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Simulation Testing of Geotextile Membranes for Reflection Cracking

Essais de simulation de la propagation des fissures avec membranes en géotextile

The use of geotextiles to prolong the life of bituminous concrete overlays is rapidly increasing in the U.S. This market has attracted many manufacturers to introduce fabrics for the paving industry. A laboratory analysis has been completed which identifies the fabric properties which are most critical to performance. The analysis separates the fabric contributions into two main mechanisms; first, they provide a moisture barrier that protects the underlying pavement structure from further degradation, and second, they provide a measure of reinforcement to the overlay which characteristically is weak under tension. Properties critical to performance are dense fabric structure and high tensile modulus. The structure of the fabric determines the amount of tack coat required to develop an effective moisture barrier and the modulus is a direct indication of the reinforcement potential of the fabric. The conclusions of this study are that high modulus fabrics consisting of a dense structure comprised of many small denier filaments provides maximum resistance to reflection cracking.

L'emploi des matières géotextiles aux Etats-Unis, afin de prolonger la durée des revetements en béton bitumineux, augmente rapidement. Nombreux producteurs, attirés par ce marché, ont présenté leurs tissus à l'industrie de pavage. Une analyse laboratoire identifie les charactéristiques du tissu les plus critiques à la performance. L'analyse donne aux contributions éffectués par le tissu deux mécanismes: les tissus présentent une barrière contre l'humidité, qui protège la structure de pavée sous-jacente contre quelque dégradation de plus: et ils pourvoient, dans une certaine mesure, unreforcement au revêtement, lequel est typiquement faible en traction. Les propriétés les plus critiques au fonctionnement sont la structure du tissu et le module de traction. La structure du tissu détermine la quantité requise du ciment asphaltique pour achever une barrière éffective contre l'humidité; et le module sécant indique directement le renforcement potentiel que peut fournir le tissu. Cet étude conclut que les tissus à module plus élevé, consistants d'une structure épaise d'un grand nombre de filets fins, pourvoient une résistance maximale aux craquements de reflexion.

INTRODUCTION

Premature failure of bituminous concrete pavements has been a serious problem for highway engineers. Escalating petroleum and construction costs emphasize the need to maximize the service life of all road work. An area of major concern is the reflection cracking of relatively new asphaltic overlays. Many attempts have been made to solve this problem including the use of stress relieving layers, seal coatings and rubberized asphalts. A method developed to reduce reflection cracking is the addition of a geotextile in the pavement structure. This use of fabrics is rapidly increasing in the U.S. and has attracted many manufacturers to introduce fabrics for the paving industry. These fabrics differ significantly in polymeric composition, methods of construction, and fabric structure. The resulting fabric properties are equally variable. While there exists substantial literature on this application, the principal mechanisms of fabric reinforcement are not well understood; the author seeks to make a contribution in this area and identify the fabric properties which are critical to system performance.

OBJECTIVES

Most industry authorities agree that a major benefit from geotextiles is that, once saturated with an asphalt cement tack coat, they provide a moisture barrier which protects the underlying structure against further degradation. There is some disagreement, however, on whether a geotextile can mechanically reinforce the pavement structure. It has been suggested that high modulus fabrics provide a measure of tensile reinforcement to the characteristically weak asphaltic concretes similar to the function of reinforcing bars in portland cement concretes. Conversely, thick, low modulus fabrics are believed to function as a stress relieving layer allowing for relatively minor displacements between the overlay and the base foundation. The objectives of this study are to evaluate a variety of commercially available geotextiles and determine which fabric properties are most critical to performance. Due to the complexity of field evaluations, the majority of this study involves the development of controlled laboratory tests for geotextiles.

EXPERIMENTAL DETAILS

A complex relationship exists between the many environmental factors and pavement performance. To determine relative differences between geotextiles, tests were developed which separate moisture barrier characteristics from reinforcement characteristics. Overall fabric performance was based on both moisture barrier and reinforcement characteristics. The relative importance of the moisture barrier versus reinforcement characteristics cannot be fully assessed without an elaborate field testing program which is beyond the scope of this study. The variable and complex environment makes it difficult to develop a direct correlation between laboratory results and anticipated field performance. All laboratory test work will be further explained in detail in the following analysis. Table I describes all of the geotextiles used in this study.

TABLE I. GEOTEXTILES USED IN REFLECTION CRACKING STUDIES

FABRIC	TRADENAME/TYPE	BASIS WEIGHT
A	Reepav® — Spunbonded Polyester	$102/m^2$
B	Petromat*—Needle punched Polypropylene	153 g/m^2
C	Bidim** — Needle punched Polyester	203 g/m^2
D	Petromat*-Needle punched Polypropylene	203 g/m^2
E	Mirafi 900X*** — Woven Polypropylene Polyester Fill	164 g/m^2

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HYDROSTATIC TESTING(1)

Moisture barrier characteristics were determined by subjecting the geotextiles, saturated with an asphalt cement, to a hydrostatic head. A schematic diagram of the test apparatus is included in Figure 1. The basic mechanics of the apparatus allows for the gradual raising of a hydrostatic head above the test specimen. The rate of head rise was controlled to between 5-10 cm/min. Specimen failure was defined as the average in head between the values shown when the first and third droplets appeared on the geotextile. This equipment was limited to a maximum head of 150 cm which is satisfactory for this application.

(1) All hydrostatic test work was conducted by Dr. R. D. Weimar at the Du Pont Spunbonded Products Research Laboratory in Wilmington, Delaware.

(2) Asphalt absorption testing conducted per Texas Department of Highways and Public Transportation Special Specification Item 3099.

(3) Hydrostatic testing per ASTM Test D.751-73

Figure 2 shows hydrostatic head at specimen failure as a function of asphalt level. First the maximum asphalt absorption(2) capability or saturation point was identified for each fabric. A series of hydrostatic tests(3) was conducted starting at the saturation point and proceeding through a set of decreasing levels of asphalt cement. Results were plotted indicating asphalt level versus hydrostatic head. Figure 2 shows values from several geotextiles plotted on the same graph with results indicating a significant difference among fabrics. All fabrics reached an asphalt level where only a marginal decrease in asphalt level caused a significant decrease in the moisture barrier. This asphalt level is defined as the threshold asphalt level.

The hydrostatic series of tests demonstrates that all the geotextiles tested will form an adequate moisture barrier provided that the threshold amount of asphalt cement tack coat is present. The exact amount of tack coat required varies depending on the individual geotextile.

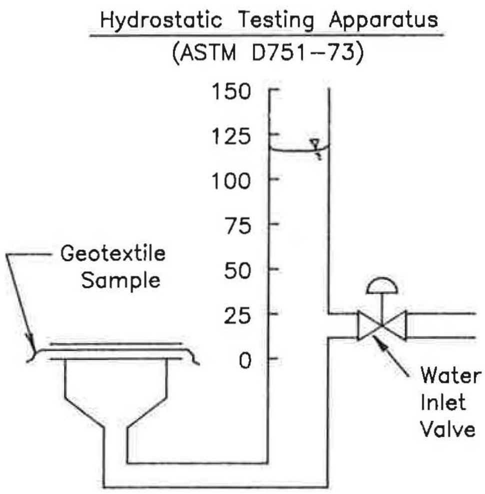

Figure 1

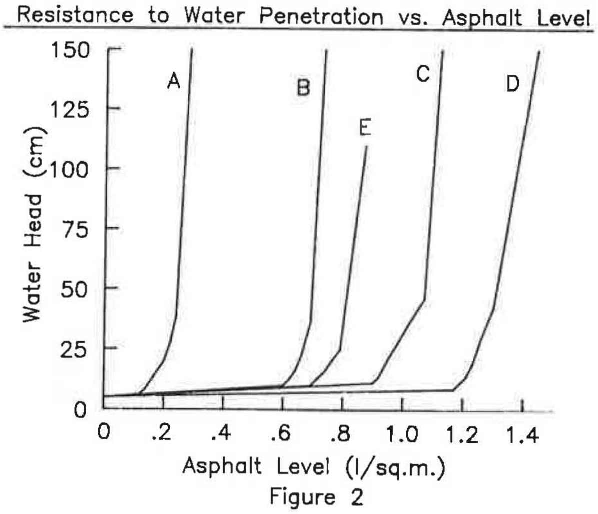

Figure 2

DYNAMIC SIMULATION TESTING

Reinforcement characteristics were determined by subjecting geotextile reinforced asphaltic beams to a dynamic load simulating interstate traffic. The equipment used to accomplish this consists of a pneumatically actuated repeated loading machine as shown in Figure 3. The apparatus was designed and assembled for Du Pont by the Georgia Institute of Technology and consists of commercially available parts. This machine can control the loading frequency from as low as 6 cycles/min. to a maximum of 130 cycles/min. at an equivalent surface pressure ranging from 275 kPa (40 psi) to 1800 kPa (260 psi).

The accuracy and reproducibility of this test program was highly dependent on the construction of uniform asphaltic beam test specimens. To insure uniformity Geotek Engineering Company, Nashville, Tennessee was contracted to manufacture the test specimens based on the State of Tennessee Surface Course Specifications 411E. The procedure used to construct the beams involved, (1) weighing of each ingredient, (2) heating and thoroughly mixing the ingredients, and (3) compaction. Analysis of the beams showed that density was uniform throughout the cross-section of each 5 cm x 7.5 cm x 35 cm (2" x 3" x 14") specimen. A summary of mix properties is included in Table II.

Testing of the fabric reinforced test specimens was conducted under controlled conditions. A standard 6.25 mm (1/4") square edged crack was constructed in the foundation with the test specimen centered above. A 6.25 mm (1/4") elastomeric pad provided flexibility to the system and was positioned below the foundation. The complete system was then installed in the dynamic testing machine and repeatedly loaded. All tests were run at a temperature of 22 $\pm$ 1°C (72 $\pm$ 2°F) , a loading frequency of 72 $\pm$ 3 cycles per minute and loaded at an

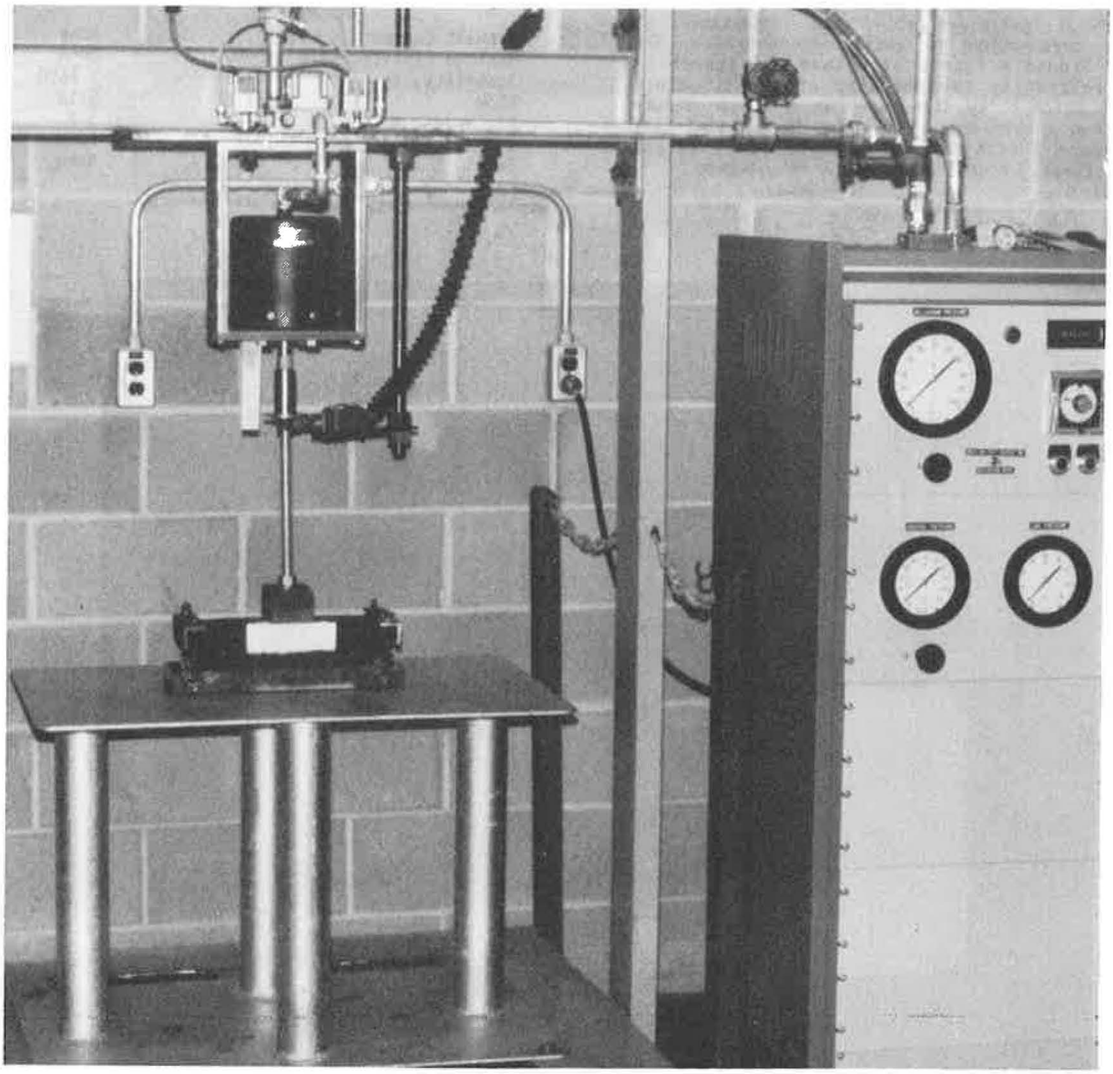

Figure 3 : Dynamic Simulation Testing Apparatus

equivalent surface pressure of 690 ± 10 kPa (100 psi). The development of a crack was monitored and failure was considered when the crack propagated to the surface of the overlay specimen. Table III lists the cycle life of all products tested and the life of non-reinforced specimens. Figure 4 shows the development of a reflected crack in the test specimen. In all cases the geotextile reinforced specimens had at least twice the life of the unreinforced samples, clearly demonstrating that geotextiles do provide a measure of tensile reinforcement.

ANALYSIS OF RESULTS

Moisture characteristics of paving fabrics were determined by simply measuring the degree of asphalt saturation required to provide a significant moisture barrier. The results in Figure 2 show that when each fabric is fully saturated an adequate moisture barrier is formed. The major discrepancy between products involves the amount of tack coat required to adequately saturate the geotextile. With asphalt cement tack coat costing approximately $400 per .5 l/sq.m. per lane km ($650 per .1 gal/sq.yd./mi.), the importance of minimizing consumption is easily recognized. The amount of liquid a fabric structure can absorb is directly related to the porosity of the structure itself. A thick bulky structure has a larger volume capacity than a thin dense structure of the same unit mass. Figure 5 is a plot of asphalt level versus fabric thickness. A good correlation is evident.

TABLE II. ASPHALTIC CONCRETE SURFACE COURSE SPECIFICATIONS

TABLE IIa. Combined Gradation for Asphalt Surface

Screen	Test Specimen Design Specifications	TN DOT Surface Course Specification 411E
12.7 mm	100	100
9.5 mm	94 ± 1	94 ± 6
4.75 mm	68 ± 1	68 ± 12
2.36 mm	50 ± 1	50 ± 10
0.600 mm	28 ± 1	28 ± 10
0.300 mm	17 ± 1	17 ± 9
0.150 mm	10 ± 1	10 ± 5
0.075 mm	6 ± 1	6 ± 4

TABLE IIb. Surface Course Mix Design

	Test Specimen Design	TN DOT Surface Course Spec. 411E
Asphalt Content, %	5.3	None
Maximum Density, Kg/m^3	2450	None
Stability, Kg	4390	≥ 2650
Flow	11.5	8-15
Air Voids, %	3.3	3-7
% Voids Filled	77	None
Swell, %	0.5	None

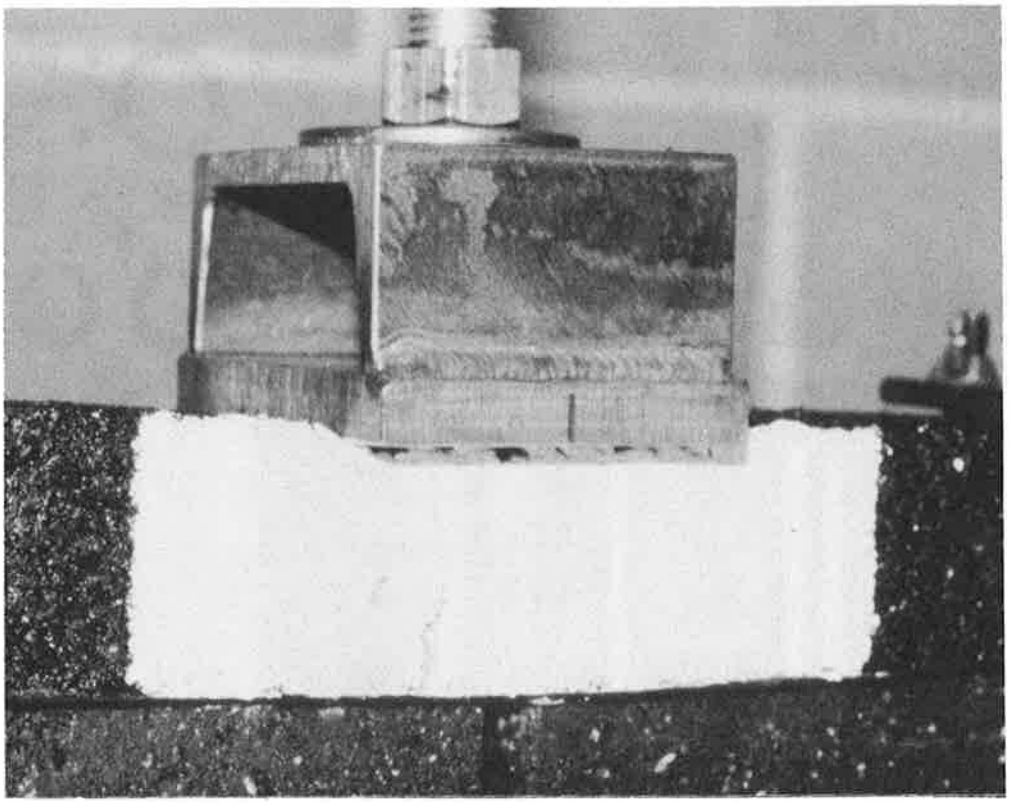

Figure 4 : Development of Reflected Crack in Specimen

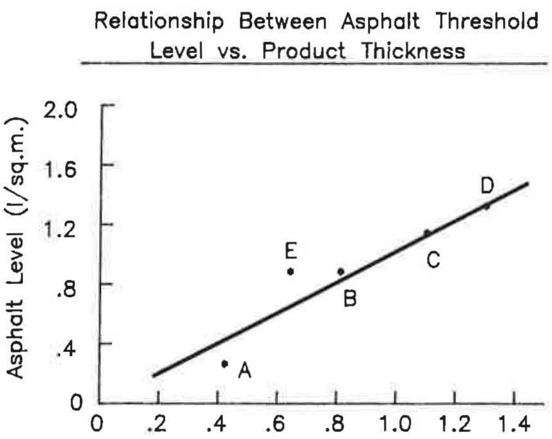

Figure 5

Examination of the dynamic simulation test results suggests that differences in fabric properties significantly affect the cycle life of the system. As shown in Table III, the cycle life of the products tested varied markedly. Depending on the fabric used, the improvement in cycle life ranged from a 2X increase over the non-reinforced control to a maximum 16X increase, thus representing an 8 fold variance in performance.

TABLE III. The Resistance to Reflection Cracking of Geotextile Reinforced Specimens

Geotextile	Dynamic Cycle Life	Standard Deviation
Control	480	50
Fabric A	7,650	575
Fabric B	1,000	55
Fabric C	2,300	880
Fabric D	3,260	610
Fabric E	2,760	570

Although many fabric properties (such as ultimate tensile strength, modulus and toughness) contribute to performance, the 5% secant modulus is the single property that best correlated with the dynamic simulation test results. This correlation is shown in Figure 6. The correlation is good except for two exceptions. First fabrics B and C have approximately the same modulus but there is a significant difference in performance. This discrepancy is the result of the difference in curvature of the respective stress-strain curves; i.e., fabric C has a higher tangential modulus at 5% than fabric B, therefore fabric C has a greater resistance to deformation at 5% elongation than fabric B. Secondly fabrics A and E both have a relatively high modulus but have a different level of performance. This difference is related to fabric slippage that prevents realization of the modulus benefits. Fabric A is a non-woven consisting of many relatively small filaments that develop a strong bond with the pavement whereas fabric E is a woven fabric consisting of a few relatively large filaments which do not bond as well.

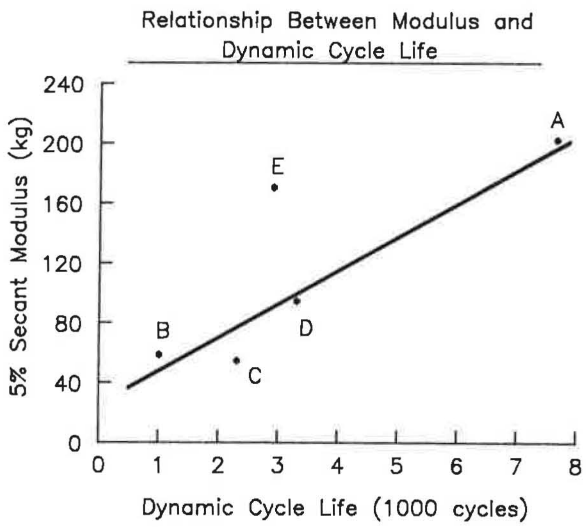

Figure 6

CONCLUSIONS

On the basis of the work described here it is concluded that:

(1) Geotextiles effectively improve the resistance of a pavement structure to reflection cracking. The principle benefits that fabrics provide to a pavement structure are:

- a moisture barrier which protects the underlying pavement structure from further degradation, and
- a degree of reinforcement to the bituminous concrete overlay which characteristically is weak when placed in tension.

(2) The fabric structure of the geotextile determines the threshold asphalt level required to form a moisture barrier.

- Dense thin structures require a significantly lower amount of asphalt than a thick porous structure.

(3) The reinforcement performance of the geotextile best correlates with the 5% secant tensile modulus. [And not the ultimate tensile strength of the product.]

- Fabric elongation is limited by the deflection of the pavement structure. Greater than 5-10% fabric elongation indicates excessive pavement deflection.

(4) A sufficient bond must be developed between the geotextile and overlay for the full reinforcement potential to be achieved.

- Fabric structures comprised of many small denier filaments form a much stronger bond than structures consisting of few large denier filaments.

(5) Engineers must consider these fabric properties in the design of overlay pavement structures.

- Overlay thickness is proportional to the amount of reinforcement required.
- Tack coat costs vary depending on the threshold asphalt level of the individual geotextile.