Potential Applications of Paving Fabrics to Reduce Reflective Cracking

FINAL REPORT

by

Farshad Amini
Department of Civil & Environmental Engineering
Jackson State University

In Cooperation with the

Mississippi Department of Transportation

and the

U.S. Department of Transportation
Federal Highway Administration

Jackson State University
Jackson, Mississippi

February 2005

Technical Report Documentation Page

1.Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/MS-DOT-RD-05-174		
4. Title and Subtitle Potential Applications of Paving Fabrics to Reduce Reflective		5. Report Date February 2005 6. Performing Organization Code MS-DOT-RD-05-174
7. Author(s) Farshad Amini		8. Performing Organization Report No.
9. Performing Organization Name and Address Jackson State University Deaprtment of Civil & Environmental Engineering P. O. Box 17068 Jackson, MS 39217-0168		10. Work Unit No. (TRAIS) 11. Contract or Grant No. State Study 174
12. Sponsoring Agency Name and Address Mississippi Department of Transportation Research Division P O Box 1850 Jackson MS 39215-1850		13. Type Report and Period Covered Final Report - February 4, 2004 - February 28, 2005 14. Sponsoring Agency Code
15. Supplementary Notes Conducted in cooperation with the Mississippi Department of Transportation and the U.S. Department of Transportation Federal Highway Administration		

16. Abstract

Asphalt concrete overlay on the existing pavement is often used as a cost-saving surface treatment for deteriorating pavements. A major problem encountered with asphalt resurfacing is the phenomenon termed reflective cracking, the propagation of existing cracks from old or existing pavement into the new overlay. Reflective cracking is one of the most significant factors in pavement deterioration. It is caused by shear and tensile stresses in the asphalt layer induced by traffic loads, change in temperature, expansive subgrade soils, moisture changes, existing cracks, and joint and crack movements in the underlying pavement.

In this project, the available literature on the applications and effectiveness of stress-relieving interlayers, known as paving fabrics, to reduce reflective cracking is synthesized. Basic functions of paving fabrics, fabric specifications, mechanism, long-term performance, life cycles and cost effectiveness, factors influencing performance, recent innovations, and lessons learned from installation are discussed. In addition, a survey of the current paving fabric applications in the State of Mississippi was conducted to determine the various practices and performances of the paving fabric systems to reduce reflective cracking. The field performance of overlays using fabric interlayers has generally been successful, although there have been cases where the paving fabric systems provided little or no improvements. In particular, paving fabrics may not reduce cracking significantly with thin overlays. A summary of current practices as well as possible directions for future research is reported.

17. Key Words	18. Distribution Statement
Paving fabrics, reflective cracking, overlays, pavement maintenance	Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72)

ACKNOWLEDGEMENT

This report presents the results of a study titled "Research on Potential Applications of Paving Fabrics to Reduce Reflective Cracking", conducted by the Department of Civil and Environmental Engineering, Jackson State University, in cooperation with the Mississippi Department of Transportation (MDOT) and the U.S. Department of Transportation, Federal Highway Administration.

The author would like to express his sincere appreciation to Mr. Barstis of the MDOT's Research Division, for his contribution and constant encouragement. Thanks are also extended to the MDOT districts engineers for participating in the survey regarding their experience with paving fabrics. Thanks are also due to the MDOT Research Advisory Committee for their interest in this project.

ABSTRACT

Asphalt concrete overlay on the existing pavement is often used as a cost-saving surface treatment for deteriorating pavements. A major problem encountered with asphalt resurfacing is the phenomenon termed reflective cracking, the propagation of existing cracks from old or existing pavement into the new overlay. Reflective cracking is one of the most significant factors in pavement deterioration. It is caused by shear and tensile stresses in the asphalt layer induced by traffic loads, change in temperature, expansive subgrade soils, moisture changes, existing cracks, and joint and crack movements in the underlying pavement.

In this project, the available literature on the applications and effectiveness of stress-relieving interlayers, known as paving fabrics, to reduce reflective cracking is synthesized. Basic functions of paving fabrics, fabric specifications, mechanism, long-term performance, life cycles and cost effectiveness, factors influencing performance, recent innovations, and lessons learned from installation are discussed. In addition, a survey of the current paving fabric applications in the State of Mississippi was conducted to determine the various practices and performances of the paving fabric systems to reduce reflective cracking. The field performance of overlays using fabric interlayers has generally been successful, although there have been cases where the paving fabric systems provided little or no improvements. In particular, paving fabrics may not reduce cracking significantly with thin overlays. A summary of current practices as well as possible directions for future research is reported.

TABLE OF CONTENTS

	Page No.
List of Figures	v
List of Tables	v
CHAPTER 1. INTRODUCTION	1
1.1 Project Objectives	2
CHAPTER 2. PAVING FABRICS APPLICATIONS	3
2.1 Reflective Cracking Problem	3
2.2 Paving Fabrics	3
2.2.1 Functions of Paving Fabrics	3
2.2.2 Paving Fabrics Specifications	4
2.3 Long Term Performance	6
2.4 Paving Fabrics Experience in Mississippi	13
2.5 Effect of Overlay Thickness	15
2.6 Factors Effecting Performance	19
2.6.1 Effect of Existing Pavement Condition	19
2.6.2 Effect of Base/Subgrade Support Condition	20
2.6.3 Environmental Factors	20
2.7 Cost Effectiveness of Paving Fabrics	22
2.8 Lessons Learned from Installation	25
2.9 Recent Innovations	28
2.9.1 Geosynthetic Reinforcement of Asphalt Overlay	28
2.9.2 Stress-Absorbing Composite Interlayers in Asphalt Overlays	28
2.9.3 Application of Paving Fabrics and Double Cheap Seal	29
CHAPTER 3. SUMMARY AND CONCLUSIONS	30
3.1 Summary	30
3.2 Recommendations for Future research	32
REFERENCES	35

List of Figures

	Page No.
Figure 1	17
Figure 2	17
Figure 3	17
Figure 4	18

List of Tables

	Page No.
Table 1	7

CHAPTER I

INTRODUCTION

Pavement rehabilitation is rapidly becoming one of the most important issues facing many highway departments. Asphalt concrete overlay is one of the commonly used methods for rehabilitating deteriorated pavements. One major type of distress influencing the life of an overlay is reflective cracking (e.g., Dempsey, 2002). When an overlay is placed on existing pavement, physical tearing of the overlay occurs because of movement at the joints and cracks in the underlying pavement layer. Temperature-associated horizontal movement of the slab, concentrated in underlying joints and cracks in the existing pavement, lead to tensile stresses, and is an important contributor to reflective cracking. Load induced vertical movements leading to shear stresses in the overlay also contribute to reflective cracking. Reflective cracking in the overlay allows water to percolate into pavement structure and weaken subbase, and contributes to many forms of pavement deterioration, including increased roughness and spalling.

Some of the treatment techniques that are used to reduce or prevent reflective cracking include reinforcement of overlay (steel wire mesh, expanded metal, fabrics such as polymer grids, and glass grids), increased thickness of asphalt overlay, asphalt mix additives (such as polymer, sulfur, and dry lime), bond breakers at joints of pavements, and the use of stress absorbing interlayers such as paving fabrics (e.g., Barksdale, 1991; and Jackson, 1980). The nonwoven geotextile interlayer systems, known as the paving fabrics, can be used to reinforce asphalt overlays by carrying tensile stress, and possibly shear stresses caused by environmental or traffic loading, and usually provide a waterproofing barrier. Studies have indicated that the cost of reflective crack control treatments is usually very high (e.g., Buttlar et al., 2000). Some literature suggests that paving fabrics provide the performance equivalency of about 1.2 in (30 mm) of asphalt concrete thickness, and may be an economical interlayer option (e.g., Buttlar et al., 2000; Synthetics Industries, 2003).

1.1 Project Objectives

Although these nonwoven fabrics have generally been successful in asphalt overlay applications, there is no synthesis to their performance. In the past, the role of paving fabrics to reduce reflective cracking has not been clearly evaluated. As a result, there is a lack of consistent considerations of paving fabric option in pavement management systems. These paving fabric materials have often been recommended in conditions where they are not suited leading to highly variable performance and sometimes-unfavorable results. The primary objective of this project is to synthesize the use, performance and design considerations for interlayer systems using a nonwoven paving fabric. Basic mechanism, long-term performance, life cycles and cost effectiveness, fabric specifications, factors influencing performance, recent innovations, and lessons learned from installation are discussed. A summary of current practices as well as possible directions for future research is presented.

CHAPTER 2

PAVING FABRICS APPLICATIONS

2.1 Reflective Cracking Problem

The propagation of existing cracks from the old or existing pavement layer into the new overlay is called reflection cracking (e.g., Jayawickrama and Lytton, 1987; Lytton, 1989). The crack propagation theory is based on the empirical fracture mechanics law and can be expressed as (Paris and Erdogan, 1963):

$$dc/dN = \mathrm{AK}^{n} \tag{1}$$

Where,

c = Crack length;

N = Number of load cycles to failure;

K = Stress intensity factor at crack tip; and

A,n = Fracture properties of the material;

If the stress intensity factor at the crack tip decreases, crack propagation decreases. This is theoretically possible with the inclusion of a reinforcement layer, which reduces the tensile stress at the crack tip (e.g., Barksdale, 1991; Paris and Erdogan, 1963; Kutuk, 1998). Several treatment techniques, as mentioned earlier, have been used to reduce or prevent reflective cracking.

2.2 Paving Fabrics

2.2.1 Functions of Paving Fabrics

The paving fabric interlayer systems are recognized to extend the service life of overlays. 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 (e.g., PIB, 1976). In the waterproofing function, the paving fabric can help to maintain lower moisture content beneath the pavement by minimizing water infiltration through the pavement (e.g., Burmania, 1988; Marienfeld and Baker, 1999; Brown, 2000). Maintaining the materials at a lower level of moisture can result in maintaining the strength of materials at higher levels. The relative contribution of the two functions depends on the pavement condition and the environment (e.g., Buttlar, et al., 1999).

2.2.2 Paving Fabrics Specifications

A polypropylene, staple fiber, needlepunched, nonwoven geotextile is often chosen for this application. The fibers are needed to form a stable network that retains dimensional stability relative to each other. Appropriate mechanical properties (such as grab tensile strength) endurance (UV resistance and melting point), physical properties (weight, thickness, and asphalt retention), fabric storage, cost, and availability in the local area are often considered during the selection.

The designer often provides specifications for the fabric properties. These properties can be tested using ASTM or AASHTO standards (e.g., Roads and Bridges, 1989). The most commonly recommended paving fabric properties include some or all of the following (e.g., Barazone, 2000):

1. Weight: oz/sq yd;
2. Grab tensile strength (weakest principle direction);
3. Elongation;
4. Asphalt retention;
5. Fabric storage; and
6. Melting point

- Weight/sq yd refers to the quantity of fabric needed to absorb a sufficient amount of tack coat to form a membrane. Most specifications are written around a four-oz/sq yd specification
- Grab tensile strength is an important property indicating the fabric's strength when it is pulled between the jaws of a testing machine until it ruptures. A grab tensile strength in the range of 115 lbs (512 N) or greater is usually needed.
- Elongation is also determined from the grab tensile test. It measures the percent the fabric stretched at maximum strength. Most agencies require an elongation of between 50 and 100%.
- Asphalt retention is an important property for this application, and is an indication of how much oil is necessary to saturate the fabric and make a bond. Various fabrics absorb different amounts of tack coat depending upon weight and thickness. A typical 4-oz/sq yd (136 gm/sq m) fabric will absorb 0.20 gal/yd^2 (0.91 liters/m^2). An additional 0.05 gal/yd^2 (0.023 liters/m^2) of tack coat must be included for bonding to the old and new asphalt concrete layers unless a freshly oiled leveling course is first installed.
- Improper storage can cause many problems. Damage to plastic wrappers allows moisture and UV rays to reach the fabric, breaking down some fibers in a very short time.
- Melting point in the range of 300 degrees F (150 degrees C) or greater are often required.

Among the above properties, grab tensile strength and asphalt retention are the most critical ones. AASHTO M288 also lists current commercial paving fabrics that satisfy AASHTO default specifications for the application (e.g., Suits and Richardson, 1998; Suits, 1999; Suits, 2001). Manufacturers typically provide at least the following information: mechanical properties (grab tensile strength, grab elongation, puncture strength, Mullen burst, and trapezoidal tear), endurance (UV resistance and melting point), physical properties (weight, thickness, and asphalt retention), fabric storage, and roll size. Several vendors including Synthetic Industries (SI), Amoco, Mirafi, and Phillips Fibers Corporation provide various types of paving fabrics. Some examples of these fabrics include Geotex Pave-Dry 461 by SI, BP 4597 by Amoco, MiraPave by Mirafi, and Petromat and Petrotac by Phillips.

2.3 Long-Term Performance

Although paving fabrics have been successfully used in pavement rehabilitation methodologies, adequate long-term performance monitoring is needed to evaluate the uses, benefits, applications, and limitations of nonwoven fabrics (e.g., Sposito and Brooks, 1999; Barnhart, 1989; Button and Lytton, 1987; Knight, 1985; McGhee, 1982; NDOT, 1979, Hughes, 1977; McGhee, 1975). Performance of nonwoven fabric is often measured by comparing the condition of overlays using fabric with overlays not using fabric. This performance is sometimes reported in two ways. First, a comparison of the performance of paving fabric/overlay section with section containing no paving fabric (control section) is done. Second, the performance of the paving fabric section with paving fabric is compared with section with no paving fabric section but with a thicker asphalt overlay. The performance is measured over a given period, preferably at least 7 years, or until a level of pavement deterioration is reached.

Carmichael and Marienfeld (1999) have gathered information on about 30 sites to study the application of paving fabrics in the rehabilitation of existing asphalt-cement concrete (ACC) pavements. As shown in table 1, of these sites, 21 are located in the United States; the remaining are in Germany, south Africa, Spain, Belgium, and Austria. Thirteen of the sites were observed for more than 5 years, and two were evaluated for 10 or more years. Almost all of these case studies (26 out of 30) indicated that the application of paving fabric treatment in the rehabilitation of pavements resulted in significant reduction in reflective cracking. The four studies that indicated no major reduction in reflective cracking between control and fabric sections had thin overlays of less than 1.5 in. (38.1 mm).

Table 1. Literature Survey of Performance of Asphalt-Cement Concrete Pavement with Paving Fabrics (Carmichael and Marienfeld, 1999)

Site Location	**Opening Date**	**Time Years**	**Observations, Results and Comments**	**Reference**
South Africa	Jun 1973	8.0	AC [2 in (50.8 mm)] overlay with fabric of existing cracked AC surface [1 in (25.4 mm) AC on cement treated base] yielded 10%, 30% and 60% reflection after 4, 5 and 8 years, respectively, of heavy traffic.	Hugo et al. (1982)
Colorado	Aug 1971	5.0	Control section [2 in (50.8 mm) AC overlay] developed 25% reflection cracking in a year and 80% reflection cracking in 5 years, while fabric developed less than 5% reflection cracking.	GDOT (1976)
Florida	Aug 1971	5.0	Control section [2 in (50.8 mm) AC overlay] developed 56% cracking in three years and 100% within 4 years, while fabric section developed less than 10% in 2 years and 80% within 5 years.	GDOT (1976)
Texas	1974	7.0	A number of sections were constructed along IH 20 at Odessa, Texas. The control section consisted of a 1.25 in (31.8 mm) AC overlay. Other sections included a 2.5 in (63.5 mm) AC overlay, fabric with a	Button (1989)

			seal coat, and fabric with 1.25 in (31.8 mm) AC overlay. The fabric with 1.25 in (31.8 mm) AC overlay displayed 5% cracking within 2 years and 37.5% within 7 years. A thicker AC overlay [2.5 in (63.5 mm)] section showed about 2% reflection cracking in two years and 25% within 7 years. The similarity in performance of the section with 1.25 in (31.8 mm) AC over fabric and the section with the 2.5 in (63.5 mm) overlay translates into a AC / fabric replacement thickness of about 1.25 in (31.8 mm).	
Georgia	Sep 1976	5.8	Control sections [1.5 in (38.1mm) AC overlay] developed 10% cracking in 1.5 years, while the fabric sections developed 2% reflection cracking within 1.5 years and 40% within 3.75 years.	GDOT (1976)
Oklahoma	Oct 1976	4.0	Most control sections exhibited extensive reflection cracking, while the fabric sections displayed significantly less reflection cracking (90% reduction). Reflection cracks that showed were substantially smaller than original reflected cracks in the control sections.	Ahlrich (1986)
Minnesota	1976		Use of fabric reduced the amount and severity of reflection cracking by 50%.	Hanson and Paulson (1985)
Oklahoma	Dec 1976	5.0	On IH 40, fabric and control sections were constructed with 1.5 in (38.1 mm) AC overlay and a 3/4 in (19.1 mm) open graded friction course. After 6 months the control section displayed 35% reflection cracking of the transverse cracks, 0 longitudinal cracks and 0.2% of random and alligator cracking, while the two fabric sections displayed only transverse reflection cracking of 0 and 9% respectively. After a year the control section displayed 56% reflection cracking of transverse cracks, no longitudinal cracks and 8% random and alligator cracking, while the fabric sections displayed only transverse reflection cracking of 8 and 17% respectively. After 5 years the control section displayed 88% reflection cracking of the transverse cracks, 27% of the longitudinal cracks and 23.5% random and alligator cracking, while the fabric sections displayed transverse reflection cracking of 34 and 37%, longitudinal reflection cracking of 19 and 27% and 1 and 14% of alligator reflection cracking. Fabric can be used as an anti-reflection cracking treatment for	Ahlrich (1986)

			both alligator and random cracking, as well as for open transverse or longitudinal cracks with widths 3/8 in (9.5 mm) or less.	
Colorado	Jul 1977	3.3	Control section [1.5 in (38.1 mm) AC overlay] developed 10% cracking in 1.25 years and 50% within 3.25 years, while fabric section developed less than 2% reflection cracking in 1.25 years and 30% within 3.25 years.	FHWA (1982)
California	Jan 1977	10.0	Paving fabric in an AC overlay resisted initial cracking for two to three years longer. The AC equivalent thickness for the fabric interlayer should be at least 0.1 ft (30.5 mm), but may be as much as 0.15 ft (45.7 mm) in AC overlays placed to attenuate reflection cracking. The fabric interlayer is somewhat beneficial in retarding initial cracking in AC overlays of less than 0.40 feet. There is little if any benefit of fabric for overlays of 0.40 feet or greater.	Predoehl (1990)
Colorado	Aug 1977	3.5	Control section [1.5 in (38.1 mm) AC overlay] developed 50% cracking in 1.5 years and 75% within 2.5 years, while fabric section developed less than 5% in 1.5 years and 40% in 2.5 years.	FHWA (1982)
Massachusetts	Oct 1977	3.8	Control section [2 in (50.8 mm) AC overlay] developed 42% cracking in 1.75 years and 54% within 3.25 years, while the fabric section developed 38% reflection cracking in 1.75 years and 67% within 3.75 years.	Maurer (1985)
Georgia	Oct 1977	3.8	Control sections (1.5 in (38.1 mm) AC overlay) developed 9% cracking in 3.75 years, while the fabric sections developed less than 10% reflection cracking in ¾ years and 50% in 3.75 years.	GDOT (1976)
Oklahoma	Jun 1978	4.0	Fabric was evaluated in stage construction of a new highway. After 4 years the control sections displayed longitudinal cracking and wheel path cracking in the driving lane, but no evidence of cracking in the passing lane. The fabric-reinforced section was reported in excellent condition with no distress in either lane.	Ahlrich (1986)
New Mexico	Nov 1978	4.9	Project consisted of four control sections [one with a 4 in (101.6 mm) AC overlay and three with 2.5 in (63.5 mm) AC overlay] and two fabric sections [with 2 in (50.8 mm) overlays. There was no reflective cracking in either the fabric or control sections for the initial three years. After 5 years the 4 in (101.6 mm) AC overlay control sections displayed 39%	Lorenz (1987)

			reflection cracking, the three 2.5 in (63.5 mm) AC control sections displayed an average of 23% reflection cracking, while the two fabric reinforced sections displayed 27 to 28% reflection cracking.	
New Mexico	Nov 1978	5.1	Project included one control section [with 5.5 in (139.7 mm) AC overlay] and two fabric sections [with 5.5 in (139.7 mm) AC overlays and fabric]. Reflective cracking was not observed in either the fabric or control sections for the first two years. Within years two and three no reflection cracking was observed in the fabric sections; however, 14.6% reflection cracking developed in the control section. After 5 years the control section displayed 51% reflection cracking and the two fabric reinforced sections displayed 22 to 30% reflection cracking.	Lorenz (1987)
New Mexico	Nov 1978	4.2	Project included one control section [with 2 in (50.8 mm) AC overlay] and two fabric sections [2 in (50.8 mm) AC overlays with fabric]. The existing pavement displayed 0 alligator cracking but numerous transverse cracking with widths between 1/4 in (6.4 mm) and 1in (25.4 mm) which extended to depths of about 8 in (203.2 mm). During construction these cracks were not completely filled. As a result reflective cracking was observed within the first five months in the fabric sections (i.e., 5% and 12% reflection cracking) and control section (42% reflection cracking). Within a year and a half 61% reflection cracking was observed in the control section while an average of 38.6% reflection cracking developed in the fabric sections. After 4.2 years the control section displayed 100% reflection cracking, while two fabric reinforced sections showed 80 and 100% reflection cracking.	Lorenz (1987)
Texas	1979	8.0	Project involved installation of 1.75 in (44.5 mm) AC overlays of an existing AC pavement [i.e., 3 in (76.2 mm) AC], which showed subgrade depressions, and extensive transverse, longitudinal and alligator cracking in the east bound travel lane, but minimal cracking in the west bound lane. No reflection cracking was observed in the westbound lane during the initial two and a half years but increased to 39% and 60% by the eighth year. Reflection cracking in the eastbound lane was less than 25% by the eighth year. The fabric sections performed little better than	Button (1989)

			the control section.	
Texas	Sep 1979	9.0	The project involved installation of 1.25 in (31.8 mm) AC overlays of an existing AC pavement [4 in (101.6 mm) AC]. The existing pavement conditions were not known. Reflection cracking was observed in both east and westbound lanes within a year. The performance of the control section in the West bound lane was better than the fabric sections, while the fabric sections performed marginally better than the control section in the East bound lane. It appears that even after cracks appear the fabric still acts as a moisture barrier.	Button (1989)
Mississippi	May 1980	4.0	Control section [1.5 in (38.1 mm) overlay] developed 30% cracking in two years and 80% within 4 years, while fabric section developed less than 5% in 2 years and 20% within 4 years.	Dykes (1985)
Washington	May 1980	4.0	Control Section [1.8 in (4.75 mm) overlay] developed 30% cracking in 3 years and 90% within 4 years, while fabric section developed less than 8% in 3 years. The winter between the third and fourth years was one of the coldest in history. The cracks were tighter in fabric sections	FHWA (1982)
Oklahoma	1981	5.0	Retards reflection of block and alligator cracking; reflected transverse cracks were small in size. Reflection of AC thickness with fabric application is 1in (25.4 mm).	Pourkhosrow (1982)
France	Jun 1982	10.0	After 2.5 years the control (non-fabric) section displayed 30% reflection cracking, while the fabric section displayed 10% reflection cracking. After 6 years reflection cracking in the control and fabric sections totaled 51% and 30% respectively. After 10 years the control section exhibited 65% reflection cracking, while the fabric section showed 40% reflection cracking.	Perfetti and Sangster (1989)
Belgium	Mar 1987	6.0	After 6 years no cracks appeared in the fabric section. Large cracks, which developed in the non-fabric sections stopped at the edge of the fabric sections.	Karam (1990)
Spain	Jan 1988	4.0	At 3 years the fabric sections displayed no cracks, while non-fabric sections displayed deflection cracking.	Karam (1990)
Belgium	Oct 1988	4.0	No cracks in fabric sections while cracks observed in non-fabric sections.	Karam (1990)
France	Oct 1988	4.0	10% reflection of existing cracks as fine cracks.	Karam (1990)
Belgium	Oct 1988	4.0	After 4 years 0 cracks were observed in the fabric sections, while cracks appeared in the non-fabric sections.	Karam (1990)

Germany	Sept 1989	2.8	No cracks observed in the fabric sections.	Karam (1990)
Belgium	Sept 1989	2.8	No cracks observed in the fabric sections.	Karam (1990)

Lorenz (1987) has reported the results of the evaluation of several interlayer systems for 4 New Mexico experimental projects. These interlayer systems to control reflective cracking included the Arizona Rubberized Asphalt (combination of asphalt, reclaimed replasticized rubber and oil), the Arkansas Mix (open-graded bituminous pavement with a coarse gradation, fine aggregate and asphalt), the heater-scarification, (preheated pavement), Sahuaro Rubberized Asphalt, Mirafi 140 paving fabric, and Petromat paving fabric. It was concluded that while all interlayer systems were effective in retarding the rate of reflective cracks, the paving fabrics (and particularly the Petromat fabric) performed best. The paving fabrics also provided cost savings in maintenance costs.

The application of four reflective treatment materials in ten state and local roads agency resurfacing projects in Illinois has been summarized by Mascunana (1981). These materials included two commercially available engineering fabrics (Petromat by Phillips Fibers Corporation, Mirafi 140 by Celanese Fibers Marketing Company), a fabricated interlayer membrane (Heavy Duty Bituthene by W. R. Grace & Company), and an asphalt-rubber membrane interlayer. The findings of this study have indicated that the treatment methods were not effective in preventing the development of transverse reflective cracking on overlays with rigid bases. However, they controlled longitudinal reflective cracking. In addition, they were generally effective in reducing or retarding both transverse and longitudinal reflective cracking on overlays with flexible bases.

Maurer and Malashekie (1989) has reported the results of early performance and evaluation of four paving fabrics, one asphalt/fiber membrane and one fiber-reinforced asphalt concrete in Pennsylvania. All treatments were compared with each other, and with a control section without treatment. The treatments included Reepave T-376 paving fabric (by Dupont), Amopave paving fabric (by Amoco), Trevira 1115 paving fabric (by Hoechst Fibers Industries), Mirafi paving fabric (by Mirafi), Fiber Pave reinforced asphalt membrane interlayer (by Hercules Inc.), and Bonfiber reinforced asphalt concrete (by Kapejo Inc.). Based on the data obtained, the use of Trevira results in the most effective treatment, while the least effective treatment was provided by Bonfiber reinforced asphalt concrete. Bonfiber, however, was the most attractive option based on cost and ease of construction. Based on a 44-month evaluation of the above treatments, Maurer and Malasheskie (1989) have indicated that the Fiber Pave reinforced membrane provided superior performance relative to others.

The performance of three paving fabric/geogrid products were also evaluated by the Pennsylvania Department of Transportation (Hughes and Somers, 2000). These products were evaluated in three test sections with two control sections at two separate locations. The paving fabric types included “Petromat”, Bit-U-Tex (combination of paving fabric and geogrid), and “Glassgrid”. Based on the results of this study, none of the above three paving fabric/geogrid types were found to be effective in preventing or retarding reflective cracking.

In summary, the long-term monitoring has generally indicated that paving fabrics are very effective in reducing reflective cracking. However, paving fabrics may not reduce cracking significantly with thin overlays.

2.4 Paving Fabrics Experience in Mississippi

The Mississippi Department of Transportation conducted a study to evaluate paving fabrics and the asphalt rubber interlayer systems, and to compare them with the use of a single bituminous surface treatment for the purpose of controlling reflective cracking (Kidd, 1990). The paving fabric included Amopave (by Amopave Fabrics Company), Fibretex (Crown Zellerbach Corp.), Mirafi (by Mirafi Inc.), and Petromat (by Phillips Fibers Corp.). The findings of this study indicated that the interlayers, in combination with a thin overlay [about 1 ½ in. (38.1 mm)], reduced and/or delayed reflective cracking over a lengthy period of time (about five years). The study recommended that the use of interlayers be seriously considered with all thin overlays.

A survey of the current paving fabric applications in the State of Mississippi was conducted to determine the various practices and performances of the paving fabric systems to reduce reflective cracking. A questionnaire was sent to all seven districts in the state. Only district 5 indicated some experience with paving fabrics. Other districts had no or very little experience.

Based on the results of the survey, no long-term monitoring or evaluation had been performed. As a result, no information regarding crack reduction or cost effectiveness of the paving fabrics was available. The survey indicted that care must be exercised that the fabric is installed properly, and that an overlay thickness of 2 in. (50.8 mm) or more should be used. In District 5, two adjacent rehabilitation projects with paving fabrics on Interstate I-20 were completed in Newton and Lauderdale Counties in 1985, and 1986, respectively. The original construction for the projects in Newton and Lauderdale Counties was completed in 1963 and 1967, respectively. It consisted of 4 in.

(101.6 mm HMA over 11 in. (27.94 cm) of soil cement treated topping over lime treated subgrade. The rehabilitation projects in 1985 and 1986 milled 1 ½ in. (38.1 mm) of the original HMA off, placed a slurry seal, followed by placement of the paving fabric and 1 ½ in. (38.1 mm) HMA. The fabric remained in place on both projects until the mid 1990's, when a 2 in. (50.8 mm) mill and overlay was performed.

The survey suggested several areas of needed research. Paving fabric applications would likely be on non-interstate routes, since the primary mode of failure on interstate routes is rutting. On non-interstate routes, extensive cracking can occur without rutting or shoving problems. Once the pavement has deteriorated to small block, alligator cracking, milling is often performed. However, many of these routes with moderate to moderately severe cracking are routinely overlayed without being milled first. Some possible recommendations for future research may include: 1) a comparison between the performance of paving fabric treatment systems for milled and non-milled surfaces; 2) the effect of overlay thickness on the performance of paving fabrics systems; and 3) a comparison between the performance of paving fabrics on sealed and non-sealed surfaces. The seal materials may include 0.19 in. (4.75 mm) HMA, a sand mix HMA, or slurry seal.

2.5 Effect of Overlay Thickness

The effect of thickness of overlay has been studied by several investigators. A Texas study, and a combination of several other studies have provided information on the effect of thickness of overlay on performance (e.g., Ahlrich, 1986; Button, 1989; Predoehl, 1990). This effect for pavements without paving fabric is demonstrated in Figure 1, where percent cracking as a function of time in service is shown. As illustrated in this figure, the 1.25 in. (31.8 mm), and 2.0 in. (50.8 mm) overlays behaved similar to each other, while the 2.4 in. (61.0) mm and 2.5 in. (63.5 mm) overlays exhibited much better performance. The thicker overlays [2.4 in. (61.0 mm) and 2.5 in. (63.5 mm)] had 2 to 3 times more years of service that the thinner overlays [2 in. (50.8 mm) or less]. Figure 1 also demonstrates that the 1.25 in. (31.8 mm) and 1.5 in. (38.1 mm) overlays displayed almost immediate reflective cracking, while the 2.0 in. (50.8 mm) and thicker overlays indicated a delay in the initiation of reflective cracking for one to two years. Similar relations for sections with paving fabric are shown in Figure 2. Although the performance trends for both figures are basically the same, the inclusion of paving fabric significantly increased the service life. For example, at a 25 percent level of reflection cracking, the inclusion of fabric increased the performances of the 1.5 in. (38.1 mm) overlays by a factor of 3 (4.5 years versus 1.5 years).

Figure 3 shows the performance of pavements with and without paving fabrics in Odessa, Texas. As shown in this figure, an increase in the overlay thickness from 1.25 in. (31.8 mm) to 2.5 in. (63.5 mm) would increase the time to 25 percent cracking from 1.25 to 7 years. As shown in this figure, the time based-reflection cracking relationships for the 1.25 in. (31.8 mm) overlay with fabric and the 2.5 in. (63.5 mm) overlay without fabric are very similar. Thus, it may be concluded that an equivalent overlay to fabric thickness of approximately 1 in. (25.4 mm) to 1.25 in. (31.8 mm) may be appropriate for the conditions in this study (Ahlrich, 1986).

The field data from a California study have indicated the benefit of increasing overlay thickness, either with or without a fabric (Predoehl, 1990). These results (demonstrated in Figure 4) have indicated that when a fabric is not used, the benefit of increasing

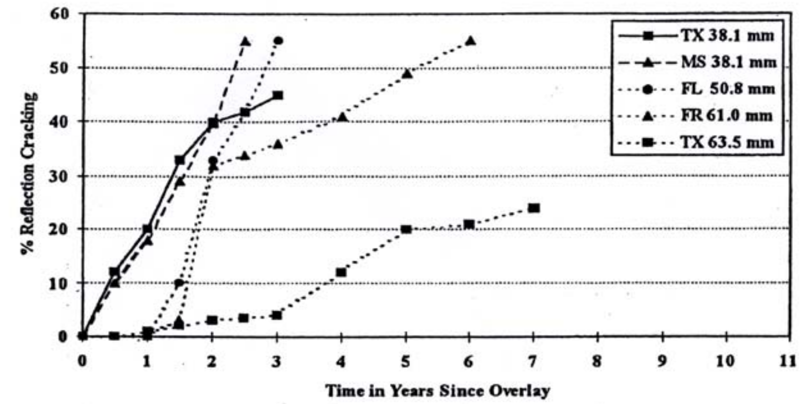

Figure 1. Performance of Pavements without Paving Fabrics for Various Overlay Thicknesses (Ahlrich, 1986; Button, 1989)

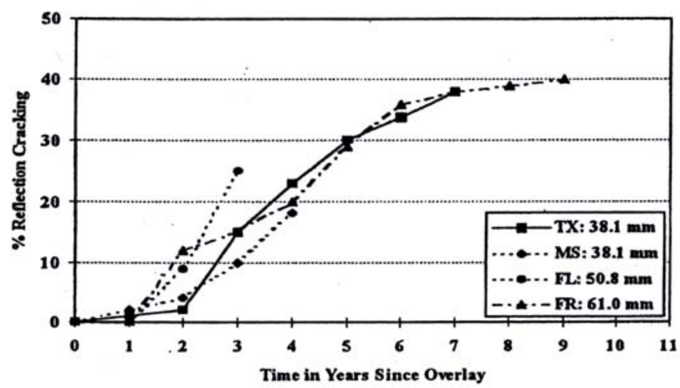

Figure 2. Performance of Pavements with Paving Fabrics for Various Overlay Thicknesses (Ahlrich, 1986; Button, 1989)

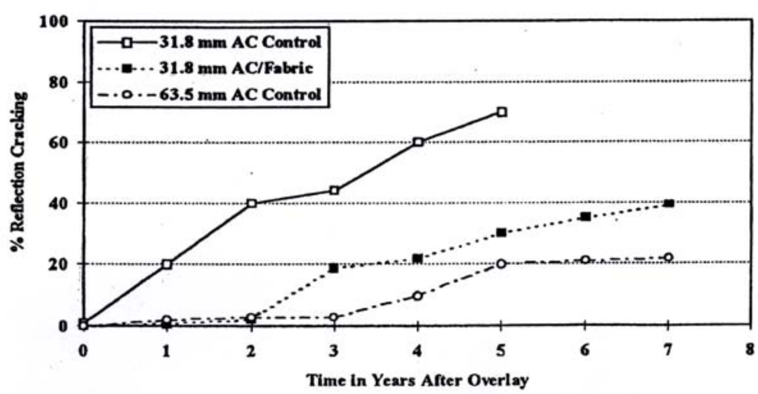

Figure 3. Performance of Pavements with and without Paving Fabrics for Various Overlay Thicknesses, Odessa, Texas (Button, 1989)

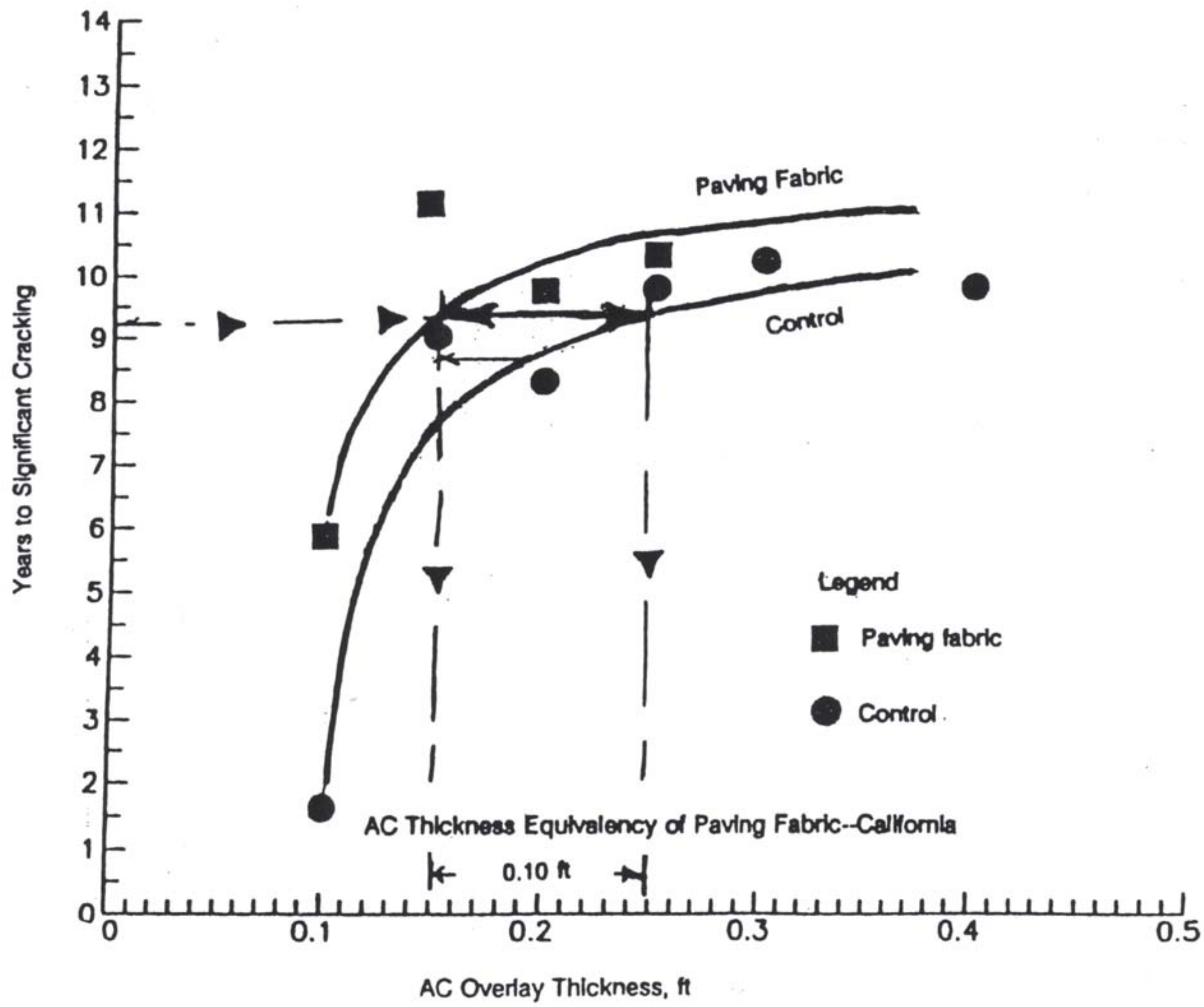

Figure 4. Estimated Paving Fabric Equivalency as a Function of AC Pavement Thickness (Prdoehl, 1990)

overlay thickness reduces rapidly for overlay thickness greater than about 3.0 in (76.2 mm). When a paving fabric is used, the breakpoint for rapidly increasing benefits is probably in the vicinity of 2.0 to 2.5 in. (50.8 to 63.5 mm). Other researchers have suggested relatively thick overlays to achieve the most benefit from paving fabrics. For example, Ahlrich (1986) suggests using a minimum of 2.0 in. (50.8 mm) in the warm climates, and 3 to 4 in. (76.2 to1 01.6 mm) in cooler climates. In moderate to high volume roads, thin overlays less than 1.5 in. (38.1 mm) thick, have led to premature failure (e.g., Button, 1989; Pourkhosrow, 1982). Epps and Button (1984) recommend using a minimum overlay thickness of 1.5 in. (38.1 mm) with paving fabrics, whereas Dykes (1980) recommends using 1 in. (25.4 mm).

In summary, although there are somewhat conflicting recommendations regarding the overlay thickness, the benefit of increasing overlay thickness, either with or without a fabric is clear. Paving fabrics may not reduce cracking significantly with thin overlays. Factors such as the local climate and the traffic volume will need to be considered prior to the design.

2.6 Factors Effecting Performance

There are several specific factors that influence the performance of paving fabric systems. These factors include a) existing pavement condition, b) base/subgrade support condition, and c) environmental factors. This section discusses these factors and special limitations of the use the paving fabric systems (Carmichael and Marienfeld, 1999).

2.6.1 Effect of Existing Pavement Condition

It is important to first quantify the severity and extent of distress in the existing pavements as part of the rehabilitation design process. In general, the existing cracks should be filled with suitable crack filler material and sealed prior to the placement of the paving fabric. This provides a uniform surface so that the tack coat is uniform in application and a smooth surface for the fabric to adhere to. Sealing the cracks is particularly important if there is a lot of random cracking, ¼- to 3/8- in. (6.3 to 9.5 mm) wide. Studies have indicated that the inclusion of paving fabrics does not significantly improve the performance if inadequate existing pavement conditions are present.

2.6.2 Effect of Base/Subgrade Support Condition

The structural conditions of the existing pavement layers and elements must be investigated in the design of a rehabilitation overlay with fabric. Visual observations of the site are usually sufficient for this purpose; however, deflection studies are sometimes needed if the functional uses of the pavement are to be upgraded. Extensive cracking of the existing pavement may require some type of deflection measurements to differentiate between poor subgrade support, fatigue, and disintegration of the pavement structure. Studies have indicated that the inclusion of paving fabrics does not significantly improve the performance if inadequate base or subgrade support pavement conditions are present. It is also noted that the inclusion of the paving fabrics does not resolve existing structural inadequacies.

2.6.3 Environmental Factors

During the rehabilitation design process, the most significant environmental factor to be considered is the temperature conditions (such as freeze-thaw cycles and extremely cold weather conditions). In severe cold climates, the freeze-thaw cycles cause contraction and expansion of water within the pavement and the road construction. This action accelerates damage from water filtration.

Ahlrich (1986) has reported the impact of hard winter on the performance of an overlay by a case study from Washington State. The project included a comparison of the performance of pavements with and without paving fabrics. Although the performance of both sections were excellent during the first two years, at the onset of a hard winter, both the control and fabric trial sections developed 90 percent cracking. The inclusion of fabric in the overlay section could not overcome the impact of the severe weather conditions. This may be explained by the fact that much of the cold-weather contraction and cracking occurred within the overlay, over the paving fabric, and was not reflected from lower layers. It should, however, be noted that the waterproofing effects can still provide long-term benefit by controlling the moisture content in the lower layer.

In general, paving fabrics have performed considerably better in warm and mild climates than in cold ones (e.g., Epps and Button, 1984; Dykes, 1980; MacMaster, 1978; Ahlrich, 1986; Verdos, 1981). Ahlrich (1986) also developed a map with climatic zones as a guide to paving fabric performance of asphalt concrete. Zone I, which generally included the warm southern (including Mississippi) and western states, provided the most favorable results. Zone III, covering the northern states, indicated the least favorable results, with Zone II (areas within central states) showing somewhat favorable results. The application of paving fabrics in Zone I should result in satisfactory reduction in reflective cracking using a minimum overlay thickness of 2 in. (5.08 cm). Pavements in Zone II should provide favorable results with a minimum overlay thickness of 3 in. (7.62 cm). Aldrich (1986) recommends that paving fabrics not be used for Zone III.

Bernard (1996) has reported the results of a seven-year research project in Canada to evaluate the benefits of paving cracking in cold climates. The performance of pavements with and without paving fabrics was considered. It was concluded that paving fabrics reduced the degree of pavement cracking in freeze-thaw environments. The paving fabric was found to be effective in reducing reflective longitudinal (those oriented in the direction of road alignment) and transverse cracks (those oriented perpendicular to the direction of road alignment). It was also noted that long-term monitoring was essential to definitely conclude that the paving fabrics met the goal of waterproofing.

In summary, it may be noted that the inclusion of paving fabric should not be expected to stop all thermal cracking. But, the moisture-control situations of the environmental regime in terms of waterproofing effects will help to minimize the freeze/thaw damage and to improve the overall pavement service life. The application of paving fabrics was most effective in warm climates such as southern states.

2.7 Cost Effectiveness of Paving Fabrics

Each DOT typically spends several millions of dollars each year on reflective crack control systems; but the cost effectiveness of these treatments has not been reliably determined. Some limited studies have addressed the cost-effectiveness and the life-cycle costs of these treatment systems. This section first presents the economic benefits of reduced reflective cracking. Then, the cost benefits of paving fabrics are discussed.

The economic benefits of reducing reflective cracking come from one or more of the following sources: a) increased life of the original pavement, b) lower maintenance costs; c) lower vehicle operating costs due to higher levels of serviceability; and d) lower user delay costs due to future preventive and rehabilitative maintenance interventions (Tighe, et al., 2003). In addition, there is an inherent benefit associated with the measurement and treatment of cracking, since the cost of measurement of existing cracks and treatment will also have to be considered. Regarding the increased life of the original pavement (mentioned above), Frechette and Shalaby (1997) have shown that an increase in crack spacing from 16.5 ft (5 m), occurring at the normal design life of 15 years, to 65.8 ft (20 m) would extend the life to 20 years. Tighe et al (2003), by providing a model to relate the amount of cracking to the loss of serviceability or reduction in service life, have indicated that a reduction of crack spacing from 16.5 ft (5 m) to 65.8 ft (20 m) would result in a cost savings of $ 25,000 per two-lane kilometer (2002 U.S. dollars).

Tighe et al. (2003) have concluded that reflective cracking can result in a reduced service life of a pavement and increased costs. Measurement and treatment of cracking can also yield significant benefits. Benefit-cost ratios from the measurement of cracking can range from 5 to 50, while proper and timely crack treatment can result in an extension of pavement life.

Several studies have addressed the cost effectiveness of reflective crack control treatments. Button (1989) studied nine test sections in Texas, each 0.25 mi (402 m) long, treated with a different type of nonwoven polypropylene or polyester fabric, ranging in weight from 3 oz/yd^2 (0.103 kg/m^2) to 8 oz/yd^2 (0.274 kg/m^2). He compared these nine sections with seal coats and control sections (no fabric). After nine years of performance, Button indicated that the paving fabric delayed the appearance of reflective cracks for about 2 to 3 years, but the paving fabrics were not found to be a cost-effective measure for treating reflective cracking.

Maurer and Malashekie (1989) conducted a 10-year life-cycle analysis in Pennsylvania in which six treated test sections (with paving fabrics) were compared with control sections. Four different paving fabrics, as well as two polymer-modified asphalt concrete mixtures, were used. The selected fabrics were non-woven, needle-punched, spunbonded polyester and polypropylene. All treatments were laid down in one location with combination of rigid and flexible bases. Fabric costs were \$1.50 to \$2.00/yd^2 (\$1.79 to \$2.39/m^2) and sealing cost at \$0.29/ft (\$0.95/m). Their study concluded that none of the fabric treatments considered were cost-effective rehabilitation measures.

A recent study evaluated the cost-effectiveness of Illinois Department of Transportation (IDOT) reflective crack control system consisting of a nonwoven polypropylene paving fabric (Buttlar, et al., 2000). The study was limited to projects constructed originally as rigid pavements and subsequently rehabilitated with one or more bituminous overlays. Performance of 52 projects across Illinois was assessed through crack mapping and from distress and serviceability data in IDOT's condition rating survey database. The performance monitoring indicated an increase in life spans by 1.1 and 3.6 years, for paving fabric strip (over lane-widening) and area applications (over the entire pavement), respectively. Life-cycle analysis indicated that the paving fabric reflective control system was marginally cost-effective in Illinois. Cost saving ranged from a break-even level for small projects [less than 1.6 lane-mile or (2.4 lane-km)] to about 6.2% for large projects [6 lane-mile (or 9.7 lane-km)] or greater where large quantities of paving fabric were used.

In summary, the studies related to cost effectiveness and life cycle costs are currently limited. Cost comparisons should be performed over the life of the overlay to determine an equivalency between two alternatives and compare their costs. The use of paving fabrics, as well as other alternatives should be compared with the cost of using an overlay of similar thickness with a crack-sealing maintenance program. Thicker overlays should also be used as a basis for comparison. A useful rule of thumb, based on typical in-place costs, is that a full-width paving fabric installed is approximately equivalent to the cost of about 0.5 to 0.6 in (12.7 mm to 15.24 mm) of asphalt concrete (Barksdale, 1991).

2.8 Lessons Learned from Installation

Several studies have reported the significance of proper installation in achieving the desired function for the paving fabric systems (e.g., Rahman, et al., 1989; Barazone, 1990; Baker, 1998; and Barazone, 2000). The fact that paving fabrics have been found to be an effective treatment system in test sections is largely due to tightly controlled installation procedures rigidly adhered to for oil temperature, spread rate, fabric placement, wrinkles and overlaps. To assure the performance record for paving fabric, the installation specifications and guidelines should be strictly enforced.

The installation of paving fabric system usually follows the same general pattern wherever it is used. First, the surface is prepared by removing loose material and sealing cracks, as necessary. Sealing the cracks is particularly important if there is a lot of random cracking, ¼- to 3/8- in. (6.3 to 9.5 mm) wide. The cracks should be filled with suitable crack filler material. Because this material will be underneath the final surface, its primary purpose is to prevent the fabric from spanning a void. A tack coat (such as asphalt-cement or bituminous oil) is then applied to the existing pavement surface. Typically, a tack-coat application of approximately 0.25 gal/yd^2 (1.1 liters/m^2) is recommended. After spraying on the tack coat, the paving fabric is rolled onto the sprayed surface. Finally an asphalt-cement concrete overlay is placed over the fabric. The heat of the overlay and the pressure applied by its compaction force the tack coat into the paving fabric and complete the process (Baker, 1998).

The application of insufficient tack coat is one of the leading causes of problems, which have been observed with paving fabrics. The absence of adequate tack coat corresponds to the loss of paving system benefits and can lead to damage the overlay. Too much tack coat will also bleed through the new asphalt. Button and Epps (1983) developed the following equation to obtain pavement fabric tack coat.

$$Q_d = 0.08 +/- Q_c + Q_s \tag{2}$$

Where Q_d = design tack quantity; gal/yd^2; Q_c = correction based on asphalt demand of the old surface, gal/yd^2; and Q_s = fabric asphalt saturation content, gal/yd^2.

Several reports including the Caltrans and Texas DOT studies have indicated that placing fabric properly is very important in the performance of the interlayer system (Barazone, 1990). Improperly placed fabric will reduce the long term benefit of the membrane system, resulting in less waterproofing, asphalt stripping (peeling away of the asphalt from the fabric) and cracks from heat damage, wrinkles, overlaps and in wheel paths. Mechanized fabric placement is faster than hand placement. When placing fabrics, the shiny, heat-bonded side should be up, exposed to traffic. If it is placed in extreme temperatures (90 to 95 degrees F), some sand should be placed on it, to keep traffic from picking up the material. Many published reports indicate that wrinkles and overlaps in the fabric can cause cracks in the new overlay if not properly handled during construction process. Winkles twice the thickness of the fabric should be slit at the bottom of the wrinkle and laid flat. Overlaps and slit wrinkles should be laid at top of each other. A 2- to 3-in. (2.54 to 7.62-cm) overlap on the fabric is often recommended (Roads and

Bridges, 1990). It should also be noted that installation around curves without producing excessive wrinkles requires proper procedures (Barazone, 2000).

Another problem during installation is the heat shrinkage. The most significant shrinkage problem often occurs when the fabric is placed into hot oil, which exceeds the fabric shrinkage temperature, rather than the melt points (Barazone, 1990). Los Angeles County, Texas, and Caltrans have documented shrinkage of polypropylene fabrics when placed in hot oils over 250 degrees F.

Barazone (1990) has indicated the minimum asphalt wearing course (overlay thickness) of 1 ½ to 2 inches (3.81 to 5.08 cm) in ideal paving temperatures (above 70 degrees F), and minimum of 2 inches (5.08 cm) in less than ideal temperatures (between 50 and 70 degrees F). Overlays should not be attempted with temperatures less than 50 degrees F. The heat from the overlay draws the oil up through the fabric making a bond. It may also be noted that paving fabrics are recyclable in both hot and cold milling processes.

Rahman, et al. (1989) documented the results of the installation of three commercial paving fabrics for the reduction of reflective cracking in asphalt overlays in Arizona. The fabrics installed were Paveprep (by PavePrep Corporation), Glassgrid (by Bay Mills Ltd.) and Tapecoat (by Tapecoat Company). Their recommendations included 1) the need for proper binder coat selection based on the expected construction conditions and product selections when paving fabrics are used in pavement rehabilitation; 2) the need for additional field testing of Paveprep on milled surfaces; and 3) caution regarding the use of Glassgrid on rough surfaces.

In summary, proper installation procedures are critical for optimum performance. Installation of paving fabrics has become more sophisticated in recent years. But it is by no means a closed science in the respect that everything has been learned.

2.9 Recent Innovations

In recent years, other techniques of using geosynthetics for the purpose of controlling reflective cracking have been proposed. Three of these methods are summarized in this section.

2.9.1 Geosynthetic Reinforcement of Asphalt Overlay

Higher-strength higher-stiffness grids and fabrics have been incorporated into asphalt overlays in recent years to provide an even higher level of crack retardation, and in some cases waterproofing. These new reinforcing interlayers rely on their high-modulus structure to reinforce the overlay while interrupting reflective crack propagating from the old surface. Sprague et al. (1998) have described the mechanisms that lead to the enhanced performance of reinforced overlays. They have shown that the high-stiffness grids and fabrics can possibly turn a reflective crack into a horizontal plane beneath the interlayer and delay reflective cracking indefinitely, provided they are constructed properly. However, specifying the appropriate reinforcing material relies on the uniform definition and measurement of stiffness of the interlayer, so that materials can be properly compared. Studies are needed to provide a reliable estimate of material stiffness.

2.9.2 Stress-Absorbing Composite Interlayer in Asphalt Concrete Overlays

Dempsey (2002) described an interlayer stress-absorbing composite (ISAC) for the purpose of alleviating or mitigating the problem of reflection cracking in an asphalt concrete (AC) overlay. The ISAC system consists of a low-modulus, low-stiffness geotextile as the bottom layer, a viscoelastic membrane layer (such as a blend of vulcanized rubber and appropriate viscosity asphalt) as the core, and a very high stiffness geotextile [(with stiffness greater than 48 kips/ft or (700 KN/m)] for the upper layer. A tack coat is needed on the existing pavement surface prior to placement of the ISAC material. A tack coat may also be required between the ISAC layer and the AC overlay. Several years of field performance testing have shown that the ISAC system is highly effective for mitigating reflective cracking in AC overlays used on both airport and highway pavement systems.

2.9.3 Application of Paving Fabrics and Double Chip Seal

Brown (2003) proposed the use of a paving fabric followed by double chip seal through trial and experimentation. He demonstrated that this system improved service life substantially, and that pavement deterioration due to oxidation and stripping has been eliminated since the air and water were unable to penetrate. It was shown that the alligator pavement cracking could be repaired without removing and replacing the damaged pavement section. Using the double chip seal also resulted in substantial cost savings based on a comparison with a conventional 2-in (5.1 cm) asphalt concrete overlay on a paving fabric system.

CHAPTER 3

SUMMARY AND RECOMMENDATIONS

3.1 Summary

The formation of reflective cracking of pavement overlays has confronted highway engineers for many years. Stress-relieving interlayers, such as paving fabrics, have been used in an attempt to reduce or delay reflection cracking. Their effectiveness in reducing reflection cracking is related to joint or crack movement in the underlying pavement, crack width, overlay thickness, subgrade conditions, climate, and traffic volume. Studies have shown that nonwoven geotextile interlayer systems, known as the paving fabric, in conjunction with asphalt overlays, typically 1.5 to 2.5 inches (38.1 to 63.5 mm), may be used to absorb the stresses normally transferred from cracks in the old pavement into the overlay, and reduce or prevent the reflective cracking. The nonwoven geotextiles are installed between the old and new asphalt layers. Paving fabrics enhance performance through two mechanisms: stress relief and waterproofing.

Specifications have been developed by several agencies for use of fabrics in interlayers. A polypropylene, staple fiber, needlepunched, nonwoven geotextile is often recommended for this application. The fibers are needed to form a stable network that retains dimensional stability relative to each other.

The field performance of overlays using fabric interlayers has generally been successful, although there have been cases where the paving fabric systems provided little or no improvements. In particular, paving fabrics may not reduce cracking significantly with thin overlays. In one study, at a 25 percent level of reflection cracking, the inclusion of fabric increased the performances of the 1.5 in. (38.1 mm) overlays by a factor of 3 (4.5 years versus 1.5 years). Although there are somewhat conflicting recommendations regarding the overlay thickness [ranging from 1 to 4 in. (25.4 to 101.6 mm)], the benefit of increasing overlay thickness, either with or without a fabric is clear. Factors such as the local climate and the traffic volume will need to be considered prior to the design of an appropriate overlay thickness.

The field performance is often related to several factors including proper installation, remedial work performed before overlay, overlay thickness, variability of pavement strength, existing pavement condition, base/subgrade support condition, traffic volume, and environmental factors including climate. In general, fabric interlayers have been most effective when used for load-related fatigue distress and have not performed well when used to delay or retard thermal cracking. Paving fabrics have been beneficial in the reduction of water entering the pavement; however, documentation showing the derived benefits needs to be developed through carefully planned field studies.

In general, the application of paving fabrics was most effective in warm climates such as southern states. The inclusion of paving fabric should not be expected to stop all thermal cracking. But, the moisture-control situations of the environmental regime in terms of waterproofing effects will help to minimize the freeze/thaw damage and to improve the overall pavement service life.

Proper construction procedures are critical for optimum performance of paving fabrics. Installation of paving fabrics has become more sophisticated in recent years. But it is by no means a closed science in the respect that everything has been learned. Some of the construction aspects that influence paving fabric systems include pavement preparation, oil temperature, spread rate, fabric placement, wrinkles and overlaps. To assure the performance record for paving fabric, the installation specifications and guidelines should be strictly enforced.

Limited studies have addressed the cost-effectiveness and the life-cycle costs of the paving fabric treatment systems. Some life-cycle analyses have indicated that the paving fabric reflective control system was marginally cost-effective. It is important that the cost comparisons be performed over the life of the overlay to determine an equivalency between various alternatives and compare their costs.

In recent years, other techniques of using geosynthetics for the purpose of controlling reflective cracking have been proposed. These include geosynthetics reinforcement of asphalt overlay, stress-absorbing composite interlayer in asphalt concrete overlays, and application of paving fabrics and double chip seal. A review of these techniques generally indicates great potential for future use.

3.2 Recommendations for Future Research

There are several areas that require further research. Additional studies are required to provide long-term field evaluation of the paving fabric system in local climate, and to evaluate its cost effectiveness. Paving fabric applications would likely be applicable on non-interstate routes, since the primary mode of failure on interstate routes is rutting. On non-interstate routes, extensive cracking can occur without rutting or shoving problems. Some possible recommendations for future research are listed below:

1. Although there have been some long-term field studies, it is important that this evaluation be performed in local climate. It has been shown that the local conditions directly influence the performance. Thus, it is recommended that long-term monitoring of paving fabric performance be performed to evaluate its

effectiveness in local conditions. This performance should be measured by comparing the condition of overlays using fabric with overlays not using fabric. This performance should be done in two ways. First, a comparison of the performance of paving fabric/overlay section with section containing no paving fabric (control section) should be done. Second, the performance of the paving fabric section with paving fabric should be compared with section with no paving fabric section but with a thicker asphalt overlay. The performance should be measured over a given period, preferably at least 7 years, or until a level of pavement deterioration is reached. Particular attention needs to be directed studying the effect of such factors as overlay thickness and traffic volume on long-term performance.

2. It should be noted that cost-effective techniques that prevent reflection cracking for the life of an overlay have not been identified. Under favorable conditions, a number of methods, including paving fabrics, can delay reflection cracking for several years. Reflection cracks are usually sealed through a maintenance program, and the costs of such a program should be considered when making cost comparisons. The Transportation Research Board (TRB) Committee on Geosynthetics has identified "the identification and cost benefits of methods used to reduce reflection cracking in asphalt overlays" as one of the "Research Needs Statements" (Suits, 1999). It is recommended that cost comparisons of different options be performed over the life of the overlay to determine an equivalency between various alternatives and compare their costs. Some of the factors to be considered include the potential benefits if deflective cracking is delayed, the

probability of success, increased life of the original pavement, lower maintenance costs, lower vehicle operating costs due to higher levels of serviceability, lower user delay costs due to future preventive and rehabilitative maintenance interventions, benefits from permeability reduction, and inherent benefit associated with the measurement and treatment of cracking.

3. In may be noted that in the state of Mississippi, once the pavement has deteriorated to small block, alligator cracking, milling is often performed. However, many of these routes with moderate to moderately severe cracking are routinely overlayed without being milled first. Some possible recommendations for future research may include: 1) a comparison between the performance of paving fabric treatment systems for milled and non-milled surfaces; and 2) a comparison between the performance of paving fabrics on sealed and non-sealed surfaces. The seal materials may include 0.19 in. (4.75 mm) HMA, a sand mix HMA, or slurry seal.

REFERENCES

1. Ahlrich, R. C. (1986). “Evaluation of Asphalt Rubber and Engineering Fabrics as Pavement Interlayers,” Final Report, Miscellaneous Paper GL-86-34, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, Nov.

2. Barazone, M. (1990). “Paving Fabric Interlayer Membranes and Installation Procedures Over the Past 20 Years,” Geotechnical Fabrics Report, Vol. 10, No. 4, pp. 16-21.

3. Barazone, M. (2000). “Installing Paving Synthetics-an Overview of Correct Installation Procedures (Part One),” Geotechnical Fabrics Report, Vol. 18, No. 2, pp. 16-18.

4. Barnhart, V. T. (1989). “Field Evaluation of Experimental Fabrics to Prevent Reflective Cracking in Bituminous Resurfacing,” Final Report, Research Project 80-NM-617, Research Report No. R-1300, Research Laboratory Section, Materials and Technology Division, Michigan Transportation Commission, Lansing, July.

5. Baker, T. (1998). “The Most Overlooked Factor in Paving-Fabric Installation,” Geotechnical Fabrics Report, Vol. 16, No. 3, pp. 48-52.

6. Barksdale, R. D. (1991). “Fabrics in Asphalt Overlays and Pavement Maintenance,” Transportation Research Board, Report No. NCHRP 171, Washington, D.C.

7. Bernard, F. (1996). “Canadian Climate Tests Paving Fabric’s Performance,” Geotechnical Fabrics Report, Vol. 14, No. 3, pp. 30-33.

8. Brown, D. (2000). “Debate on Road Waterproofing,” World Highways, Vol. 9, No. 2, pp. 57-59.

9. Brown, N. R. (2003). “Solution for Distressed Pavements and Crack Reflection,” Transportation Research Record, No. 1819, pp. 313-317.

10. Burmania, D. (1988). “Geotextiles May Bolster Pavement Performance,” Roads & Bridges, Vol. 26, No. 1, pp. 88-93.

11. Buttlar, W. G., Bozkurt, D. and Dempsey, B. J. (1999). “Evaluation of Reflective Crack Control Policy,” Final Report, Report No. ITRC FR 95/96-4, Illinois Transportation Research Center, Edwardsville, IL, p. 184.

12. Buttlar, W. G., Bozkurt, D. and Dempsey, B. J. (2000). “Cost-Effectiveness of Paving Fabrics Used to Control Reflective Cracking,” Transportation Research Record, Transportation Research Board, No. 1730, pp. 139-149.

13. Button, J. W., and Epps, J. A. (1983). "Evaluation of Mirafi Fabrics for Pavement Overlays," Texas Transportation Institute, Final Report 3424-6.

14. Button, J. W. and Lytton, R. L. (1987). "Evaluation of Fabrics, Fibers and Grids in Overlays," Proc., 6th International Conference on Structural Design of Pavements, Vol. 1, Ann Arbor, Michigan, pp. 925-934.

15. Button, J. W. (1989). "Overlay Construction and Performance Using Geotextiles," Transportation Research Record, No. 1248, pp. 24-33.

16. Carmichael, R. F., and Marienfeld, M. L. (1999). "Synthesis and Literature Review of Nonwoven Paving Fabrics Performance in Interlayers," Transportation Research Record, No. 1687, pp. 112-124.

17. Dempsey, B. J. (2002). "Development and Performance of Interlayer Stress-Absorbing Composite in Asphalt Concrete Overlays," Transportation Research Record 1809, pp. 175-183.

18. Dykes, J. W. (1980). "Use of Fabric Interlayers to Retard Reflective Cracking," Proc., AAPT, Vol. 49, pp. 354-368.

19. Dykes, J. W. (1985). "Paving Fabrics with Asphalt Overlays," Proc., Geotechnical Fabrics Conference, Cincinnati, Ohio, International Fabrics Association International, June.

20. Epps, J. A., and Button, J. W. (1984). "Fabrics in Asphalt Overlays-Design, Construction and Specifications," Report No. 261-3F, Texas Transportation Institute.

21. Frechette, L. and Shalaby, A. (1997). "Reflective Cracking Trends in C-SHRP LTPP Sites," Transportation Association of Canada, Ottawa, Ontario.

22. FHWA (1982). "Report on Performance of Fabrics in Asphalt Overlays," Office of Highway Operation, Experimental Application and Evaluation Branch, Sept.

23. Hanson, M. A. and Paulson, R. (1985). "Reinforcement Objective: Residential Street Resurfacing," Geotechnical Fabrics Report, Industrial Fabrics Association International, St. Paul, Minn., July/Aug., p. 9.

24. Herbst, G. (1988). "Asphalt Overlay on Cracked-Sealed Concrete Pavement," Reflective Cracking in Pavements, Austria, June.

25. Hughes, C. S. (1977). "Minimization of Reflection Cracks in Flexible Pavements," Final Report, Report No. VHTRC 78-R5, Virginia Highway & Transportation Research Council.

26. Hughes, J. J., and Somers, E. (2000). "Geogrid Mesh for Reflective Crack Control in Bituminous Overlays," Final Report, Report No. PA 200-013-86-001, Pennsylvania Department of Transportation.

27. Hugo, F., Struss, P., and Schnitter, O. (1982). "The Control of Reflection Cracking with the Use of a Geotextile," A Ten Year Case History, Proc. 2nd International Conference on Geotextiles, Las Vegas, Nevada, Vol. 2, IFAI, St. Paul, Minn., Aug., pp. 517-522.

28. Georgia Department of Transportation (1976). "Interim Status Report 302," Paving Information Bulletin.

29. Jackson, R. D. (1980). "Use of Fabrics and Other Measures for Reflective Cracking of Alphabetic Concrete Overlays," Final Report, Report No. WES/MP/GL-80-2, FAA/RD-80/8, Waterways Experiment Station, Corps of Engineers, Vicksburg, MS.

30. Jayawickrama, P. W. and Lytton, R. L. (1987). "Methodology for Predicting Asphalt Concrete Overlay Life Against Reflection Cracking," Proc. of the Sixth Inter. Conference on Structural Design of Pavements, Ann Arbor, Michigan, pp. 912-924.

31. Karam, G. (1990). "Experience of DuPont de Numours in Reflective Cracking: Site Follow up," Reflective Cracking in Pavements, Austria.

32. Kidd, S. Q. (1990). "Paving Fabric and Asphalt Stress Absorbing Membrane Interlayers (SAMI)," Final Report, Report No. MSHD-RD-90-67-6, Mississippi State Highway Department Research and Development Division, Jackson, MS.

33. Knight, N. E. (1985). "Heavy Duty Membranes for the Reduction of Reflective Cracking in Bituminous Concrete Overlays," Final Report, Research Project 79-6, Pennsylvania Department of Transportation, Aug.

34. Kutuk, B. (1998). "Performance of Flexible Pavements Reinforced with Geogrids," Department of Civil and Environmental Engineering, West Virginia University, Morgantown, West Virginia.

35. Lorenz, V. M. (1987). "New Mexico Study of Interlayers Used in Reflective Crack Control," Geotechnical Fabric Report, May/June, pp. 17-26.

36. Lytton, R. L. (1989). "Use of Geotextiles for Reinforcement and Strain Relief in Asphalt Concrete," Geotextiles and Geomembranes, Vol. 8, No. 3, pp. 217-237.

37. MacMaster, J. B. (1978). "Control of Reflection Cracking by Use of pavement Material," Report EM-11, Ontario Ministry of Transportation and Communications, Engineering Materials Office.

38. Marienfeld, M. L. and Baker, T. L. (1999). "Paving Fabric Interlayer as a Pavement Moisture Barrier," TRB Circular No. E-C006.

39. Maurer, D. A. (1985). "Comparison of Methods to Retard Reflective Cracking in Bituminous Concrete Using Fabrics and Fibers," Report No. FHWA-PA-85-015, Pennsylvania Department of Transportation.

40. Mascunana, I. (1981). "An Evaluation of Engineering Fabric in Pavement Rehabilitation (IHD-21)," Final Report, Physical Research Report No. 88, Illinois Department of Transportation.

41. Maurer, D. A. and Malashekie G. J. (1989). "Field Performance of Fabrics and Fibers to Retard Reflective Cracking," Transportation Research Record, No. 1248, pp. 13-23.

42. McGhee, K. H. (1975). "Efforts to Reduce Reflective Cracking of Bituminous Concrete Overlays of Portland Cement Concrete Pavements," VHTRC 76-R20, Virginia Highway and Transportation Research Council, Charlottesville, VA, Nov.

43. McGhee, K. H. (1982). "Control of Reflection Cracking in a Fabric-Reinforced Overlay on Jointed Portland Cement Pavement," VHTRC 83-R8. Virginia Highway and Transportation Research Council, Charlottesville, VA, Aug.

44. North Dakota State Highway Department, (1979). "Petromat," Final Evaluation Report, Project DP-RF-1-083 (12) 145.

45. Paris, P. C., and Erdogan, F. A. (1963). "Critical Analysis of Crack Propagation Laws," Transactions of ASME, Journal of Basic Engineering, Series D, 85, No. 3, pp. 528-534.

46. Perfetti, J., and Sangster, T. (1989). "The Function of Geotextiles in Pavement Structures," Proc., Geosynthetics' 89, Vol. 2, San Diego, Calif., IFAI, Feb., pp. 334-344.

47. Pourkhosrow, G. (1982). "The Evaluation of Non-Woven Fabrics: Petromat and Mirafi," Final Report, FHWA/OK 82(6), Oklahoma Department of Transportation, May.

48. Predoehl, N. H. (1990). "Evaluation of Paving Fabric Test Installations in California," Final Report, Report FHWA/CA/TL-90/02, California Department of Transportation, Feb.

49. Paving Information Bulletin, (1976). “Petromat Controls Reflective Cracking,” Petromat, October.

50. Rahman, M., Scofield, L., and Wolf, T. (1989). “Paving Fabrics for Reducing Reflective Cracking,” Report No. FHWA-AZ-8801, Arizona Transportation Research Center, Prepared for Arizona Department of Transportation.

51. Roads & Bridges (1989). “Specifier’s Guide to Paving Fabrics,” Vol. 27, No. 5, pp. 75.

52. Roads & Bridges (1990). “Right Specification, Installation Key to Fabric Use,” Vol. 28, No. 9, pp. 30-31.

53. Sposito, B., and Brooks, E. (1999). “Geosynthetics for Reflective Crack Control,” Report No. OR-RD-99-20, Oregon Department of Transportation.

54. Sprague, C. J., Allen, S., and Tribbett, W. (1998). “Tensile Properties of asphalt Overlay Geosynthetic Reinforcement,” Transportation Research Record, No. 1611, pp. 65-69.

55. Suits, L. D., Richardson, G. N. (1998). “The Updated AASHTO Geotextile Specifications,” Geotechnical Fabrics Report, Vol. 16, No. 2, pp. 39-41.

56. Suits, L. D. (1999). “Wrapping up the 1999 TRB Meeting,” Geotechnical Fabrics Report, Vol. 17, No. 2, pp. 14-15.

57. Suits, L. D. (2001). “AASHTO NTPEP and Specification M-288 for Geotextiles,” Geotechnical Fabrics Report, Vol. 19, No. 5, pp. 20-25.

58. Synthetics Industries (2003). “Pave-Dry Nonwoven Asphalt Overlay Fabrics,” SI Geosolutions Publication.

59. Tighe, S., Hass, R., and Ponniah, J. (2003). “Life Cycle Cost Analysis of Mitigating Reflective Cracking,” Transportation Research Record, No. 1823, pp. 73-79.

60. Verdos, P. J. (1981). “Evaluation of Membrane Interlayers for Prevention of Crack Reflection in Thin Overlays,” Miscellaneous Paper GL-81-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.