ENGINEERING BULLETIN

PAVING FABRIC INTERLAYER SYSTEM AS A PAVEMENT MOISTURE BARRIER

Paving fabric interlayer systems have been used in more than 230,000 lane-kilometers (142,000 lane-miles)of pavement in the U.S. Paving fabrics are a special class of geosynthetic which provide the generally acknowledged functions of a stress absorbing interlayer and a waterproofing membrane (1). The stress related performance has been easily verified by the observed reductions of cracking in pavement overlays.The waterproofing benefit is not easily verified, yet improved overlay performance can also be attributed to a lower moisture content in a pavement base and subgrade. This Engineering Bulletin presents a compilation of studies that collectively verify and quantify the waterproofing effectiveness of the paving fabric interlayer system.

The waterproofing effectiveness of an asphalt cement saturated fabric layer has been investigated both in the laboratory and in pavements in the field. Results of the moisture barrier system testing from various laboratories are presented. Next, this document reports on field evaluations of the moisture barrier in pavements. These evaluations utilized some interesting measures including large scale pavement permeability testing and ground penetrating radar.

The general problem of water in a pavement section will be discussed including sources of water and the detrimental effects of the water. The use of proper pavement drainage to achieve significant benefits from AASHTO design drainage coefficients is discussed. However, for existing pavements retrofitting a drainage system is often not an effective rehabilitation option. It appears that pavement waterproofing may be the most practical option for solving pavement moisture problems.

The objective of this Engineering Bulletin is to provide a source of background information for persons who are unfamiliar with the use of geotextiles, commonly referred to as paving fabrics, as moisture barriers in pavements. The problem of moisture in pavements is first reviewed. This document then presents the mechanics by which moisture barriers work and provides a summary of work conducted by others in investigating their effectiveness. Also provided, is a reference list of other works, which have been used in developing the report.

The following report has undergone two peer reviews by the Transportation Research Board Committee A2K07, and was recommended by the Committee for publication as a TRB circular.

Keywords: Pavements, waterproofing, paving fabrics, geotextiles, geosynthetics

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Paving Fabric Interlayer System As A Pavement Moisture Barrier

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INTRODUCTION

Moisture is frequently the root cause of damage to pavements. Although the sources of water and the mechanics of how moisture damages a pavement are understood, these principles are not widely incorporated into design. In some cases it may be difficult to incorporate drainage improvements into pavement rehabilitation. For these reasons, pavement rehabilitation techniques generally address the repair of actual pavement damage instead of treating the moisture problem, the root cause.

Although many agencies have studied pavement moisture, the authors could find little widely published literature in the area of pavement structure moisture measurement. The control of moisture has not generally been a focus of pavement design or maintenance. The technology to control the moisture sources is, however, available but not widely recognized or practiced compared to traditional pavement repair technologies. There are two general ways to control moisture in pavement structures; by the use of subsurface drainage, or by capping (sealing) the pavement to reduce infiltration through the pavement. The latter is the focus of this circular that examines the sealing effectiveness of paving fabric interlayer systems. A paving fabric interlayer system consists of a nonwoven geotextile, paving fabric, of about 140grams per square meter (4.1 ounces per square yard) which is field applied over an asphalt cement tack coat of approximately 1.1 liters per square meter (0.25 gallons per square yard). The fabric and asphalt tack coat combine to form an interlayer system when covered with an asphalt concrete (AC) overlay or a chip seal surface treatment.

THE PROBLEM – MOISTURE WITHIN PAVEMENT STRUCTURES

The primary source of moisture in pavement structures is rain water that infiltrates through the pavement. Moisture can also enter a pavement from subsurface sources such as from lateral seepage from a drainage ditch or from subsurface flow such as from a spring. In most areas, these water sources are secondary to rain water coming through the pavement itself. Extensive studies have been done to examine surface infiltration of rain water. An FHWA study (2) of numerous pavement sections found that 33 to 50 percent of the precipitation water falling on an asphalt concrete (AC) pavement and 50 to 67 percent for Portland cement concrete (PCC) pavement could infiltrate through the pavement to the road base. Oklahoma studies of edgedrain effectiveness (3) found similar results. In these studies, sections of pavement were isolated to measure rainfall amounts. Then, the corresponding amount of water that infiltrated that pavement section was recovered by a highway edgedrain and measured. In individually monitored rainfall events, edgedrains recovered very high percentages, up to 80 percent (3). Comparing the total amount of rainfall for a year to the total discharge for the year showed as high as 32 percent recovery of water that infiltrated through the pavement in this study. Ridgeway (4) found global infiltration rates of about 0.001 to 0.002 mm/sec. A summary of previous work in Ridgeway (5) for seven new AC pavements had an average potential infiltration rate of 0.32 mm/sec and five old AC pavements had an average potential infiltration rate of 0.015 mm/sec. In another study by Los Angeles County, California, (6) it was shown that the permeability of AC pavements is highly dependent on the amount of AC pavement compaction achieved. Tightly controlled compaction efforts reduce the permeability of a pavement. Often, however, the design mix and/or the level of compaction achieved may result in a pavement that can pass a significant amount of water to the pavement base. Tests (6) have indicated the addition of rubber to the asphalt mix resulted in little improvement in the waterproofing effectiveness of the pavements. Therefore, sound pavements are quite permeable and water infiltration through the pavement is the general source of moisture in the pavement base. Pavement cracking can increase the water infiltration rates up to nearly 100 percent and further increase moisture problems in the pavement structure.

The problems caused by the presence of water in a pavement structure are many. If a pavement base becomes saturated, pore water pressures due to traffic loading can negate the load spreading support function of the base stone.

Consequently, the traffic load will be applied to the subgrade over a small area. This localized loading may exceed the bearing capacity of the subgrade causing progressive failure of the pavement. If a pavement base is saturated as little as 10 percent of the time, the useful life of the pavement can be reduced by 50 percent (2). The results of cyclic load tests on crushed stone and on gravel, suggest that saturation levels above about 60 percent to 70percent, can result in large deformations (5). Pore pressures can also result in significant scouring and jetting pressures. Water jetting from cracks or joints can transport base and subgrade materials to the road surface creating a void under the pavement and eventual pavement failure.

Another way moisture damages pavement structures is by weakening the subgrade soil. Ultimately, it is the subgrade that bears the load of the pavement. It is customary to perform soaked CBR or undrained triaxial testing to determine the bearing capacity of a subgrade. It is the authors' opinion that these tests usually overestimate the subgrade soil strength for a cohesive subgrade beneath a wet base. The constant loading and unloading of the subgrade, while exposed to water, can remold the soil resulting in a lower shear strength and a higher moisture content than is currently simulated by 96 hour laboratory soaking required for the CBR test. Further research in this area, to better simulate the moisture and stress conditions for subgrade testing, is encouraged. Evidence of the weakening of the subgrade is the frequently observed migration of the subgrade soil up into a base stone if no separation geotextile is used. This migration deteriorates the strength of the base stone layer. As low as 10percent fines in the base stone has been shown to dramatically reduce the resilient modulus of an aggregate base course (7) due to loss of good rock to rock contact when compared to the same material with a lower fines content. The added fines content will also dramatically lower the permeability (drainability) of the base (5).

Another moisture related effect is freeze/thaw damage that can occur in the base, subbase, or subgrade depending on the porosity and permeability of each layer and the depth of frost penetration. It may be difficult in fold regions to maintain a drainable pavement base throughout the cold season. A practical alternative where water migration from the surface is the principal source of moisture leading to freeze/thaw damage may be to keep the moisture out of the base structure by providing a sealing layer in the pavement.

Pavements are exposed to different levels of moisture damage depending on how quickly the pavement structure drains after receiving rain water infiltration. For a given amount of infiltration, drainage time is a function of the type of stone, the gradation of the base, the thickness of the base, the contamination of the base by subgrade intrusion,and the slope of the base layer.

AASHTO STRUCTURAL CREDIT FOR GOOD DRAINAGE

AASHTO Guide for Design of Pavement Structures, 1993 (8) provides for a structural credit or a structural penalty to a flexible pavement design based on the effectiveness of the drainage system. Drainage coefficients are applied to the structural number (SN) of the pavement's untreated base and subbase materials. These coefficients may represent the most significant variables in pavement design and range from 1.4 to 1.2 for excellent drainage to 0.95 down to 0.4 for very poor drainage. This implies that an aggregate base material with an effective drainage system can be assigned up to three times the SN of the same base aggregate which is not allowed to drain. It also means that a base with fines, such as a crusher run base, would be greatly penalized from an SN standpoint while a clean free draining base with a drainage system would receive a significant structural bonus. These factors are often overlooked for several reasons. One is that an aggregate with appreciable fines content may be less expensive. Second, tighter, or more dense, bases have been traditionally used to help choke off fines upward migration from the subgrade. Also, constructability problems may be encountered with open bases.

Roads without an aggregate base can hold moisture in the asphalt pavement or the treated base, which is detrimental to the subgrade and to the pavement structure. AASHTO 1993 (8) states that although the drainage coefficients are only applied to untreated base or subbase, improved drainage is also beneficial to pavements with treated bases and no bases. The AASHTO design method also utilizes structural penalties or credits for rigid pavements based on the drainability of the pavement.

All the benefits of a dense, low permeability base have minimal impact on the pavement cost compared to the effect or the drainage coefficients, yet this area has not received the attention it should in research and in field application.Studies by Cedergren (2) and McEnroe (9) agree that a base must have permeabilities greater than 1 mm/sec to achieve AASHTO excellent drainage and 10-1 to 1 mm/sec to be classified as good drainage. In a study by Roy(10), hydraulic conductivity tests were carried out on three different granular bases (granite, limestone, and shale),characterized with fines contents of 2, 7, and 12 percent. The study showed one to three orders of magnitude reduction in permeability between 2 percent and 7 percent fines depending on the type of rock. The work is continuing but it suggests that a 7 percent maximum fines specification, for example, allows too many fines to achieve proper drainage. Similar results were also reported in Ridgeway (5).

Ridgeway (5) makes the point that drainage systems will only remove free water that is not held by capillary forces. The consequence of this is that bases with over about 5 percent to 10 percent fines will tend to always be in a state of relatively high saturation, up to 85%. The implication is that only a small amount of additional water infiltration will fully saturate the base. Often, the drainability of a pavement base is overestimated because bases assumed to be free draining have significantly more fines than discussed above. The high fines content may result from migration of fines from the subgrade, as previously described, or result from deterioration of the base course aggregate during construction. Bases must also be tied into effective drainage systems to promote rapid drainage.

The technology exists to place a truly free draining base stone layer without the fear of subgrade fines contamination by placing a separation geotextile between the subgrade soil and the base stone. In many existing roads, the bases have poor to very poor drainage by AASHTO definition. This limited permeability is due to the original design including a low permeability base or due to fines contamination of an originally free draining base layer resulting from the lack of a separation geotextile.

EDGEDRAINS

When considering rehabilitation of an existing pavement, one way to increase the effective support of the subgrade,subbase, and base layers is to improve the drainage and reduce the length of time the base is saturated. This would allow the use of a higher AASHTO drainage coefficient and thus a higher pavement structural number. This can be accomplished by the installation of pavement edgedrains if the base is permeable enough to transmit water to the edgedrain system. However, most existing flexible pavements do not have a free draining base and placing an edgedrain is not always an effective solution. Studies have been conducted looking at the effectiveness of highway edgedrains (3, 11). Lack of drainage has often been blamed on the type of edgedrain used or on damage or clogging of the drain, when slow drainage of the base course may be the problem. These edgedrain tests show some bases draining over a long period (e.g., over a week) or maybe not even draining. Therefore, edgedrains are helpful only if they significantly increase the rate at which water is removed from beneath a pavement. Some reports indicate that where base permeabilities are less than 10-1 to 1 mm/sec, edgedrains may not improve subsurface drainage of the pavement (5). Thus, the number of cases where an edgedrain may improve the drainage may be limited. In these cases a possible solution to moisture rehabilitation is to use a durable seal such as a paving fabric interlayer to limit moisture infiltration through the pavement.

SEALING A PAVEMENT

Several methods have been used over the years to limit surface water infiltration through a pavement. These methods include interlayers of modified asphalts, asphalt and chip, asphalt and fiber, and fabric reinforced asphalt.Other methods include surface treatments such as chip seals, slurry seals and various other surface dressings. The effectiveness of the systems vary widely. Surface treatments tend to be short lived with cracking and infiltration returning quickly. Interlayers are protected by the overlay and as such tend to stay in place and be more effective.The costs of the systems also vary so transportation agencies must perform a cost benefit analysis to decide which system to use.

An effective hydraulic barrier within a pavement can be evaluated based on the typical infiltration rates observed in the previously mentioned studies and the approximate time it takes to saturate the base. Based on these studies,typical pavement infiltration rates might be on the order of 0.002 to 0.005 mm/sec. For typical pavement widths,slopes, base thickness and base porosity and initial saturation it may take about 1 to 5 hours to saturate the base material. At the low permeabilities common for bases it may then take from 60 days to more than a year for the base to drain down to 50% saturation. In this period it may be likely that an additional rain may occur such that the base never fully drains down to 50% saturation. A moisture barrier that can reduce the 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. For the example cited, that would increase the length of time that it must rain to saturate the pavement 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 event 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 can not drain. Thus tobe effective, a moisture barrier should reduce the pavement permeability by at least one order of magnitude and proper surface drainage should be addressed.

The focus of this circular is on the waterproofing effectiveness of fabric reinforced membrane interlayers,commonly referred to as paving fabrics. According to the Industrial Fabrics Association International, paving fabric usage has exceeded 100 million square meters per year for the past several years in the U.S. Although many engineers think the paving fabric system is mainly used as a stress relieving interlayer to retard reflective and fatigue cracking, a principal function of the system is waterproofing (1). Briefly, the system involves spraying approximately 1.1 liters per square meter (0.25 gallons per square yard) of asphalt cement tack coat then applyinga nonwoven fabric of about 140 grams per square meter (4.1 ounces per square yard) onto the tack coat. The asphalt concrete (AC) overlay is then placed on top of the fabric. The heat and pressure of the overlay reactivates the asphalt tack coat drawing it up into the fabric and bonding it to the overlay. The resultant interlayer is a fairly thick asphalt saturated fabric reinforced layer. This layer forms a waterproofing membrane and a stress absorption layer. The system can also be effectively applied beneath chip seal surfacing.

The American Association of State Highway and Transportation Officials (AASHTO) has published a national geotextile guideline specification, AASHTO M 288-96, which includes paving fabric (12). This specification requires a unit weight of 140 grams per square meter, a grab tensile strength of 450 Newtons with greater than50% elongation and a melting point of 150°C. The specification also provides guidance on construction details including tack coat application.

MOISTURE BARRIER EVALUATION OF PAVING FABRIC INTERLAYER SYSTEMS

Several researchers have conducted field and laboratory investigations to determine the effectiveness of paving fabric interlayer systems in minimizing surface water infiltration through the pavement. Laboratory investigations included permeability testing of pavement core samples taken from roads containing a paving fabric with varying years of service and permeability testing on pavement specimens produced in the lab. Field testing included the monitoring of moisture contents within the pavement structure with and without paving fabric systems and a large-scale field permeability evaluation of a pavement containing a paving fabric system. The following is a discussion of the laboratory and field investigations.

LABORATORY INVESTIGATIONS

The following is a synopsis of several laboratory evaluations of the paving fabric interlayer system. Inherent problems with laboratory evaluations include limited area tested compared to the field, variations in the permeability of the asphalt concrete, the difference between small area permeability versus global or large area field permeabilities, and better control of asphalt tack coat quantities than is often achieved in field applications.The following studies were aimed at determining the amount of water that can infiltrate through a pavement having paving fabric interlayer system in place.

Bushey, 1976 (13)
This study reviewed the performance of a number of test installations in California that included paving fabric as well as other proposed treatments to reduce reflective cracking. Up to two years after the overlay had been placed pavement cores were obtained for testing. The section that included paving fabric was placed with a tack coat of0.9 liters per square meter (0.20 gallons per square yard) and had AC overlays of 60 mm (0.2 feet) and 90 mm(0.3 feet). Control sections with no fabric were constructed with 60 and 90 mm (0.2 and 0.3 feet) overlays.

Permeability tests were performed on some of the cores. A vacuum system was employed and the amount of water that had been pulled through the core in 100 seconds was recorded. Six cores containing paving fabric and three control cores were tested. Test results for the control cores showed 0 to 8.25 ml of water in 100 seconds and averaged 3.6 ml. The cores containing paving fabric had 0 to 0.04 ml of water in 100 seconds and averaged 0.01ml. This indicated a substantial waterproofing benefit, greater than two orders of magnitude improvement, with the paving fabric interlayer system.

Some of the cores were taken where cracks extended through the overlay. In areas where paving fabric was present, visual observations indicated that the paving fabric moisture barrier system was still intact.

Guram, 1983 (14)
Twelve sites across the United States were cored in an effort to quantify the waterproofing effect of paving fabric. At each site, control sections without paving fabric and sections with paving fabric were sampled. In areas where paving fabric was present an effort was made to take cores in cracked and uncracked areas. A total of 63 cores were taken for testing. The cores were tested using constant head tests in two configurations. First the test was performed with a gravity head of 89 mm (3.5 inches) of water. The second series of tests also used a constant head of 89 mm (3.5 inches) of water and a vacuum of 138 kPa (20 psi) on the bottom of the specimens. The water flow was collected for 15 minutes and a permeability calculated for the core. After testing, the paving fabric was removed from the core and the asphalt tack retained by the fabric was determined.

On the average, the cores containing paving fabric had about one to two orders of magnitude lower permeability (10-4 to 10-6 mm/sec) than the control section cores (10-3 to 10-4 mm/sec). The asphalt extraction from the paving fabric indicated that a relatively high percentage of the samples had less than the recommended amount of tack coat in the fabric. This suggests that with improved construction inspection and control, better saturation of the paving fabric with asphalt cement tack could be expected. Thus, with this improvement the paving fabric may provide a better barrier than indicated by the test results.

The results of tests on the cores where a crack was present both above and below the paving fabric indicated that the permeability was still relatively low at about 10-2 to 10-3 mm/sec, which was lower than the control section without paving fabric. This suggests that even when underlying cracks reflect to the surface, the paving fabrics still provide a good barrier to limit intrusion of water into the pavement subgrade.

Smith, 1984 (15)
This work was performed in an attempt to quantify in-service performance of fabric interlayers and the amount of tack coat required with various paving fabrics. The study included 12 different paving fabrics. Tests were configured to simulate in-service conditions and fabric behavior. The performance characteristics simulated included fabric asphalt retention, flexural fatigue, interlayer shear, differential movement, fabric heat resistance and permeability.

The permeability tests were performed on a 50 mm (two inch) high block of asphalt concrete with a paving fabric in the middle. A falling head test was then performed on the assembly. The tests were performed for an hour starting at a head of 200 mm (eight inches). In 33 of the 36 trials, the paving fabrics used allowed significantly less water flow than a control with no paving fabric.

This study also investigated cores from AC and Portland cement concrete (PCC) pavements with AC overlays and paving fabric, with some cracking in the AC overlay. Where the original pavement was AC, the fabric was found to be intact and still providing waterproofing after the overlay had cracked. In the case of a PCC original pavement, the fabric was ruptured due to excessive joint movement and no longer provided waterproofing.

Lancaster, 1994 (6)
The purpose of this work was to study the sensitivity of the permeability of AC mixes to three variables. The variables included binder type, amount of binder and degree of compaction of the AC pavement core. The principal variable was the binder type. Both regular asphalt cement, AR-4000, and a rubber asphalt were used. The amount of binder varied from 7.6 percent to 9.2 percent for the rubber asphalt and 5.0 percent to 5.6 percent for the samples using AR-4000. The rubber asphalts were tested at relative compactions of 90 percent and 95 percent. The cores containing AR-4000 were all compacted to about 95 percent. A core containing paving fabric was also tested. The paving fabric contained a 0.8 liters per square meter (0.18 gallons per square yard) tack coat. The core containing paving fabric had an asphalt content of 5.3 percent.

Falling head permeability tests were performed on the cores and the results are as follows. The cores with a rubber asphalt content of 7.6 percent had permeabilities of about 10-1 to 10-3 mm/sec depending on the degree of compaction. An average permeability of about 10-4 mm/sec was measured on the highly compacted cores containing 5.6 percent AR-4000 binder. However, this study also showed the great variability in permeability of AC cores compacted to different degrees. It is possible to achieve a satisfactory compaction level so that the pavement does not exhibit permanent deformation but is difficult to attain a high enough level of compaction to significantly reduce the permeability of the AC pavement. From a permeability viewpoint the level of compaction is not as critical when a paving fabric moisture barrier is used. The core containing paving fabric had a somewhat smaller amount of binder but achieved a permeability of about 10-5 mm/sec.

Baker, 1997 (16)
The permeability of the paving fabric system was investigated along with the sensitivity of the permeability to various asphalt contents. An equipment setup and melt-through procedure, which closely models the steps in the installation of paving fabric, was used to impregnate the fabric. An objective measurement of effectiveness was desired, so permeability tests were performed on the asphalt saturated paving fabric samples. The paving fabric used throughout this investigation was a staple fiber, needle punched, nonwoven fabric made from polypropylene weighing approximately 140 grams per square meter (4.1 ounces per square yard).

Various amounts of AC-20 asphalt tack coat were applied to the fabric in the field installation simulation. Then, specimens were cut from the asphalt saturated paving fabric samples to perform water permeability tests. The permeability tests were performed using a modified version of the falling head method given in ASTM D 4491, permittivity for geotextiles. The modification consisted of increasing the head of the water over the sample to attain flow through low permeability samples.

For the paving fabric used in this investigation the manufacturer recommends a tack coat application rate of 1.13 liters per square meter (0.25 gallons per square yard), anticipating that about 0.23 liters per square meter (0.05 gallons per square yard) will be absorbed by the existing pavement and the new overlay. This implies that 0.91 liters per square meter (0.20 gallons per square yard) will be available to the paving fabric. If a tack coat rate of only 0.91 liters per square meter (0.20 gallons per square yard) is applied to a pavement the results of these tests indicate that the fabric would be allowed to absorb only about 0.68 liters per square meter (0.15 gallons per square yard). This closely conforms to the results of cores taken by Guram (14) where the average asphalt retention of the paving fabrics was 0.72 liters per square meter (0.16 gallons per square yard).

The results of permeability tests performed on specimens cut from the asphalt absorption tests are shown in Figure 1. Applied tack coat values shown on Figure 1 include the amount of asphalt actually absorbed into the paving fabric during these tests plus 0.23 liters per square meter (0.05 gallons per square yard) which is typically required to bond the interlayer to the pavement layers. On Figure 1 it can be seen that minor improvement in waterproofing can be expected until the tack coat application is at levels above 0.91 liters per square meter (0.20 gallons per square yard). At tack coat levels above 1.04 to 1.09 liters per square meter(0.23 to 0.24 gallons per square yard) the paving fabric starts to achieve permeabilities of 10-5 mm/sec or less which will greatly enhance the waterproofing of a pavement. These levels are consistent with manufacturer's recommended tack coat rates for paving fabrics of the weights used in this study.

LABORATORY TESTING SUMMARY

The paving fabric interlayer system provides much improved moisture barrier properties compared to asphalt concrete or even rubber modified asphalt concrete alone. Even with the limitations on laboratory testing, results of permeability tests of pavements with the paving fabric system were generally one or more orders of magnitude less permeable than AC without a paving fabric. It was shown that AC densities and permeabilities can be widely variable due to compactive efforts. The principal causes for variations in the paving fabric interlayer system permeability are the amount and uniformity of the asphalt cement tack coat. The amount of tack coat should be a controllable amount.Although easily monitored, this is probably the greatest concern with paving fabric interlayer systems--making sure that the fabric is installed with sufficient tack asphalt to become impermeable which is essential to the performance of paving fabric systems.

The other fact summarized by these investigations is, in cores from actual AC pavements, the asphalt saturated fabric system is quite durable and pliable and can remain a waterproofing membrane even at the bottom of a crack that has opened up in the overlay.

FIELD INVESTIGATIONS OF MOISTURE BARRIER EFFECTIVENESS

The paving fabric interlayer system is widely recognized to extend the service life of overlays. Caltrans has done extensive research on paving fabrics. Based on the evaluation of numerous test sites, their findings indicate that using the paving fabric interlayer can provide extended service life equivalent to placing an extra 30 mm (1.2 inches) of overlay thickness (17). The life extension is attributed to both the stress absorbing function, which can retard reflective cracking and the waterproofing function, which protects the pavement structure. In the waterproofing function, the paving fabric can help maintain a lower moisture content beneath the pavement by minimizing rain water infiltration through the pavement. Maintaining the materials at a lower level of moisture can result in maintaining the strength of the materials at a higher level. Exactly which of the these two functions of the paving fabric system provides the greatest benefit to the pavement structure is difficult to quantify. The relative contribution of the two functions seems to depend on the pavement condition and the environment. Although many papers written on the performance of paving fabrics cite the waterproofing benefits, there has been limited actual field quantification of the waterproofing. The previously discussed laboratory studies verified the waterproofing in both laboratory produced specimens and in cores from actual pavements. Field studies have been performed including field core evaluations,investigation of the moisture levels beneath pavements with and without the paving fabric system and investigation of the subgrade strength improvement due to lowering of the moisture content beneath a paving fabric system. Also, al arge field permeability test was conducted on a paving fabric interlayer system. The following is a discussion of these field studies.

Pourkhosrow, 1985 (18)

A study was performed in Oklahoma to evaluate the performance of paving fabric in retarding reflective cracking and in reducing water infiltration through cracks in AC pavements. Experimental installations were made with thin AC overlays and chip seals over existing AC pavements. After two years, cores were taken where cracks had reflected through the overlay and visually examined. The visual examination indicated that where polypropylene, needle-punched, nonwoven paving fabric was used, the asphalt saturated fabric was still intact.

Button, 1989 (19)

In this study, performance of paving fabric in several locations in Texas was examined and compared to control sections. At a section near Amarillo, five different paving fabrics as well as control sections for comparison were installed. A 30 mm (1.25 inch) overlay was placed over 100 mm (4 inches) of existing asphalt. After rains, sections containing fabric exhibited less pumping deformation than control sections. This implies that the subgrade modulus was higher in the paving fabric sections due to lower moisture contents than in the control sections. This benefit was realized even after some cracking in the thin overlay treatment had occurred.

Sutherland 1990 (20)
Paving fabric systems are extensively used in Australia in combination with chip seal type surfacing. These treatments are used in areas of expansive clays serving the dual purpose of limiting surface water infiltration and limiting evaporation from the subgrade clay. This keeps the expansive clay inactive by maintaining a fairly constant moisture level. In this field study using paving fabrics under chip seal treatments, the moisture sensitive clay subgrade remained well below optimum moisture maintaining a stable bearing surface. Adjacent sections without the paving fabric system were at optimum or higher moisture content yielding a weaker clay subgrade condition.Also, moisture levels under the paving fabric remained stable (±2 percent) despite seasonal weather variations.This limits swelling and shrinking of expansive clays.

Phillips, 1993 (21)
In this Australian field investigation, pavements with a paving fabric seal performed better for significantly more traffic cycles than pavements without the paving fabric system even though the pavements with fabric were exposed to water and the conventionally sealed pavements were not. It was interesting that the only areas that experienced active swelling of the clays on the roads with fabric were the edges where water had entered laterally. The report suggests extending the fabric system onto the shoulder to guard the traffic lanes against swelling clay damage. The study also included tests on core samples with and without the fabric seal. No infiltration was noted in the fabric sealed sections while there was infiltration in sections without the fabric.

Rahman, 1996 (3)
In 1996 this study was performed to evaluate the effectiveness of drainable bases and edgedrain systems in the state of Oklahoma. Five pavement sections were monitored for up to three years. The five sections of pavement had varying degrees of permeable bases and had some differences in edgedrain systems.

The data presented for the monitored sections included the total rainfall, total duration of rainfall, peak rainfall, peak outflow from the edge drains, total outflow from the edge drains and the percentage of the rainfall flowing from the edge drains. In the areas of the free draining base, the outflow from the edge drains was up to about 80 percent of the rainfall but generally about 20 percent to 40 percent. Based on the assumption that where free draining base is present the total outflow from the edge drains represents the infiltration through the pavement during a rain event,global infiltration rates of up to 4x10-3 mm/sec can be inferred from the data, however values of about 3 to 5 x 10-4mm/sec were more typically measured in this study.

Flow tests were performed on the three sites with free draining base and confirmed that the bases did allow the free passage of water. Interpretation of the results of the flow tests suggests permeabilities on the order of 1 to 10 mm/sec for the asphalt stabilized base and 1 mm/sec for the cement stabilized free draining base.

One of the pavement sections consisted of a break and seat (crack and seat) PCC pavement with broken sections averaging in the 100 to 300 mm (4 to 12 inch) size. Over the broken and seated concrete, a leveling course was placed followed by a paving fabric system and a surface course. The edgedrains in this section of highway showed almost no response to precipitation events. This lack of response was initially thought to be due to a lack of permeability of the break and seat base or due to rock flour from the break and seat base clogging the edgedrain system. Another potential reason for no response was that the in place paving fabric system was stopping the infiltration of precipitation water into the road base.

In 1997, the researchers returned to this site to determine why water was not draining from the pavement. In their investigation, they cored through the paving fabric system to the top of the break and seat base layer. A percolation flow test was then run by pumping water into the hole to see if it would flow to the edgedrain system. The water did flow and the break and seat base was determined to have an AASHTO drainage capacity of “good”.

Therefore, since the base was drainable, the most probable reason that water was not flowing from the pavement after a rain was the paving fabric system restricting the infiltration from reaching the base layer. This, in a sense, was a large scale field permeability test of an in-place paving fabric system. The average actual flow to the edgedrains in this pavement was less than 1 percent of precipitation some of which could have “backed” into the edgedrain from the pavement shoulder. Any agency having such a section of pavement, with a permeable base, edgedrains, and a paving fabric interlayer system, has the necessary ingredients to run such a test to verify the barrier properties of the paving fabric system.

The results of this testing raise the interesting question of whether pavement drainage is needed if the precipitation water can be stopped before it reaches the pavement base. Most pavements to be rehabilitated do not have a free draining base and therefore cannot be effectively drained with an edgedrain. A potential way to decrease the water in these pavement bases is to limit surface water infiltration. When a properly installed paving fabric interlayer system keeps the water away from the base, this equates to at least the good to excellent AASHTO drainage classification since there is limited water dwell time in the pavement base. Therefore, it may be possible to apply a structural credit,normally used for improved drainage, where a paving fabric system is used.

Al-Qadi, 1997 (22)

The final field test reported herein was done by Al-Qadi (22). Here, a ground penetrating radar (GPR) system was employed to detect the presence of moisture beneath pavements with and without paving fabric membrane systems.Two roads were evaluated in Kernersville, North Carolina. Each road had sections with and without the paving fabric membrane system. The GPR antenna was built into a durable box that was pushed along the pavement surface.Microwave signals penetrated the pavement and the reflectance or absorption of these microwaves were monitored.The output signal was examined on site and stored for future analysis.

Changes in the amplitude of the first reflected signal were used as the criteria to determine if moisture existed below the pavement layer. When the amplitude of the first reflected signal is high, moisture presence is also high. Otherwise, the changes in the signal would be minimal and would only result from the change in dielectric properties of the pavement layers. Different color codes can be used in the output scan to enhance the reflected signals.

The results of the testing on both roads showed significantly higher moisture levels in the road base and subgrade in the sections without the paving fabric interlayer system. This GPR system shows promise as a pavement evaluation tool since, as discussed earlier, moisture in pavements is one of the most important factors in pavement service life yet it is rarely monitored or measured.

SUMMARY OF FIELD EVALUATIONS

The field investigations were found to be in good general agreement with the laboratory studies. Where flows were monitored, the field results verified greater than one order of magnitude reduction in pavement permeability due to the presence of the paving fabric interlayer system. Lower moisture levels in the pavement structure were also indicated by observed strength increases in pavement support structures when a paving fabric interlayer system was used. Nondestructive ground penetrating radar technology also appears to be a useful tool and did verify lower moisture contents beneath pavements containing paving fabric interlayer systems.

CONCLUSIONS

The following conclusions are drawn based on the laboratory and field evaluations of the waterproofing effectiveness of a paving fabric interlayer system:

- Both laboratory and field pavement cores indicate that the presence of a properly installed paving fabric interlayer system reduces the permeability of a pavement by one to three orders of magnitude. By reducing the infiltration by one or more orders of magnitude, the system becomes an efficient moisture barrier to enhance pavement performance.
- In the AASHTO pavement design methodology, structural benefits, based on improved drainage, should be considered when a paving fabric interlayer system is used because reduced infiltration equates to improved drainage. Benefits can be incorporated by using larger drainage coefficients in AASHTO new pavement and rehabilitation designs.
- The moisture levels beneath the pavement layers are decreased below pavements with paving fabric interlayers. This maintains the strength of the subgrade, subbase, and base layers, limiting damage due to saturated condition pore pressures.
- To provide a continuous moisture barrier, sufficient asphalt cement tack coat quantity must be used to saturate the paving fabric and bond the interlayer system - generally about 1.04 to 1.13 liters per square meter (0.23 to 0.25 gallons per square yard). Lesser amounts of asphalt cement diminish the waterproofing effect. The tack coat must also be uniformly applied. Field installation quality control is important.
- Pavement drainage improvement is only a viable option for rehabilitation if pavement bases have a permeability greater than 1 to 10-1 mm/sec. When drainage improvement is not an option, placement of a paving fabric moisture barrier should be considered.

More research is needed in the area of moisture in pavements and improved tools need to be developed for better monitoring and measurement. Meanwhile, cost effective technology exists to create a moisture barrier in a pavement using paving fabric interlayer systems.

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PAVING FABRIC PERMEABILITY AS FUNCTION OF TACK COAT APPLICATION

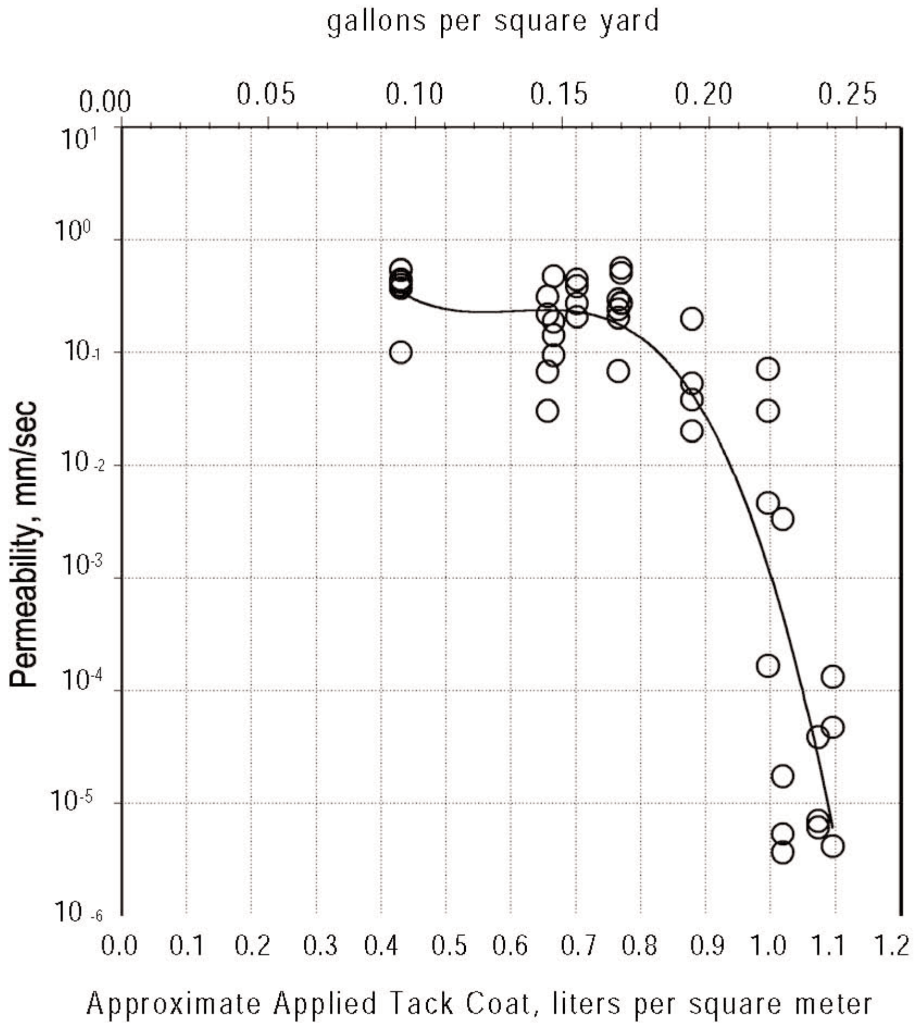

Figure 1 - Results of permeability tests on paving fabric specimens cut from melt through asphalt absorption tests. The asphalt quantity is the amount absorbed by the paving fabric plus the required 0.23 l/m2 (0.05 gal/yd2) for interlayer system bonding.

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