BUTTON, J. W., EPPS, J. A., and LYTTON, R. L.
Texas Transportation Institute, Texas A & M University, Texas, USA
HARMON, W. S.
Celanese Fibers Marketing Company, North Carolina, USA

Fabric Interlayer for Pavement Overlays

Textile interposé entre revêtement ancien et nouveau

Laboratory experiments were conducted to establish the mechanisms responsible for the performance of commercially available engineering fabrics as effective reflection crack arrestors and determine fabric properties which provide the desired field performance. Tests were developed and performed to determine asphalt requirements and shrinkage characteristics of fabrics. Tests on paving mixtures containing fabrics were conducted to determine resistance to thermal reflection cracking, shear strength of the fabric interlayer, flexural fatigue characteristics, tensile properties and probability of pavement cracking caused by fabric shrinkage. Results showed that fabrics improved tensile properties, increased fatigue life, reduced crack propagation rate and will not compound overlay slippage problems when properly installed.

Des essais de laboratoire ont été effectués pour mettre en évidence les mécanismes permettant à des géotextiles disponibles sur le marché d'arrêter la propagation des fissures et pour déterminer les propriétés du textile qui régissent la performance en place. Des essais ont été mis au point et effectués pour déterminer les spécifications du bitume et les caractéristiques de retrait des textiles. Des essais sur des revêtements contenant des textiles ont été réalisés pour déterminer la résistance à la propagation des fissures thermiques, la résistance au cisaillement au niveau du géotextile, les caractéristiques de fatigue en flexion, le comportement en traction et la probabilité de fissuration du revêtement causée par le retrait du géotextile. Les résultats montrent que les textiles améliorent le comportement en traction, augmentent la résistance à la fatigue, réduisent la vitesse de propagation des fissures et n'aggravent pas le problème du glissement de la couche rajoutée lorsqu'ils sont correctement installés.

INTRODUCTION

The major portion of highway pavement expenditures in the United States during the next 20 years will be for reconstruction, rehabilitation and maintenance of our existing facilities rather than construction of new facilities. This ecomomic prognosis has increased research and development efforts aimed at pavement overlay systems that will eliminate, reduce or delay cracks from reflecting from the old pavement through the new overlay. The use of fabrics in combination with asphalt concrete overlays is one of several promising systems for reducing or delaying reflection cracks.

This is a summary report of a laboratory study (1) sponsored by the Celanese Fibers Marketing Company.

Laboratory tests were developed to help identify parameters which contribute to early cracking of fabric overlays. Fabric shrinkage tests were conducted by both Celanese and Texas A&M University and a "construction crack test" was developed. Results from these tests illustrate the importance of using "low" shrinkage force fabrics and the importance of proper construction techniques to reduce fabric wrinkles.

The investigation of potential slippage problems included the development of a special "airport shear" test to determine the shear strength of the interface between the fabric and the old asphalt concrete and the new asphalt concrete overlay.

Specific objectives of the laboratory study are listed below:

1. Establish the mechanisms responsible for the performance of fabrics as effective reflection crack arrestors,

2. Determine fabric properties which provide the desired field performance under a variety of conditions and

3. Define and delineate satisfactory field installed procedures for utilizing fabrics as part of an overlay system to reduce or prevent reflection cracking.

The laboratory testing program includes testing of fabrics to determine the following properties:

1. Asphalt content at saturation,

2. Temperature shrinkage characteristics,

3. Shear strength of old pavement-fabric-new overlay interface,

4. Tensile strength of fabric-mixture system,

5. Flexural fatigue properties of fabric-mixture system and

6. Resistance to reflection cracking (overlay tester).

MATERIALS

Eight fabrics, labeled A,B,C,D,E,F,G, and H, supplied by Celanese Fibers Marketing Company, were tested to determine the properties listed above.

Asphalt concrete paving mixtures containing AC-10 asphalt cement were utilized to evaluate the fabrics under simulated field conditions.

DESCRIPTION OF TESTS

Laboratory apparatus were designed and developed to mechanistically evaluate fabrics in a logical sequence of tests. These new test methods were developed to simulate field loading conditions and hence are capable of evaluating overlay systems on a relative basis. First, a fabric was evaluated to see if it could withstand temperatures encountered in hot mix pavement construction; if so, the appropriate quantity of asphalt tack was determined. Asphalt concrete specimens containing fabric were fabricated and tested to define the effects of fabrics in overlay slippage, and to separately evaluate the performance of fabrics in the reduction of fatigue and thermal cracking.

SATURATION TEST

This test method involves the saturation of a piece of fabric 200 x 200 mm (8 x 8 - in) in AC-10 asphalt cement at 121°C (250°F) for 1 minute. The saturated fabric is allowed to cool and then pressed with a hot iron between two absorbent papers to remove the excess asphalt. This method produces a uniformly appearing saturated fabric.

Fabric saturation contents are shown in Table 1.

Table 1. Fabric Saturation Quantities and Recommended Tack Coat Quantities.

Fabric	Saturation Content, $m^3/m^2 \times 10^{-4}$ (gal/yd^2)	Asphalt Tack Coat Quantity, $m^3/m^2 \times 10^{-4}$ (gal/yd^2)
A	1.8 (0.04)	6.3 (0.14)
B*	0.9 (0.02)	5.4 (0.12)
C	1.8 (0.04)	6.3 (0.14)
D	5.9 (0.13)	10.4 (0.23)
E	14.9 (0.33)	18.1 (0.40)
F	1.4 (0.03)	5.9 (0.13)
G	4.5 (0.10)	9.1 (0.20)
H	6.8 (0.15)	11.3 (0.25)

These quantities were utilized as the design asphalt content for the test specimens prepared in this laboratory testing program.

Fabric asphalt saturation content is one parameter that is utilized to determine field tack coat quantities for adequate adhesion between pavement layers. The tack coat quantity may be estimated from the equation below:

$$Q_d = 0.08 + Q_s \pm Q_c \qquad \text{(Equation 1)}$$

where:

Q_d = design tack coat quantity, gallons per square yard

Q_s = fabric asphalt saturation content, gallons per square yard,

Q_c = correction to tack coat quantity based on asphalt demand of old surface, gallons per square yard.

The quantity, 0.08 gallons per square yard is based on field experience for overlays with no fabric. This equation, developed earlier in this research program (2), was utilized to determine asphalt tack coat quantities for laboratory testing purposes. A value of +0.02 was selected for Q_c based on the surface conditions of the laboratory samples.

LINEAR SHRINKAGE TEST

This test involves soaking of the fabric in asphalt cement to simulate the application of a hot asphalt concrete overlay. Four pieces of fabric with dimensions of 100 x 100 mm (4 x 4-inches) were submerged in 121°C (250°F) and 149°C (300°F) asphalt cement. One piece of fabric was removed after elapsed times of 1, 5, 15 and 30 minutes and allowed to cool then measured along the run of the fabric to determine the effects of heat on length change as a function of time and temperature.

The results at 149°C (300°F) are plotted in Figure 1.

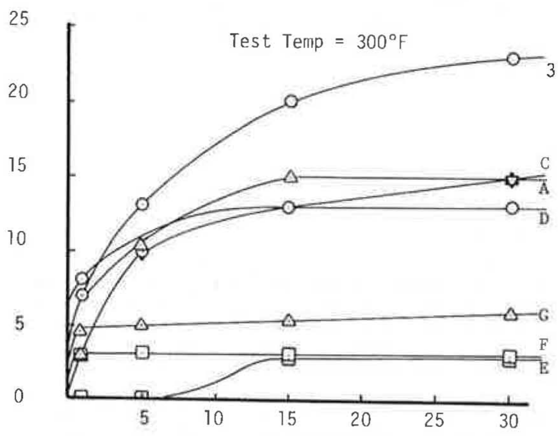

Figure 1. Temperature Stability of Fabrics in 300°F Asphalt Cement.

As expected the higher temperature caused more fabric shrinkage. The lower test temperature (149°C) appears to be located near a critical temperature; that is, below this temperature very little shrinkage occurs, but above this temperature significant shrinkage occurs in most of the fabrics. Fabrics E,F and G, with linear shrinkage values of 5 percent or less after 15 minutes, have the lowest temperature susceptibility. Fabric B, the most temperature susceptible fabric tested, as well as C and G apparently would have continued to shrink after 30 minutes exposure to the hot asphalt cement. Most of the other fabrics reached a maximum shrinkage after 30 minutes exposure.

CONSTRUCTION CRACKING TEST

It is fairly common knowledge that heat (149°C or more) will cause varying degrees of shrinkage in most currently available fabrics. This shrinkage may be advantageous at least temporarily, as a "post-tensioned" fabric would improve the tensile properties of the system, particularly at low strains. The temporary nature of these benefits are due to stress relaxation in the viscoelastic system.

When wrinkles (or cuts without adequate overlap) are present in a fabric during an overlay operation, tensile forces caused by fabric shrinkage can produce a significant displacement of the fabric normal to the wrinkle or cut. Shrinkage occurs while the asphalt concrete overlay is hot and without appreciable tensile strength; thus, the fabric displacement carries the hot overlay with it resulting in a crack in the new overlay along the wrinkle or cut.

A laboratory test was developed to identify possible causes of cracking within hot asphalt concrete during the early life (first few hours) of the overlay. The test consists of the placement of a hot asphalt concrete mixture over a fabric which has been placed in a rectangular mold.

Two rectangular molds 1,220 mm (48-inches) long by 140 mm (5 1/2-inches) wide, were fabricated from wood (Figure 2). One mold was fabricated with 32 mm (1/8-inch) transverse crack near the center; the other mold contained no crack. An appropriate quantity of tack was placed in the bottom of the mold, depending on the

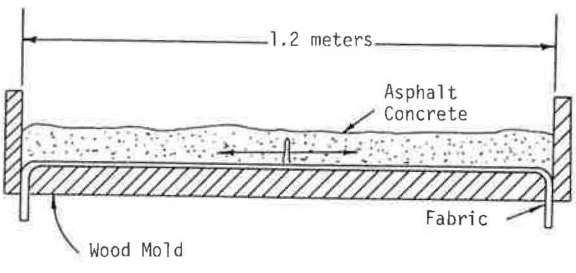

Figure 2. Apparatus Used to Determine Likelihood of Construction Cracking.

requirements of the fabric. Fabric was placed over the tack coat in one of three different orientations: (1) control samples - either no fabric or smooth fabric with no wrinkles, (2) one 10mm (3/8-inch) wrinkle in the fabric near the center of the mold (wrinkle down in crack when using mold with crack), and (3) fabric cut transversely near the center of the mold. The fabric was 140 mm (5 1/2-inches) wide and securely fastened to each end of the mold (Figure 4). Hot mix asphalt concrete was placed in the mold over the fabric and compacted using a hand tamper. The compacted asphalt concrete, which ranged in thickness from 19mm (3/4-inch) to 38 mm (1 1/2-inch) was observed periodically to check for cracking. If cracks did appear in the overlay it was usually within 15 minutes after placement and compaction. In some tests smaller cracks appeared after more than one hour of time elapsed.

Test results using the four foot mold are given in Table 2. No shrinkage cracks appeared in any of the tests conducted using a two foot mold which was used initially. However, cracks did appear in certain similar tests using the four foot mold. This indicates the shrinkage forces that accumulated over a one foot length of fabric on each side of the wrinkle were not sufficient to cause cracking in the hot overlay. Furthermore, the shrinkage forces in some fabrics are capable of acting from a distance greater than one foot to produce cracking in a hot asphalt overlay.

Fabrics E and F, which exhibited very little shrinkage in the temperature stability test, did not produce cracks in this test. And conversely, Fabric B,

Table 2. Construction Cracking Test Results.

Fabric	Overlay Thickness, Inches	Type Test	Results
B	3/4	C+W	Crack
	1 1/2	C+W	Crack
	3/4	Cut	Large Crack
E	3/4	W	No
	1 1/2	W	No
	1 1/2	C+W	No
	3/4	Cut	No
F	3/4	C+W	No
	3/4	C+W	No
	3/4	W	No
	3/4	Cut	No
G	1 1/2	W	No
	3/4	C+W	Small Cracks
	1 1/2	C+W	No
	3/4	Cut	Small Cracks
Control	3/4	C (No Fab)	No
	3/4	C (Smooth)	No
	3/4	No Crack No Fabric	No

C+W = Crack in mold + wrinkle in fabric
W = Wrinkle in fabric, no crack in mold
C = Crack in mold, no wrinkle in crack

which exhibited excessive shrinkage in the temperature stability test, produced the largest cracks and was the only fabric tested that produced a crack in the 38 mm (1 1/2-inch) overlay. In the temperature stability test, Fabric G exhibited comparatively little shrinkage but shrank over a relatively long time period, similarly, in this test, it produced small cracks in the thin overlays and more than an hour elapsed before they appeared.

Although the number of tests were not sufficient to make positive statements, the following conjectures are made based on test observations: (1) There was no noticeable difference in crack propagation between tests using emulsion and asphalt cement tack coats, (2) The cut fabric allowed slightly more cracking than the wrinkle alone or the wrinkle in the crack, (3) The thicker overlay was less likely to crack due to fabric shrinkage, (4) Fabrics with free shrinkage (1) in excess of about 7 percent may cause cracking during construction, (5) Fabrics with high shrinkage forces (1) are more likely to cause cracking, (6) Fabric-asphalt cement systems with linear shrinkages greater than 5 percent after soaking in 149°C (300°F) asphalt for 30 minutes are likely to cause cracking during construction.

INTERFACE SHEAR STRENGTH

Adequate shear strength must be attained or pavement slippage failures will occur. Slippage failures, typically crescent shaped, are associated with high shear stress areas of a pavement and are most likely to occur during braking or turning operations when ambient temperatures are high.

A test method was developed and used to determine the shear strength of the fabric interface. Tests were conducted at 20, 40, and 60°C (68, 104 and 140°F) at a deformation rate of approximately 220 mm/sec (13 in/sec). A statistic vertical load of 178 N (400 lbs.) was applied to the 75 x 75 x 50 mm (3 x 3 x 2 inch) samples. Specimens at 60°C (140°F) would not support the vertical load and were thus tested with no appreciable vertical load.

Individual and mean values of interface shear strength are presented in Table 3. Optimum tack coat was established by use of Equation 1. Low tack coat is one-half the optimum value while high tack coat is twice the optimum value.

Table 3. Shear Strength Test Results.

Specimen Identification	Test Temp°c(°F)	Shear Strength in psi @		
		Low Tack	Opt. Tack	High Tack
A	20 (68)	230	240	-
	40 (103)	160	190	240
	60 (140)	-	120	-
D	20 (68)	200	280	-
	40 (103)	190	190	290
	60 (140)	-	120	-
E	20 (68)	310	390	400
	40 (103)	240	265	-
F	20 (68)	185	340	390
	40 (103)	170	170	-
G	20 (68)	150	260	-
	40 (103)	130	180	170
Control-1 No Fabric 0.05 Tack	20 (68)	-	350	-
	40 (103)	-	180	-
	60 (140)	-	130	-
Control-2 Asphalt Concrete with no interface	20 (68)	-	440	-
	40 (103)	-	290	-
	60 (140)	-	150	-

Control-1 samples were fabricated to simulate typical old pavement-new overlay interfaces using 0.00023 m^3/m^2 (0.05 gal/yd^2) of tack. Control-2 specimens were fabricated with no construction interface in the plane of shear. As expected, the shear strength of the Control-2 sample is greater than that of the Control-1 samples. At the optimum tack coat and low temperatures the shear strength of those samples without a fabric at the interface (Control-1) is usually in excess of those samples with fabric at the interface. At the higher temperatures the shear strength of samples with fabric at the interface approaches the shear strength of those samples without fabric at the interface. The tack coat quantity called "high" was, without doubt, more asphalt cement than should be used in an actual overlay operation. Shear strength, however, increased with increased tack coat for most of the fabrics. Hence, the optimum tack coat based on maximizing shear strength is different from that indicated by Equation 1. This increase in shear strength with increased tack coat is probably due to excess asphalt which migrated into the mixture adjacent to the shear plane thus creating a more tenacious bond in the critical area. However, this may not always occur with certain fabrics, especially at higher temperatures.

Shear strength with fabric E is, in general, notably higher than that with the other fabrics. It is noteworthy that Fabric E is thicker and fuzzier than the other fabrics. Therefore, it appears that shear strength is directly related to the bulk of a fabric or, more likely, the asphalt saturation level and surface friction of the fabric. This seems reasonable in that the "fuzz" could act as numerous little roots to provide reinforcement at the fabric interface and this provide increased shear strength.

From a pavement performance standpoint, it is important to have sufficient shear strength at the interface between the old pavement and the new overlay to prevent slippage failures. The magnitude of the required shear strength is dependent upon the type of traffic, speed of traffic, severity of braking and wheel turning movements, ambient temperature and location of the interface within the pavement structure. At the present time an acceptable level of interface shear strength cannot be firmly established.

As a general guide, it is desirable to have interfacial shear strength of the same order of magnitude as that associated with conventionally constructed overlays (Control-1). By adjusting tack coat quantity and/or asphalt grade, all fabrics can meet this interim criteria.

FLEXURAL FATIGUE

Beam fatigue tests were performed to provide information for prediction of the fatigue life of pavements. Fatigue cracking of pavements is caused by repeated wheel loads and will appear as cracks in the wheel path. These cracks will have a pattern similar to "chicken wire" or "alligator skins".

Flexural fatigue characteristics of asphalt concrete mixtures with and without fabric were determined at 20°C (68°F). Loads are applied at the third points of the beam, four inches on center, using one inch wide steel blocks. The machine is operated in the load control mode with a half-sine wave form at a frequency of 100 cycles per minute (1.67 Hz) and a load duration of 0.1 seconds. The test specimens are oriented such that the fabric is subjected to tensile stress during the loading phase. A reverse load is applied at the end of each load cycle to insure that the specimen returns to its original at-rest position after each cycle.

Peak stress, initial bending strain (bending strain at the 200th cycle), initial stiffness modulus (200th cycle) and estimated total input energy were calculated for each specimen. Table 4 summarizes results of those tests conducted at a peak stress level of 100 psi. Test results indicate that, generally, certain fabrics with appropriate tack coats placed within a flexural fatigue specimen in the region of tensile stress will improve fatigue life.

Table 4. Simple Statistics of Flexural Fatigue Data.**

Sample No.	Bending Strain, in/in	Cycles to Failure	Initial Stiffness Modulus, psi	Total Energy Input, lb-in
Control	.00074	6,400	151,000	5,500
Fabric A (Low)	0.00130	3,100	80,000	4,800
Fabric A (Optimum)	0.00064	9,200	177,000	7,200
Fabric A (High)	0.00130	4,900	78,000	7,800
Fabric D (Optimum)	0.00056	9,300	196,000	7,200
Fabric E (Optimum)	0.00087	79,000	147,000	76,000
Fabric F (Optimum)	0.00123	4,600	88,000	6,500
Fabric G (Low)	0.00077	7,400	133,000	7,600
Fabric G (Optimum)	0.00081	8,600	134,000	9,600
Fabric G (High)	0.00064	16,200	133,000	7,600

* Log Mean ** Only those specimens tested at a stress near 100 psi are included in the mean.

Fifteen fatigue tests were conducted on the control beams and beams containing Fabric G to define the relationships between bending stress or initial bending strain and number of load applications to failure. The plotted results are given in Figure 3. Dashed lines on this figure represent the locus of the regression equations for the Control specimens. Hence, at a given bending stress the control beam would fail in fewer load applications than the beam containing Fabric G. (The same is true for initial bending strain.)

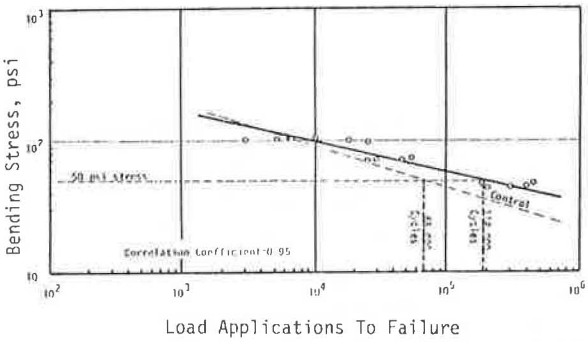

Figure 3. Stress versus Load Applications to Failure for Specimens Containing Fabric G at Optimum Asphalt Content.

1 psi = 6.894kPa

There appeared to be some relationship between fatigue characteristics of a specimen and the fabric's ability to hold asphalt as well as the fabric's surface texture. Fabrics A and F, thin slick fabrics not capable of retaining an appreciable quantity of asphalt cement, exhibited relatively poor fatigue performance. Fabric E, on the other hand, a very thick fuzzy fabric with the ability to retain a considerable quantity of asphalt, exhibited significantly longer fatigue lives than any of the other specimens.

It should be noted that increased fatigue performance at high asphalt tack rates may be attributed in part to excess asphalt which migrated into the hot asphalt mixture as a result of the kneading action during compaction. The additional asphalt cement will decrease air voids in the mixture and thus enhance fatigue performance. In order to dispel this notion, it would be desirable to fatigue test specimens with interlayers containing asphalt tack coat but no fabric.

RESISTANCE TO THERMAL REFLECTION CRACKING

The "overlay tester" (Figure 4), developed at Texas A&M University, is essentially a displacement controlled fatigue testing machine designed to initially produce a small crack (due to tension) in a test specimen and then continue to induce repetitive longitudinal displacement at the base of the crack which causes the crack to propagate upward through the specimen. This process is intended to simulate the cyclic stressing of a pavement due to periodical thermal variation. Results obtained with this apparatus should prove very useful in predicting pavement service life extension effected by systems purported to reduce reflection cracking.

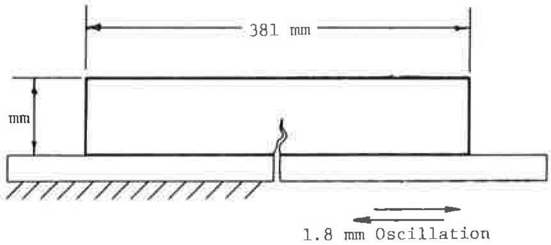

Figure 4. Skematic of Overlay Tester.

Construction materials and fabrication procedures for the specimens tested in this experiment were identical to those used for the flexural fatigue specimens. All test specimens containing fabric were made using only the optimum tack rate except those containing Fabric G which utilized the three tack rates. All tests were conducted at 25°C (77°F).

The machine was allowed to oscillate until complete specimen failure occurred, that is, until the crack propagated completely through the beam specimen. Ideally, complete failure would be defined as the cycle at which the load approached zero, however, with those specimens containing fabric, a measurable load was supported by the fabric even after the asphalt concrete specimen was completely ruptured.

Test results showed that the number of cycles to failure is proportional to tack coat quantity. This demonstrates the strain relieving ability of the thicker asphalt tack layer, however, it may be at least partly a result of migration of excess asphalt tack into the voids within the adjacent asphalt concrete during compaction which would increase tensile strength of the asphalt concrete.

Figure 5 shows average peak loads as a function of number of load cycles. On the average, those specimens containing fabric exhibit about six times more cycles to failure than the Control-1 specimens.

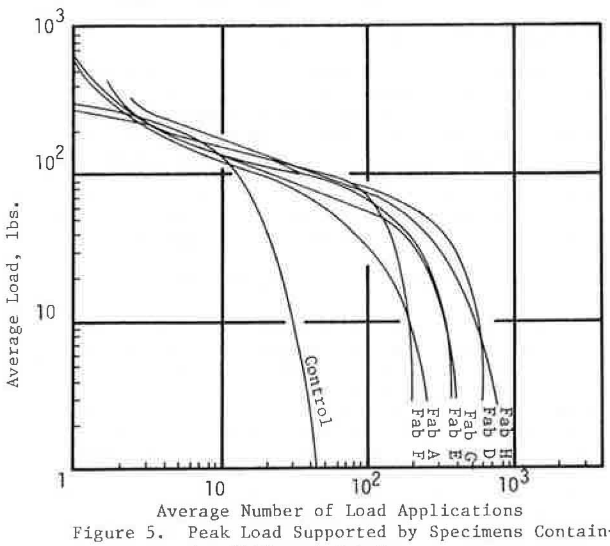

Figure 5. Peak Load Supported by Specimens Containing Different Fabrics.
2.2 lbs. = 1 kg.

GENERAL CONCLUSIONS

Based on the laboratory test results the following conclusions appear warranted:

1. To date, field performance is not well defined, however, fabrics show promise in retarding reflection cracking from pavement exhibiting fatigue distress,

2. At the current state-of-the-art, economic benefits to be gained from the use of fabrics in overlay applications are marginal.

3. Shrinkage of some fabrics associated with the high temperatures of newly placed asphalt concrete can cause premature cracking of the overlay. This cracking can be controlled by utilizing proper construction techniques and by modifying the fabrics shrinkage characteristics.

4. The potential for pavement slippage at the fabric-pavement interface is no greater for fabric overlay systems than for conventional overlays. Fabrics do not affect the interfacial shear strength of an asphalt overlay at the higher temperatures where shear strength becomes critical. Fabrics will decrease interfacial shear strength at lower temperatures where shear strength is already more than adequate.

5. Fabrics will improve pavement fatigue performance.

6. Fabrics will improve resistance to reflective cracking in asphalt concrete overlays.

7. Tensile properties of asphalt concrete is improved by the use of fabrics.

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2. Epps, J.A. and Button, J.W., "MIRAFI[R] Fabric Tack Coat Requirements for Asphalt Overlays", Interim Report RF 3424-1, Texas Transportation Institute, July 1977.