (Appendix B). A moisture-susceptible layer should be removed prior to further pavement maintenance or rehabilitation.

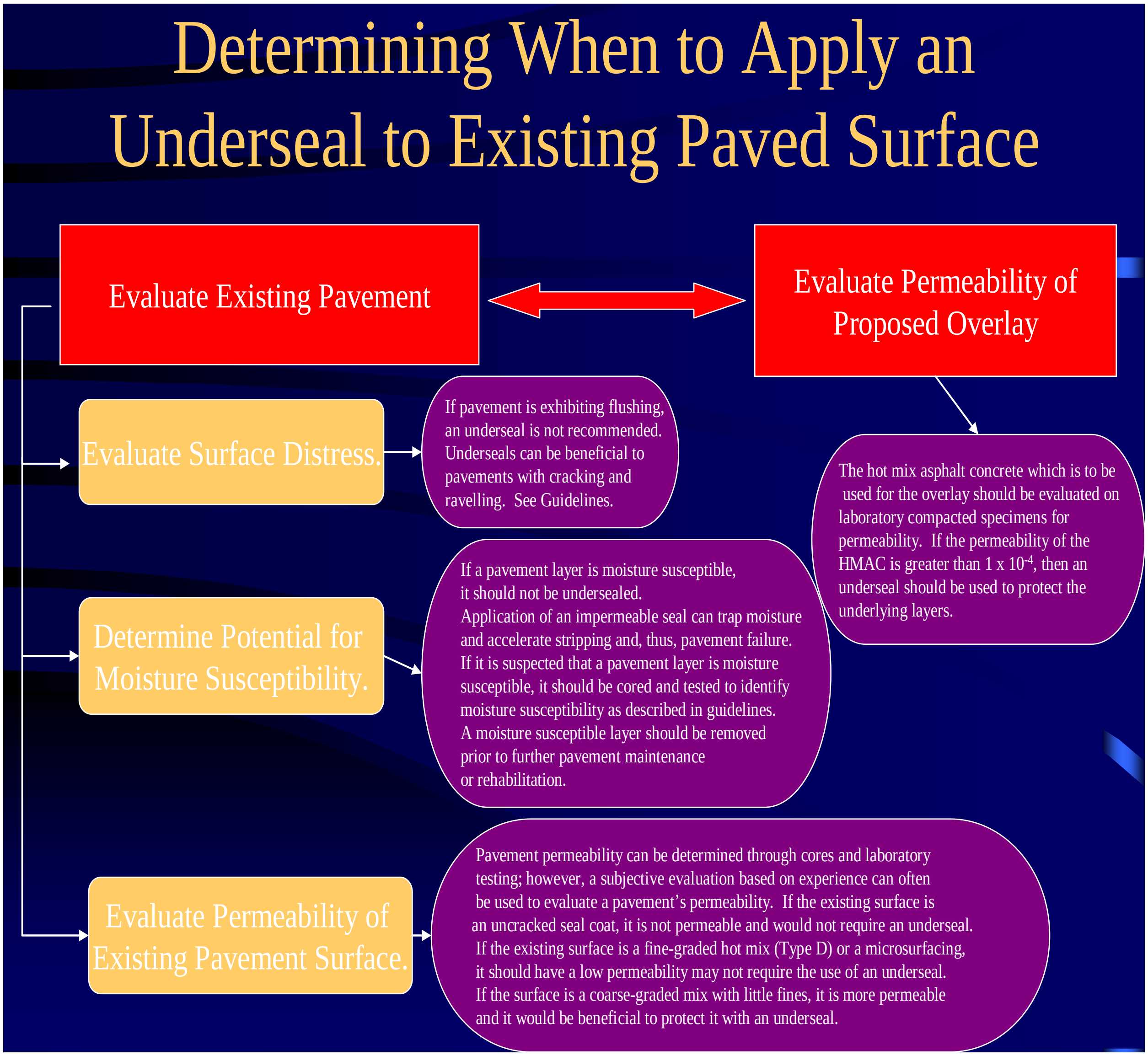
C. Evaluate permeability of existing pavement surface.

Pavement permeability can be determined through cores and laboratory testing; however, a subjective evaluation based on experience can often be used to evaluate a pavement's permeability. If the existing surface is an uncracked seal coat, it is not permeable and would not require an underseal. If the existing surface is a fine-graded hot mix (Type D) or a microsurfacing, it should have low permeability and may not require the use of an underseal. If the surface is a coarse-graded mix with little fines, it is more permeable and it would be beneficial to protect it with an underseal.

2. Evaluate Permeability of Proposed HMAC Overlay

   The hot mix asphalt concrete which is to be used for the overlay should be evaluated on laboratory-compacted specimens for permeability. If the permeability of the HMAC is greater than 1 x 10^{-4} cm/sec, then an underseal should be used to protect the underlying layers.

The following is a presentation of the same information in a schematic representation of a decision tree.



Determining When to Apply an Underseal to Existing Paved Surface

Evaluate Existing Pavement

Evaluate Permeability of Proposed Overlay

Evaluate Surface Distress.

If pavement is exhibiting flushing, an underseal is not recommended. Underseals can be beneficial to pavements with cracking and ravelling. See Guidelines.

The hot mix asphalt concrete which is to be used for the overlay should be evaluated on laboratory compacted specimens for permeability. If the permeability of the HMAC is greater than 1 x 10^{-4}, then an underseal should be used to protect the underlying layers.

Determine Potential for Moisture Susceptibility.

If a pavement layer is moisture susceptible, it should not be undersealed.
Application of an impermeable seal can trap moisture and accelerate stripping and, thus, pavement failure.
If it is suspected that a pavement layer is moisture susceptible, it should be cored and tested to identify moisture susceptibility as described in guidelines.
A moisture susceptible layer should be removed prior to further pavement maintenance or rehabilitation.

Evaluate Permeability of Existing Pavement Surface.

Pavement permeability can be determined through cores and laboratory testing; however, a subjective evaluation based on experience can often be used to evaluate a pavement's permeability. If the existing surface is an uncracked seal coat, it is not permeable and would not require an underseal. If the existing surface is a fine-graded hot mix (Type D) or a microsurfacing, it should have a low permeability may not require the use of an underseal. If the surface is a coarse-graded mix with little fines, it is more permeable and it would be beneficial to protect it with an underseal.

Determining When to Apply an Underseal to a Compacted Base Layer

1. Evaluate Moisture Susceptibility of Base

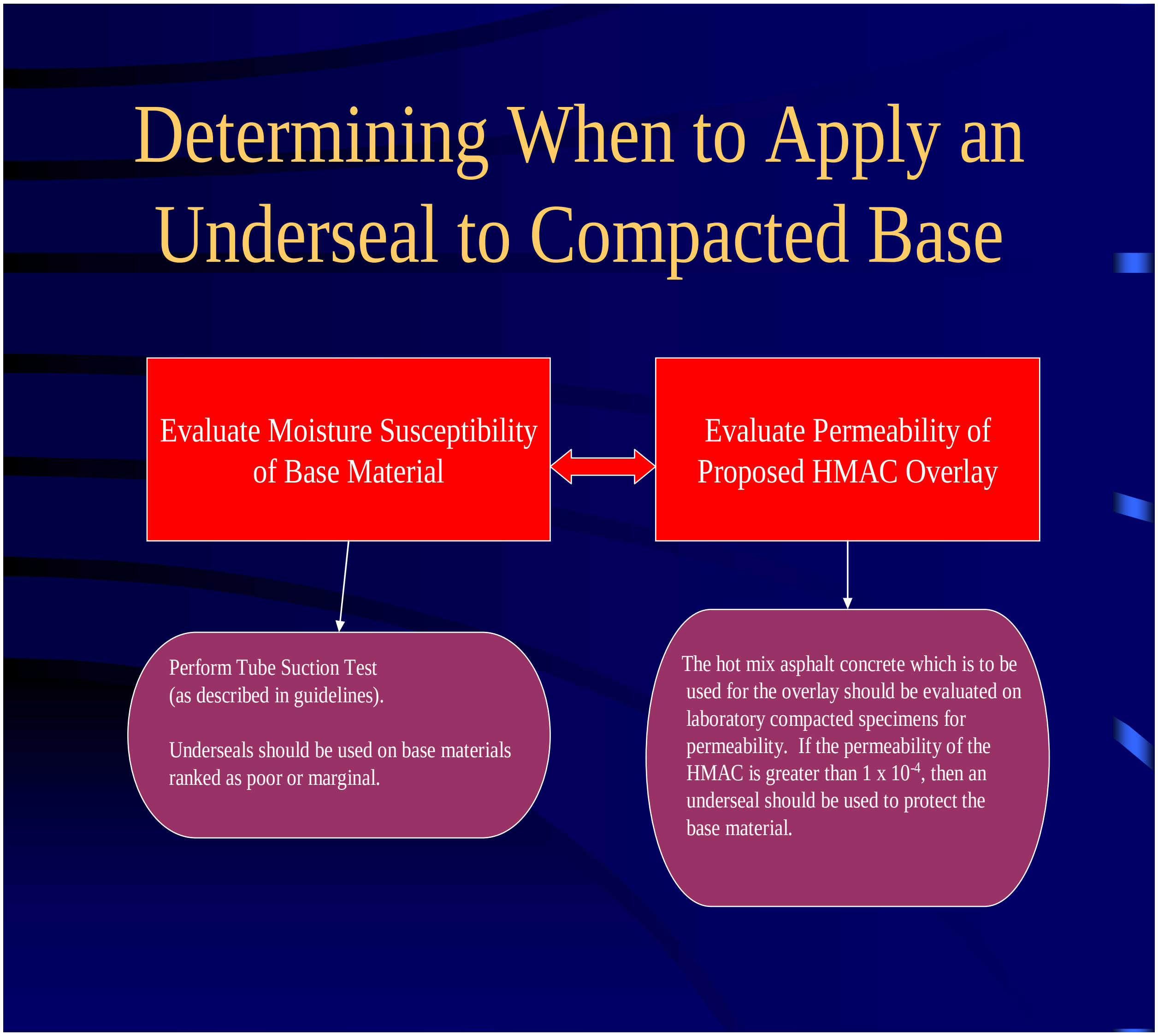
   Perform Tube Suction Test (as described in the guidelines [Appendix B]).

   Underseals should be used on base materials ranked as poor or marginal (exhibiting dielectric values of 10 or more).

2. Evaluate Permeability of Proposed HMAC Overlay

   The hot mix asphalt concrete which is to be used for the overlay should be evaluated on laboratory compacted specimens for permeability. If the permeability of the HMAC is greater than 1×10^{-4} cm/sec, then an underseal should be used to protect the base material.

The following is a presentation of the same information in a schematic representation of a decision tree.



Determining When to Apply an Underseal to Compacted Base

Evaluate Moisture Susceptibility of Base Material

Evaluate Permeability of Proposed HMAC Overlay

Perform Tube Suction Test
(as described in guidelines).

Underseals should be used on base materials ranked as poor or marginal.

The hot mix asphalt concrete which is to be used for the overlay should be evaluated on laboratory compacted specimens for permeability. If the permeability of the HMAC is greater than 1 x 10^{-4}, then an underseal should be used to protect the base material.

Chapter 6 Evaluation of Methodology

General

The following is a description of field and laboratory investigations which were conducted to support the criteria developed in Chapter 5.

Laboratory Evaluation of Underseal Permeability

It was identified previously that the function of an underseal is to provide an impervious membrane to prevent the intrusion of surface water into underlying layers. The question was raised in the study, “do some seals allow moisture to penetrate?” GPR data from the Atlanta district showed that moisture appeared to be penetrating the underseal after a rainfall. Also, there was a question as to whether the porous nature of lightweight aggregates allowed moisture to pass through to the underlying layers.

Two aggregate gradations are commonly used for the construction of seal coat underseals: Grade 3 and Grade 4. TxDOT Standard Specification Item 302, Aggregates for Surface Treatments, describes the size and gradation requirements for these aggregates. Because a Grade 3 aggregate is larger than a Grade 4, it is designed with higher binder application rates. This may provide for better sealing qualities.

The experiment shown in Table 13 was designed to evaluate the permeabilities associated with different types of seal coats used as underseals. Type C hot mix asphalt concrete was sampled from a local plant, and samples were fabricated in the laboratory. Seal coats were placed on top of the fabricated laboratory specimens according to the materials and aggregate combinations and rates shown in Table 13. Specimens were then subjected to laboratory permeability tests. All of the Grade 4 seal coat specimens were fabricated and tested first. All specimens were determined to have a permeability of virtually zero. Tests were not conducted on the Grade 3 specimens since the binder application rates were even higher for Grade 3.

These results indicate that underseals have the potential to behave as an impervious membrane. However, these laboratory tests do not take into account damage which may occur due to the action of traffic.

Table 13. Experiment Design to Determine Permeability of Typical Binder/Aggregate Combinations.

AGGREGATE GRADATION	APPL. RATE, GSY	AGGR. TYPE	BINDER TYPE			
			AC-20-5TR	AC-10	AC-5 with Latex	CRS-2P
Grade 3	0.40	Limestone	X	X	X	X
		Gravel	X	X	X	X
		Lightwt.	X	X	X	X
Grade 4	0.30	Limestone	X	X	X	X
		Gravel	X	X	X	X
		Lightwt.	X	X	X	X

IH 37 Atascosa County

About 7 miles of IH 37 in Atascosa County was reconstructed in February of 2002 and consists of 2 inches of Type C HMAC, 4 inches of Type B HMAC base, an underseal, 12 inches of Type A Grade 1 flex base containing 30 percent RAP reclaimed from the surface of the old structure, and 16 inches of cement treated subbase. Pictures taken in the summer after construction show moisture seepage which would typically occur for extended periods of time following rainfall (Figure 39).

The area office dug lateral “French drains” at the pavement outside shoulder to allow the free water to escape. In areas where an extended detour shoulder remained, the trenches were dug through this 4 ft temporary structure to the edge of the rehabilitated structure. Following rain events, water would be expelled through the drains from days to weeks afterward. In June of 2003, the District began sealing the surface of the outside south-bound lane and spot sealing portions of the outside north-bound lane where the development of fatigue cracking and potholes had surfaced. The potholes can be described as popouts where the Type C mix had debonded from the underlying Type B mix, fatigued, and then was removed from the structure through the action of traffic.

TxDOT’s Construction Division (Personal communication from Jeff Seiders, TxDOT Construction Division, to David Kopp, San Antonio District Construction Engineer, 2004) performed GPR in the summer of 2003 which showed that there was a significant increase in the dielectric properties at the interface of the Type C and Type B layers. There was no indication of increased moisture levels within the base materials or at the subgrade that might be indicative of underground springs.

Figure 39. Moisture Seepage from IH 37 in Atascosa County.

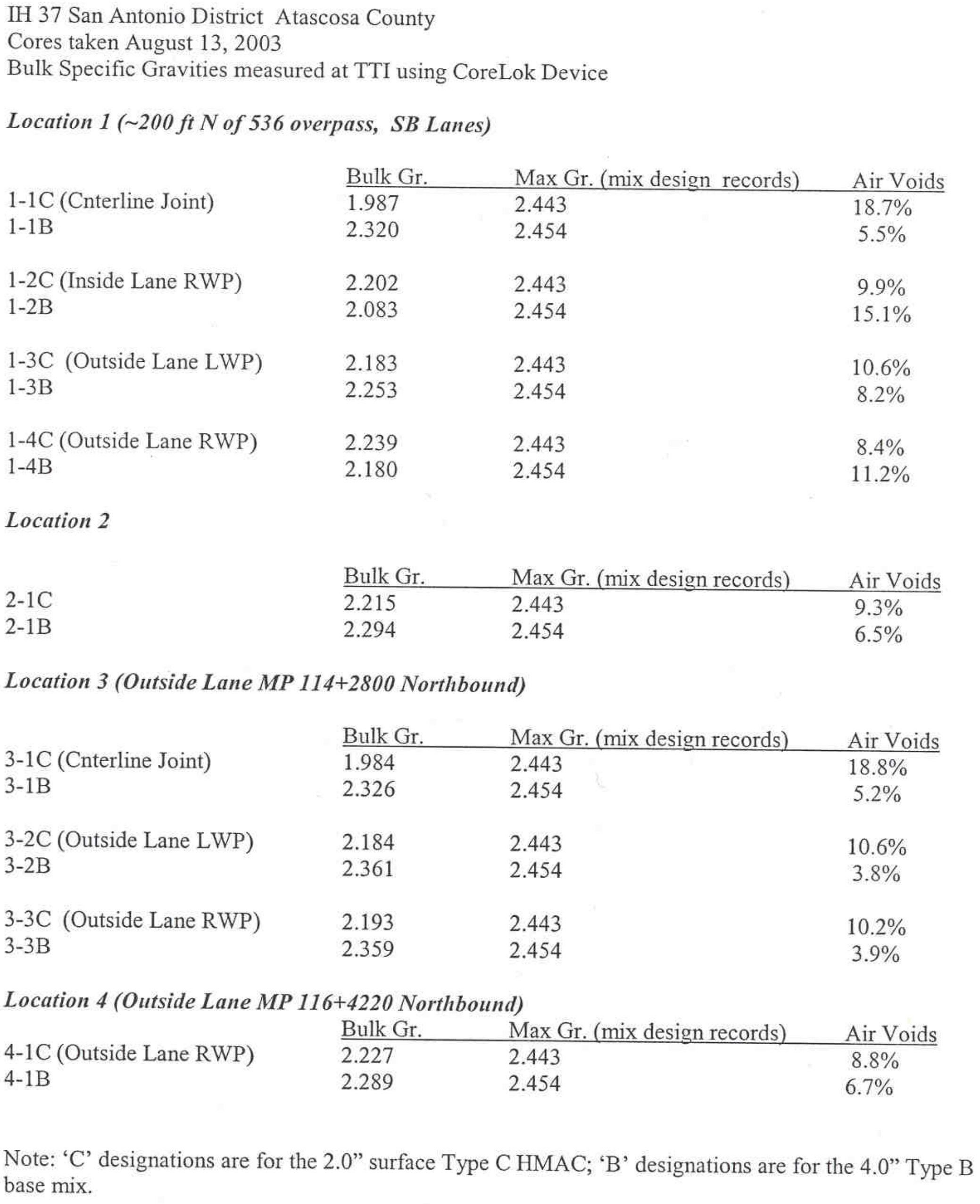
Cores were taken from areas that had moisture-related problems during construction (two locations in the southbound (SB) lanes and two from the northbound (NB) lanes. Location 3 from the NB lanes had moisture problems during construction that required base repairs to the location while under construction. During the coring operations, researchers and TxDOT staff examined the core hole carefully and identified that water was draining from the Type B layer. The underlying layers did not appear overly moist.

Density of the cores are shown in Table 14 . Monitoring wells were also installed by the District but did not show any accumulation of water (bottom of well at 5.0 ft below the surface).

Hamburg Wheel Tracking tests were performed on cores from two of the locations: Location 1 (SB lane) and Location 3 (NB lane). The wheel tracking tests were performed on cores taken from the wheelpaths of both the Type C and the Type B layers. These results are shown in Table 15.

All indications are that moisture is entering the structure from the surface, most likely through the longitudinal joints in the Type C layer. Air void ratios are as high as 18 percent in the Type C mix and as high as 15 percent in the Type B mix.

Table 14. Core Densities from IH 37 in Atascosa County.



IH 37 San Antonio District Atascosa County
Cores taken August 13, 2003
Bulk Specific Gravities measured at TTI using CoreLok Device

Location 1 (~200 ft N of 536 overpass, SB Lanes)

	Bulk Gr.	Max Gr. (mix design records)	Air Voids
1-1C (Cnterline Joint)	1.987	2.443	18.7%
1-1B	2.320	2.454	5.5%
1-2C (Inside Lane RWP)	2.202	2.443	9.9%
1-2B	2.083	2.454	15.1%
1-3C (Outside Lane LWP)	2.183	2.443	10.6%
1-3B	2.253	2.454	8.2%
1-4C (Outside Lane RWP)	2.239	2.443	8.4%
1-4B	2.180	2.454	11.2%

Location 2

	Bulk Gr.	Max Gr. (mix design records)	Air Voids
2-1C	2.215	2.443	9.3%
2-1B	2.294	2.454	6.5%

Location 3 (Outside Lane MP 114+2800 Northbound)

	Bulk Gr.	Max Gr. (mix design records)	Air Voids
3-1C (Cnterline Joint)	1.984	2.443	18.8%
3-1B	2.326	2.454	5.2%
3-2C (Outside Lane LWP)	2.184	2.443	10.6%
3-2B	2.361	2.454	3.8%
3-3C (Outside Lane RWP)	2.193	2.443	10.2%
3-3B	2.359	2.454	3.9%

Location 4 (Outside Lane MP 116+4220 Northbound)

	Bulk Gr.	Max Gr. (mix design records)	Air Voids
4-1C (Outside Lane RWP)	2.227	2.443	8.8%
4-1B	2.289	2.454	6.7%

Note: 'C' designations are for the 2.0" surface Type C HMAC; 'B' designations are for the 4.0" Type B base mix.

Table 15. Hamburg Wheel Tracking Test Results on Cores from IH 37.

Coring Location	**Pavement Layer**	**Estimated Hamburg Rut Depth at 20,000 Cycles**
Location 1 (Southbound Outside Lane)	1st (Type C Mix)	8.0
	2nd (Type B Mix)	7.6
Location 3 (Northbound Outside Lane)	1st (Type C Mix)	9.8
	2nd (Type B Mix)	4.8

TxDOT's Construction Division recommended the following:

"The best remedial action would be to allow a path for moisture trapped in the HMAC to exit the structure, then seal the pavement surface using an ultra thin-bonded wearing course (such as Novachip or equivalent). Resealing should be scheduled for summer months wher prolonged dry spells are more likely as this will also aid in ensuring trapped moisture is released first. In areas where delamination has already started, the Type C mix should be milled off and a levelup course put in its place…..

To address the problem of moisture trapped in the HMAC layers, installation of continuous edge drains is one option but may not be cost effective for the situation, especially if the drainage is largely acting as a temporary measure to eliminate trapped water prior to sealing. Also, there is no guarantee that moisture can travel laterally uninterrupted everywhere within the HMAC because densities tend to improve away form the joints. Too, it appears that 2002-2003 was wetter than usual and climate may return to "normal" allowing for less frequent infiltration and better transpiration. Edge drains are typically constructed using 4-6 in. diameter perforated pipe with laterals at 300-ft maximum intervals. To protect the PVC pipe, a substantial cover would be necessary, requiring trenching to a depth of approximately 2 ft. Alternatively, a localized provision for allowing lateral moisture drainage should be considered. A process similar to that used by the area office consisting of French drains dug through the temporary detour shoulders <u>and</u> other locations where the back-filled pavement edge slopes may actually be hindering expeditious drainage could be used. Caution against over-excavation and improper channel bottom inclination at these drain locations is urged to ensure that the drains do not act as conduits to introduce runoff water back into the pavement system. Hence, the depth of the drains should not exceed 10 in. below the pavement. As a trial, two or three locations of 100 to 200 ft in length should be selected, at least one of which should be located along a section where seepage is currently visible. Along this 100-200 ft section, the existing shoulder ACP and other material would be removed to a depth of 8-10 in. and replaced by an open-graded mix tapered and "day-lighted...."

In summary, researchers conclude that had an underseal been placed at the bottom of the Type C layer, moisture would not have collected in the Type B base mix and these problems could have been averted.

US 84 Lamb County

A relatively new pavement on US 84 in Lamb County began to exhibit cracking distress as shown in Figure 40 and 41. The pavement cross section consisted of a Type C HMAC, underseal, and an aggregate base with 3 percent fly ash.

Cores taken in the middle of the mat and at the joint are shown in Figure 42. Laboratory tests indicated a high permeability at the longitudinal construction joint.

Tube suction tests were performed on the fly ash-stabilized base and compared with samples taken from an older section of the roadway which had performed satisfactorily. These results are shown in Figure 43. Bases with dielectric values above 16 (after a ten day soak) are expected to provide poor performance. The base material in question reached this value in about 2 days.

District personnel indicated that the base material may not have cured sufficiently and that the underseal was damaged by traffic prior to overlay.

Figure 40. Damage on US 84 in West Texas.

Figure 41. Close-Up of Damage on US 84.

Figure 42. Cores of US 84.

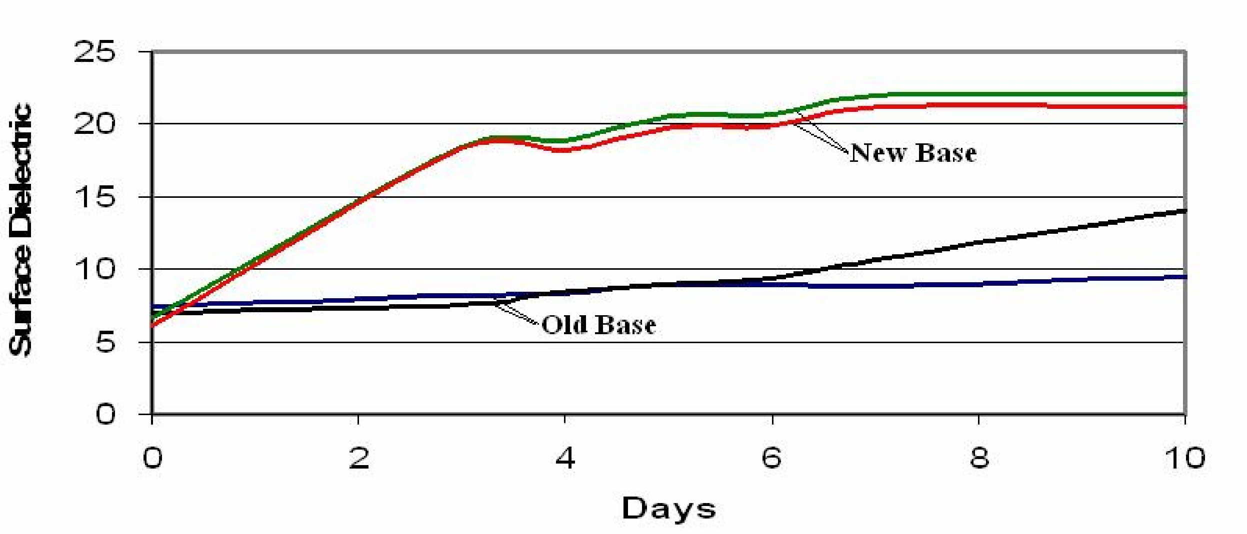


Figure 43. Tube Suction Test Results for Base Materials (US 84).

Field Test Sections

Three test sections were selected as candidates for future monitoring if so desired by TxDOT. The test sections selected are considered to have materials which are vulnerable to moisture or are in a location (i.e. along the coastline) where moisture is likely to be a threat to pavement performance. These are described below.

FM 2821

This test road is located in Walker County with the test section in the westbound lane of FM 2821 beginning at 1190 ft from RM 670 and continuing west for a distance of 656 feet. The construction project included restoration of the existing roadway consisting of cement treatment of existing river gravel base including four inches of existing subgrade, followed by a one-course surface treatment and 2.75 inches of HMAC. Researchers obtained samples of the base material and performed tube suction tests. These test results are shown below in Figure 44. Based on the the results shown in Figure 44, this base material had a value greater than 16 after 10 days of soak and would be considered to have poor moisture susceptibility.

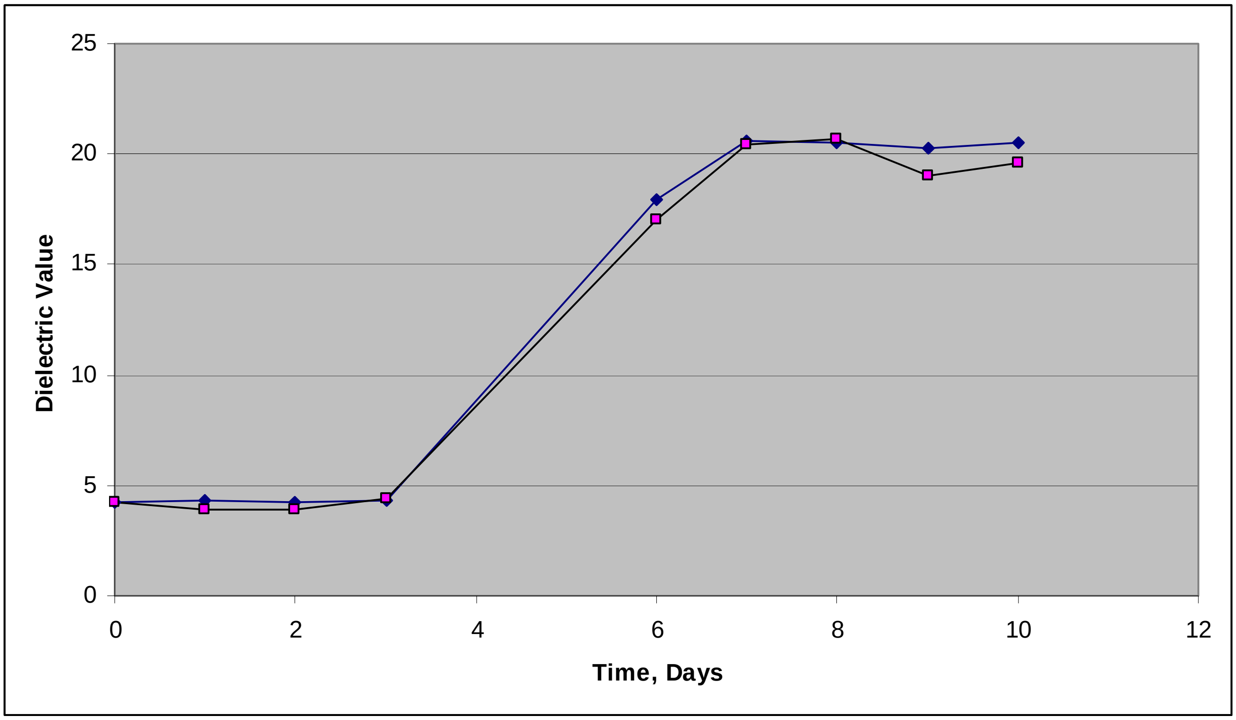


Figure 44. Tube Suction Test Results for Base Material on FM 2821.

SH 40

This test road is located in Brazos County with the test section in the northbound lane of SH 40 beginning 500 feet south of Barron Road and continuing north for a distance of 500 feet. The construction project was completely new construction and consisted of Item 247 Flex Base (crushed limestone), followed by a one course surface treatment and 3 inches of HMAC. Researchers obtained samples of the base material and performed tube suction tests. These test results are shown below in Figure 45. Based on the the results shown in Figure 45, this base material had a value greater than 16 after 10 days of soak and would be considered to have poor moisture susceptibility.

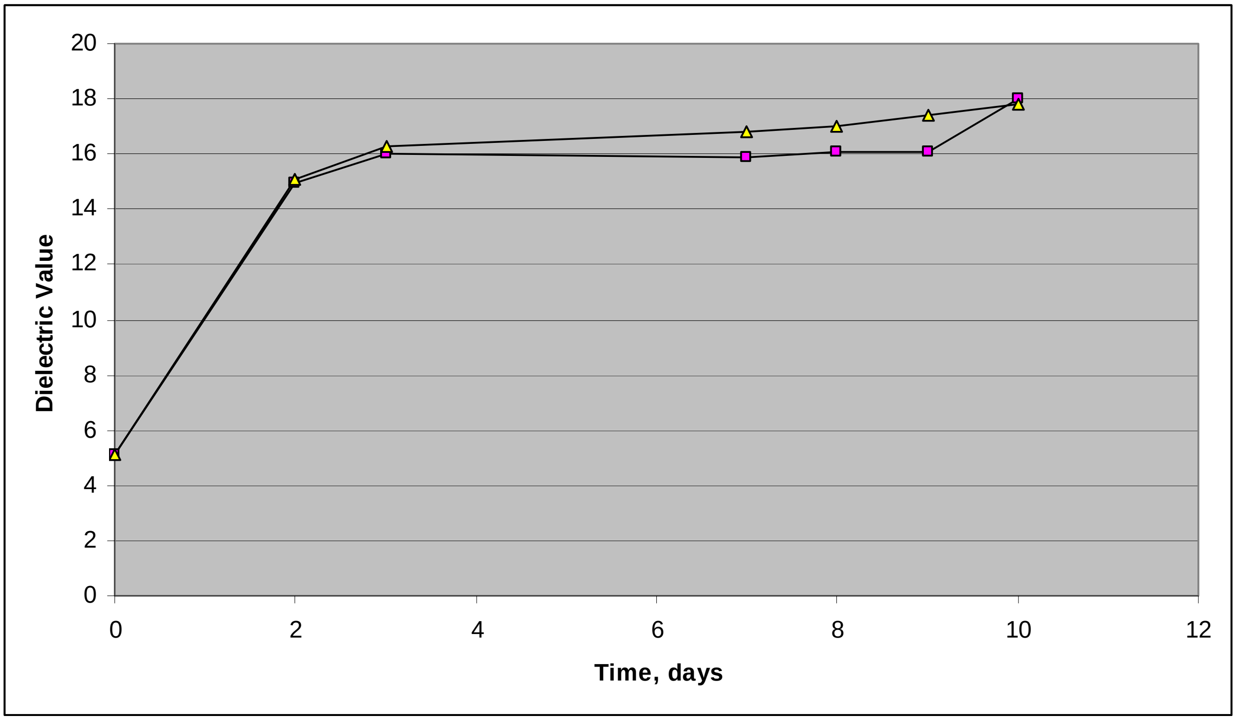


Figure 45. Tube Suction Test Results for Base Material on SH 40.

FM 3005

The Houston District's Galveston Area Office constructed an asphalt concrete pavement overlay with an underseal on an existing asphalt concrete pavement. The project is located on FM 3005 from the San Luis toll bridge to Salt Ceder Drive along Galveston Island as shown in Figure 46.

Figure 46. FM 3005 Test Section Location.

The Galveston Area Office agreed to omit the underseal from a portion of the project to evaluate the effects of the underseal at a future time. The test section location (with no underseal) is located in the west bound lane from Station 73+00 (4th crossover past Catalina Drive) to 1000 ft west as shown in Figure 47.

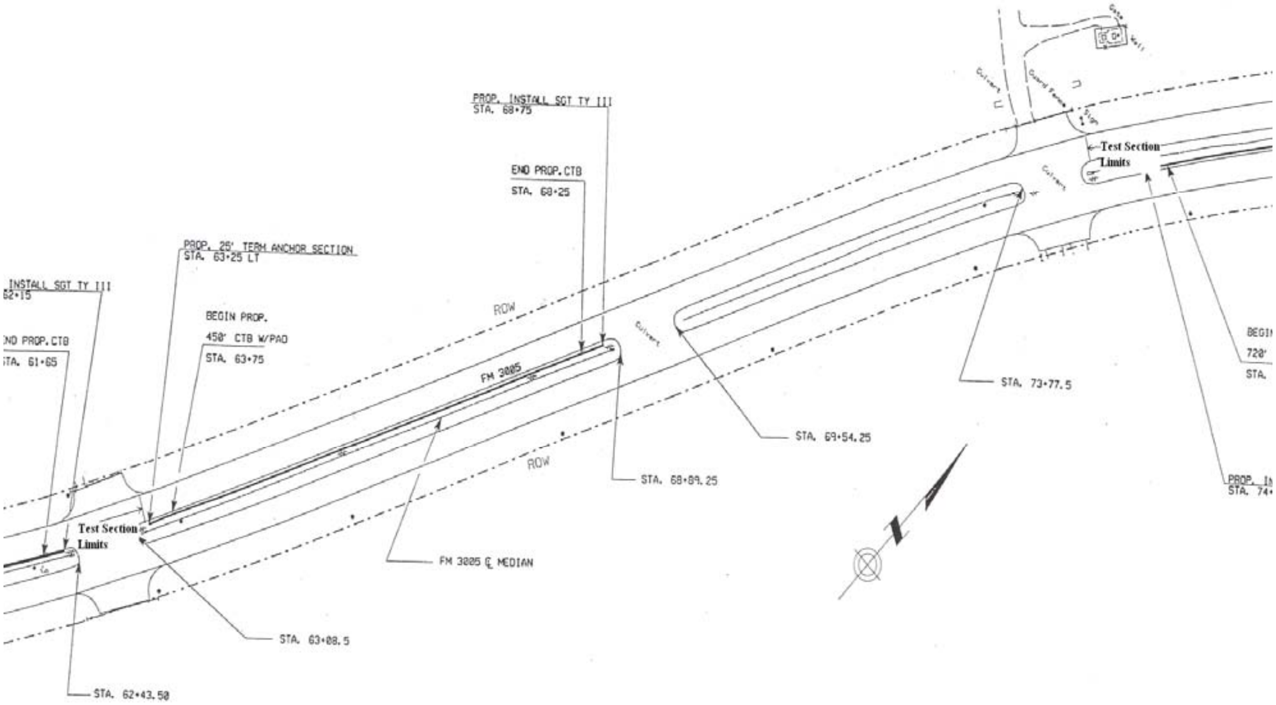


Figure 47. Test Section Location on FM 3005.

Chapter 7 Conclusions

The following conclusions were drawn from this research study:

- Records of experimental road tests have documented that during periods when pavements contain large amounts of free water the rates of deterioration range from 10 or 20 up to hundreds and thousands of times greater than during times when they contain little or no free water. The effects of excess water in a pavement structure can overshadow many other pavement design factors such as stress and strain, deformation, volume change, and fatigue.
- When base materials which contain more than 5 to 10 percent fines (which are most of the flex base materials in Texas) become saturated, these bases will not drain freely due to capillary forces. If base materials are not designed to drain freely, they should be protected from the intrusion of surface water.
- In most cases, water which enters a pavement's structure comes through the pavement surface. In those few cases where groundwater seepage is entering the pavement structure, drainage provisions should be made to intercept this type of water.
- The infiltration of water through the pavement surfaces depends on the global permeability, which is affected by the mixture type, density, and degree of cracking for AC pavements. For PCC pavements, the global permeability is affected by the condition of the cracks and/or joints. An FHWA study of numerous pavement sections found that 33 to 50 percent of the precipitation water falling on an AC pavement and 50 to 67 percent for PCC pavement could infiltrate through the pavement surface to the road base.
- One hundred percent of TxDOT districts surveyed consider the primary function of an underseal to be to serve as a moisture barrier to prevent the intrusion of surface water into underlying layers. Another function which is considered important is that it enhances the bond with the subsequent pavement layer. A few districts mentioned that they believed there was a secondary benefit associated with delayed reflection cracking and preventing the movement of subsurface moisture into the surface layer.
- Underseals are used on all types of surfaces: existing HMAC, PCC, and aggregate bases. The most common use is to apply an underseal to seal off cracks in an existing pavement (PCC or ACP) prior to overlay. However, several districts (about one-third of those surveyed) routinely use an underseal any time a hot mix overlay is placed.
- The most common type of binder used for seal coats applied as underseals is AC-20-5TR, and the most common aggregate grade is Grade 4. Some districts select binder based on specific criteria (such as weather and traffic). Both lightweight and natural aggregates are used for underseal construction.
- Testing and evaluation performed by some districts prior to underseal and overlay include coring (and visual evaluation of cores for signs of stripping), FWD, GPR, ride quality, check PMIS scores, and perform visual evaluation to determine if milling is required.
- Dense-graded types C and D mixes are the most common surfaces applied over underseals.

- The main problems or failures experienced with underseals include: (1) asphalt binder from the underseal bleeds through to the surface of the overlay; (2) underseals (on aggregate bases) sometimes get damaged by traffic or construction operations prior to overlay, allowing water to leak into the base; (3) underseal traps moisture in a moisture-susceptible layer causing it to fail.
- Excessive binder application rates for underseals can cause the binder to bleed through to the surface of the HMAC overlay. This is true for both very high viscosity asphalt binders, such as asphalt rubber, as well as low viscosity binders. There is some evidence to suggest that low viscosity binders (even when applied at appropriate application rates) have a propensity for bleeding.
- Poor construction and quality control practices on the underseal can reflect through to the performance of the HMAC overlay.
- Underseals can be very effective in protecting base materials from the intrusion of surface water. This is evidenced from failures which occurred in areas where the underseal was damaged prior to overlay. This has been a problem in regions of the state with low rainfall as well as high rainfall rates. The need for an underseal may be more a function of the moisture susceptibility of the base material than the region in which it is used.
- Base materials should be adequately cured prior to prime and surface treatment. This helps to ensure a good bond of the surface treatment and prevent highway traffic or construction traffic from damaging the surface treatment prior to overlay. Any damaged areas should be repaired. Even small and isolated areas associated with a damaged underseal have lead to failure of the underlying base and HMAC overlay.
- While concern has been speculated over underseals trapping moisture in underlying layers which eventually leads to pavement failures, researchers could find no evidence to document this. On the other hand, there is evidence to show that any moisture susceptible ACP layer which is overlayed (even without an underseal) has the potential to strip.
- Concern has also be expressed that when a seal is placed under an HMAC overlay, water penetrates the HMAC and collects on top of the underseal where it remains until evaporation. There is a fear that the action of traffic in these conditions will accelerate damage to the mix. In pavements where GPR data were collected one day after a heavy rain and which showed this situation to exist, these pavement have performed very well.
- Because of the permeability associated with most asphalt concrete pavements or their longitudinal construction joints, rainfall will penetrate through most overlays. Without an underseal, this water will proceed to the underlying layers.
- GPR data collected one day after a heavy rainfall showed that moisture seems to be penetrating the underseal on some pavements. This could be due to cracking in the underlying layer, damage which occurred to the underseal prior to overlay, or that in some cases the underseal may be completely impermeable.

References

Cedergren, H.R., 1977, *Seepage, Drainage, and Flow Nets*, Second Edition, John Wiley & Sons, Inc., NY.

Cedergren, H.R., 1987. *Drainage of Highway and Airfield Pavements.* Second Edition, Robert E. Krieger Publishing Company, Inc., Malabar, FL.

Cedergren, H.R., K.H. O'Brien, and J.A. Arman, 1973. *Guidelines for the Design of Subsurface Drainage Systems for Highway Structural Sections*, Final Report Number FHWA-RD-73-14, Federal Highway Administration, Washington, D.C.

Estakhri, C.K., O. Pendleton, and R.L. Lytton, 1993. *Evaluation of Asphalt-Rubber Interlayers,* Report Number 187-20, Texas Transportation Institute, Texas A&M University, College Station, TX.

Estakhri, C.K., T.J. Freeman, and C.H. Spiegelman, 2001. *Density Evaluation of the Longitudinal Construction Joint of Hot-Mix Asphalt Pavements,* Report Number 1757-1, Texas Transportation Institute, College Station, TX.

FHWA, 1972. *Guidelines for the Design of Subsurface Drainage Systems for Highway Structural Sections.* Federal Highway Administration, Washington, D.C.

Izzo, R.P., and J.W. Button, 1997. *Permeability of Coarse Matrix-High Binder Mixtures and Its Effects on Performance,* Report Number 1238-1F, Texas Transportation Institute, Texas A&M University, College Station, TX.

Marienfeld, M.L., and T.L. Baker, 1999. *Paving Fabric Interlayer as a Pavement Moisture Barrier*, Transportation Research Circular E-C006, Transportation Research Board, National Research Council, Washington D.C.

National Oceanic and Atmospheric Administration, National Weather Service, Precipitation Frequency Data Server. http://hdsc.nws.noaa.gov/hdsc/pfds/index.html.

Ridgeway, H.H., 1982. *Pavement Subsurface Drainage Systems,* National Cooperative Highway Research Program Synthesis of Highway Practice Number 96, Transportation Research Board, National Research Council, Washington, D.C.

Shuler, T.S., C.K. Adams, and M. Lamborn, 1985. *Asphalt-Rubber Binder Laboratory Performance,* Report Number 347-1F, Texas Transportation Institute, Texas A&M University, College Station, TX.

Tahmoressi, M. and T. Scullion, 2002. *A Follow-Up Evaluation of Hot-Mix Pavement Performance in Northeast Texas.* Report 4104-1, Texas Transportation Institute, Texas A&M University, College Station, TX.

Texas Department of Transportation, 1998. *An Evaluation of Factors Affecting Moisture Susceptibility of Pavements in Northeast Texas.* Volume 1, Texas Department of Transportation, Austin, TX.

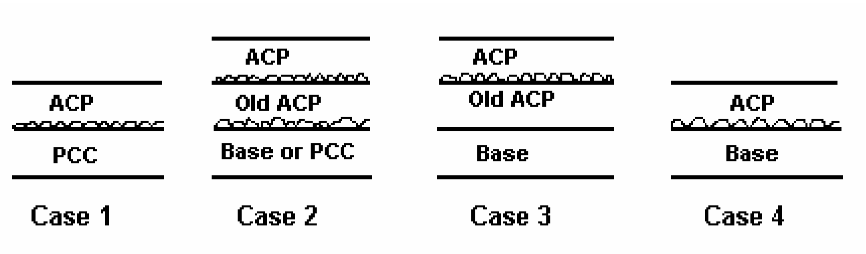
Appendix A
Survey Responses

Questionnaire

The placement of a seal prior to overlaying a pavement (commonly called an underseal) has been considered beneficial and necessary to provide an impervious membrane to stop the intrusion of surface or subsurface moisture. It is also specified to enhance bonding with subsequent layers. However, it is thought that premature cracking, rutting, stripping, and flushing or bleeding have occurred on pavements because this seal was installed. The objective of this research study is to develop the criteria needed to determine when and where to place an underseal.

We need your help in establishing the current practices, experiences, and problems within your district regarding underseals.

Definition of underseal for purposes of this research: a seal coat or microsurfacing placed on an asphalt layer, flexible base layer, or portland cement concrete (PCC) layer and topped with an asphalt surface layer. A graphical representation of four different types of underseal situations is shown below.



1. Which of the four types of underseal cases shown above are used in your district?
2. What do you see is the function of the underseal?
3. Describe the situation in which you would definitely use an underseal and when you would not use an underseal.
4. What type of hot mix is used as the final surface?
5. For cases 2 and 3 shown above, is there any testing done on the old ACP layer prior to placement of the underseal?
6. Describe the typical underseal itself? i.e. microsurfacing or seal coats
7. If a seal coat is used as the underseal, what types of binders are used? What grade of aggregate is used?
8. Are variable nozzles used for binder application of the underseal?
9. Describe the highway type on which an underseal is used ? i.e. traffic volume, curb & gutter
10. Discuss district successes or failures regarding the use of underseals. Identify and delineate those failures in which the underseal caused a problem in a lower layer or the combination of the underseal with the overlay failed.
11. Do you know the cause or can you speculate as to the causes of failures your district has experienced?
12. As a result of failures, what remedies and new approaches have been adopted?

Question	**Abilene District**	**Amarillo District**
1	3 and 4.	All 4.
2	Prevent the infiltration of water into underlying layers and to bridge cracks; to some degree prevent crack propagation.	Mainly to seal surface water intrusion.
3	*Would Use:* On existing pavement with a remaining life where we are doing an overlay. *Not Use:* In full depth construction.	Anytime there is a thin hot mix layer, an underseal is used. They are lately using thick hot mix layers (4 inches Type B and 2 inches of Type D) in which case no underseal is used.
4	Type C, Type D, Superpave, and CRM mix.	Type D.
5	Yes.	No.
6	1 course surface treatment.	Seal Coat.
7	*Winter:* CRS-1P *Summer:* AC -20-5TR, AC 5 or 10 with latex, CRS-2	AC-5, precoated limestone or gravel Grade 4.
8	Yes.	No.
9	Anywhere we are trying to salvage the existing pavement structure.	Almost any type.
10	We do not use a latex modified underseal if we are laying hot mix over it because of problems with the laydown machine pulling up the underseal.	
11	Refer to Answer No. 10.	No.
12	We use a different binder now that does not have latex when we place the overlay.	

Question	**Atlanta**	**Austin District – Response 1**
1	Cases 1, 2 and 4. The only instance close to Case 3 that I can think of is SL 390 from US 59 to roughly SH 43 in Harrison Co. Atlanta will always place a seal between the base and ACP. However, given the scenario of Case 3 before overlaying the old ACP, I would be in favor of placing a seal as shown. In Case 2, if PCC instead of base, seal the surface of the concrete….period. If additional ACP overlay is to be placed do not place seal between ACP layers.	All 4 cases.
2	Moisture barrier to prevent downward migration of moisture. Does make some contribution towards keeping the ACP from slipping (for thin overlay). Acts as a temporary-wearing course to accommodate construction phasing prior to placing the final surface.	Moisture barrier.
3	See answer 1. Do not trap moisture in ACP layer between concrete surface and underseal.	In all 4 cases, we would use an underseal. We would not use an underseal with full depth asphalt.
4	In Case 5 use “dense” graded ACP. Do not use Superpave, CMHB or mix that has a lot of interconnecting voids. High percentage of trucks is a factor here.	CMHB PG 76-22, PG 70-22, PG 64-22.
5	We have cut some cores and applied the “Gene Rudd” screwdriver test in the field. We have collected some FWD data on flexible pavement structures. Wish there were some guidance on what is too much deflection for mixes with PG 64-22 and PG 76-22.	Visual only.
6	Choice of underseal is a surface treatment.	One course surface treatment or two course on bridges.
7	Recommend a Grade 3 stone except for interstates. We have used a lightweight Grade 4 in the past. Use hot asphalt cement or CRS-2 when long-term traffic is not a concern. Otherwise a modified asphalt such as CRS-2p or AC-20-5TR	HFRS-2, HFRS-2p, AC-20, generally a Grade 4 or Grade 5 aggregate.
8	It is not required.	No.
9	See answer 1 and 3.	All.
10	See answer 1 and 3.	The only failures regarding the use of underseals is occasional flushing and asphalt pushing at intersections.
11	Same as above.	The asphalt flushing could be the result of a heavy application of binder.
12	Same as above.	The asphalt flushing has been controlled to a certain extent by keeping a closer eye on the rate of application. The asphalt pushing at intersections has been controlled by stopping the seal coat short at intersections.

Question	**Austin District – Response 2**	**Austin District – Response 3**	**Austin District – Response 4**
1	Case 3 and 4.	Case 3, Case 4 (occasionally).	Case 3 and 4.
2	To seal the existing cracks prior to the application of the new surface so any moisture which does get through does not penetrate.	Seal in moisture in base. Seal cracks of ACP.	As a membrane impervious to water and to enhance bonding.
3	When the pavement being overlaid is moderately cracked.	On cracked pavement prior to HMA overlay and on milled areas prior to HMA overlay.	Not used on fresh seal coat; use on most other cases if money available.
4	Usually Type C or CMHB-C.	Type C.	Type C.
5	No. But if the asphalt layer is badly cracked, in some situations we have milled it off prior to undersealing.	No.	No.
6	Seal coat.	Seal coat.	Grade 4 seal coat.
7	Usually emulsions are used with crushed limestone, either Grade 4 or 5.	AC 20-5TR, Grade 4 and Grade 5 (but mostly Grade 4).	AC-15P or AC 20-5TR; PB Grade 4.
8	Not sure, I know they are used on seal coats which are not underseals.	Not known.	No.
9	Not sure.	All types.	All roadways.
10	We've had some cases where the underseal was placed with too high of an asphalt application rate and it bled through the overlay.	Unknown.	Cannot point to a failure related only to underseal.
11	Too much asphalt used in the underseal.	Not placing at the correct temperature (range), especially placing in low temperatures.	Shoving – possibly from poor bonding or poor mix.
12	More careful on determining asphalt application rates.	We watch out for air temperatures, surface temperatures, and material temperature…much more.	Better tack application; higher grade of PG binder.

Question	Austin District – Response 5	Austin District – Response 6
1	Cases 2, 3 and 4.	Case 3 mainly, Case 4 occasionally.
2	The primary functions are to protect the base course from water penetration and to provide a bond between the old and new ACP. I feel that, whether we admit it or not, the seal does arrest some of the cracking in the surface of the old pavements. We do not seal a pavement that has visible alligator cracking – we mill or otherwise remove the damaged pavement that we see. I think that the seal coat serves to somewhat bond the damaged surface that we do not see. To support this, I site the Parmer Lane Roadway from Loop 1 to RM 620 several years ago. The pavement surface had a great deal of alligator cracking in the wheel paths. Our maintenance forces sealed the pavement and had essentially no failures for two years. I think that the seal penetrates the cracks and provides some structural value. I think that the seal coat bonds better to existing pavement than a HMA layer. The thin layer of a OCST is rolled directly into the pavement with minimal lateral movement. HMA is rolled with some lateral movement (roll down, etc.) I feel that this prevents debonding (delamination) in some cases. The underseal allows the designer to move traffic into desired patterns so the the ACP seams are at lane lines. Especially important in phased construction.	Seal cracks in old pavement. Seal moisture from base.
3	*__Would Use:__* Old pavement with AC loss in the surface and/or with possible cracking. *__Would not use:__* On reasonably new ACP or a seal with no cracking/good history.	
4	Many types. We typically use Type C. We have used D and CMHB. We certainly would use a seal on pavement such as CMHB that have a penetrable surface. Would use a seal on microsurfacing for the same reasons as above.	Type C.
5	No. Just visual and history review.	No.
6	Seal coat with Grade 4 aggregate. Microsurfacing does not provide the desirable sealing effect (adds skid value only) so would not be used.	Seal coat.
7	Emulsion or AC modified. Grade 4 aggr.	PG 64-22, AC 20-5TR, Grade 4 or 5.
8	No.	Unknown.
9	All.	All types.
10	Had big problems with IH 35 main lanes from Grand Ave. to Rundberg. This was a microsurfacing with an HFRS underseal. Had rutting and bleeding under very high traffic. This was a lot of asphalt cement for a thin surface; contractor had poor quality control that made it much worse.	When underseal placed under microsurfacing.
11	A lot of asphalt for a very thin surface.	Low temperatures and rock placement.
12	Cut back on asphalt for seal used under microsurfacings. Very tight quality control. Subsequent frontage road project went much better.	

Question	Beaumont District	Brownwood District
1	Case 3 is most common.	All cases.
2	Same as above.	Better bond between old and new pavement structure. Seal existing cracks and retard or prevent them from reflecting through to the surface. Prevent moisture from getting to base from the surface and from the surface to the base.
3		If the existing pavement structure to be sealed has cracks, then I would definitely place an underseal prior to overlay. I believe we should always place an underseal.
4	Type C is most common.	C or D.
5	The Beaumont District performs core sampling in the distressed areas to determine if the distressed layer should be milled.	Coring and falling weight deflectometer testing to determine structural adequacy and overlay.
6	Seal coat – typical aggregates are Grade 3 lightweight and CRS-2p asphalt emulsion.	Seal coat. I do not believe we should use microsurfacing as an underseal because it does not seal cracks.
7	Same.	Asphalt rubber seal coat with a Grade 3 precoat aggregate when placing an overlay over PCC. AC-20-5TR with Grade 4 precoat aggregate when placing an overlay over ACP.
8	Yes.	No.
9	FM roads mostly – light traffic for others, no curb and gutter.	All roadways.
10	We have had very good fortune with underseals. However, sometimes after several layers of level-up/underseal the pavement section becomes weak and ruts/flushes.	We have had good success with underseals. We had one failure on US 190 in San Saba County. Spots of the overlay separated at the underseals.
11		The underseal was an emulsion seal coat with a Grade 4 lightweight aggregate. Probably, the underseal did not bond very well to either the old or new surface.
12		Mill overlay and underseal and place new underseal. After 2 years of service it looks good.

Question	**Bryan District**	**Childress District**
1	Case 2.	Cases 2, 3, and 4.
2	To seal off cracks in the underlying pavement.	Prevent moisture intrusion into lower pavement layers.
3	We use underseals on all projects except complete new construction (sometimes on new projects depending on sequence of work).	We use underseals on all ACP applications (both rehab, overlay, mill and overlay).
4	Type C or CMHB-C.	Type D.
5	FWD, pavement cores, GPR and profiler (for ride quality).	No.
6	Seal coat and hot rubber seal on concrete pavements.	Seal coat.
7	AC-20-5-TR or AC-15p with either precoated aggregate Grade 3 or 4. During cold weather use HFRS-1p or CRS-1p with uncoated Grade 3 or 4.	AC-5 or AC-10 for low volume roadways. AC-20-5TR for high volume roadways. Type B or PB, or modified. Modified meets ASTM Grade 7 specification.
8	Not at this time, left up to area offices to decide.	No.
9	All types, any highway that will receive an overlay.	Primarily rural roadways, very little curb and gutter. AC 5 or AC 10 for low volume (~< 750) AC 20-5TR for high volume (~> 750)
10	The district has had very good success with underseals. Although we have had a few problems with the asphalt bleeding through the hot mix and the seal “leaking,” allowing base to get wet.	Primarily all successes. Occasionally experience bleeding (or flushing) of the underseal upwards through the ACP.
11	Bleeding – too much asphalt in underseal. Leaking – construction problems in underseal.	Have not really experienced any failures.
12	Considering using variable nozzles.	To alleviate flushing, we have simply cut back on the asphalt rate of application and/or used a larger aggregate.

Question	**Corpus Christi District**
1	In the Corpus District we mainly have Case 3 when we have an overlay project and Case 4 on rehab and reconstruction projects. We have a few projects where we overlay the roadway and there is a part of the roadway that has a layer of concrete pavement that fits in Case 2.
2	The function of the underseal is a moisture barrier to protect the flex base from moisture.
3	We use underseals on all projects that have a riding surface of HMAC. In the past the Corpus Christi District we didn't use an underseal when there were two layers of HMAC (Type C or D and Type B base). We have stopped that and are using an underseal on all projects with HMAC as the riding surface.
4	We are using Type C HMAC as a final surface layer. Depending on the roadway, traffic count, and percent trucks we use PG binder in the HMAC and specify L or S in the material to be used.
5	In some cases we mill the existing asphalt surface, we check the PMIS scores and do a visual inspection of the roadway to see if the existing needs to be milled off or not.
6	The typical underseal consists of a one course surface treatment. In some cases we use a two-course surface treatment if we are going to open to traffic for a long period of time prior to placing the HMAC surface. We have used microsurfacing on several roadways to improve skid numbers. Microsurfacing is used in urban areas where there is a lot of stop and go traffic where you might have problems with a seal coat. In some cases we have placed a seal coat and covered the seal with a microsurface prior to opening to traffic.
7	The type of binders used for an underseal vary depending on what the underseal is to be placed on. If the placement is on treated or untreated flex base, we use AC-5, AC-10, CRS-2 or HFRS-2. If the underseal is to be placed on an existing asphalt surface then we use AC-15P, CRS-2p or HFRS-2p. The type of aggregate used is usually Grade 4 (mod) and in some cases we use Grade 4.
8	Variable nozzles are not usually used for an underseal, however they are used on our district-wide seal coat program.
9	We use underseals on all roadways where the riding surface is HMAC, FM, SH, US, and IH. We use underseals on curb and gutter roadways both new construction rehab and overlay type projects where the riding surface is HMAC.
10	I think we have had a project where we had a failure due to the underseal; however, we had some projects where we used a microsurfacing and it was later covered up by an overlay project then a few years later we started having trouble with the roadway.
11	We have had some failures but they are limited to areas where in the past we did not place an underseal below the HMAC or a project where we had a microsurfacing layer that trapped moisture below and as a result we had some pavement failures.
12	In the areas where we have had a previous microsurfacing project, we mill off the existing surface to below the microsurface then apply a seal coat over the roadway.

Question	**Dallas District**
1	Primarily Case 1. We typically remove the overlay down to the PCC pavement, then rout and clean the cracks, apply fabric strips over the cracks, then apply a seal coat prior to overlay. Almost all the pavements in the district are originally PCC.
2	Seal concrete from surface water.
3	Use on cracked concrete pavement.
4	Type C or D.
5	No.
6	Fabric and seal coat.
7	AC 20-5 TR and either Grade 3 or Grade 4.
8	No, not for underseal.
9	High volume traffic.
10	Most of the time this underseal is successful. The biggest problem is when the seal coat is left uncovered for too long (usually due to weather) and begins to debond in the area where fabric is located.
11	We recommend that temperature be above 50°F and the pavement be totally dry. If bad weather is imminent, try to cover it immediately. Otherwise can leave the seal under traffic about a week. Since we now have QC/QA specs there are not enough “teeth” in the spec to control the contractor in light of impending weather.
12	

Question	Houston District
1	Case 2 and 3.
2	Provide a better surface for the ACP overlay, better bond with the ACP, and better than crack sealing.
3	A pavement with a lot of cracks I would use an underseal. On a new pavement construction I would not use an underseal.
4	Previously we were using Type D only and now we are using Type C for high traffic and allowing Type D for low volume roads.
5	In most cases, no.
6	Seal coat.
7	We are now starting to require AC-20-5TR for seal coats.
8	
9	Low volume FM roads.
10	
11	
12	

Question	**Lubbock District**
1	Case 2, 3, and 4.
2	To prevent the intrusion of surface water.
3	Would not use an underseal in new construction. Typical cross section would consist of a 2-inch overlay of CMHB, over hot rubber underseal, over levelup, over surface treatment, over flexible base. In some cases, the underseal is a geotextile fabric tacked with asphalt cement on top of a seal coat on existing hot mix.
4	CMHB, sometimes Type C.
5	
6	Seal coat.
7	Hot asphalt rubber. Grade 3 or 4.
8	No.
9	US Highways.
10	
11	
12	

Question	**Lufkin District**	**Odessa District**
1	All.	Mainly 3 and 4.
2	Prevent water intrusion, help bonding between new pavement and old pavement.	To prevent the intrusion of surface water, to delay reflective cracking.
3	If the new layer is 1 inch or less.	Underseals are not used on flex base if the surface mix is dense graded. Would use when the surface mix is CMHB and when an underlying asphalt concrete pavement is cracked.
4	Type C.	CMHB, crumb rubber hot mix.
5	Usually cores and FWD.	Cores, FWD, GPR.
6	One-course surface treatment.	
7	Overlay of existing if carry traffic: RC-250 & Grade 5. No Traffic: AC-5 and Grade 4.	
8	No.	
9	All that have ACP.	
10	All surfaces over seal; no problem yet.	
11	Had problems with bleeding and rutting.	
12		

Question	**Pharr District**
1	We have Cases 2, 3, and 4.
2	The function of the underseal is to prevent moisture from entering the flex base. Another function is that of traffic control for reconstruction projects. In other words, we can use a seal coat during a phase of construction and place traffic on it without having to use an overlay (i.e., can use a seal coat and 1.5 inches of ACP instead of 3 inches of ACP).
3	We use underseals on all projects with 3 inches of ACP or less. I would not use an underseal as a rehab measure on an existing pavement that has rutting or excessive cracking.
4	The Pharr District uses predominantly Type D as a final surface layer. We use a PG 76-22 on all expressway projects and NAFTA routes.
5	No. We do look at traffic data.
6	We use a two-course surface treatment with a precoated aggregate. We use AC-20 with 5% tire rubber. We have used a micro seal on rural projects.
7	We use AC-20 with 5% tire rubber. The aggregate is Grade 4 mod.
8	No.
9	As mentioned previously, we use seal coats on all projects with 3 inches or less of ACP. This includes curb and gutter projects as well as all rehab and reconst. projects.
10	We have not experienced any major failures. We are monitoring a project in which we milled 3 inches of a heavily traveled roadway and then placed a seal coat and overlaid 3 inches of ACP. This roadway was experiencing a large amount of cracking, both transverse and longitudinal. We will evaluate whether the seal coat will prevent the cracks from propagating through.
11	I would say that the limited failures that we have experienced have been attributed to us trying to remedy a situation that actually warranted more than just a seal coat.
12	The project mentioned in question 10 is a new approach that we will continue to monitor.

Question	**San Antonio District**	**San Angelo District**
1	Case 2, 3, and 4.	Case 3 and 4.
2	Primarily to seal off the old surface, particularly if it is cracked.	Moisture barrier.
3	Would definitely use an underseal if the pavement is old and cracked. We use an underseal on all new construction and typically seal the pavement layer (in the structure) that is the most porous.	Would definitely use an underseal on existing asphalt concrete pavement if it is cracked.
4	Usually a Type C or SMA.	
5	In most cases, no.	CMHB or Type C.
6	Seal coat.	Seal coat.
7	Either polymer modified AC or AC with tire rubber with Grade 4 precoat. In cool weather, we use a CRS 2p.	AC-15P or AC 20-5TR, Grade 3 or Grade 4 precoat.
8	No.	No.
9	All types of roadways.	None.
10	Have had trouble getting good quality construction for underseals. Sometimes contractors and inspectors are inexperienced. In one case, an underseal was placed with a CRS-2p, and all the rock was lost immediately after construction. Placed another CRS-2p seal and then overlayed. This excessive amount of binder then bled through to the surface of the hot mix.	Starting to consider the use of fabrics (Petromat) as moisture barriers.
11		
12		

Question	Waco District
1	We have used all four cases in our district at one time or another. The only difference is a prime or emulsion is normally used on the base. Depending on the application, it could be used to waterproof or adhere to the next course (HMAC or Surface Treatment).
2	Underseals have historically been used to seal the moisture from cracked pavements prior to overlays. This seal should prevent water from penetrating the “old” pavement form the surface. It may also be effective in preventing damage to the “new” pavement by preventing moisture from entering the system from the subgrade.
3	I would use an underseal in an overlay situation that involved a milled surface (to correct any transverse profile problems – such as rutting) and on a section of roadway that has extensive cracking. I would not use an underseal prior to a levelup course. I would apply it after the levelup. I would utilize tack to ensure the bond between the levelup and the old surface. Note: it is Bridge Division policy to utilize a two-course surface treatment when placing an overlay on a bridge. This is done to prevent salts from penetrating the bridge deck. This is one of the few instances where we have had trouble with the underseals “bleeding” through the surface of our overlays. I would not do this if I didn’t have to. We use very little salt (none) in the Waco District.
4	For surface mix, we use dense-graded Type C and Type D, 12.5 and 19 mm Superpave and ½ in and ¾ in SMA. We also use PFC on some high volume freeways.
5	None to my knowledge.
6	Our normal seal coat consists of a Grade 4 aggregate covering asphalt cement or an asphalt emulsion. Microsurfacing is not used as an underseal to HMAC. But seal coats have been used as underseals for microsurfacing.
7	UNDERSEAL (TO BE OVERLAYED VERY SOON AFTER APPLICATION) **a) For High Traffic Applications:** Basis of estimation – Use an AC-20-5 TR or AC-15P (SBS) asphalt at a rate of 0.35 gallons per square yard (SY) for Grade 4 aggregate @ 1 CY per 125 SY aggregate. The aggregate used should be Type PB Grade 4. **b) For Low Traffic Applications:** Basis of Estimate – Use AC (AC-15P (SBS)) or emulsion (CRS-2P or HFRS-2P) **Asphalt Cement Applications** Use 0.35 gallons per SY asphalt and 1 CY per 125 SY aggregate (Type B Grade 4). Note: If you are using lightweight aggregate or if you are applying an underseal to a rotomilled surface, then you may want to increase the asphalt rate. **Emulsified Asphalt Application** Use 0.45 gallons per SY emulsion and 1 CY per 125 SY aggregate (Type B Grade 4). The above rates are used for a Basis of Estimate; the actual rate of asphalt cement, emulsion or aggregate used would depend on the actual roadway condition.
8	We have used variable rate nozzles on some seal coats. I can’t recall an occasion where these nozzles were used on an underseal. We do not use these nozzles as a rule and it is unlikely there are any personnel left with the experience to oversee such an operation.
9	We use underseals on all overlays regardless of traffic type, traffic volume or roadway type. There are only a few exceptions. One is a roadway that has received a maintenance treatment (seal) in the recent past prior to an overlay.
10	Most of our experiences with underseals have been favorable. If we have had a noticeable problem, it has been on bridges, which was delineated above. The only problem I can think of involves microsurfacing. We had some problems with a microsurface placed over an existing microsurface on IH 35. There appeared to be a bonding problem between the two treatments causing the microsurface to come up. We also have some isolated incidents of underseals bleeding through the HMAC overlay.
11	On the bridges, I feel the problem was in the amount of asphalt cement needed to get the proper embedment of the Grade 4 aggregate combined with over asphalted mixes. Being placed on a bridge deck, the “free” asphalt had nowhere to go but up. We, for the most part, don’t place micros over one another any longer. We have applied a seal coat followed with another microsurface. This application seems to work as long as the underseal below doesn’t bleed. If it does, the free asphalt goes to the surface and you have a mess.
12	I know of no remedies other than use the applications in the areas in which we had the failures.

Question	Tyler District	Wichita Falls District
1	All 4.	All 4.
2	Sealing from surface water intrusion. We have had various discussions in the district regarding where to put the underseal when placing multiple layers of hot mix. We have decided that since we are trying to protect the pavement structure from surface water, we should put the underseal as close to the surface as we can so we always put it directly under the final surface layer. If we are paving over PCC we always place an underseal directly on the PCC.	Sealing from surface water intrusion.
3	Always use an underseal. It may be that it's part of seal coat program and surface layer is not placed until the following year, but pretty much always use an underseal.	On US highways (higher traffic volumes).
4	Usually Type D, sometimes C.	CMHB, Type C, or D.
5	If we are doing a significant amount of hot mix work, core existing pavement and do a visual evaluation to determine if there are any signs of stripping. If so, we mill the old surface.	
6	Seal coat.	Seal coat.
7	AC-20-TR, Grade 3 or 4, lightweight or limestone.	AC-20-5TR, hot rubber seals, AC seals. Grade 3 or 4 lightweight or limestone.
8	No, not lately.	No.
9	All types, including curb and gutter.	Higher traffic volume.
10	Don't know of any failures.	Failures associated with hot rubber seal. It seals too well, too impermeable.
11		
12		

Question	Yoakum District
1	All.
2	Case 2, 3, and 4: Prevents downward movement of moisture into underlying layer, keeps moisture "available" for evaporation. Case 1: Prevents upward movement of sub-slab moisture.
3	*Would Use:* Over cracked ACP (but not known stripping) and over bare concrete pavements. *Would Not Use:* Over a potential stripping ACP.
4	Conventional C and D mixes.
5	No.
6	Seal coat when an underseal is proposed. However, even though we think a microsurfacing is not an effective sealant, I wish to make it clear that I strongly believe that a microsurface left in place and subsequently overlaid has caused a problem that we are investigating in this research. Microsurfacing has not been used as a true underseal in that substantial time elapses before the overlay is placed. I am assuming that a true underseal is an operation that involves a subsequent overlay being placed soon after the seal is placed. We have used microsurfacing as remedies for low skid resistance and for minor rutting and surface defects. I am concerned that microsurfacing over ACP (when left in place and overlaid) may trap moisture or prevent evaporation even though it does not seal.
7	Generally hot rubber. Some AC-15P. Grade 4 aggregate.
8	No.
9	An underseal could be specified for any highway type but especially for one that has been milled. An old ACP surface once it has been milled may exhibit distress caused by oxidation. We feel this surface must be "renewed" and possibly "held together" until the overlay is placed. Milling within curb and gutter areas is common and practically as a rule we do not want to be filling in the gutter or causing a drop-off there. We have used underseals and allowed microsurfacing to remain as an interlayer here. IH10 is the Yoakum District's reason for concern with proper placement of underseals.
10	General: Bare CRCP is always sealed with hot rubber before ACP is applied to improve ride and reduce punch-out failures. In at least two instances, another seal or a microsurfacing on top of the ACP was placed as a maintenance or corrective measure some years after the overlay. Then when rutting or ride became a problem again, another overlay was placed. The second overlay had a short life and caused us to remove everything above the concrete and start again with bare concrete.
11	Speculating: Moisture is trapped in the lower ACP layer causing it to strip. How it got in is a mystery, but apparently there is too much material on top to allow proper evaporation. Is the underseal (or micorsurfacing allowed to stay as an interlayer) a "one-way valve"? Heavy traffic aggravates the situation.
12	I do not think we have changed our designs or methods. We continue to "take our chances" and proceed with underseals.

Appendix B

Guidelines on the Use of Underseals

Chapter 1
Introduction

Functions of an Underseal

An underseal, for purposes of these guidelines, is an impermeable or low permeability membrane, such as a seal coat, that is placed underneath a hot mix asphalt concrete (HMAC) overlay to prohibit the infiltration of surface water into underlying layers. An underseal may be placed on an existing bituminous pavement surface, concrete pavement surface, or compacted base material. Sometimes underseals provide additional benefits such as absorbing the stress of moving cracks thereby retarding the rate at which the cracks reflect through to the surface.

Sources of Moisture in Pavements

Moisture is often attributed to be the root cause of many pavement failures. The source of moisture in a pavement structure is primarily from rainwater which penetrates through the pavement surface. Moisture may also enter the pavement structure from subsurface sources, but this is usually secondary to infiltration from the surface.

In an FHWA study on numerous pavement sections, researchers found that 33 to 50 percent of the rainwater that falls onto an asphalt concrete pavement infiltrates to the pavement base (Figure 1-1). For portland cement concrete pavements, this infiltration could be as high as 50 to 67 percent.

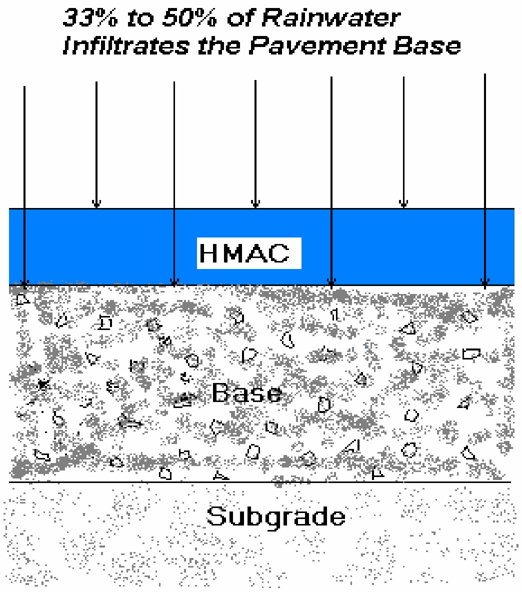


Figure 1-1. Illustration of Water Infiltration.

Studies in Oklahoma found similar results. (Rahman et al. 1996) Sections of pavement were isolated to measure rainfall amounts. The corresponding amount of water that infiltrated that pavement section was recovered by highway edge drains and measured. Comparing the total rainfall for a year to the total discharge for the year showed 32 percent of the water infiltrated through the pavement.

Effect of a Moisture Barrier or Underseal

The rate of water infiltration through the surface layer of a pavement is dependent on the density and void structure of the HMAC. Based on the studies mentioned above, typical infiltration rates might be on the order of 0.002 to 0.005 mm/sec (Marienfeld and Baker 1999). For typical pavement widths, slopes, base thickness, and base porosity, it may take about 1 to 5 hours of rain to saturate the base material. At the low permeabilities common for most bases in Texas, it may take from 60 days to more than a year for the base to drain down to 50 percent saturation. In this period, it may be likely that an additional rain may occur such that the base never fully drains down to 50 percent saturation. A moisture barrier that can reduce the rate of infiltration rate by an order of magnitude would also increase the length of time required to initially saturate the base by an order of magnitude. In this example, this would increase the length of time that it must rain to saturate the base to approximately 10 to 50 hours. By extending the time to saturate the base, it becomes less likely that the pavement will experience a rainfall of sufficient length and intensity that the base will become saturated and even less likely that rainfall events of that duration will recur frequently enough that the base cannot drain.

Marienfeld, M.L. and T.L. Baker, 1999. “Paving Fabric Interlayer as a Pavement Moisture Barrier,” *Transportation Research Circular Number E-C006,* Transportation Research Board, Washington, D.C.

Rahman, M., T. Curtis, M., and Zaman, 1996 *Field Evaluation of Drainable Bases in Oklahoma,* Report Item 2181: ORA 125-4299, Oklahoma Department of Transportation.

Chapter 2
Guidelines for the Use of Underseals on Existing Pavement Surfaces

Determining if an Underseal is Warranted

Evaluating Existing Pavement

Most any pavement which is a good candidate for a seal coat will also be acceptable for a seal coat applied as an underseal. Since the purpose of an underseal is to “seal” the surface prior to overlay, it is generally not necessary to place an underseal if the existing surface is an intact, uncracked seal coat and is still functioning as intended. If the existing surface is a fine-graded (Type D) or a microsurfacing, it should have low permeability and may not require the use of an underseal. If the surface is a coarse-graded mix with little fines, it is more permeable and it would be beneficial to protect it with an underseal.

If the pavement surface is bleeding, then a seal coat may not be the best choice for an underseal. The binder used for the seal coat plus the additional binder present due to the bleeding asphalt on the pavement surface may tend to migrate through the HMAC overlay. It may be possible to use a larger maximum size aggregate (such as a Grade 3) since it creates more void space in the rock layer to accommodate excess asphalt. A better choice for the underseal may be a microsurfacing. But the best choice may be no underseal at all. If the pavement surface is bleeding, it is likely that it is relatively impermeable. If bleeding is primarily restricted to the wheelpaths, variable rate nozzles can be used to reduce the rate of asphalt application in the wheelpath areas.

There have been some cases in Texas where a moisture susceptible HMAC layer is performing acceptably until it is sealed and overlaid. In these cases, moisture has been sealed into that susceptible layer, causing it to disintegrate. If an HMAC layer is exhibiting signs of moisture susceptibility, it should not be sealed with an impermeable membrane. If it is suspected that the layer is moisture susceptible, it should be cored and tested. A representative sampling of the pavement consisting of 6-inch diameter cores should be obtained and subjected to Hamburg wheel tracking tests as shown in Figure 2-1. This test will generally reveal moisture susceptible HMAC. If it is determined that the layer is moisture susceptible, the pavement layer should probably be removed.

Evaluating the Proposed HMA Overlay

The HMAC which is to be used for the overlay should be evaluated on laboratory compacted specimens for permeability. If the permeability of the HMAC is greater than 1 x 10^{-4} cm/sec, then an underseal will be beneficial at protecting underlying layers.

Figure 2-1. Hamburg Wheel Tracking Test.

Selecting Type of Underseal

The type of underseal most commonly used by TxDOT is a seal coat. Other types sometimes used include microsurfacing, slurry seal, Type D or Type F levelup, or geotextiles. Guidelines already exist on the use of geotextiles and are not addressed in this manual.

There are often several factors which an engineer may consider when selecting the type of underseal to be used. In addition to providing a moisture barrier, a microsurfacing or thin layer of dense-graded HMA may be used to level-up the pavement. Sometimes, an underseal is also expected to serve as a crack-relief layer. The designer, however, should be aware that some types of pavement surfacings do a better job of sealing the pavement than others. Table 2-1 shows some laboratory-measured permeabilties for different types of materials used as underseals.

Table 2-1. Permeabilities of Different Types of Underseals.

Micro-Surfacing	*Type D HMA*	*Seal Coat*
5.2×10^{-5} cm/sec	2.0×10^{-3} cm/sec	0.0 cm/sec

Selecting Materials for Seal Coat Underseals

Binder Considerations

There are many different choices when it comes to selecting seal coat materials. Suitable binder choices for underseals would be the same as used for seal coats as described in TxDOT Standard Specifications, Item 300: AC-5, AC-10, AC-5 w/2% SBR, AC-10 w/2% SBR, AC-15p, AC-20-5TR, HFRS-2, MS-2, CRS-2, CRS-2H, HFRS-2p, CRS-2p, and asphalt rubber Types II and III.

Many of the seal coat binders mentioned above contain additives which improve some of the properties of the binder. These additives include tire rubber (TR or asphalt rubber), styrene butadiene rubber (SBR), polymer (P), and latex. Additives can reduce the loss of aggregate which can cause vehicular damage during the construction of seal coats. These additives help the seal coat resist damage and scuffing caused by stopping, starting, and turning movements under vehicular tires. Additives can also provide for a binder that resists oxidative aging, thereby retaining its elasticity for a longer time. These additives, however, increase the cost of a seal coat binder and should be carefully considered when using for underseals which may never be directly exposed to traffic. These considerations are listed in Table 2-2.

Table 2-2. Considerations Regarding the Use of Polymer Modified Binders in Underseal Applications.

Effect Modified Binders on Performance	*Potential Benefits for Seal Coats*	*Potential Benefits for Seal Coat Underseals*
Improved Adhesion	Enhances the aggregate retention, thereby reducing damage to vehicles.	Benefits are minimal for underseals whose surface is not exposed to traffic.
Improved Toughness	Enhances the seal coat's resistance to scuffing by traffic tires due to stopping, starting, and turning movements.	This may be a benefit for underseals depending on the amount of construction vehicular traffic exposure. May also be of benefit if underseal is also serving as a stress relieving interlayer.
Improved Aging Resistance	Enhances the life of binder flexibility since a seal coat binder is near the pavement surface and subject to oxidative aging.	Benefits are minimal for underseals because they are not subject to aging at their pavement depth. Research has shown that no significant oxidative aging occurs deeper than ½ inch below pavement surface.

Sometimes cutback asphalt cement is used in cool weather for the construction of seal coats. This type of binder is not recommended for use in underseals. Cutback asphalt cements contain a solvent which must completely evaporate for the binder to adequately cure. An underseal is often overlaid with HMAC within a short time of its placement (a few days). It may still have traces of solvent and if overlaid too soon may not ever fully cure, which could cause a softening of the binder in the overlay.

Aggregate Considerations

There are four types of aggregates which are used for the construction of seal coat underseals:

- Crushed gravel – natural gravel that has been crushed to change the particle shape from round to angular and the surface from smooth to rough.

- Crushed stone – large stone or pieces of bedrock which have gone through a series of crushing processes. In Texas, this is predominantly limestone, but also includes sandstone.
- Natural limestone rock asphalt – limestone rock asphalt is a limestone which is naturally impregnated with asphalt.
- Lightweight aggregate – expanded shale, clay, or slate produced by a rotary kiln method.

While any of these may be appropriate for underseals, the use of lightweight aggregate is not recommended since it tends to be more expensive and its benefits do not apply to underseals. Lightweight aggregate has a low specific gravity and tends to cause less windshield and vehicular damage when used in seal coats. It also has excellent skid-resistance properties. These properties are highly desirable for seal coats but not necessary for underseals, which are not directly exposed to traffic.

Two aggregate gradations are commonly used for the construction of seal coat underseals: Grade 3 and Grade 4. TxDOT Standard Specification Item 302, Aggregates for Surface Treatments, describes the size and gradation requirements for these aggregates. Because a Grade 3 aggregate is larger than a Grade 4, it is designed with higher binder application rates. This may provide for better sealing qualities and may be particularly beneficial for pavements exhibiting a significant amount of cracking.

Design Considerations for Seal Coat Underseals

One of the most common problems associated with the use of underseals is the application of too much binder. This excess binder tends to migrate through the HMAC overlay and is exhibited as flushing on the pavement surface as shown in Figure 2-2. This type of problem can be so severe that it requires removal and replacement. Binder application rates should be lower for seal coats that will be used for underseals and are not exposed to traffic.

Figure 2-2. Excess Asphalt from Underseal Migrating Through to HMAC Surface.

Seal coats in Texas are typically designed according to the Modified Kearby design method as described in Chapter 4 of TxDOT's *Seal Coat and Surface Treatment Manual*. Asphalt application rate for asphalt cement is obtained from Eq. 1 below.

$$A = 5.61E(1 - W/62.4G)T + V \tag{1}$$

Where A = asphalt rate in gal/SY at 60°F

E = embedment depth calculated using Eq. 2

G = dry bulk specific gravity of the aggregate

T = traffic correction factor (Table 4-1 of Seal Coat Manual)

V = correction for surface condition (Table 4-2 of Seal Coat Manual)

$$E = e * d \tag{2}$$

Where e = percent embedment expressed as a decimal from Figure 4-2 of TxDOT Seal Coat Manual

d = average mat depth in inches, as calculated from Eq. 3

$$d = 1.33Q/W \tag{3}$$

Where Q = aggregate quantity determined from the board test in lb/SY

W = dry loose unit weight in lb/CF

For underseals which are not directly exposed to traffic the following modifications are suggested for determining asphalt application rate:

- Traffic correction T should always be equal to 1.0; and

- Tack coat application rate which is to be applied prior to overlay should be subtracted from the seal coat binder application rate. For example, if the design binder application rate from Eq. 1 is calculated to be 0.35 gsy and the seal coat is to receive a tack coat prior to overlay of 0.05 gsy, then the actual binder application rate for the underseal should be 0.30 gsy.

Quality Control of Underseal Construction

Guidelines as presented in TxDOT's *Seal Coat and Surface Treatment Manual* should be followed when constructing underseals. There is sometimes a tendency to relax the construction quality control for underseals since the seal will be covered by a HMA overlay. Poor quality control exercised in the construction of underseals is often revealed in the surface of the overlay as shown in Figure 2-3.

Figure 2-3. Improper Underseal Joint Construction Revealed in the HMA Overlay Surface.

Chapter 3

Guidelines for the Use of Underseals on Compacted Base Material

Use of Underseals on Compacted Base Material

Underseals are used extensively by TxDOT on compacted base materials to prohibit the infiltration of surface water. They are also used to provide a riding surface for traffic prior to application of the overlay. In research Project 0-4391, *Develop Guidelines for Placing an Underseal*, one of the primary types of pavement failures identified with the use of underseals on compacted bases occurred when moisture infiltrated the base in areas where the underseal was damaged prior to overlay.

Determining if an Underseal is Warranted

Evaluating the Base Material

Some base materials are very susceptible to moisture, which can be a primary catalyst for pavement damage. If a base material is moisture susceptible, then the use of an underseal to protect the base from the infiltration of surface water is highly recommended. To determine the moisture susceptibility of a base material, the Tube Suction Test (described below) should be performed on the base. This test rates the resistance of the base to moisture damage as good, marginal, or poor. This moisture susceptibility ranking is based on the final surface dielectric values of compacted specimens after a 10-day capillary soak in the laboratory. A dielectric probe is employed to measure the dielectric values of specimens.

Bases with final dielectric values less than 10 are expected to provide good performance, while those with dielectric values above 16 are expected to provide poor performance. Aggregates having final dielectric values between 10 and 16 are expected to be marginally moisture susceptible.

Underseals should be used on base materials ranked as poor or marginal (exhibiting dielectric values of 10 or more).

Evaluating the Proposed HMA Overlay

The hot mix asphalt concrete which is to be used for the overlay should be evaluated on laboratory compacted specimens for permeability. If the permeability of the HMAC is greater than 1 x 10^{-4} cm/sec, then an underseal should be used to protect the base material.

Base Preparation

Prior to application of a prime and/or surface treatment (underseal), the base should be prepared and compacted, then bladed to grade. One should not create a smooth surface at this point, which could result in a weak interface. This practice can cause excess fines to be floated to the surface of the base and often results in delamination of the surface treatment prior to overlay.

When stabilized bases are used, caution should particularly be exercised regarding application of excess water during finish rolling. Excess water applied to the surface of the base material, in effect, increases the water/cement ratio near the surface also causing a weak interface.

The surface of the fully compacted base should be broomed until all loose or caked fines and foreign materials have been removed and some stone particles are exposed.

Base Curing

In the TxDOT Techical Advisory of October 31, 2001, *Proof Rolling and Base Curing Advisory,* it is recommended that flexible base materials be allowed adequate time to cure prior to priming or sealing. It is recommended that the moisture content of the base be at least 2 percentage points below optimum prior to placing a prime coat.

Adequate curing of the base is also very important prior to sealing stabilized bases, particularly fly ash bases. Fly ash is slower to cure and develop strength than cement stabilized bases. Sealing the base prior to adequate strength development can cause moisture to collect below the underseal in the upper portion of the base, causing an increase in the water/cementitious material ratio. This weak interface can cause the underseal to delaminate from the base.

Determine if a Prime Coat is Needed Prior to Underseal

A prime coat is used to promote adhesion between a granular base and a subsequently applied bituminous surfacing by precoating the surface of the base and penetrating the voids near the surface. In general, it is recommended that a compacted granular base be primed before application of a surface treatment or an asphalt pavement less than 3 inches thick. The need for a prime can be dependent on the characteristics of the granular base and its susceptibility to damage by weather and traffic.

A typical crushed limestone base has a tightly bonded, dense surface. For this type of base, a prime coat may be omitted or the prime application quantity reduced when an underseal precedes the asphalt concrete layer. If the prime coat is omitted, construction of the underseal must proceed without delay to avoid damage to the compacted base by weather and traffic. The residual binder for the underseal should be increased by 0.03 gal/SY more than that typically used for a primed base to allow for absorption by the dry surface. If base is not primed, emulsion should be used for the surface treatment binder.

Natural gravel bases and some poorly graded crushed stone bases may have relatively high permeable voids and thus relatively high absorptive properties. These types of bases are more likely to need a prime to prevent surface damage from construction traffic.

Priming the Base

Once it is determined that the base material is adequately cured, a prime coat material may be applied. A sprayed-on application of prime (such as an MC-30) should be at a rate sufficient to coat the surface thoroughly and uniformly with no puddles and no tackiness that would cause vehicle tires to dislodge the prime surface.

If puddles or a tacky surface is evident after the prime has been allowed to cure for as long as possible, these areas should be covered with a light application of small aggregate (icing stone) or preferably precoated stone (Grade 5). Sand and crusher dust used for this purpose may diminish the bonding ability of the prime and create a shear susceptible surface. Excess stone and dust must be swept from the surface prior to application of the underseal.

Emulsified asphalts should not normally be considered for a prime spray-on application since they do not penetrate the base sufficiently. When using emulsified asphalt for prime, it is usually desirable to mechanically mix the prime with the uppermost 1 to 2 inches of base to achieve desirable penetration depth. Complete guidelines on the use of emulsified asphalts as prime materials are presented in TTI research report 1334-1F, *Prime Coat Methods and Materials to Replace Cutback Asphalt.*

Curing the Primed Base

After the prime coat is applied, it cures through the loss of water or volatiles. Drying time depends on a number of factors such as type of prime, rate of application, base permeability, and weather conditions (temperature, solar radiation, humidity, and wind velocity). A prime is considered fully cured when it is no longer tacky and will permit light traffic without excessive pick-up on the primed surface. One advantage of emulsions over cutbacks is that they cure faster and may be trafficked sooner since evaporation of large quantities of solvent is not necessary.

Traffic must be kept off the primed surface until it has dried or until it is no longer picked up by vehicle tires. Where it is necessary to allow traffic to use the road before the prime has dried, the primed surface must be covered with a layer of small stone. Before proceeding with the underseal, loose stones must be removed from the surface. The stone layer should not be applied unless required.

Selecting Materials for Surface Treatment Underseals

Guidelines on selection of materials for binder and aggregates for the use of underseals on compacted bases are essentially the same as presented in Chapter 2.

Design Considerations for Surface Treatment Underseals

Design considerations for the use of surface treatments as an underseal are the same as if the surface treatment were the final surface. TxDOT’s *Seal Coat and Surface Treatment Manual* should be used consulted for design considerations.

TUBE SUCTION TEST

This test method evaluates the moisture susceptibility of granular base materials used in pavements.

Significance and Use

The selection of base materials with adequate resistance to damage under traffic and environmental loading is important in maximizing the life of a pavement. Moisture ingress is a primary catalyst for pavement damage, and moisture susceptibility, or the degree to which moisture ingress degrades the engineering properties of aggregates, plays a key role in the performance of these materials in the field.

Research studies demonstrate that moisture susceptibility is related to the matric and osmotic suction properties of aggregates. Matric suction is mainly responsible for the capillary phenomenon in aggregate layers, and osmotic suction is the suction potential resulting from salts present in the pore water of an aggregate matrix.

The Tube Suction Test (TST) rates the resistance of aggregates to moisture damage as good, marginal, or poor. This moisture susceptibility ranking is based on the final surface dielectric values of compacted specimens after a 10-day capillary soak in the laboratory. The Adek Percometer™, a 50 MHz dielectric probe, is employed in the test to measure the dielectric values of specimens.

The dielectric value of a three-phase system comprised of aggregate particles, air, and water depends on the volumetric percentages and dielectric values of each constituent. The dielectric value of dry aggregate particles generally varies from 4 to 6, and the dielectric value of air is 1. The dielectric value of water depends on its state of bonding in the aggregate matrix. Tightly bound, or adsorbed, water has a dielectric value of about 3 or 4, but the dielectric value of unbound water is substantially higher at 81. Unbound water can migrate within the pavement structure to balance changes in suction caused by chemical contaminations, changes in the pore structure, or fluctuations in the water content.

For materials with high suction potential and sufficient permeability, substantial amounts of unbound water rise within the aggregate matrix during soaking and lead to higher dielectric values in the test. Conversely, non-moisture-susceptible materials maintain a strong moisture gradient throughout the test, with little moisture reaching the surface, and have lower dielectric values at the end of testing. Beneficiation techniques such as stabilization, blending, or reducing the fines content should be considered for effectively reducing the moisture susceptibility of poor-performing aggregates.

Apparatus

- Apparatus outlined in Test Method Tex-101-E, Part II,
- Apparatus outlined in Test Method Tex-103-E, Part I,
- Apparatus outlined in Test Method Tex-113-E,
- Triaxial cells, lightweight stainless steel cylinders,
- Cylindrical plastic molds with inside diameter of 152.4 mm (6 in.) and minimum height of 50.8 mm (2 in.),
- Power drill with 1.5 mm (1/16 in.) drill bit,
- Drying oven maintained at 60 ± 5 °C (140 ± 9 °F),
- Flat-bottomed plastic pan, wide and shallow, for soaking specimens,

- Adek Percometer^{TM}, and
- Ice chest for enclosing at least three cylindrical plastic molds.

Materials

- Distilled water.

Sample Preparation

Prepare the sample as in Test Method Tex-101-E, Part II.

Test Record Forms

Record sample preparation and testing data on the Tube Suction Test Data Collection Form (Figure 1). After tests are completed, summarize results on the Tube Suction Test Data Analysis Report (Figure 2).

Procedure

Step	Action
1	Use Test Method Tex-113-E for determining the optimum moisture content (OMC) and maximum dry density (MDD) of the material for molding the test specimens.
2	Obtain three cylindrical plastic molds. At approximately 6 mm (1/4 in.) above the outside bottom of each mold, drill 1.5 mm (1/16 in.) diameter holes around the circumference of the mold at a horizontal spacing of 12.5 mm (1/2 in.). This equates to 38 or 39 holes around the mold base. Also drill one 1.5 mm (1/16 in.) diameter hole in each quadrant of the bottom of the mold about 50 mm (2 in.) from the center. Trim the cylinder as necessary to a height of 50 mm (2 in.) to create a reusable plastic base cap. Make two vertical cuts in each base cap, equally spaced around the circumference as shown in Figure 3, to enable easier installation and removal. Place a 152.4 mm (6 in.) diameter circle of filter paper or paper towel in the bottom of each cap. Weigh the caps to the nearest 1 g (0.0022 lb.) and record as W_{CAP}.

3	Obtain a representative sample of prepared material in sufficient quantity to prepare three specimens. Bring the material to optimum moisture using distilled water. (Ions in regular tap water can influence the results of the test by increasing the osmotic suction component of the aggregate.)
4	Compact three specimens at optimum moisture and maximum dry density according to Test Method Tex-113-E. The specimens should be 152.4 mm (6 in.) in diameter and 203.2 ± 6.4 mm (8 ± 0.25 in.) in height and should be wetted, mixed, molded, and finished as nearly identical as possible. The surface of each specimen should be made as smooth as possible after compaction. Remove or reposition any coarse aggregate protruding from the specimen surface and fill any large voids as necessary. (Application of fines across the whole specimen surface should be avoided, however.)
5	After removal of specimens from the compaction sleeve, install a base cap on the bottom of each specimen. Weigh three clean, dry triaxial cells to the nearest 1 g (0.0022 lb.), and record as W_{CELL}. Slide the triaxial cell down over the specimen so that only the lower 25 mm (1 in.) of the base cap remains exposed. Weigh the specimen with the base cap and triaxial cell to the nearest 1 g (0.0022 lb.) and record as W_{OMC}.
6	Place the specimens in an oven maintained at 60 ± 5 °C (140 ± 9 °F) for 48 ± 4 hours.
7	Remove the specimens from the drying oven and weigh each specimen with base cap and triaxial cell to the nearest 1 g (0.0022 lb.) and record as W_{DRY}. Use the Adek Percometer^{TM} to take six initial dielectric readings on each specimen surface as shown in Figure 4. Five should be equally spaced around the perimeter of the specimen, and the sixth should be in the center. Press down on the probe with a force of 9.1 ± 2.3 kg (20 ± 5 lb.) to ensure adequate contact of the probe on the specimen surface. This pattern should be followed each time dielectric values are measured.
8	Place the samples inside an ice chest on a level surface in a laboratory room maintained at 25 ± 5 °C (77 ± 9 °F) and fill the ice chest with distilled water to a depth of 12.5 ± 3.2 mm (1/2 ± 1/8 in.). The water bath should be maintained at this depth throughout the testing. Avoid splashing the specimen surfaces with water during the test. Close the ice chest lid.
9	Take six dielectric readings on each specimen surface once a day for 10 days. If the water content is to be monitored through time, the sample weight should be recorded daily to the nearest 1 g (0.0022 lb.) and recorded as W_{WET} at each time interval. Wipe the bottom of the mold dry before weighing. Close the ice chest lid after taking measurements.
10	The test is completed when the elapsed time exceeds 240 hours. Measure and record final surface dielectric values and weights. If triaxial strength testing is desired in this soaked condition, carefully remove the base cap and perform the test.
11	Determine the final moisture content of each specimen according to Test Method Tex-103-E, Part I, but use the entire sample in the procedure. Wash all aggregate particles from the base cap and interior of the triaxial cell, as well as from any porous stones used in triaxial testing, into the drying pan. Record the weight of the oven-dry aggregate particles as W_S. Though the moisture content determined in this way after triaxial testing may not represent the moisture content at the conclusion of soaking, the value of the latter can be calculated using W_S as shown in the next section.

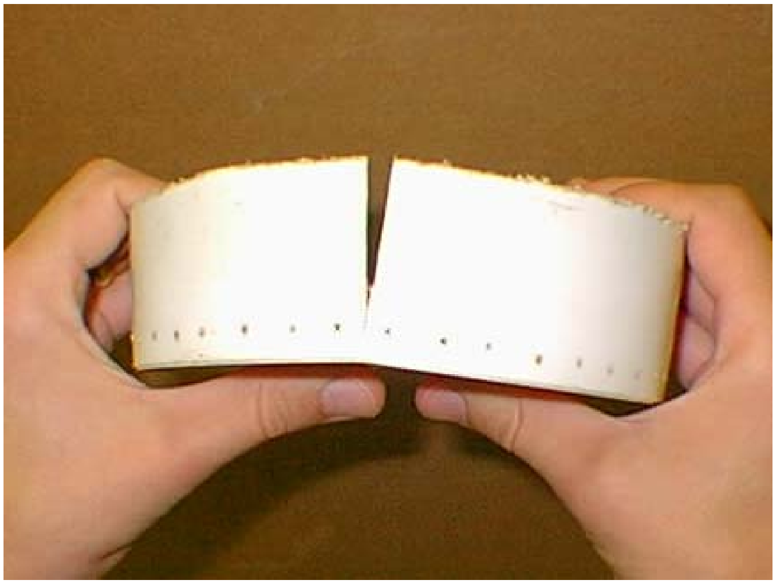


Figure 3-1. Finished Base Cap.

Figure 3-2. Using the Adek Percometer^{TM}.

Calculations

- Calculate the actual gravimetric water content (WC_{OMC}, %) of each specimen just after compaction at the optimum moisture content,

  $$WC_{OMC} = 100\ (W_{OMC} - W_{CAP} - W_{CELL} - W_S) / W_S$$

  Where:

  W_{OMC} = weight of specimen with base cap and triaxial cell just after compaction, g (lb)
  W_{CAP} = weight of plastic base cap, g (lb)
  W_{CELL} = weight of clean, dry triaxial cell, g (lb)
  W_S = weight of oven-dry aggregate particles, g (lb)

- Calculate the gravimetric water content (WC_{DRY}, %) of each specimen just after the two-day drying period,

  $$WC_{DRY} = 100\ (W_{DRY} - W_{CAP} - W_{CELL} - W_S) / W_S$$

  Where:

  W_{DRY} = weight of specimen with base cap and triaxial cell after two-day drying period, g (lb)
  W_{CAP} = weight of plastic base cap, g (lb)
  W_{CELL} = weight of clean, dry triaxial cell, g (lb)
  W_S = weight of oven-dry aggregate particles, g (lb)

- Calculate the percentage of water loss (P_{LOSS}, % of OMC) for each specimen during the two-day drying period,

  $$P_{LOSS} = 10000\ (\ (W_{OMC} - W_{DRY}) / W_S) / WC_{OMC}$$

  Where:

  W_{OMC} = weight of specimen with base cap and triaxial cell just after compaction, g (lb)
  W_{DRY} = weight of specimen with base cap and triaxial cell after two-day drying period, g (lb)
  W_S = weight of oven-dry aggregate particles, g (lb)
  WC_{OMC} = gravimetric water content just after compaction, %

- Calculate the average percentage of water loss for the three specimens.

- Calculate the gravimetric water content (WC_{WET}, %) of each specimen at each time interval during the soaking period,

  $$WC_{WET} = 100\ (W_{WET} - W_{CAP} - W_{CELL} - W_S) / W_S$$

  Where:

  W_{WET} = weight of specimen with base cap and triaxial mold at time of interest during soaking period, g (lb)
  W_{CAP} = weight of plastic base cap, g (lb)

W_{CELL} = weight of clean, dry triaxial cell, g (lb)
W_S = weight of oven-dry aggregate particles, g (lb)

- Calculate the average gravimetric water content of the three specimens at the end of the soaking period.

- For each specimen at each time interval, discard the highest and lowest dielectric readings. Calculate the average dielectric value from the remaining four readings for plotting against time.

- Calculate the average final mean dielectric value of the three specimens to determine an overall moisture susceptibility ranking. Aggregates with final dielectric values less than 10 are expected to provide good performance, while those with dielectric values above 16 are expected to provide poor performance as base materials. Aggregates having final dielectric values between 10 and 16 are expected to be marginally moisture susceptible.

Graphs

- Plot the dielectric-time curve for each specimen.
- Plot the moisture-time curve for each specimen if requested.

Test Report

Report the average final dielectric value after soaking and the corresponding moisture susceptibility ranking of good, marginal, or poor.

Also, report the average final gravimetric water content of the specimens after soaking and the average percentage of water loss with respect to OMC during the two-day drying period. The former is indicative of the water content this aggregate may attain in the field given the availability of water, and the latter, if less than 50 percent, suggests that special construction considerations may be required in moist conditions to avoid trapping water in the pavement.

Appendix C

Training Materials

Guidelines on the Use of Underseals
Training Class Outline

Class description:	**One 3-hour class for engineers, inspectors, and laboratory personnel.**
Class size and attendees:	**To be determined at the district level.**
Handouts:	**Single notebook containing** **1. Copy of Powerpoint presentation for notetaking.** **2. Guidelines.** **3. Decision tree.**

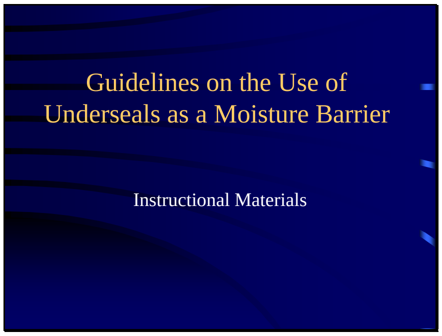
Section	**Topic**	**Approx. Length**
I.	***Introduction and Background*** **A. Provide an overview of the course and materials.** **B. Describe an underseal, it's functions and applications.** **C. Discuss problems and questions associated with underseals which prompted a research study.** **D. Discuss findings in the literature regarding the movement of moisture through pavements.**	**5 minutes**
II.	***District Experience*** **A. Describe the different practices among the districts regarding the use of underseals.** **B. Discuss problems in general that districts have experienced.** **C. Discuss binders and aggregates used for underseal, final surface mixes.** **D. Provide time for discussion of district practice, experiences, and problems.**	**20 minutes**
III.	***Case Histories of Underseal Failures*** **A. Detail the individual case studies identified in the research project.** **• 3 to 5 projects where underseal placed on flex base.** **• 3 to 5 projects where underseal placed on existing paved surface.** **Show GPR data, lab tests, photos of projects, conclusions regarding failures.**	**30 minutes**
Break		**15 minutes**

Section	Topic	Approx. Length
IV.	*Use of Underseals on Existing Pavement Surfaces* A. Evaluate the existing pavement. • Identify pavement surface, assess it's condition and the predominant types of distresses. Provide examples of different types of pavement surfaces and how the condition affects the selection of the use of an underseal and types of materials to be used.(i.e. bleeding, ravelling, seal coat, cracked, joints) • Identify underlying layers, i.e. multiple hot mix layers over base. Know what you're trying to protect from moisture.	5 minutes
	B. Determine if pavement is moisture susceptible.	5 minutes
	C. Evaluate permeability of proposed overlay. Describe permeability test. Pass around samples of cores and marked with their permeability.	5 minutes
	D. Select materials for the underseal • Binder considerations. Benefits of polymer modification, Hot AC vs. emulsion, no cutback. • Aggregate considerations. Discuss use of lightweight. Discuss aggregate grade selection (3 or 4).	10 minutes
	E. Design considerations for the binder/aggregate application rates on for the seal (will it be under traffic, will a tack coat be used prior to overlay).	10 minutes
	F. Discuss underseal application. Describe important quality control issues regarding the seal coat construction.	10 minutes
		Total 45 min

Section	**Topic**	**Approx. Length**
V.	*Use of Underseals on Compacted Base* **A. Evaluate the base material in terms of moisture susceptibility.** **• Describe tube suction test and interpretation of results regarding the need for underseal.**	**10 minutes**
	B. Describe base preparation and base curing. **• Emphasize not creating a weak interface - don't float the fines to create smooth surface. Discuss effects of excess water used in finish rolling on the water/cementitious ratio of stabilized bases. Discuss fly ash stabilized bases and their characteristically slow cure. Check moisture content to be sure it is at least 2% below optimum prior to seal.**	**5 minutes**
	C. Determine if prime is needed, materials to be used, and material quantities.	**5 minutes**
	D. Priming the base. **• Discuss how to evaluate the application rate (surface should be uniformly coated with no puddles, or tackiness).** **• Discuss need for icing stone, discuss how the use of sand can diminish bonding ability creating shear susceptible surface, sweeping prior to underseal.** **• If emulsified asphalt is used for prime, do not spray on but mechanically mix to a depth of 1 to 2 inches. Show 7 minute how-to video of how to use emulsified asphalt as prime.** **• Curing the primed base. Discuss factors which affect "drying" time (type of prime used, rate of application, base permeability, weather conditions). Describe how to know when prime is fully cured.**	**20 minutes**
	E. Materials and Construction considerations (where different than previously discussed for Section IV.)	**<u>5 minutes</u>** **Total 45 min.**
VI	*Conclusion* **(summarize, recap, go over decision tree, refer to the guidelines in their information packet).**	**10 minutes**

Total Course Length 2 hrs 50 min.

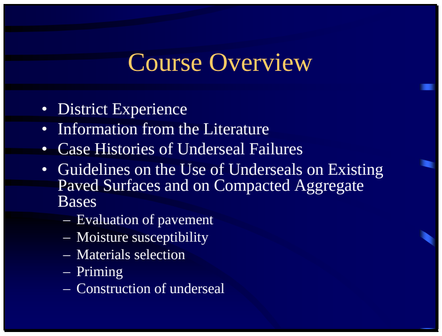
Slide 1



Guidelines on the Use of Underseals as a Moisture Barrier

Instructional Materials

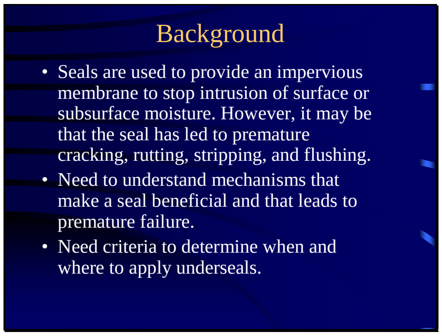
Slide 2



Course Overview

- District Experience
- Information from the Literature
- Case Histories of Underseal Failures
- Guidelines on the Use of Underseals on Existing Paved Surfaces and on Compacted Aggregate Bases
  - Evaluation of pavement
  - Moisture susceptibility
  - Materials selection
  - Priming
  - Construction of underseal

Slide 3



Background

- Seals are used to provide an impervious membrane to stop intrusion of surface or subsurface moisture. However, it may be that the seal has led to premature cracking, rutting, stripping, and flushing.
- Need to understand mechanisms that make a seal beneficial and that leads to premature failure.
- Need criteria to determine when and where to apply underseals.

Slide 4

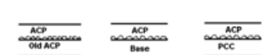
Project Objective

- Develop criteria needed to determine when and where to place an underseal.

Slide 5

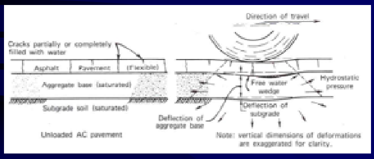
Definition of Underseal:

a seal coat or microsurfacing placed on asphalt layer, flex base, or PCC and topped with asphalt surface layer



Slide 6

Action of Free Water in AC Pavement



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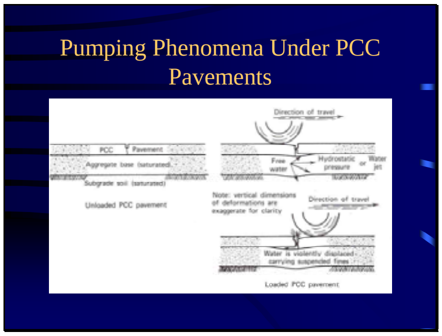
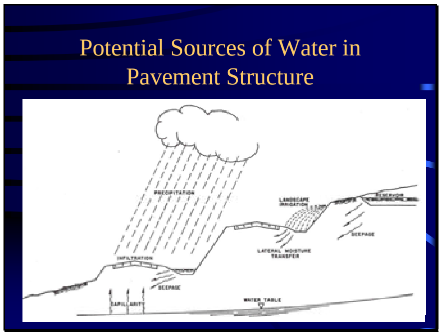


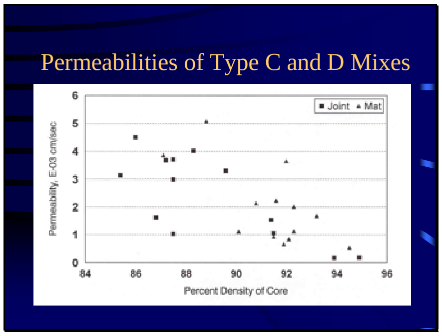
Pumping Phenomena Under PCC Pavements

Slide 8



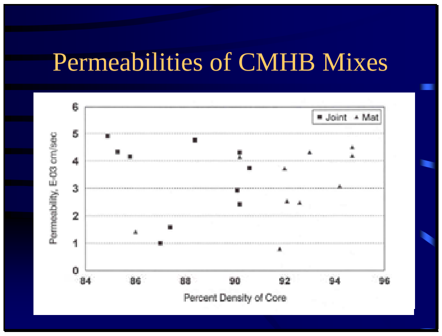
Potential Sources of Water in Pavement Structure

Slide 9



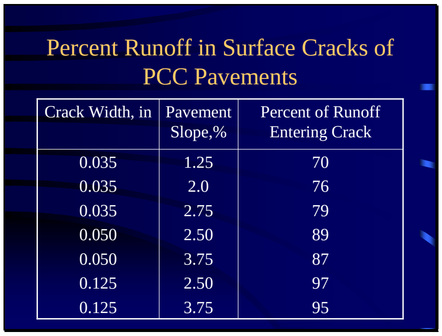
Permeabilities of Type C and D Mixes

Slide 10



Permeabilities of CMHB Mixes

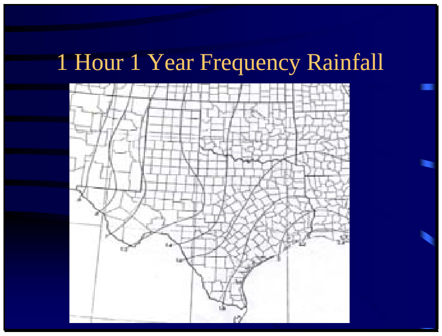
Slide 11



Percent Runoff in Surface Cracks of PCC Pavements

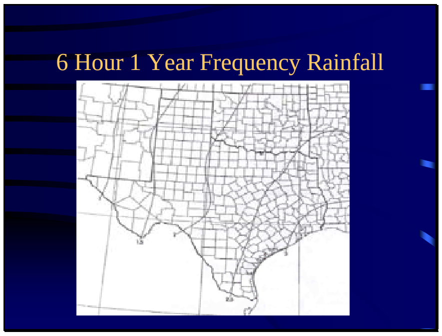
Crack Width, in	Pavement Slope,%	Percent of Runoff Entering Crack
0.035	1.25	70
0.035	2.0	76
0.035	2.75	79
0.050	2.50	89
0.050	3.75	87
0.125	2.50	97
0.125	3.75	95

Slide 12



1 Hour 1 Year Frequency Rainfall

Slide 13



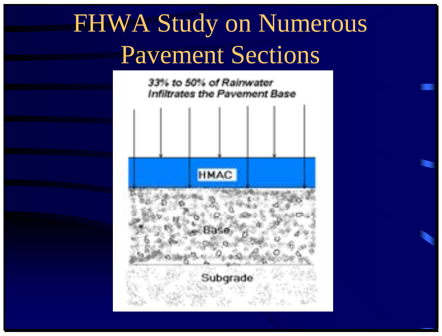
6 Hour 1 Year Frequency Rainfall

Slide 14

Oklahoma Study

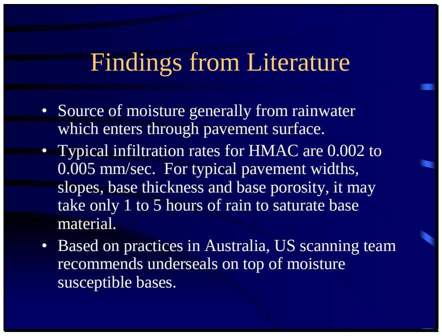
- Researchers isolated pavement sections to measure rainfall amounts.
- Infiltrated rainfall was recovered by highway edge drains and measured.
- Total rainfall for the year compared to total discharge for year showed 32 percent of water infiltrated the pavement.

Slide 15



FHWA Study on Numerous Pavement Sections

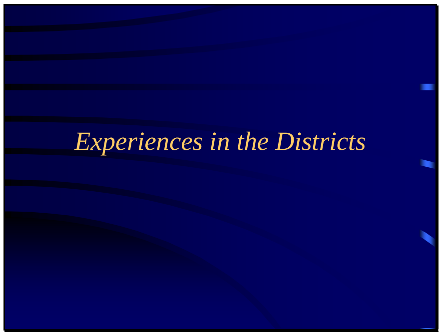
Slide 16



Findings from Literature

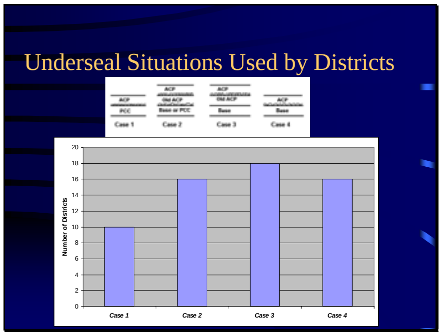
- Source of moisture generally from rainwater which enters through pavement surface.
- Typical infiltration rates for HMAC are 0.002 to 0.005 mm/sec. For typical pavement widths, slopes, base thickness and base porosity, it may take only 1 to 5 hours of rain to saturate base material.
- Based on practices in Australia, US scanning team recommends underseals on top of moisture susceptible bases.

Slide 17



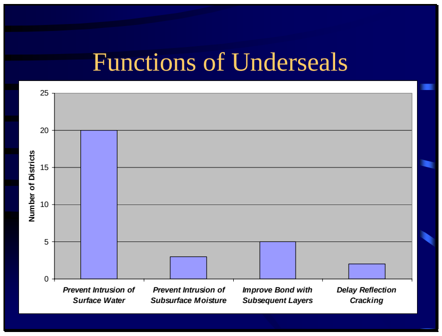
Experiences in the Districts

Slide 18



Underseal Situations Used by Districts

Slide 19



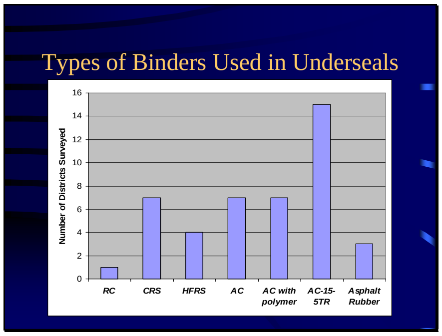
Functions of Underseals

Slide 20

Secondary functions of an underseal:

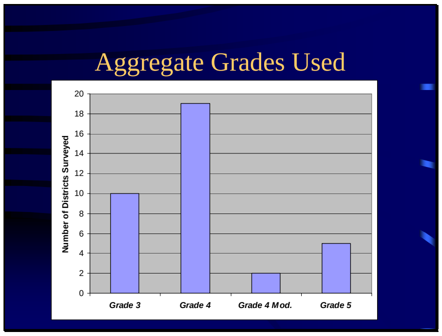
- Retard crack propagation.
- Provide temporary wearing course to accommodate construction phasing.
- Improves bond between existing pavement or base and new ACP overlay.

Slide 21



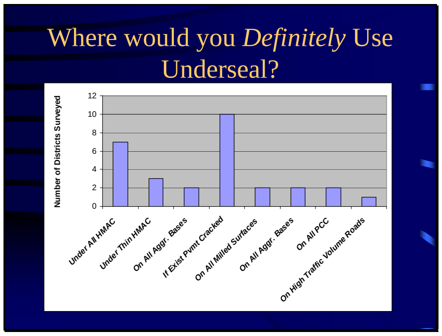
Types of Binders Used in Underseals

Slide 22



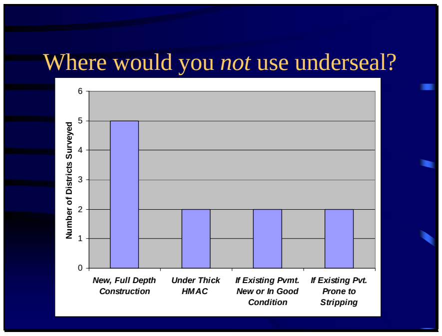
Aggregate Grades Used

Slide 23



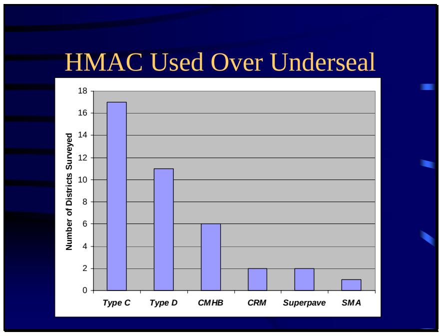
Where would you *Definitely* Use Underseal?

Slide 24



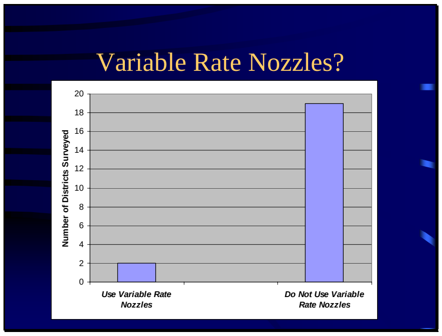
Where would you *not* use underseal?

Slide 25



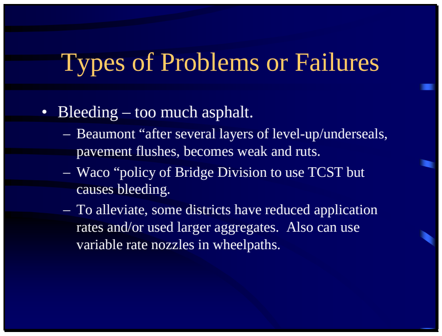
HMAC Used Over Underseal

Slide 26



Variable Rate Nozzles?

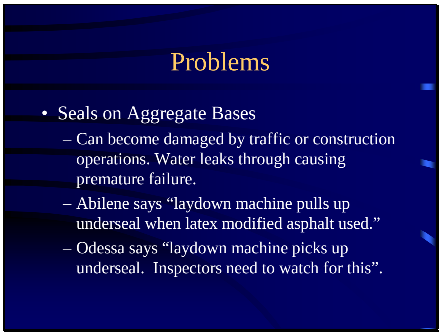
Slide 27



Types of Problems or Failures

- Bleeding – too much asphalt.
  - Beaumont “after several layers of level-up/underseals, pavement flushes, becomes weak and ruts.
  - Waco “policy of Bridge Division to use TCST but causes bleeding.
  - To alleviate, some districts have reduced application rates and/or used larger aggregates. Also can use variable rate nozzles in wheelpaths.

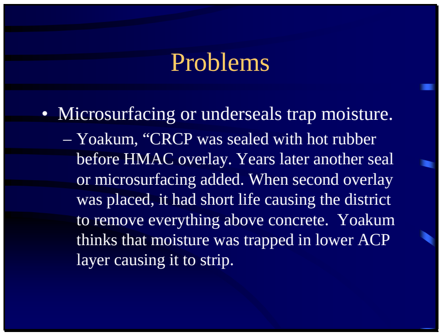
Slide 28



Problems

- Seals on Aggregate Bases
  - – Can become damaged by traffic or construction operations. Water leaks through causing premature failure.
  - – Abilene says “laydown machine pulls up underseal when latex modified asphalt used.”
  - – Odessa says “laydown machine picks up underseal. Inspectors need to watch for this”.

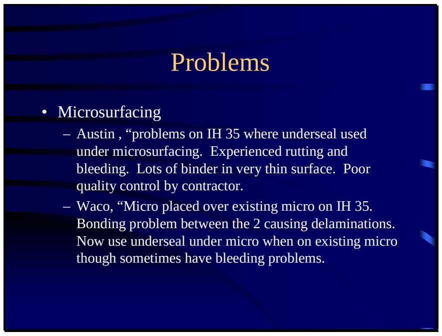
Slide 29



Problems

- Microsurfacing or underseals trap moisture.
  - – Yoakum, “CRCP was sealed with hot rubber before HMAC overlay. Years later another seal or microsurfacing added. When second overlay was placed, it had short life causing the district to remove everything above concrete. Yoakum thinks that moisture was trapped in lower ACP layer causing it to strip.

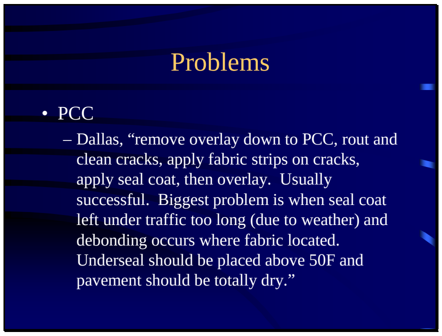
Slide 30



Problems

- Microsurfacing
  - – Austin , “problems on IH 35 where underseal used under microsurfacing. Experienced rutting and bleeding. Lots of binder in very thin surface. Poor quality control by contractor.
  - – Waco, “Micro placed over existing micro on IH 35. Bonding problem between the 2 causing delaminations. Now use underseal under micro when on existing micro though sometimes have bleeding problems.

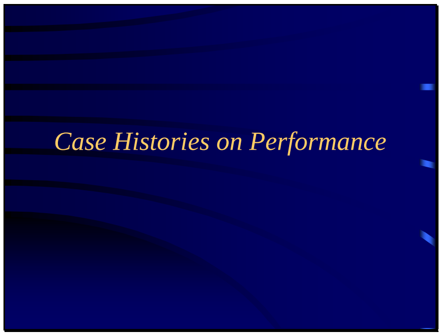
Slide 31



Problems

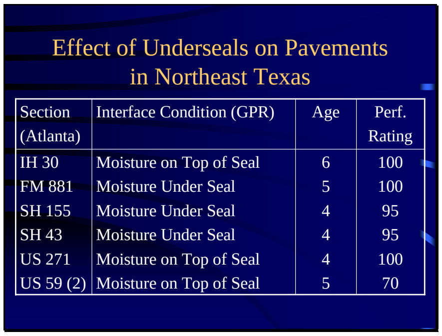
- PCC
  - Dallas, "remove overlay down to PCC, rout and clean cracks, apply fabric strips on cracks, apply seal coat, then overlay. Usually successful. Biggest problem is when seal coat left under traffic too long (due to weather) and debonding occurs where fabric located. Underseal should be placed above 50F and pavement should be totally dry."

Slide 32



Case Histories on Performance

Slide 33



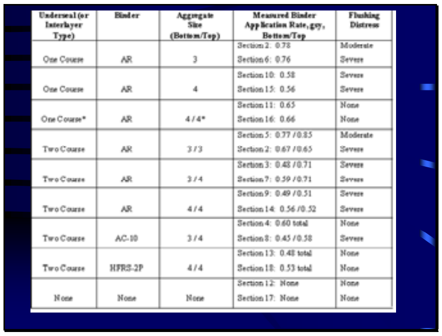
Effect of Underseals on Pavements in Northeast Texas

Section (Atlanta)	Interface Condition (GPR)	Age	Perf. Rating
IH 30	Moisture on Top of Seal	6	100
FM 881	Moisture Under Seal	5	100
SH 155	Moisture Under Seal	4	95
SH 43	Moisture Under Seal	4	95
US 271	Moisture on Top of Seal	4	100
US 59 (2)	Moisture on Top of Seal	5	70

Slide 34

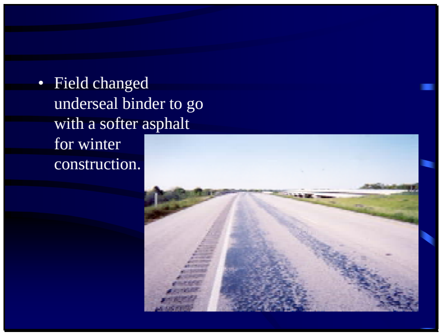
Underseal Bleeding

Slide 35



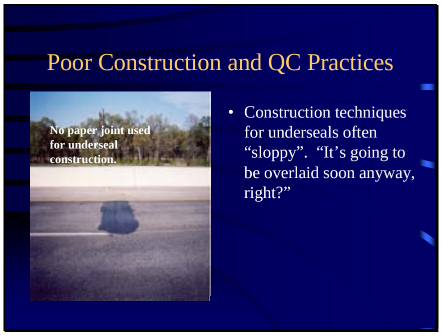
Underseal (or Interlayer Type)	Binder	Aggregate Size (Bottom/Top)	Measured Binder Application Rate, gsy, Bottom/Top	Flushing Distress
One Course	AR	3	Section 2: 0.78 Section 6: 0.76	Moderate Severe
One Course	AR	4	Section 10: 0.58 Section 15: 0.56	Severe Severe
One Course*	AR	4 / 4*	Section 11: 0.65 Section 16: 0.66	None None
Two Course	AR	3 / 3	Section 5: 0.77 / 0.85 Section 2: 0.67 / 0.65	Moderate Severe
Two Course	AR	3 / 4	Section 3: 0.48 / 0.71 Section 7: 0.59 / 0.71	Severe Severe
Two Course	AR	4 / 4	Section 9: 0.49 / 0.51 Section 14: 0.56 / 0.52	Severe Severe
Two Course	AC-10	3 / 4	Section 4: 0.60 total Section 8: 0.45 / 0.58	None Severe
Two Course	HFRS-2P	4 / 4	Section 13: 0.48 total Section 18: 0.53 total	None None
None	None	None	Section 12: None Section 17: None	None None

Slide 36



- Field changed underseal binder to go with a softer asphalt for winter construction.

Slide 37



Poor Construction and QC Practices

No paper joint used for underseal construction.

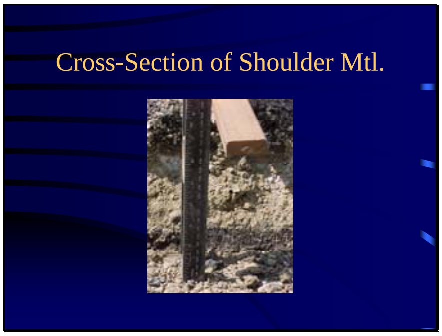
- Construction techniques for underseals often “sloppy”. “It’s going to be overlaid soon anyway, right?”

Slide 38

SH 7 - Type C/Surf. Trt./Stab. Base

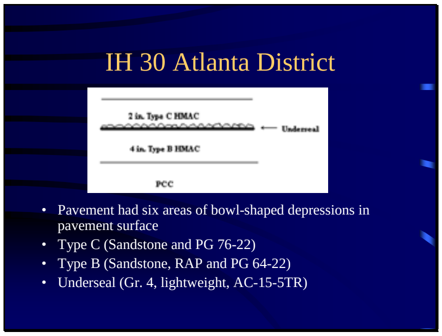
- FWD data indicated that existing stabilized base was strong in both lanes.
- GPR data indicated irregularities just below hot mix.
- Maintenance personnel said there were problems with seal coat - patching occurred just prior to laydown operation.
- Seal coat may not have covered full width.

Slide 39



Cross-Section of Shoulder Mtl.

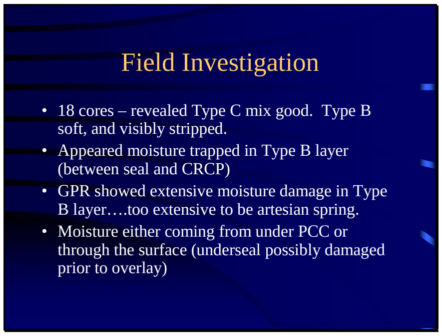
Slide 40



IH 30 Atlanta District

- Pavement had six areas of bowl-shaped depressions in pavement surface
- Type C (Sandstone and PG 76-22)
- Type B (Sandstone, RAP and PG 64-22)
- Underseal (Gr. 4, lightweight, AC-15-5TR)

Slide 41



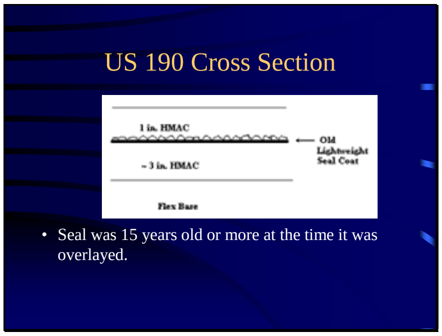
Field Investigation

- 18 cores – revealed Type C mix good. Type B soft, and visibly stripped.
- Appeared moisture trapped in Type B layer (between seal and CRCP)
- GPR showed extensive moisture damage in Type B layer….too extensive to be artesian spring.
- Moisture either coming from under PCC or through the surface (underseal possibly damaged prior to overlay)

Slide 42

US 190 San Saba

Slide 43



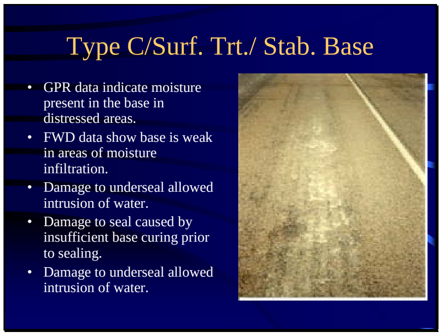
US 190 Cross Section

- Seal was 15 years old or more at the time it was overlayed.

Slide 44

Field Investigation

Slide 45



Type C/Surf. Trt./ Stab. Base

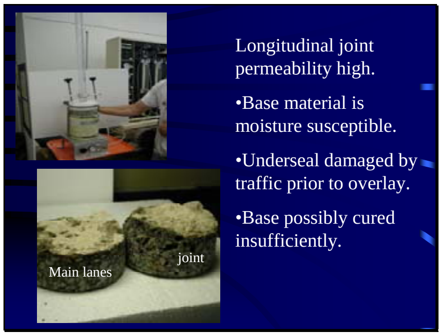
- GPR data indicate moisture present in the base in distressed areas.
- FWD data show base is weak in areas of moisture infiltration.
- Damage to underseal allowed intrusion of water.
- Damage to seal caused by insufficient base curing prior to sealing.
- Damage to underseal allowed intrusion of water.

Slide 46

Slide 47

HMAC/Surf. Trt./ Stab. Base/ Flex Base

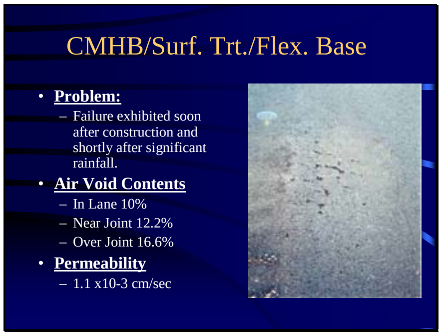
Slide 48



Longitudinal joint permeability high.

- Base material is moisture susceptible.
- Underseal damaged by traffic prior to overlay.
- Base possibly cured insufficiently.

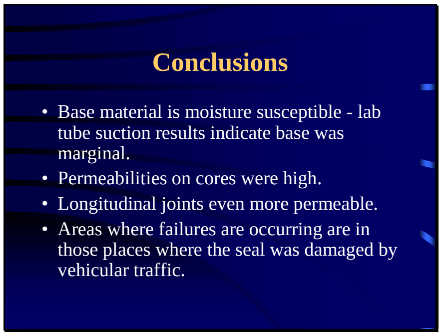
Slide 49



CMHB/Surf. Trt./Flex. Base

- **Problem:**
  - Failure exhibited soon after construction and shortly after significant rainfall.
- **Air Void Contents**
  - In Lane 10%
  - Near Joint 12.2%
  - Over Joint 16.6%
- **Permeability**
  - 1.1 x10-3 cm/sec

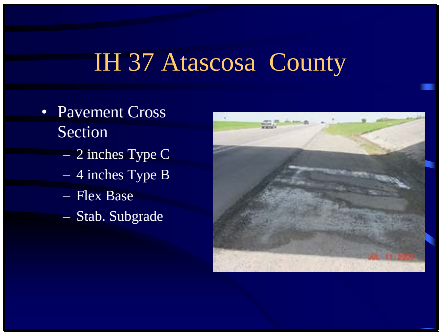
Slide 50



Conclusions

- Base material is moisture susceptible - lab tube suction results indicate base was marginal.
- Permeabilities on cores were high.
- Longitudinal joints even more permeable.
- Areas where failures are occurring are in those places where the seal was damaged by vehicular traffic.

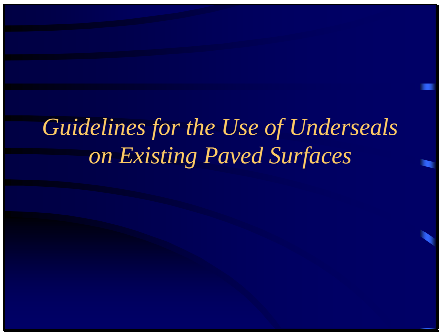
Slide 51



IH 37 Atascosa County

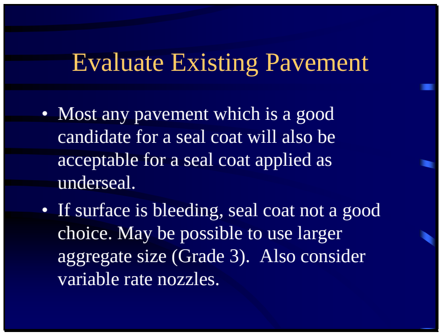
- Pavement Cross Section
  - 2 inches Type C
  - 4 inches Type B
  - Flex Base
  - Stab. Subgrade

Slide 52



Guidelines for the Use of Underseals on Existing Paved Surfaces

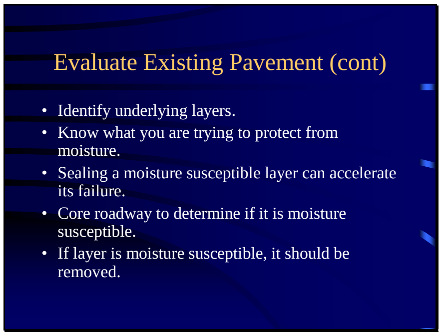
Slide 53



Evaluate Existing Pavement

- Most any pavement which is a good candidate for a seal coat will also be acceptable for a seal coat applied as underseal.
- If surface is bleeding, seal coat not a good choice. May be possible to use larger aggregate size (Grade 3). Also consider variable rate nozzles.

Slide 54



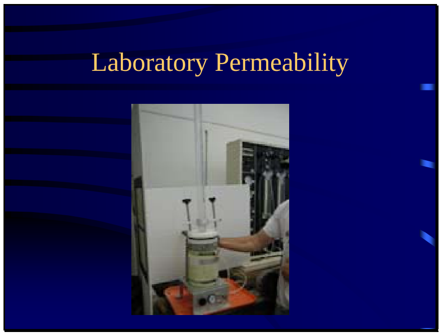
Evaluate Existing Pavement (cont)

- Identify underlying layers.
- Know what you are trying to protect from moisture.
- Sealing a moisture susceptible layer can accelerate its failure.
- Core roadway to determine if it is moisture susceptible.
- If layer is moisture susceptible, it should be removed.

Slide 55

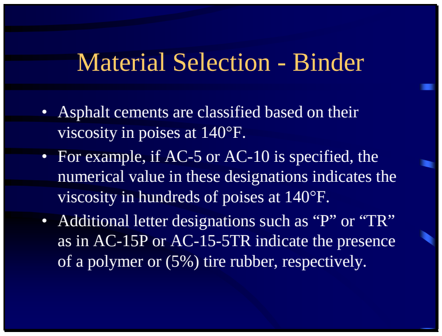
Hamburg Wheel Tracking Test

Slide 56



Laboratory Permeability

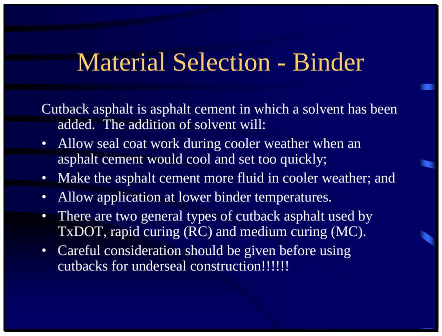
Slide 57



Material Selection - Binder

- Asphalt cements are classified based on their viscosity in poises at 140°F.
- For example, if AC-5 or AC-10 is specified, the numerical value in these designations indicates the viscosity in hundreds of poises at 140°F.
- Additional letter designations such as “P” or “TR” as in AC-15P or AC-15-5TR indicate the presence of a polymer or (5%) tire rubber, respectively.

Slide 58

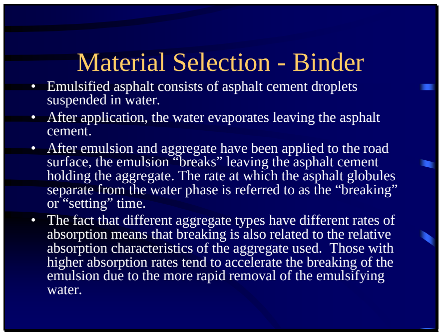


Material Selection - Binder

Cutback asphalt is asphalt cement in which a solvent has been added. The addition of solvent will:

- Allow seal coat work during cooler weather when an asphalt cement would cool and set too quickly;
- Make the asphalt cement more fluid in cooler weather; and
- Allow application at lower binder temperatures.
- There are two general types of cutback asphalt used by TxDOT, rapid curing (RC) and medium curing (MC).
- Careful consideration should be given before using cutbacks for underseal construction!!!!!!

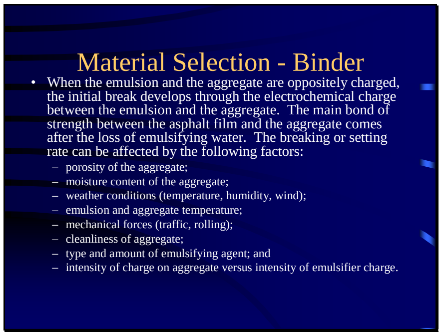
Slide 59



Material Selection - Binder

- Emulsified asphalt consists of asphalt cement droplets suspended in water.
- After application, the water evaporates leaving the asphalt cement.
- After emulsion and aggregate have been applied to the road surface, the emulsion “breaks” leaving the asphalt cement holding the aggregate. The rate at which the asphalt globules separate from the water phase is referred to as the “breaking” or “setting” time.
- The fact that different aggregate types have different rates of absorption means that breaking is also related to the relative absorption characteristics of the aggregate used. Those with higher absorption rates tend to accelerate the breaking of the emulsion due to the more rapid removal of the emulsifying water.

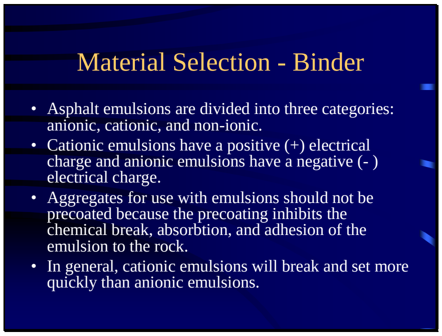
Slide 60



Material Selection - Binder

- When the emulsion and the aggregate are oppositely charged, the initial break develops through the electrochemical charge between the emulsion and the aggregate. The main bond of strength between the asphalt film and the aggregate comes after the loss of emulsifying water. The breaking or setting rate can be affected by the following factors:
  - porosity of the aggregate;
  - moisture content of the aggregate;
  - weather conditions (temperature, humidity, wind);
  - emulsion and aggregate temperature;
  - mechanical forces (traffic, rolling);
  - cleanliness of aggregate;
  - type and amount of emulsifying agent; and
  - intensity of charge on aggregate versus intensity of emulsifier charge.

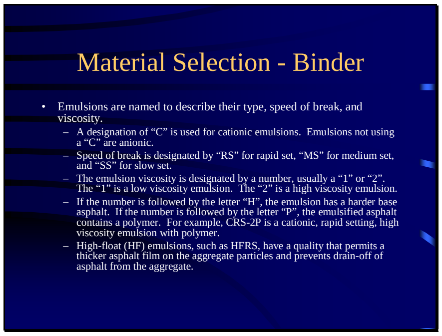
Slide 61



Material Selection - Binder

- Asphalt emulsions are divided into three categories: anionic, cationic, and non-ionic.
- Cationic emulsions have a positive (+) electrical charge and anionic emulsions have a negative (-) electrical charge.
- Aggregates for use with emulsions should not be precoated because the precoating inhibits the chemical break, absorbtion, and adhesion of the emulsion to the rock.
- In general, cationic emulsions will break and set more quickly than anionic emulsions.

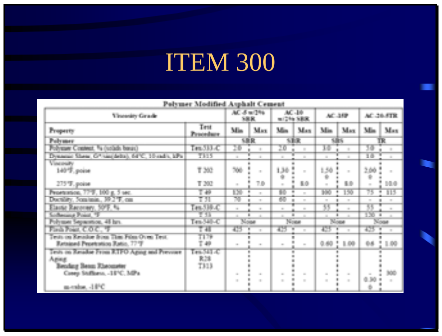
Slide 62



Material Selection - Binder

- Emulsions are named to describe their type, speed of break, and viscosity.
  - A designation of “C” is used for cationic emulsions. Emulsions not using a “C” are anionic.
  - Speed of break is designated by “RS” for rapid set, “MS” for medium set, and “SS” for slow set.
  - The emulsion viscosity is designated by a number, usually a “1” or “2”. The “1” is a low viscosity emulsion. The “2” is a high viscosity emulsion.
  - If the number is followed by the letter “H”, the emulsion has a harder base asphalt. If the number is followed by the letter “P”, the emulsified asphalt contains a polymer. For example, CRS-2P is a cationic, rapid setting, high viscosity emulsion with polymer.
  - High-float (HF) emulsions, such as HFRS, have a quality that permits a thicker asphalt film on the aggregate particles and prevents drain-off of asphalt from the aggregate.

Slide 63

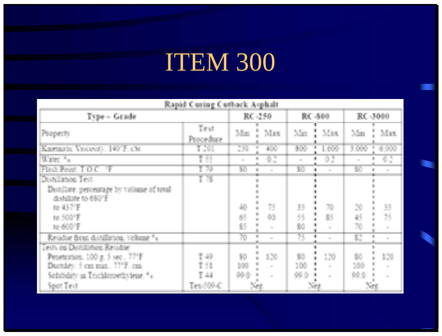


ITEM 300

Polymer Modified Asphalt Cement

Viscosity Grade		AC-5 w/2% SBR		AC-10 w/2% SBR		AC-15P		AC-20-5TR	
Property	**Test Procedure**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Polymer		SBR		SBR		SBS		TR	
Polymer Content, % (solids basis)	Tex-533-C	2.0	-	2.0	-	3.0	-	3.0	-
Dynamic Shear, G*/sin(delta), 64°C, 10 rad/s, kPa	T315	-	-	-	-	-	-	1.0	-
Viscosity 140°F, poise	T 202	700	-	1,300	-	1,500	-	2,000	-
275°F, poise	T 202	-	7.0	-	8.0	-	8.0	-	10.0
Penetration, 77°F, 100 g, 5 sec.	T 49	120	-	80	-	100	150	75	115
Ductility, 5cm/min., 39.2°F, cm	T 51	70	-	60	-	-	-	-	-
Elastic Recovery, 50°F, %	Tex-539-C	-	-	-	-	55	-	55	-
Softening Point, °F	T 53	-	-	-	-	-	-	120	-
Polymer Separation, 48 hrs.	Tex-540-C	None		None		None		None	
Flash Point, C.O.C., °F	T 48	425	-	425	-	425	-	425	-
Tests on Residue from Thin Film Oven Test: Retained Penetration Ratio, 77°F	T179 T 49	-	-	-	-	0.60	1.00	0.6	1.00
Tests on Residue From RTFO Aging and Pressure Aging Bending Beam Rheometer	Tex-541-C R28 T313								
Creep Stiffness, -18°C, MPa		-	-	-	-	-	-	-	300
m-value, -18°C		-	-	-	-	-	-	0.300	-

Slide 64

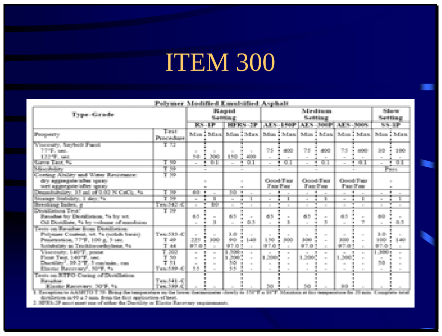


ITEM 300

Rapid Curing Cutback Asphalt

Type – Grade		**RC-250**		**RC-800**		**RC-3000**	
Property	Test Procedure	Min	Max	Min	Max	Min	Max
Kinematic Viscosity, 140°F, cSt	T 201	250	400	800	1,600	3,000	6,000
Water, %	T 55	-	0.2	-	0.2	-	0.2
Flash Point, T.O.C., °F	T 79	80	-	80	-	80	-
Distillation Test:	T 78						
Distillate, percentage by volume of total distillate to 680°F							
to 437°F		40	75	35	70	20	55
to 500°F		65	90	55	85	45	75
to 600°F		85	-	80	-	70	-
Residue from distillation, volume %		70	-	75	-	82	-
Tests on Distillation Residue:							
Penetration, 100 g, 5 sec., 77°F	T 49	80	120	80	120	80	120
Ductility, 5 cm min., 77°F, cm	T 51	100	-	100	-	100	-
Solubility in Trichloroethylene, %	T 44	99.0	-	99.0	-	99.0	-
Spot Test	Tex-509-C	Neg.		Neg.		Neg.	

Slide 65



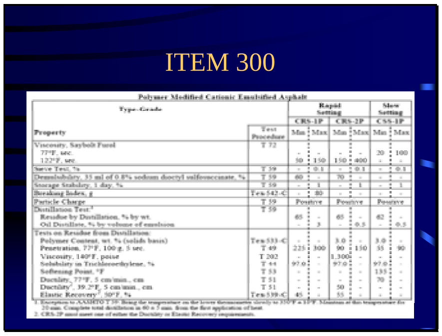
ITEM 300

Polymer Modified Emulsified Asphalt

Type–Grade		**Rapid Setting**				**Medium Setting**						**Slow Setting**	
		RS-1P		**HFRS-2P**		**AES-150P**		**AES-300P**		**AES-300S**		**SS-1P**	
Property	Test Procedure	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Viscosity, Saybolt Furol	T 72												
77°F, sec.		-	-	-	-	75	400	75	400	75	400	30	100
122°F, sec.		50	200	150	400	-	-	-	-	-	-	-	-
Sieve Test, %	T 59	-	0.1	-	0.1	-	0.1	-	0.1	-	0.1	-	0.1
Miscibility	T 59	-		-		-		-		-		Pass	
Coating Ability and Water Resistance:	T 59												
dry aggregate/after spray wet aggregate/after spray		- -		- -		Good/Fair Fair/Fair		Good/Fair Fair/Fair		Good/Fair Fair/Fair		- -	
Demulsibility, 35 ml of 0.02 N CaCl₂, %	T 59	60	-	50	-	-	-	-	-	-	-	-	-
Storage Stability, 1 day, %	T 59	-	1	-	1	-	1	-	1	-	1	-	1
Breaking Index, g	Tex-542-C	-	80	-	-	-	-	-	-	-	-	-	-
Distillation Test:[1]	T 59												
Residue by Distillation, % by wt.		65	-	65	-	65	-	65	-	65	-	60	-
Oil Distillate, % by volume of emulsion		-	3	-	0.5	-	3	-	5	-	7	-	0.5
Tests on Residue from Distillation:													
Polymer Content, wt. % (solids basis)	Tex-533-C	-	-	3.0	-	-	-	-	-	-	-	3.0	-
Penetration, 77°F, 100 g, 5 sec.	T 49	225	300	90	140	150	300	300	-	300	-	100	140
Solubility in Trichloroethylene, %	T 44	97.0	-	97.0	-	97.0	-	97.0	-	97.0	-	97.0	-
Viscosity, 140°F, poise	T 202	-	-	1,500	-	-	-	-	-	-	-	1,300	-
Float Test, 140°F, sec.	T 50	-	-	1,200	-	1,200	-	1,200	-	1,200	-	-	-
Ductility[2], 39.2°F, 5 cm/min., cm	T 51	-	-	50	-	-	-	-	-	-	-	50	-
Elastic Recovery[2], 50°F, %	Tex-539-C	55	-	55	-	-	-	-	-	-	-	-	-
Tests on RTFO Curing of Distillation Residue:	Tex-541-C												
Elastic Recovery, 50°F, %	Tex-539-C	-	-	-	-	50	-	50	-	30	-	-	-

1. Exception to AASHTO T 59: Bring the temperature on the lower thermometer slowly to 350°F ± 10°F. Maintain at this temperature for 20 min. Complete total distillation in 60 ± 5 min. from the first application of heat.
2. HFRS-2P must meet one of either the Ductility or Elastic Recovery requirements.

Slide 66



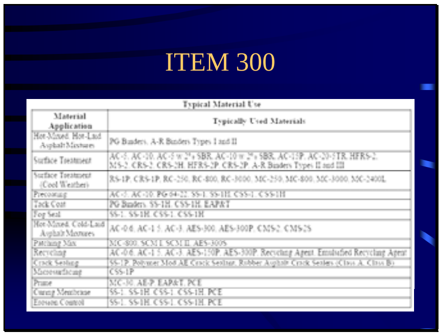
ITEM 300

Polymer Modified Cationic Emulsified Asphalt

Type–Grade		**Rapid Setting**				**Slow Setting**	
		CRS-1P		**CRS-2P**		**CSS-1P**	
Property	**Test Procedure**	Min	Max	Min	Max	Min	Max
Viscosity, Saybolt Furol	T 72						
77°F, sec.		-	-	-	-	20	100
122°F, sec.		50	150	150	400	-	-
Sieve Test, %	T 59	-	0.1	-	0.1	-	0.1
Demulsibility, 35 ml of 0.8% sodium dioctyl sulfosuccinate, %	T 59	60	-	70	-	-	-
Storage Stability, 1 day, %	T 59	-	1	-	1	-	1
Breaking Index, g	Tex-542-C	-	80	-	-	-	-
Particle Charge	T 59	Positive		Positive		Positive	
Distillation Test:[1]	T 59						
Residue by Distillation, % by wt.		65	-	65	-	62	-
Oil Distillate, % by volume of emulsion		-	3	-	0.5	-	0.5
Tests on Residue from Distillation:							
Polymer Content, wt. % (solids basis)	Tex-533-C	-	-	3.0	-	3.0	-
Penetration, 77°F, 100 g, 5 sec.	T 49	225	300	90	150	55	90
Viscosity, 140°F, poise	T 202	-	-	1,300	-	-	-
Solubility in Trichloroethylene, %	T 44	97.0	-	97.0	-	97.0	-
Softening Point, °F	T 53	-	-	-	-	135	-
Ductility, 77°F, 5 cm/min., cm	T 51	-	-	-	-	70	-
Ductility[2], 39.2°F, 5 cm/min., cm	T 51	-	-	50	-	-	-
Elastic Recovery[2], 50°F, %	Tex-539-C	45	-	55	-	-	-

1. Exception to AASHTO T 59: Bring the temperature on the lower thermometer slowly to 350°F ± 10°F. Maintain at this temperature for 20 min. Complete total distillation in 60 ± 5 min. from the first application of heat.
2. CRS-2P must meet one of either the Ductility or Elastic Recovery requirements.

Slide 67



ITEM 300

Typical Material Use

Material Application	**Typically Used Materials**
Hot-Mixed, Hot-Laid Asphalt Mixtures	PG Binders, A-R Binders Types I and II
Surface Treatment	AC-5, AC-10, AC-5 w/2% SBR, AC-10 w/2% SBR, AC-15P, AC-20-5TR, HFRS-2, MS-2, CRS-2, CRS-2H, HFRS-2P, CRS-2P, A-R Binders Types II and III
Surface Treatment (Cool Weather)	RS-1P, CRS-1P, RC-250, RC-800, RC-3000, MC-250, MC-800, MC-3000, MC-2400L
Precoating	AC-5, AC-10, PG 64-22, SS-1, SS-1H, CSS-1, CSS-1H
Tack Coat	PG Binders, SS-1H, CSS-1H, EAP&T
Fog Seal	SS-1, SS-1H, CSS-1, CSS-1H
Hot-Mixed, Cold-Laid Asphalt Mixtures	AC-0.6, AC-1.5, AC-3, AES-300, AES-300P, CMS-2, CMS-2S
Patching Mix	MC-800, SCM I, SCM II, AES-300S
Recycling	AC-0.6, AC-1.5, AC-3, AES-150P, AES-300P, Recycling Agent, Emulsified Recycling Agent
Crack Sealing	SS-1P, Polymer Mod AE Crack Sealant, Rubber Asphalt Crack Sealer (Class A, Class B)
Microsurfacing	CSS-1P
Prime	MC-30, AE-P, EAP&T, PCE
Curing Membrane	SS-1, SS-1H, CSS-1, CSS-1H, PCE
Erosion Control	SS-1, SS-1H, CSS-1, CSS-1H, PCE

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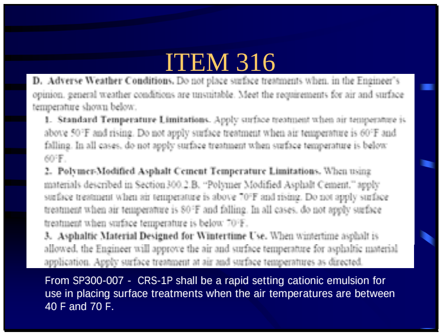

ITEM 316

D. Adverse Weather Conditions. Do not place surface treatments when, in the Engineer's opinion, general weather conditions are unsuitable. Meet the requirements for air and surface temperature shown below.

1. **Standard Temperature Limitations.** Apply surface treatment when air temperature is above 50°F and rising. Do not apply surface treatment when air temperature is 60°F and falling. In all cases, do not apply surface treatment when surface temperature is below 60°F.
2. **Polymer-Modified Asphalt Cement Temperature Limitations.** When using materials described in Section 300.2.B, "Polymer Modified Asphalt Cement," apply surface treatment when air temperature is above 70°F and rising. Do not apply surface treatment when air temperature is 80°F and falling. In all cases, do not apply surface treatment when surface temperature is below 70°F.
3. **Asphaltic Material Designed for Wintertime Use.** When wintertime asphalt is allowed, the Engineer will approve the air and surface temperature for asphaltic material application. Apply surface treatment at air and surface temperatures as directed.

From SP300-007 - CRS-1P shall be a rapid setting cationic emulsion for use in placing surface treatments when the air temperatures are between 40 F and 70 F.

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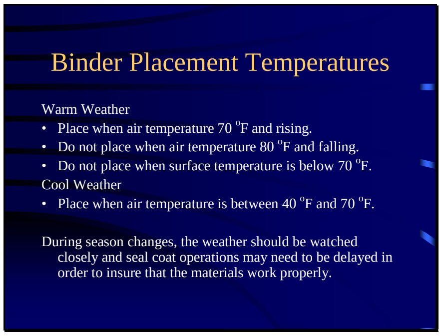

Binder Placement Temperatures

Warm Weather
- Place when air temperature 70 ^{o}F and rising.
- Do not place when air temperature 80 ^{o}F and falling.
- Do not place when surface temperature is below 70 ^{o}F.

Cool Weather
- Place when air temperature is between 40 ^{o}F and 70 ^{o}F.

During season changes, the weather should be watched closely and seal coat operations may need to be delayed in order to insure that the materials work properly.

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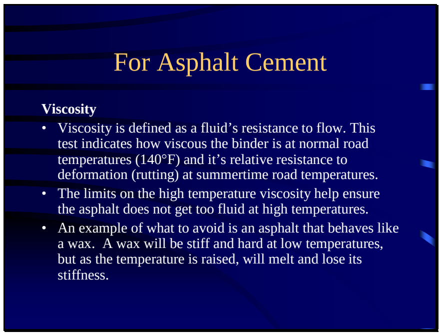

For Asphalt Cement

Viscosity

- Viscosity is defined as a fluid's resistance to flow. This test indicates how viscous the binder is at normal road temperatures (140°F) and it's relative resistance to deformation (rutting) at summertime road temperatures.
- The limits on the high temperature viscosity help ensure the asphalt does not get too fluid at high temperatures.
- An example of what to avoid is an asphalt that behaves like a wax. A wax will be stiff and hard at low temperatures, but as the temperature is raised, will melt and lose its stiffness.

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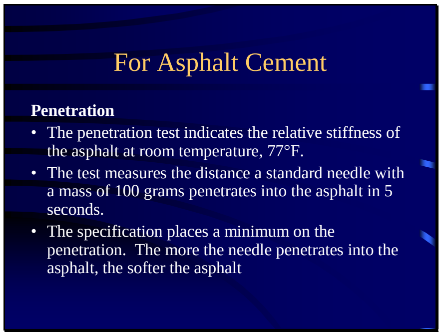

For Asphalt Cement

Penetration

- The penetration test indicates the relative stiffness of the asphalt at room temperature, 77°F.
- The test measures the distance a standard needle with a mass of 100 grams penetrates into the asphalt in 5 seconds.
- The specification places a minimum on the penetration. The more the needle penetrates into the asphalt, the softer the asphalt

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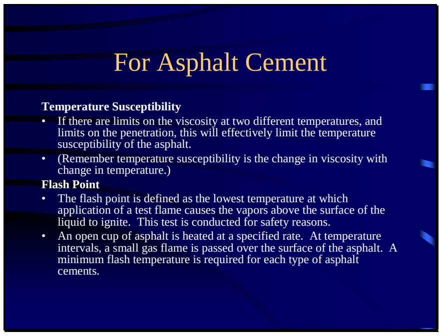

For Asphalt Cement

Temperature Susceptibility

- If there are limits on the viscosity at two different temperatures, and limits on the penetration, this will effectively limit the temperature susceptibility of the asphalt.
- (Remember temperature susceptibility is the change in viscosity with change in temperature.)

Flash Point

- The flash point is defined as the lowest temperature at which application of a test flame causes the vapors above the surface of the liquid to ignite. This test is conducted for safety reasons.
- An open cup of asphalt is heated at a specified rate. At temperature intervals, a small gas flame is passed over the surface of the asphalt. A minimum flash temperature is required for each type of asphalt cements.

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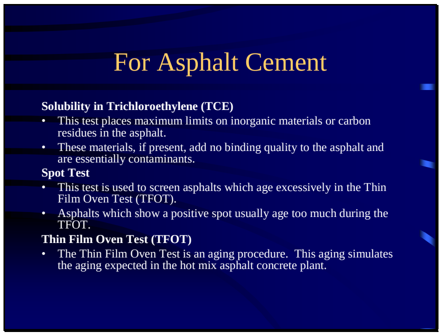

For Asphalt Cement

Solubility in Trichloroethylene (TCE)

- This test places maximum limits on inorganic materials or carbon residues in the asphalt.
- These materials, if present, add no binding quality to the asphalt and are essentially contaminants.

Spot Test

- This test is used to screen asphalts which age excessively in the Thin Film Oven Test (TFOT).
- Asphalts which show a positive spot usually age too much during the TFOT.

Thin Film Oven Test (TFOT)

- The Thin Film Oven Test is an aging procedure. This aging simulates the aging expected in the hot mix asphalt concrete plant.

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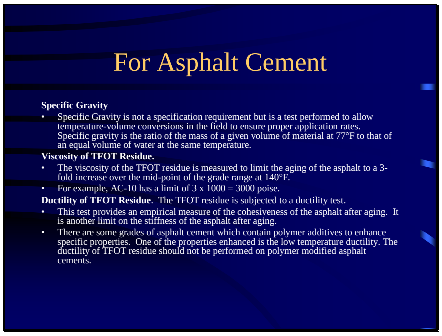

For Asphalt Cement

Specific Gravity

- Specific Gravity is not a specification requirement but is a test performed to allow temperature-volume conversions in the field to ensure proper application rates. Specific gravity is the ratio of the mass of a given volume of material at 77°F to that of an equal volume of water at the same temperature.

Viscosity of TFOT Residue.

- The viscosity of the TFOT residue is measured to limit the aging of the asphalt to a 3-fold increase over the mid-point of the grade range at 140°F.
- For example, AC-10 has a limit of 3 x 1000 = 3000 poise.

Ductility of TFOT Residue. The TFOT residue is subjected to a ductility test.

- This test provides an empirical measure of the cohesiveness of the asphalt after aging. It is another limit on the stiffness of the asphalt after aging.
- There are some grades of asphalt cement which contain polymer additives to enhance specific properties. One of the properties enhanced is the low temperature ductility. The ductility of TFOT residue should not be performed on polymer modified asphalt cements.

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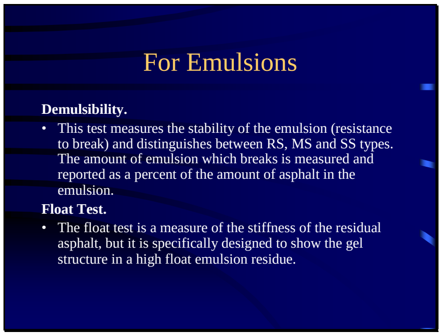

For Emulsions

Demulsibility.

- This test measures the stability of the emulsion (resistance to break) and distinguishes between RS, MS and SS types. The amount of emulsion which breaks is measured and reported as a percent of the amount of asphalt in the emulsion.

Float Test.

- The float test is a measure of the stiffness of the residual asphalt, but it is specifically designed to show the gel structure in a high float emulsion residue.

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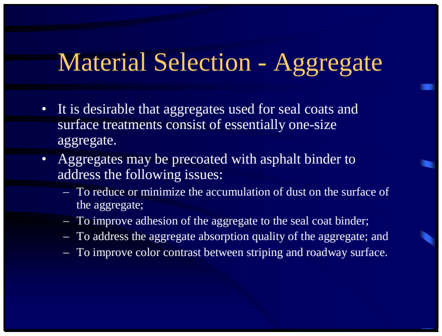

Material Selection - Aggregate

- It is desirable that aggregates used for seal coats and surface treatments consist of essentially one-size aggregate.
- Aggregates may be precoated with asphalt binder to address the following issues:
  - To reduce or minimize the accumulation of dust on the surface of the aggregate;
  - To improve adhesion of the aggregate to the seal coat binder;
  - To address the aggregate absorption quality of the aggregate; and
  - To improve color contrast between striping and roadway surface.

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Use of Underseals on Compacted Bases

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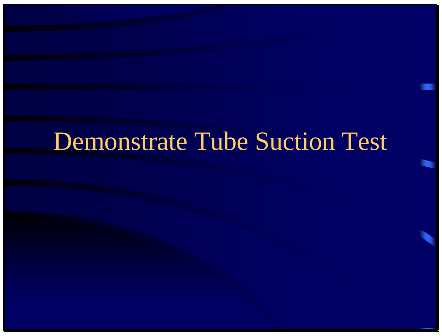

Demonstrate Tube Suction Test

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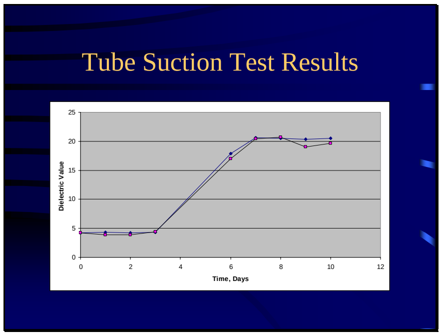

Tube Suction Test Results

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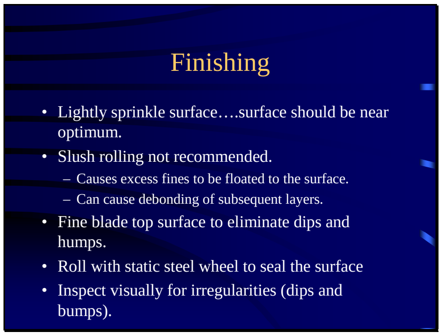

Finishing

- Lightly sprinkle surface….surface should be near optimum.
- Slush rolling not recommended.
  - Causes excess fines to be floated to the surface.
  - Can cause debonding of subsequent layers.
- Fine blade top surface to eliminate dips and humps.
- Roll with static steel wheel to seal the surface
- Inspect visually for irregularities (dips and bumps).

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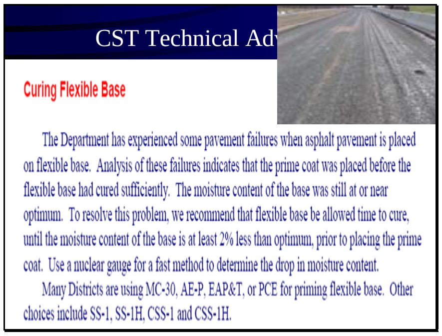

CST Technical Adv

Curing Flexible Base

The Department has experienced some pavement failures when asphalt pavement is placed on flexible base. Analysis of these failures indicates that the prime coat was placed before the flexible base had cured sufficiently. The moisture content of the base was still at or near optimum. To resolve this problem, we recommend that flexible base be allowed time to cure, until the moisture content of the base is at least 2% less than optimum, prior to placing the prime coat. Use a nuclear gauge for a fast method to determine the drop in moisture content.

Many Districts are using MC-30, AE-P, EAP&T, or PCE for priming flexible base. Other choices include SS-1, SS-1H, CSS-1 and CSS-1H.

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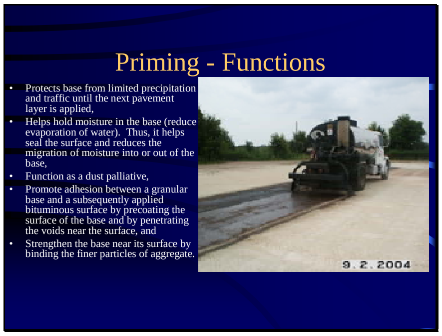

Priming - Functions

- Protects base from limited precipitation and traffic until the next pavement layer is applied,
- Helps hold moisture in the base (reduce evaporation of water). Thus, it helps seal the surface and reduces the migration of moisture into or out of the base,
- Function as a dust palliative,
- Promote adhesion between a granular base and a subsequently applied bituminous surface by precoating the surface of the base and by penetrating the voids near the surface, and
- Strengthen the base near its surface by binding the finer particles of aggregate.

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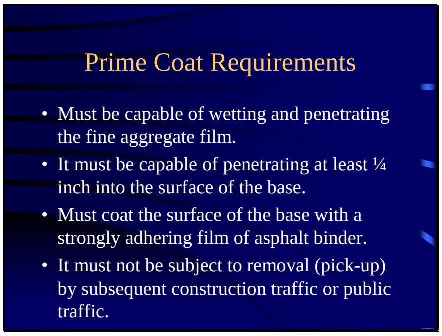

Prime Coat Requirements

- Must be capable of wetting and penetrating the fine aggregate film.
- It must be capable of penetrating at least ¼ inch into the surface of the base.
- Must coat the surface of the base with a strongly adhering film of asphalt binder.
- It must not be subject to removal (pick-up) by subsequent construction traffic or public traffic.

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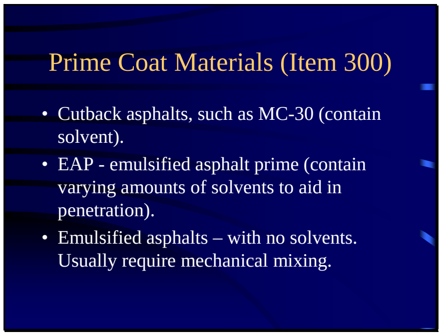

Prime Coat Materials (Item 300)

- Cutback asphalts, such as MC-30 (contain solvent).
- EAP - emulsified asphalt prime (contain varying amounts of solvents to aid in penetration).
- Emulsified asphalts – with no solvents. Usually require mechanical mixing.

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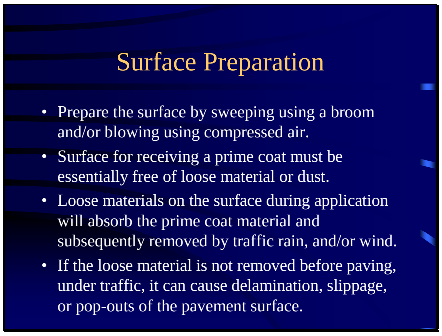

Surface Preparation

- Prepare the surface by sweeping using a broom and/or blowing using compressed air.
- Surface for receiving a prime coat must be essentially free of loose material or dust.
- Loose materials on the surface during application will absorb the prime coat material and subsequently removed by traffic rain, and/or wind.
- If the loose material is not removed before paving, under traffic, it can cause delamination, slippage, or pop-outs of the pavement surface.

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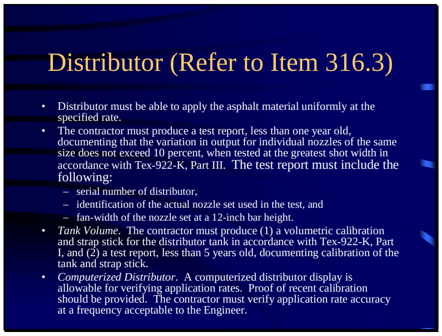

Distributor (Refer to Item 316.3)

- Distributor must be able to apply the asphalt material uniformly at the specified rate.
- The contractor must produce a test report, less than one year old, documenting that the variation in output for individual nozzles of the same size does not exceed 10 percent, when tested at the greatest shot width in accordance with Tex-922-K, Part III. The test report must include the following:
  - serial number of distributor,
  - identification of the actual nozzle set used in the test, and
  - fan-width of the nozzle set at a 12-inch bar height.
- *Tank Volume.* The contractor must produce (1) a volumetric calibration and strap stick for the distributor tank in accordance with Tex-922-K, Part I, and (2) a test report, less than 5 years old, documenting calibration of the tank and strap stick.
- *Computerized Distributor.* A computerized distributor display is allowable for verifying application rates. Proof of recent calibration should be provided. The contractor must verify application rate accuracy at a frequency acceptable to the Engineer.

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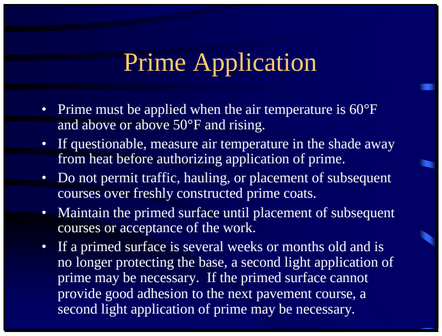

Prime Application

- Prime must be applied when the air temperature is 60°F and above or above 50°F and rising.
- If questionable, measure air temperature in the shade away from heat before authorizing application of prime.
- Do not permit traffic, hauling, or placement of subsequent courses over freshly constructed prime coats.
- Maintain the primed surface until placement of subsequent courses or acceptance of the work.
- If a primed surface is several weeks or months old and is no longer protecting the base, a second light application of prime may be necessary. If the primed surface cannot provide good adhesion to the next pavement course, a second light application of prime may be necessary.

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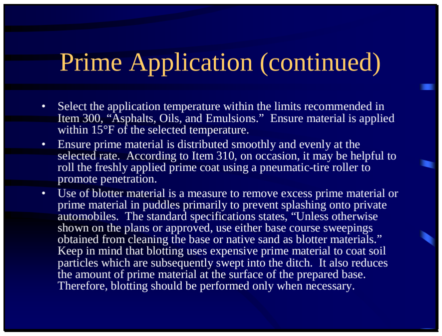

Prime Application (continued)

- Select the application temperature within the limits recommended in Item 300, “Asphalts, Oils, and Emulsions.” Ensure material is applied within 15°F of the selected temperature.
- Ensure prime material is distributed smoothly and evenly at the selected rate. According to Item 310, on occasion, it may be helpful to roll the freshly applied prime coat using a pneumatic-tire roller to promote penetration.
- Use of blotter material is a measure to remove excess prime material or prime material in puddles primarily to prevent splashing onto private automobiles. The standard specifications states, “Unless otherwise shown on the plans or approved, use either base course sweepings obtained from cleaning the base or native sand as blotter materials.” Keep in mind that blotting uses expensive prime material to coat soil particles which are subsequently swept into the ditch. It also reduces the amount of prime material at the surface of the prepared base. Therefore, blotting should be performed only when necessary.

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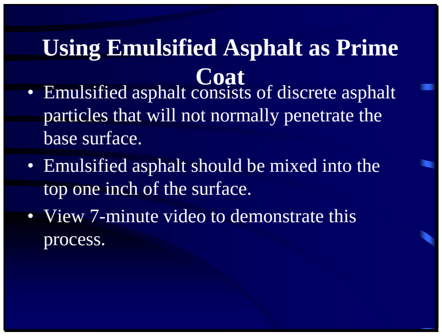

Using Emulsified Asphalt as Prime Coat

- Emulsified asphalt consists of discrete asphalt particles that will not normally penetrate the base surface.
- Emulsified asphalt should be mixed into the top one inch of the surface.
- View 7-minute video to demonstrate this process.

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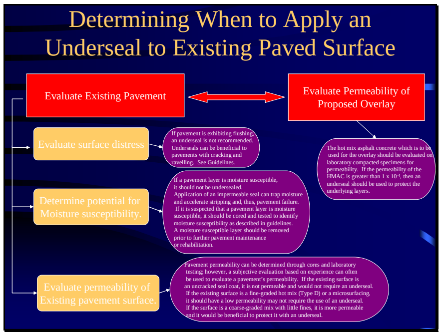

Determining When to Apply an Underseal to Existing Paved Surface

Evaluate Existing Pavement

Evaluate Permeability of Proposed Overlay

Evaluate surface distress

If pavement is exhibiting flushing, an underseal is not recommended. Underseals can be beneficial to pavements with cracking and ravelling. See Guidelines.

The hot mix asphalt concrete which is to be used for the overlay should be evaluated on laboratory compacted specimens for permeability. If the permeability of the HMAC is greater than 1 x 10^{-4}, then an underseal should be used to protect the underlying layers.

Determine potential for Moisture susceptibility.

If a pavement layer is moisture susceptible, it should not be undersealed. Application of an impermeable seal can trap moisture and accelerate stripping and, thus, pavement failure. If it is suspected that a pavement layer is moisture susceptible, it should be cored and tested to identify moisture susceptibility as described in guidelines. A moisture susceptible layer should be removed prior to further pavement maintenance or rehabilitation.

Evaluate permeability of Existing pavement surface.

Pavement permeability can be determined through cores and laboratory testing; however, a subjective evaluation based on experience can often be used to evaluate a pavement’s permeability. If the existing surface is an uncracked seal coat, it is not permeable and would not require an underseal. If the existing surface is a fine-graded hot mix (Type D) or a microsurfacing, it should have a low permeability may not require the use of an underseal. If the surface is a coarse-graded mix with little fines, it is more permeable and it would be beneficial to protect it with an underseal.

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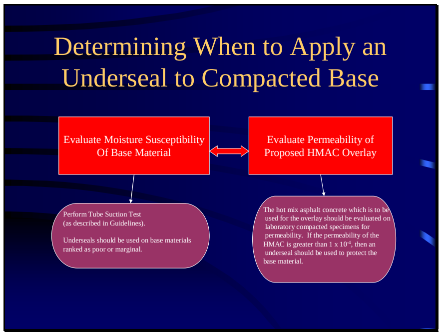

Determining When to Apply an Underseal to Compacted Base

Evaluate Moisture Susceptibility Of Base Material

Evaluate Permeability of Proposed HMAC Overlay

Perform Tube Suction Test
(as described in Guidelines).

Underseals should be used on base materials ranked as poor or marginal.

The hot mix asphalt concrete which is to be used for the overlay should be evaluated on laboratory compacted specimens for permeability. If the permeability of the HMAC is greater than 1 x 10^{-4}, then an underseal should be used to protect the base material.