EVALUATION OF MIRAFI FABRICS

FOR

PAVEMENT OVERLAYS

by

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Final Report 3424-6

Prepared for

Mirafi Inc

by the

Texas Transportation Institute

Texas A&M University Research Foundation

College Station, Texas 77843

January, 1983

EXECUTIVE SUMMARY

The overall objective of this research was to define the performance of fabrics in delaying or reducing the severity of reflection cracks in asphalt concrete overlays. Laboratory experiments were conducted at Texas A&M University and field test projects in several states were observed to accomplish the objectives.

Fabrics and asphalt concrete paving mixtures containing fabrics were tested in the laboratory using the following methods:

1. Asphalt content of fabrics at saturation,
2. Temperature-shrinkage characteristics of fabrics,
3. Shear strength of pavement-fabric-overlay interface,
4. Flexural fatigue properties of fabric-mixture system,
5. Resistance to thermal reflection cracking and
6. Tensile properties of fabric-mixture system.

These test methods are designed to simulate certain field conditions and, therefore, should be capable of evaluating the relative effectiveness of fabrics from a field performance standpoint.

Three second generation fabrics manufactured by Mirafi Inc were tested and compared to similar test results on first generation fabrics reported previously.

Asphalt content of fabrics at saturation was determined in order to estimate the optimum tack coat quantity required. Optimum tack for these fabrics was relatively low when compared to that for most fabrics marketed for use with asphalt concrete overlays.

Linear shrinkage exhibited by the three fabrics tested was comparatively low and should not be expected to cause problems during

normal construction operations.

Shear strength of asphalt concrete at a fabric interlayer increases with asphalt tack rate and decreases with increasing temperature. Fabrics will cause a decrease in interfacial shear strength at lower temperatures where shear strength is already more than adequate. It appears that shear strength at temperatures above 140°F is not diminished appreciably by the presence of a fabric. Shear strength is influenced by properties of the fabric such as surface texture, thickness, porosity and fuzziness. Second generation fabrics resulted in higher shear strengths than most of the fabrics tested.

Fatigue performance of asphalt concrete containing a fabric is influenced by fabric characteristics such as surface texture, porosity, and asphalt holding capacity. Thick fabrics hold more asphalt which improves their performance as a stress relieving interlayer (thus, fatigue performance). Fatigue performance of thin fabrics is more sensitive to asphalt tack application rate. Two of the three second generation fabrics are capable of giving acceptable fatigue performance.

According to laboratory test results fabrics significantly reduce the growth rate of reflection cracks in asphalt concrete test specimens. Fabrics remain intact after complete rupture of the asphalt concrete. Reflected cracks are often offset from the original crack and may appear as 2 or more smaller cracks which, in the field, would probably allow less surface water to penetrate to the base. The small cracks would most likely be more easily "healed" by the kneading action of traffic in warm weather. However, two cracks in close proximity may allow loss of paving material between them due to traffic. Two of the second generation fabric exhibited resistance to reflection cracking that is superior to any other specimens tested at optimum asphalt content.

In the uniaxial tensile test, ultimate tensile stress may be either increased or decreased by the use of fabrics. Ultimate tensile strain usually increases when fabrics are employed. Initial tangent modulus is improved by the use of fabrics which indicates that an asphalt-soaked layer of fabric will favorably influence the tensile properties of asphalt concrete, particularly at very small strains. This appears to be advantageous from a pavement performance standpoint, since strains due to repetitive traffic loads are usually only a small percentage of the strain (load) required to produce failure. Generally, tensile strength of specimens containing second generation fabrics are comparable to the tensile strength of the other specimens tested.

A portion of the research program was devoted to a study of the field performance of pavement interlayer systems. Review of recent literature and observation of field test projects in more than six states reveals that a "clear cut" performance advantage is not often evident when fabrics currently marketed are installed to reduce reflection cracking. Types of pavements, pavement distress and environmental condition must be carefully selected if fabrics are to be economically employed. Unfortunately, sufficient detailed data are not available which clearly define these conditions. Based on observations, fabrics are most likely to be successful when employed to reduce reflection of fatigue cracks in otherwise structurally sound asphalt concrete pavements. Fabrics are least likely to be successful when employed to reduce reflection of large transverse cracks or construction joints in portland cement concrete pavements.

This report contains a summary of design implications which should be applied to minimize problems and maximize long-term performance of fabrics installed to arrest reflection cracking.

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INTRODUCTION

In the past ten years, synthetic fabrics have emerged as construction materials for highway pavements. During this period considerable laboratory and field research on construction fabrics has been conducted.

A cooperative research program was sponsored by Mirafi Inc at the Texas Transportation Institute which is a part of the Texas A&M University System. The overall objective of this research was to define the performance of fabrics in delaying or reducing the severity of reflection cracks in asphalt concrete overlays. Specific objectives of this research are given below:

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

2. Define conditions (existing type of pavement, overlay thickness, environmental conditions) under which Mirafi fabrics are an effective crack arrestors,

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

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

These objectives have been achieved by laboratory testing of fabrics and fabric-asphalt concrete systems and field evaluations of fabric-asphalt concrete overlay installations. The following is a list of reports which have emanated from this study:

1. Mirafi Fabric Tack Coat Requirements for Asphalt Overlays (1)
2. Asphalt Overlays with Mirafi Fabric - The Slippage Question on Airport Pavements (2)
3. Laboratory Evaluation of Fabrics Designed to Reduce Reflection Cracking (3)
4. Mechanistic Analysis of Fabrics in Retarding Reflection Cracking (4)
5. Asphalt Tack Coat Permeability (5)
6. Fabric Reinforced Overlays to Retard Reflection Cracking (6)

During the conduct of this research, more than twenty commerically produced construction fabrics have been evaluated either in the laboratory or in the field or both. Specialized laboratory tests have been developed to categorize selected fabric properties and determine which were advantageous and which might be detrimental to overlay construction and performance.

This report describes three second generation fabrics produced by Mirafi Inc and compares laboratory test results on these fabrics to results of similar tests obtained previously on first generation fabrics. Selected field installations (some containing a Mirafi product) in six states are described and their performance is evaluated. These data are used to formulate guidelines which can be employed during design and construction stages to minimize problems and maximize long-term performance of fabrics installed to reduce reflection cracking.

MATERIALS

The asphalt cement and aggregates used to fabricate asphalt concrete test specimens have been used throughout this research program (1, 2, 3, 4 and 5) and are currently used laboratory standards in the Texas A&M University materials laboratory (7).

Asphalt Cement

The asphalt cement utilized in this study in preparation of asphalt concrete or as a tack coat was on AC-10 obtained from the American Petrofina Refinery located near Mt. Pleasant, Texas. Optimum asphalt tack quantity was defined by the saturation test discussed later. Tack quantity termed "low" and "high" were one-half and twice the optimum asphalt tack coat, respectively. Properties of the asphalt cement are given in Table 1.

Aggregates

A subrounded, siliceous gravel obtained from a Gifford-Hill plant located near the Brazos River at College Station, Texas, was used to fabricate all asphalt concrete specimens except those used to determine shear strength. The shear test specimens were fabricated from a very hard crushed limestone which was obtained from the White's Mines quarry located near Brownwood, Texas. Standard sieves (ASTM E-11) were used to separate the aggregates into fractions, then prior to mixing with asphalt, the various aggregate sizes were recombined in accordance with

Table 1. Summary of Asphalt Cement Properties

Grade of Asphalt	AC-10
Viscosity @ 77°F (25°C), poise	5. 8 x 10^5
Viscosity @ 140 °F (60°C), poise	1576
Viscosity @ 275°F (135°C), poise	3.76
Penetration @ 39.2°F (4°C), dmm	26
Penetration @ 77°F (25°C), dmm	118
Penetration Ratio, %	107 (41.7)
R & B Softening Pt, °F (°C)	1.020
Specific Gravity @ 60°F (16°C)	615 (323.9)
Flash Point (COC), °F (°C)	99.9
Solubility in $C_2H_3Cl_3$,%	Negative
Spot Test	
Thin Film Oven Test Residue Properties	
Viscosity @ 140°F (60°C), poise	3054
Penetration @ 77°F (25°C), dmm	68
Ductility @ 77°F (25°C), cm	150

ASTM D-3515-77 5A grading specifications (Figure 1). Physical properties of the aggregates are presented in Table 2.

Mixtures

Asphalt concrete mixtures were prepared using 3.8 percent asphalt with the subrounded gravel and 4.5 percent asphalt with the crushed limestone. Properties of these mixtures are shown in Table 3.

Fabrics

Three fabrics labeled P, Q and R were supplied by Mirafi Inc. Fabric R was manufactured on a production-run basis by Mirafi Inc. It is a woven fabric comprised of two different types of strands running perpendicular to one another. The warp is a black polypropylene tape approximately one-sixteenth-inches wide. The weft is a fluffy white yarn composed of fine polyester fibers. The tape is designed to increase fabric modulus and minimize wrinkling during construction while the yarn increases asphalt absorption capacity and improves adhesion of the fabric to the roadway surface.

Fabric P is the original prototype identical in construction to Fabric R.

Fabric Q is composed of a woven tape fabric and a nonwoven filament fabric mechanically laminated together to form a single unit.

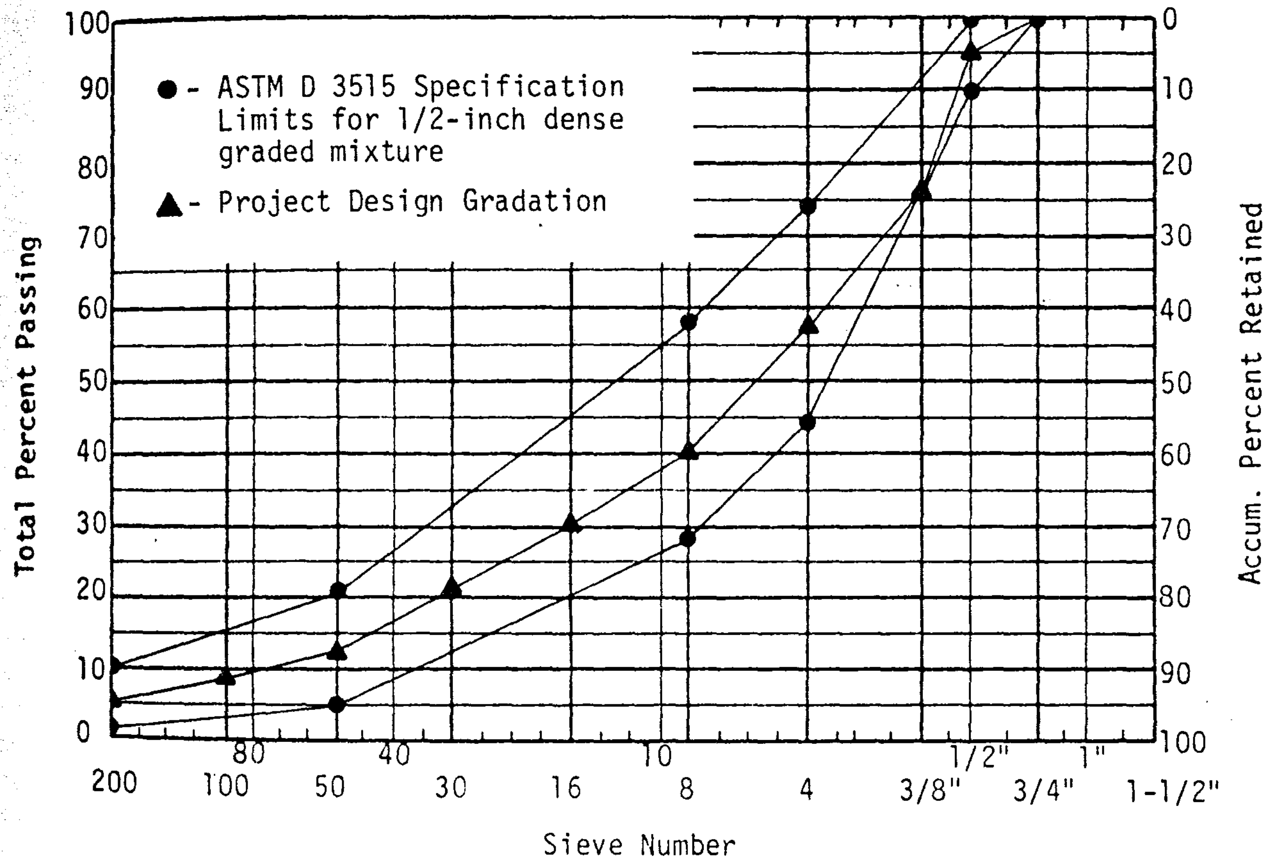

Figure 1. Limits for ASTM Gradation Specification and Project Design Gradation.

Table 2. Physical Properties of Aggregates

Physical Property	Test Designation	Aggregate Grading	Test Gravel	Results Limestone
Bulk Specific Gravity Bulk Specific Gravity (SSD) Apparent Specific Gravity Absorption, percent	ASTM C 127 AASHTO T 85	Coarse Material*	2.621 2.640 2.672 0.72	2.663 2.678 2.700 0.7
Bulk Specific Gravity Bulk Specific Gravity (SSD) Apparent Specific Gravity Absorption, percent	ASTM C 218 AASHTO T 84	Fine Material**	2.551 2.597 2.675 1.8	2.537 2.597 2.702 2.2
Bulk Specific Gravity Apparent Specific Gravity Absorption, percent	ASTM C 127 & C 128 AASHTO T 84 & T 85	Project Design Gradation	2.580 2.671 1.3	2.589 2.701 1.56
Abrasion Resistance, percent loss	ASTM C 131 AASHTO T 96	Grading C	19	23
Compacted Unit Weight pcf	ASTM C 29 AASHTO T 19	Project Design Gradation	129	122
Surface Capacity, percent by wt. dry aggregate	Centifuge Kerosene Equivalent	Fine Material**	3.0	4.1
Surface Capacity, percent oil retained by wt. agg.	Oil Equivalent	-3/8 inch to + No. 4	1.8	2.3
Estimated Optimum Asphalt Content, percent by wt. dry aggregate	C.K.E. and Oil Equivalent	Project Design Gradation	4.7	5.5

*Material retained on No. 4 sieve from Project Design Gradation

**Material passing No. 4 sieve from Project Design Gradation

Table 3. Mixture Properties at Optimum Asphalt Content

Property	Rounded Gravel	Crushed Limestone
Design Asphalt Content percent by wt. aggregate	3.8	4.5
Marshall Specimens		
Unit Weight, pcf (gm/cc)	152(2.44)	153(2.45)
Air Void Content,	2.1	3.0
VMA, percent	9.1	10.5
VMA Filled w/Asphalt percent	80	78
Marshall Stability, lbs (N)	1270(5650)	2740(12,200)
Marshall Flow, .01 in (mm)	7(1.8)	11(2.8)
Hveem Specimens		
Unit Weight, pcf (gm/cc)	151(2.42)	154(2.47)
Air Void Content, percent	2.9	2.5
VMA, percent	9.7	9.1
VMA Filled w/Asphalt, percent	76	81
Hveem Stability, percent	25	54
Resilient Modulus, (psi)kPa	570,000(3.9×10^6)	590,000(4.1×10^6)
Elastic Modulus, @ Failure*, psi (kPa)	39,000(0.27×10^6)	26,000(0.18×10^6)

*From Splitting Tensile Test

LABORATORY TEST PROGRAM

The fabrics investigated were treated, as closely as practicable, in a manner identical to those studied earlier in this research program (1, 2, 3 and 4). For purposes of comparison, several of the plots have been extracted from Reference 3 and used herein with the subsequent data from Fabrics P, Q and R. The laboratory tests that were employed (Table 4) attempt to realistically simulate field loading conditions, however, it is difficult, if not impossible, to predict field performance from these test results. One might expect the relative performance of fabrics in the field to correlate with their performance in the laboratory. A brief description of the test equipment and procedures are given below; a more detailed description is presented in Reference 3.

Saturation Test

Saturation is defined as that quantity of asphalt a fabric will absorb while in service under an overlay. Saturation content is estimated by soaking a piece of fabric 8 x 8-inches (200 x 200 mm), in AC-10 asphalt cement at 250°F (121°C) for one minute. After cooling, the fabric is pressed with a hot iron between two absorbent papers to remove the excess asphalt. This produces a uniformly appearing saturated fabric. The quantity of asphalt retained by the fabric is determined gravimetrically.

Asphalt content of a saturated fabric is utilized to determine field (or laboratory) tack coat quantities which are adequate for

Table 4. Laboratory Testing Program.

Fabric Code and Tack Quantity	Saturation	Temp Stability	Airport Shear*	Fatigue	Overlay Test	Direct Tension
P 0.11 gal/yd^2 tack	T	T	T	T	T**	T
P 0.19 gal/yd^2 tack	-	-	-	T	T	-
Q 0.21 gal/yd^2 tack	T	T	T	T	T	T
R 0.19 gal/yd^2 tack	T	T	T	T	T	T
Control (0.05 Tack @ Interface)	-	-	T	T	T	T
G 0.20 gal/yd^2 tack	-	-	T Opt. Tack Only	T	T	-
D 0.23 gal/yd^2 tack	-	-	-	-	T	-

T means tested at given conditions.

*Airport Shear conducted at 3 tack rates (low, optimum and high) unless otherwise specified.

**Tested at tack rate below optimum.

adhesion of adjacent pavement layers.

Results of these tests are given in Table 5.

Fabric Shrinkage

Four pieces of each fabric with dimensions of 4 x 4 inches (100 x 100 mm) were submerged in 250°F (121°C) and 300°F (149°C) asphalt cement. One of the four pieces of fabric was removed after elapsed times of 1, 5, 15 and 30 minutes and allowed to cool then measured to determine the effects of heat. The test results are given in Table 6 and plotted in Figure 2.

All three fabrics tested began to shrink within the first minute at 300°F. Only fabric P exhibited shrinkage at 250°F and more than 5 minutes had elapsed before any shrinkage was observed (Table 6). This is in agreement with previous research (3) which showed that 250°F (121°C) is a critical temperature below which little shrinkage occurs in any fabrics during this test and above which shrinkage occurs in most fabrics during this test.

Most shrinkage occurred in the weft of Fabrics P and R, whereas, shrinkage was about equal in weft and warp for Fabric Q. As mentioned earlier, Fabrics P and R are similar in construction. Figure 2 shows that the shrinkage which occurred in Fabrics P, Q and R is comparatively low.

When wrinkles or cuts without adequate overlay are present in a fabric during an overlay operation, tensile forces caused by a shrinking fabric can produce significant displacement of the fabric normal to the

Table 5. Fabric Saturation Quantity and Recommended Tack.

Fabric	Saturation Content, gal/yd^2 of Fabric ($m^3/m^2 \times 10^{-4}$)	Optimum Asphalt Tack Quantity, gal/yd^2 ($m^3/m^2 \times 10^{-4}$)
P	0.11 (5.0)	0.19 (8.6)
Q	0.13 (5.9)	0.21 (9.5)
R	0.11 (5.0)	0.19 (8.6)

Table 6. Temperature Stability Test Results

Fabric Type	Asphalt Temp. °F	Time Min.	Percent Linear Shrinkage	Remarks
P	250	1	0	Difficult to conduct this test with good precision because of the loosely woven strands
		5	0	
		15	5	
		30	7	
	300	1	4	Most shrinkage occurred in the weft of the fabric
		5	6	
		15	6	
		30	6	
Q	250	1	0	Shrinkage was about equal in either direction
		5	0	
		15	0	
		30	0	
	300	1	2	
		5	5	
		15	5	
		30	9	
R	250	1	0	Most shrinkage occurred in the weft of the fabric
		5	0	
		15	0	
		30	0	
	300	1	6	
		5	2	
		15	2	
		30	2	

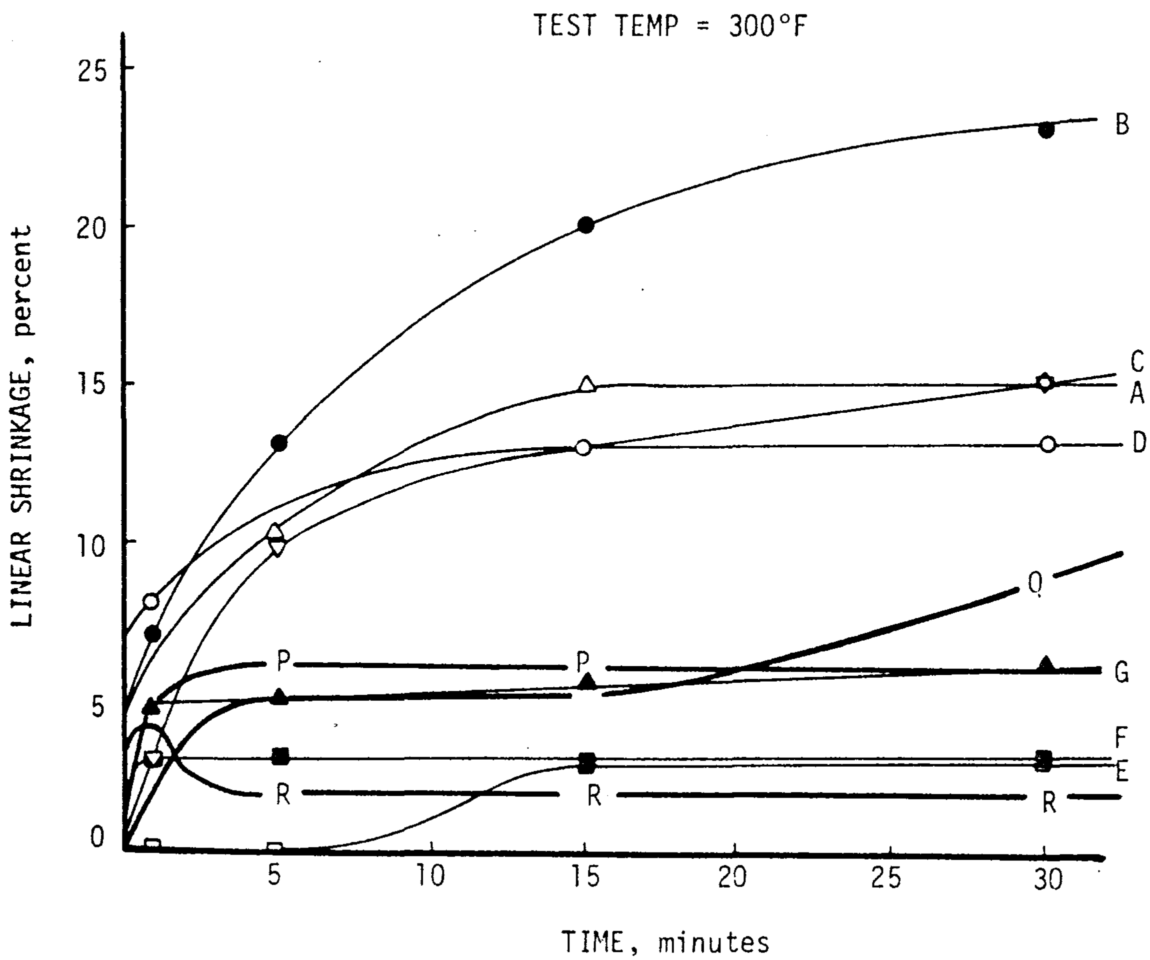

Figure 2. Temperature Stability of Fabrics in 300°F Asphalt Cement (after Reference 3).

wrinkle or cut. Shrinkage occurs while the asphalt concrete overlay is hot and without appreciable tensile strength; thus, the motion of the fabric displaces the hot overlay resulting in a crack in the new overlay along the wrinkle or cut (3). According to test results in Reference 3, Fabric R would not be expected to cause overlay cracking during construction because of its very low shrinkage. However, Fabrics P and Q are borderline and may produce cracking under severe conditions (thin, very hot overlay).

Interface Shear Strength

Overlay shear strength at the old pavement-fabric-new pavement interface was determined. Tests were conducted at 68, 104 and 140°F (20, 40 and 60°C, respectively) at a deformation rate of approximately 13 inches per second (330 mm/sec). A static vertical load of 400 pounds (1,780 N) was applied to the 3 x 3 x 2-inch specimens.

Test specimens were prepared from crushed limestone as described in Reference 3. Asphalt concrete beams with dimensions of 3 x 3 x 15-inches (75 x 75 x 375 mm) were compacted in three 1-inch layers at 250°F (121°C). Following compaction of the first two layers, the specimen was allowed to cool to less than 100°F (38°C). Then the appropriate quantity of tack coat (depending on individual fabric requirements) was applied evenly to the upper surface, a 3 x 15-inch piece of fabric was applied over the tack coat, and the third one-inch layer of asphalt concrete was compacted. The beams were sawed transversely to yield 3 x 3 x 2-inch shear test specimens.

Specimens were made containing low, optimum and high tack quantities. Low tack is one-half optimum and high tack is twice optimum. Optimum tack quantities are given in Table 5.

Results of the shear strength tests are given in Table 7 and plotted in Figures 3 through 6.

Control-1 specimens and those containing Fabric G were retested during this phase of research to provide confidence that the data reported herein can be compared directly with the work reported in Reference 3. Values of shear strength from retesting these specimens are remarkably similar to those obtained from the original tests; therefore, comparisons are considered to be valid.

Generally, shear test results are in agreement with previous results (3, 4). That is, shear strength of specimens with and without fabric approach similar values as the test temperature increases. Shear strength increases with asphalt tack rate and shear strength decreases with increasing temperature.

Specimens containing Fabrics P and R exhibited shear strength near those of specimens containing fabrics which are currently giving satisfactory performance in the field. Based on shear strength, Fabrics P and R should be considered satisfactory for field installation.

Fabric Q, which has no relatively smooth textured surface on the woven tape side, yielded the lowest shear strength at each condition of any test reported herein. This is in agreement with other research (4) which showed that certain fabrics with relatively low asphalt permeability and at least one low textured surface will significantly reduce the interfacial shear strength.

Table 7. Results of Shear Strength Tests.

Fabric	Tack Coat, gal/yd^2	Temp. °C (°F)	Mean Shear Strength, psi	Air Voids, percent
P	Low	40	170	8.5
	Optimum	20 40 60	330 190 150	10.4
	High	40	200	9.5
Q	Low	40	120	8.8
	Optimum	20 40 60	210 150 85	10.9
	High	40	170	9.8
R	Low	40	190	9.7
	Optimum	20 40 60	360 160 130	7.5
	High	20 40	340 280	10.1
G	Optimum	20 40 60	330 170 95	8.9
Control-1 (No Fabric, 0.05 gal/yd^2 Tack @ Interface)		20 40 60	460 315 150	7.6

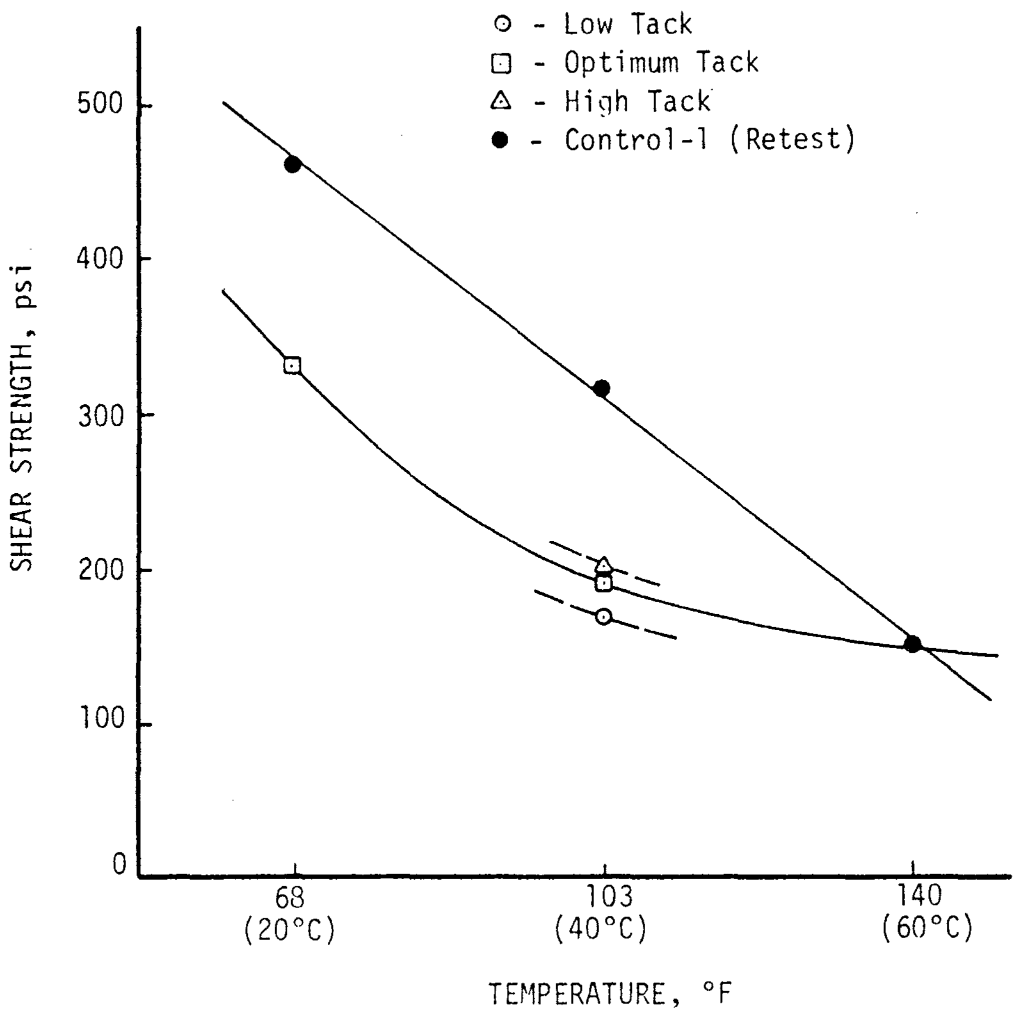

Figure 3. Overlay Shear Test Results on Mixtures Containing Fabric P.

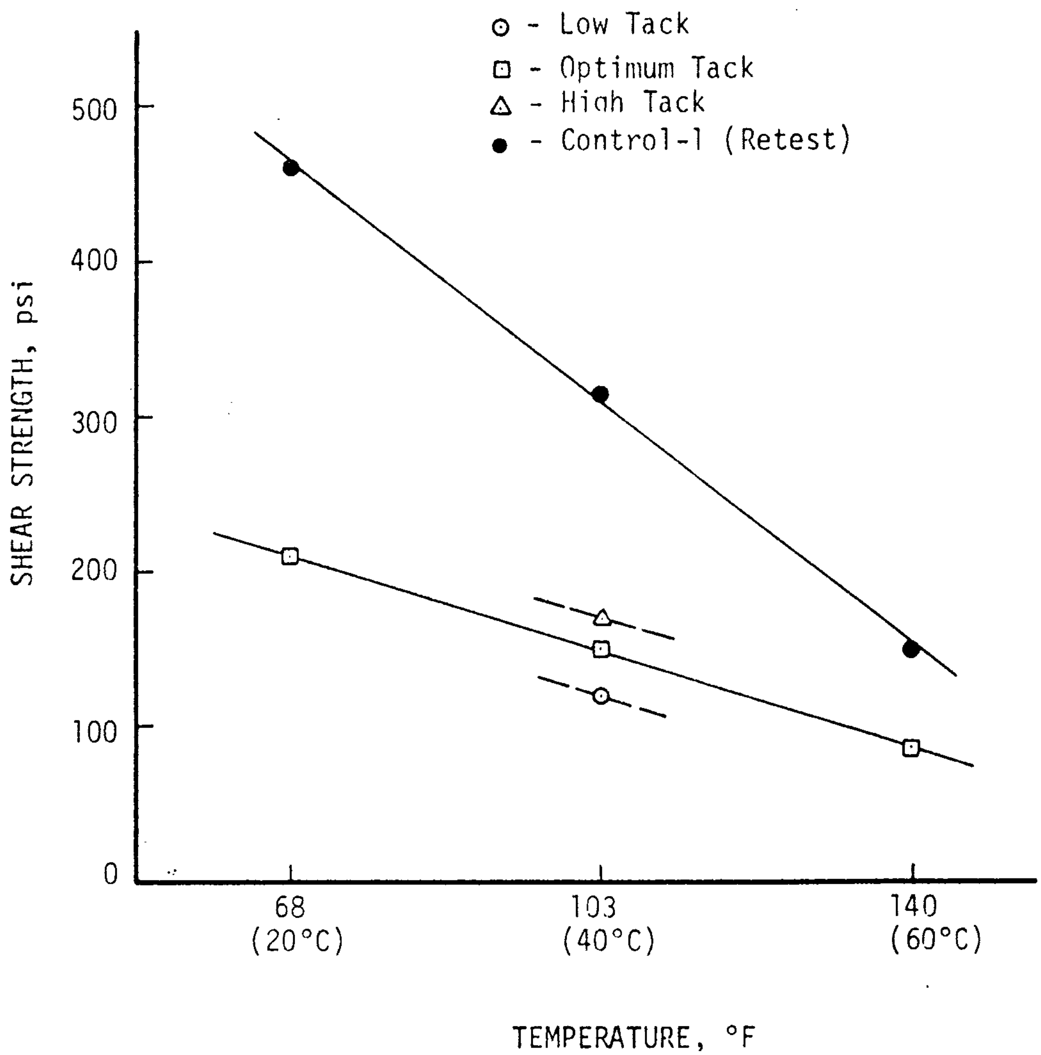

Figure 4. Overlay Shear Test Results on Mixtures Containing Fabric Q.

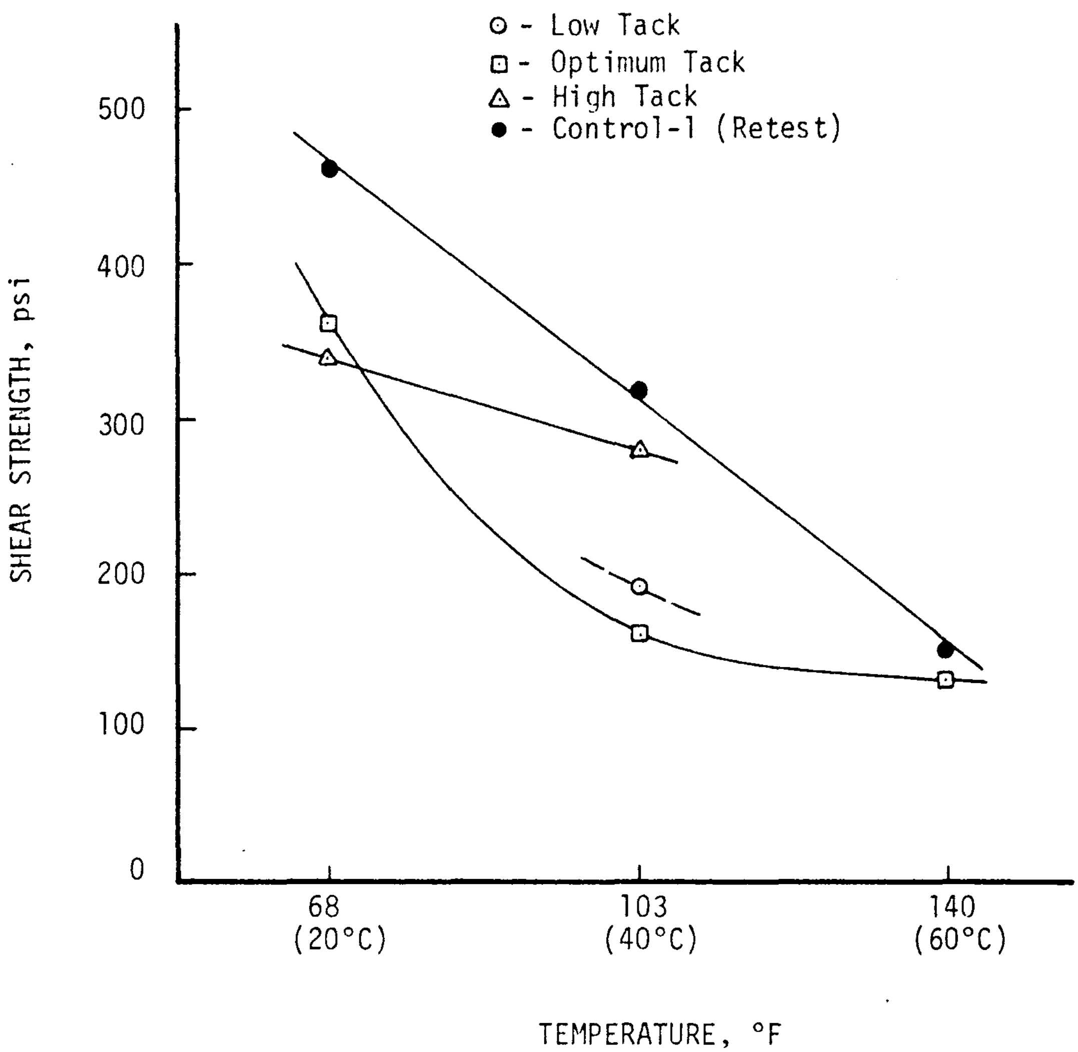

Figure 5. Overlay Shear Test Results on Mixtures Containing Fabric R.

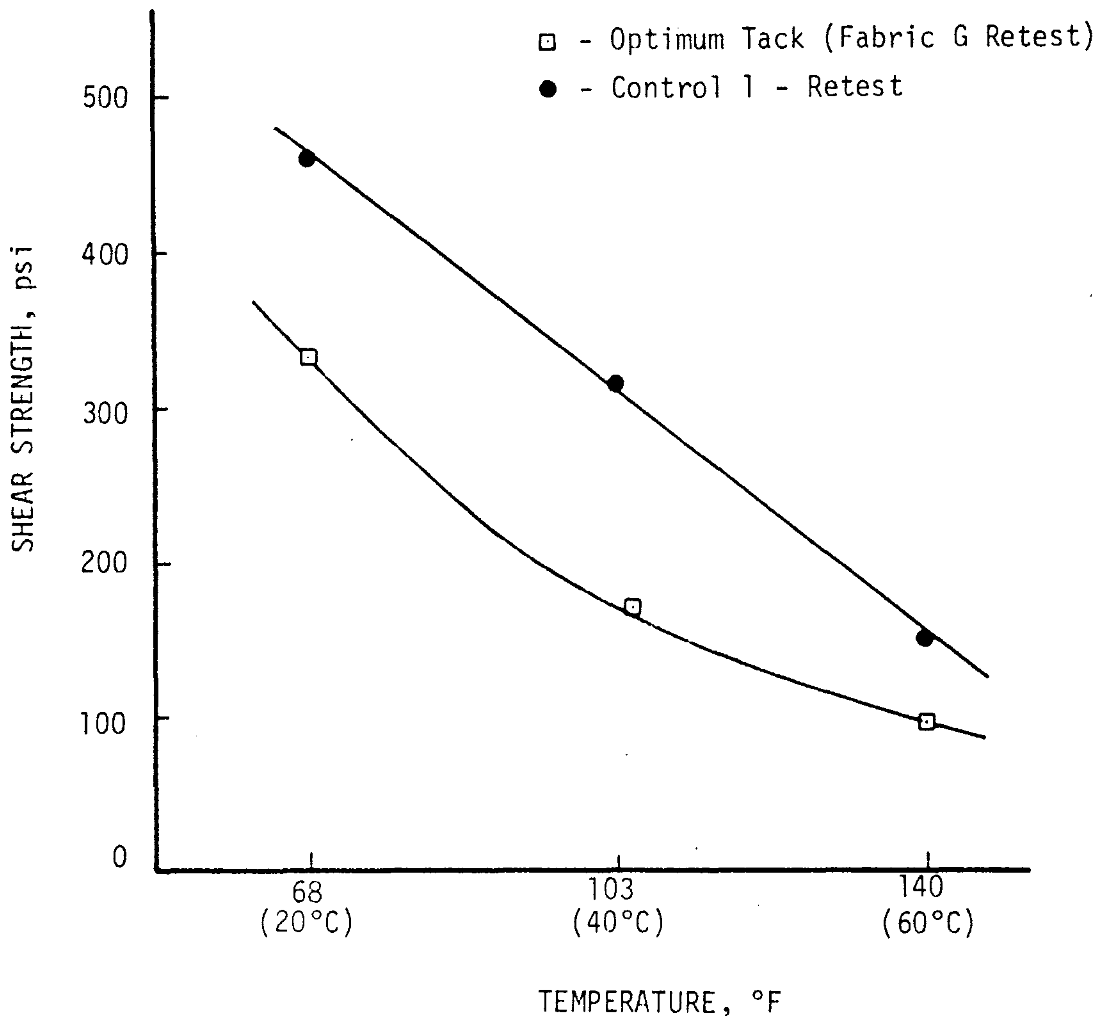

Figure 6. Overlay Shear Test Results on Mixtures Containing Fabric G.

Based on these test results, properly designed and correctly installed fabrics will not reduce the shear strength of an overlay below acceptable levels.

Flexural Fatigue

Flexural fatigue characteristics of asphalt concrete mixtures with Fabrics P, Q and R were determined using the same compaction and testing procedures and equipment described in Reference 3. Specimens containing Fabric G were retested to provide confidence that the beam fatigue data reported herein can be compared directly with the beam fatigue data reported in Reference 3. The retested specimens show acceptable similarity to the original test specimens. It is concluded, therefore, that direct comparisons of the fatigue test results are valid even though the specimens tested in this latter phase contained, on the average, 2 percent more air voids.

Loads are applied at the third points of the beam, four inches on center, with 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 will return to its original "at-rest" position after each cycle. Upon rupture of the specimen, limit sqitches shut off the testing machine, and a cycle counter indicates the number of cycles to complete rupture.

The following procedure was utilized in the fabrication of the

3 x 3 x 15-inch beam test specimens containing Fabrics P, Q, R and G:

1. Compaction of a 3/4-inch (19-mm) layer of asphalt concrete,
2. Applying a 3 x 15-inch (76 x 380-mm) of presoaked fabric and
3. Compacting two 1 1/8-inch (29-mm) layers of asphalt concrete over the fabric.

All beam specimens were fabricated with the black tape strands (warp) in the longitudinal direction.

Results from individual flexural fatigue test specimens are given in Table A1 of Appendix A. Formulae employed to compute the fatigue test parameters are also presented in Appendix A. Table 8 gives a statistical summary of the results. Figures 7, 8 and 9 compare results of this study with those reported in Reference 3.

Control-1 specimens contained 0.05 gallons per square yard tack coat with no fabric at the interface. A statistical summary of the test results (Table 8) shows that the Control-1 specimens gave better fatigue performance than any of the specimens containing fabric. This may be attributed in part to the asphalt tack coat which likely migrated into the hot mixture as a result of the kneading action during compaction. The additional asphalt cement would decrease air voids in the region of the mixture experiencing maximum tensile stresses and thus enhance fatigue performance. In support of this theory is the fact that fatigue tests on Control-2 specimens (3) (no tack and no fabric) resulted in a mean initial bending strain of 0.00074 inches per inch and only 6,400 cycles to failure.

Fabrics P and G with optimum tack produced specimens exhibiting a greater mean number of cycles to failure (N_f) than Fabrics Q and R

Table 8. Simple Statistics of Flexural Fatigue Data

Sample Type	Statistic	Specific Gravity	Air Voids, Percent	Input Stress, psi	Initial Bending Strain, in/in	Log Mean Cycles to Failure	Initial Stiffness Modulus, psi	Total Energy Input, lb-in	Max. Energy Density lb-in/in^3
Fabric P (0.11 gal.yd^2 tack)	Mean	2.314	6.9	98	0.0010	3300	100,300	3900	0.043
	Std Dev	0.006	0.2	1	0.00020	-	20,400	730	0.009
	Coef Var	0.3%	3%	1%	19%	27%	20%	19%	20%
Fabric P (0.19 gal/yd^2 tack)	Mean	2.321	6.6	97	0.00068	11,400	147,300	9600	0.0283
	Std Dev	0.003	0.15	1	0.000048	-	8,900	4200	0.0025
	Coef Var	0.1%	2%	1%	7%	45%	6%	44%	9%
Fabric Q (0.13 gal/yd^2 tack)	Mean	2.309	7.1	98	0.0013	220	78,400	4300	0.056
	Std Dev	0.012	0.5	1	0.00026	-	13,000	930	0.011
	Coef Var	0.5%	7%	1%	20%	31%	17%	22%	20%
Fabric R (0.19 gal/yd^2 tack	Mean	2.306	7.2	98	0.00086	7300	128,100	8100	0.0342
	Std Dev	0.018	0.75	0.9	0.000149	-	22,000	6100	0.0059
	Coef Var	0.8%	10%	1%	17%	96%	17%	75%	17%
Control-1 (0.05 gal/yd^2 tack)	Mean	2.335	6.1	98	0.00046	13,700	219,100	8000	0.0197
	Std Dev	0.005	0.15	0.2	0.000074	-	37,600	270	0.0035
	Coef Var	0.2%	3%	2%	16%	10%	17%	3%	18%
Fabric G (0.20 gal/yd^2 tack)	Mean	2.288	8.0	96	0.00065	11,400	162,200	8700	0.0270
	Std Dev	0.011	0.45	0	0.000216	-	48,400	3700	0.0089
	Coef Var	0.5%	6%	0%	34%	55%	30%	42%	33%

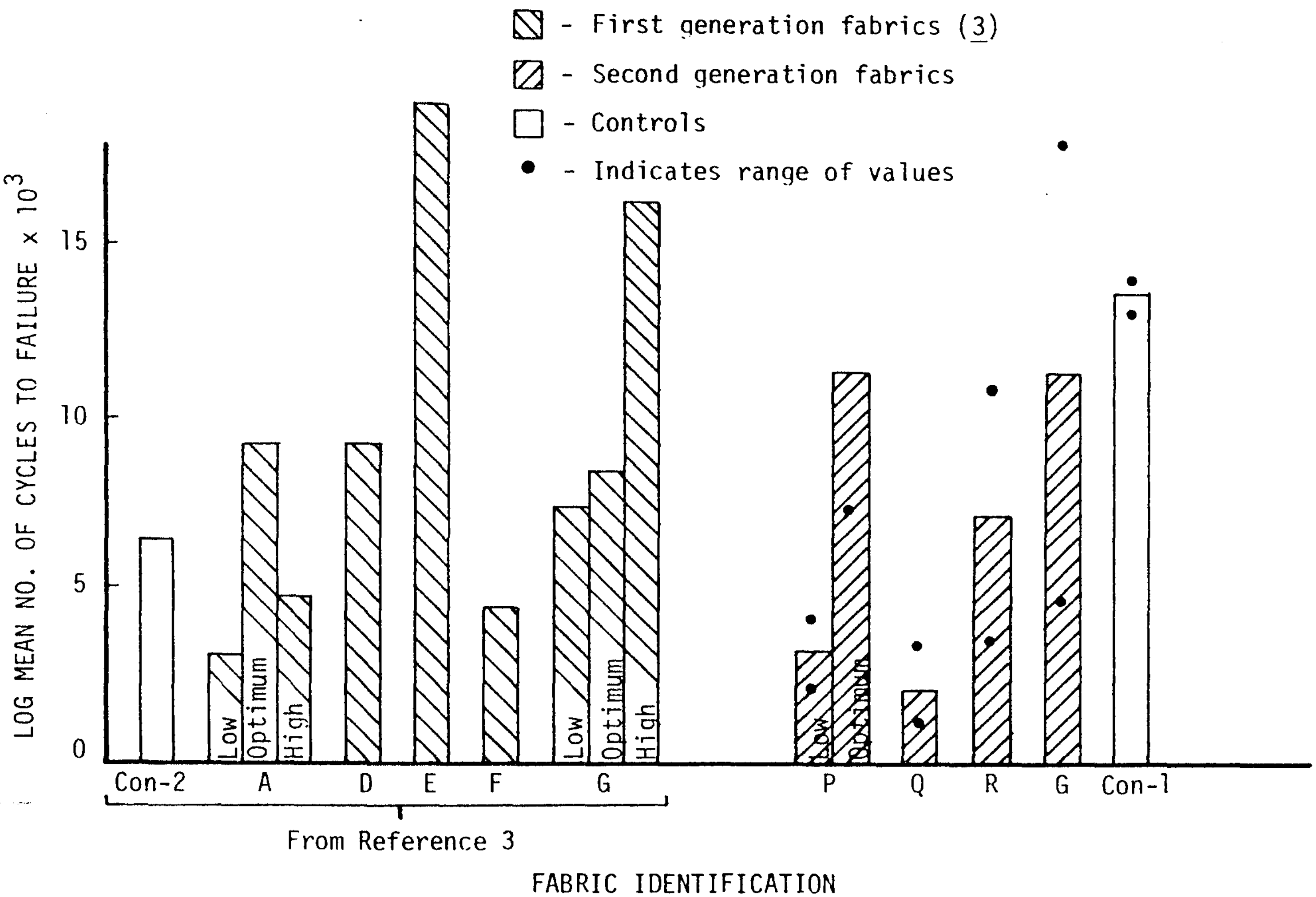

Figure 7. Mean Number of Load Cycles to Failure from Flexural Fatigue Tests at or near 100 psi peak stress in extreme fiber.

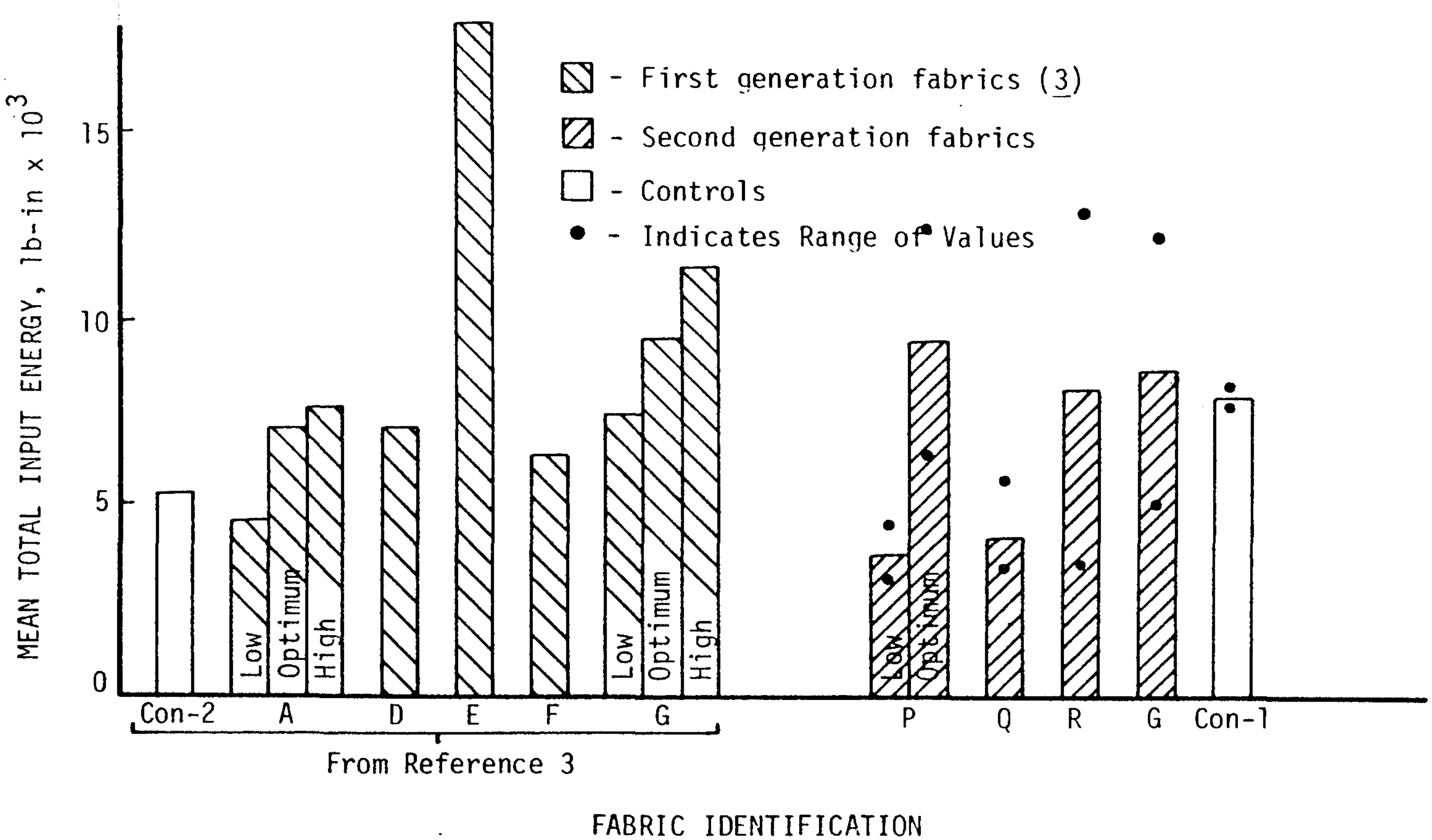

Figure 8. Mean Total Input Energy Required to Fail Each Specimen.

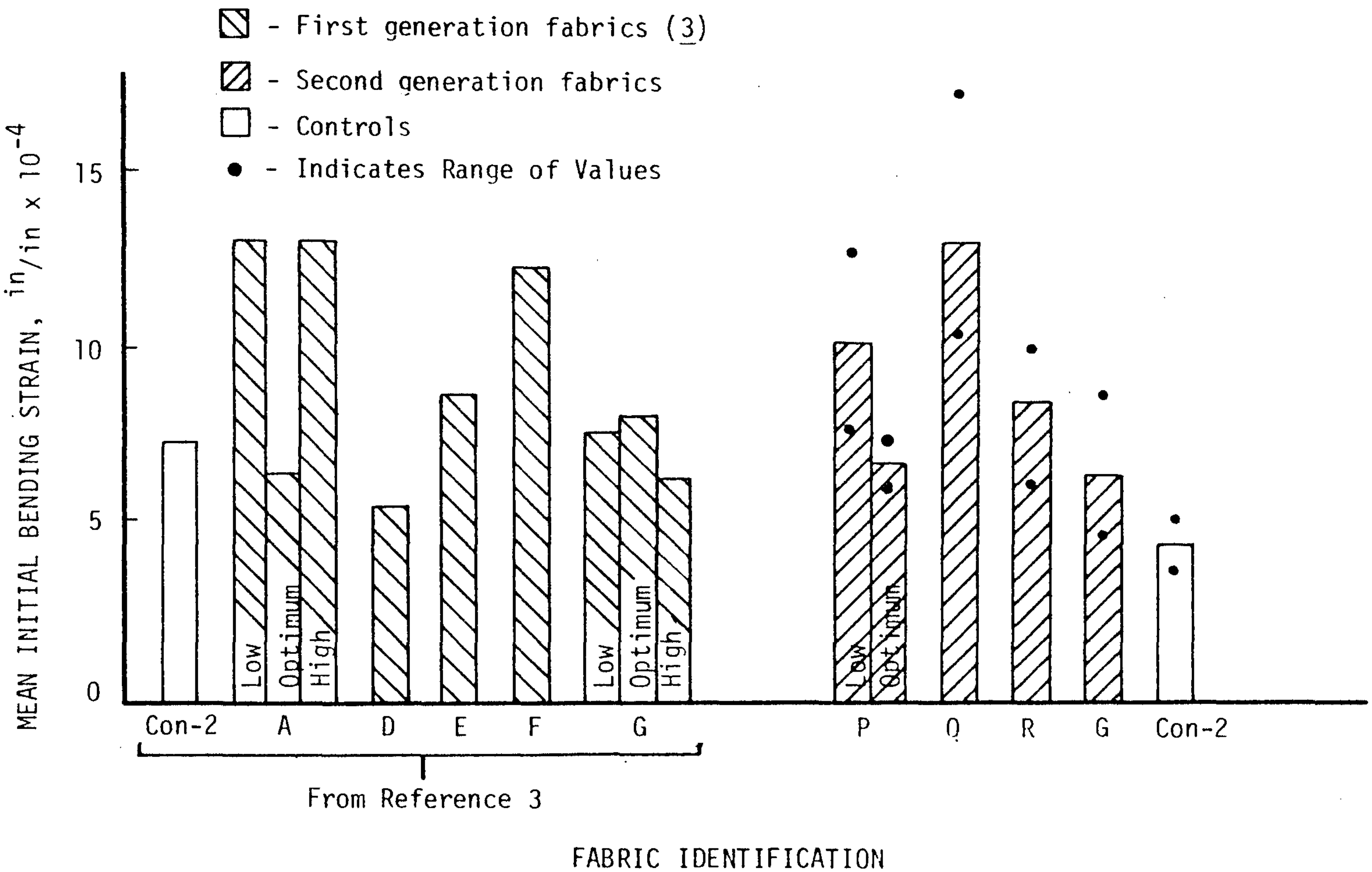

Figure 9. Mean Initial Bending Strain (200th cycle) from Flexural Fatigue Tests.

(Figure 7). On the average, then, Fabrics P and G give better fatigue performance. However, the range of values of N_f for those specimens containing P, R and G overlap the range for the Control-1 specimens. This indicates that, under a given set of conditions, specimens containing Fabrics P, R and G and Control-1 specimens may give approximately equal performance from a fatigue life standpoint. On this basis, Fabrics P and R are expected to perform satisfactorily in a field installation.

Fabric Q produced specimens of relatively poor fatigue performance. Fatigue test results of similarly constructed fabrics, the results of which are reported in Reference 4, also gave relatively poor fatigue performance. The dual layer construction of these fabrics or the wide variation in surface texture of opposite sides of these fabrics may be related to fatigue properties.

Mean values of total input energy (Figure 8), support the results shown by mean numbers of cycles to failure (Figure 7). A notable difference is the comparatively good performance of specimens containing Fabric R (Figure 8).

Greater stiffness of the Control-1 specimens is manifested by the higher initial stiffness moduli (Table 8) and lower initial bending strain (Figure 9). This likely results from the additional asphalt tack at the interface, however, the presence of a layer of asphalt-soaked fabric in a beam specimen may permit some longitudinal strains at the interface resulting in increased vertical deformation (and bending strain); whereas, with no fabric, the asphalt enriched tensioned region (mentioned previously) of the Control-1 specimens may reduce the resultant strain, particularly at the 68°F (20°C) temperature. It is this longitudinal strain permitted by the fabric-asphalt layer which is purported to aid in reducing reflection cracking. Control-2 specimens (3), with on interface and, thus, no tack, are seen to give considerably poorer fatigue performance (Figures 7, 8 and 9), which supports this theory.

The larger coefficients of variation exhibited by those specimens containing fabrics suggest that more intense quality control is necessary when preparing specimens containing fabrics. This is also most likely applicable in the field.

Resistance to Thermal Reflection Cracking

The "overlay tester" (3) is essentially a displacement controlled fatigue testing machine designed to measure the resistance of an asphalt concrete mixture to reflection cracking. Initially, a small crack is produced (due to tension) in a test specimen and then the device continues to induce repetitive longitudinal displacements 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 periodic thermal variation.

The construction materials as well as the fabrication procedures for the specimens tested in this experiment were identical to those used in the preparation of the 3 x 3 x 15-inch (7.6 x 7.6 x 38 mm) beams tested in flexural fatigue. Test results are presented in Table 9 and compared with previous tests (3) in Figure 10.

Specimens containing Fabrics D and G at optimum tack were retested to provide confidence that the overlay test data reported herein can be

Table 9. Results from "Overlay" Test Specimens.

Fabric	Sample No.	Air Voids Percent	Mean Air Voids	Cycles to Failure	Mean Cycles to Failure
P	P1	6.7		550	
(0.11 gal/yd^2, tack)	P2	6.8	6.8	200	320
	P3	6.6		200	
P	P4	-		500	
(0.19 gal/yd^2, opt. tack)	P5	-	-	500	570
	P6	-		700	
Q	Q1	6.7		300	
(0.15 gal/yd^2, tack)	Q2	6.8	6.7	275	380
	Q3	6.6		525	
R	R1	6.8		600	
(0.19 gal/yd^2, (opt. tack)	R2	8.7	7.7	700	650
	R3	7.7		650	
D	D1	7.1		490	
(0.23 gal/yd^2, opt. tack)	D2	7.5	7.1	250	310
	D3	6.8		200	
G	G1	7.6		110	
(0.20 gal/yd^2, opt. tack)	G2	8.1	7.7	200	240
	G3	7.5		400	
Control	1	8.1		75	
(0.05 tack, no fabric)	2	8.6	8.3	70	70
	3	8.2		60	

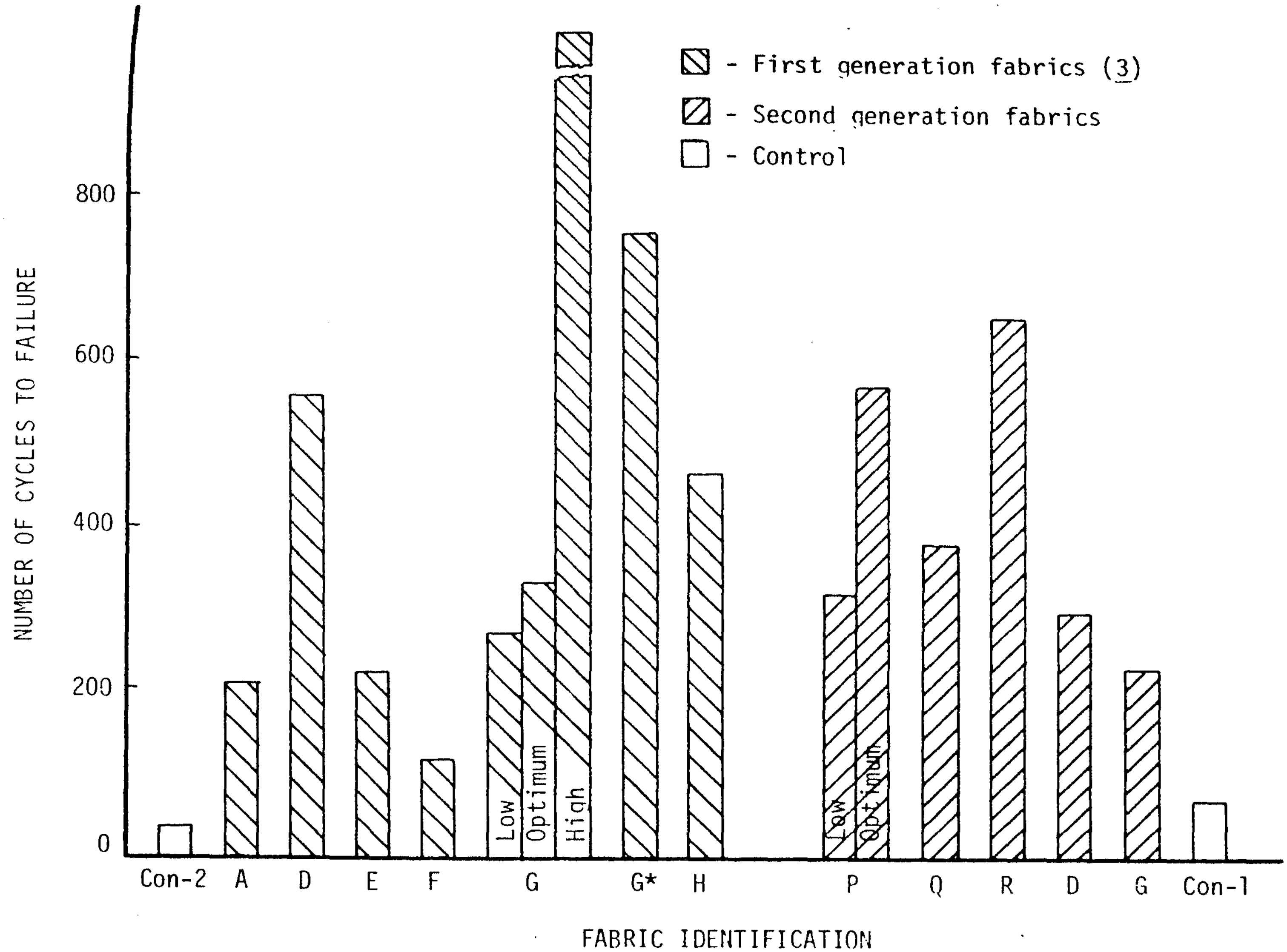

Figure 10. Mean Number of Cycles to Failure for Overlay Test Specimens.

compared directly with the overlay data reported in Reference 3. Air voids contained in the specimens prepared in this phase of the study were greater than those in the specimens reported in Reference 3. Consequently, the more recent specimens resulted in significantly less resistance to cracking. On the average, the previously tested beams (3) containing Fabrics D and G required about 50 percent more cycles for complete failure.

Generally, fabrics significantly reduce the rate of cracking of asphalt concrete in this mode of testing (Figure 10). Specimens containing Fabrics D (similar to Fabric H) and G resulted in more cycles to failure than any of the other specimens studied in Reference 3. Yet in this latter phase of work, specimens containing Fabrics P and R resulted in more cycles to failure than any of the other specimens tested under similar conditions, including those containing Fabrics D and G. By indirect comparison of results from the overlay tester, it appears that specimens containing Fabrics P and R exhibited resistance to reflection cracking that is superior to any other specimens previously tested at optimum asphalt content.

Even at the higher air void content, the Control-1 specimens gave more cycles to failure than the Control-2 specimens. The reader is reminded that Control-1 specimens have 0.05 gallons per square yard tack in an interface with no fabric while the Control-2 specimens have no fabric and no tack (no interface). Some of the asphalt tack in the Control-2 specimens probably migrated into the asphalt concrete mixture adjacent to the interface during compaction thus improving the tensile properties of the beam in that region.

Figures 11 and 12 show approximate peak loads (based on average values) as a function of number of deformation cycles. Figure 11 shows that in this mode of testing, specimens containing a fabric, even with insufficient tack, give better results than specimens with tack and no fabric (Control-1). This is in agreement with previous research (3). Overall, those specimens containing fabric exhibited about 6 times more cycles to failure than the Control-1 specimens.

As shown in References 3 and 4 and again herein the rate of crack growth begins to decrease as the crack tip approaches the fabric-asphalt layer and reaches a minimum as the crack tip penetrates the fabric-asphalt layer. An example of this is given in Figures 13 and 14.

When the crack in the specimen begins to appear on the other side of the fabric-asphalt layer, it may be offset laterally up to approximately one-inch from the original crack or it may appear as two more smaller cracks. These smaller cracks would most likely be more easily "healed" by the kneading action of traffic in warm weather.

At the point of failure, the fabrics remained intact and even supported a small load (typically 10 to 15 lbs. or 44 to 66 N) which is probably insignificant from a structural standpoint. However, the asphalt-soaked fabric would probably allow less intrusion of surface water into the base.

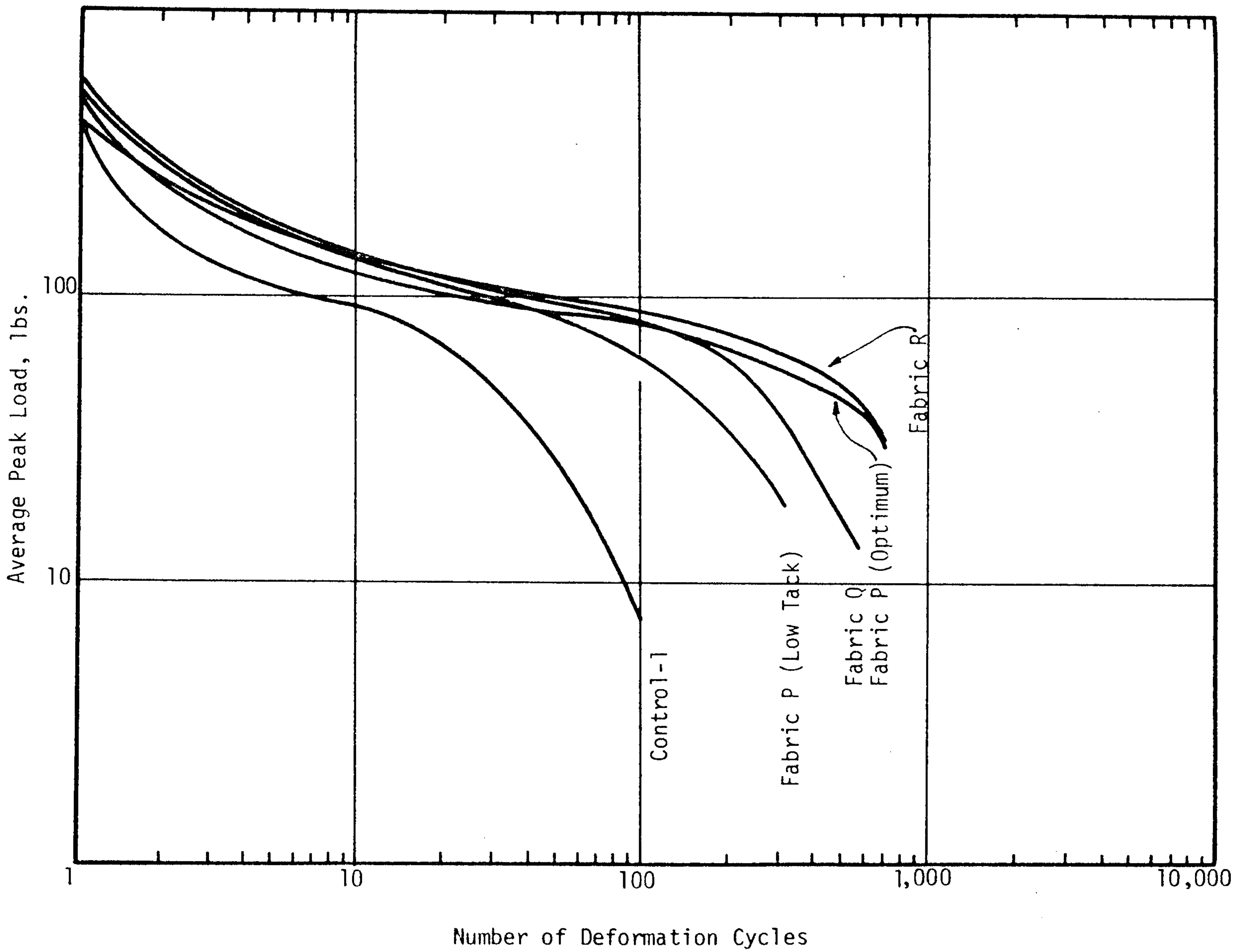

Figure 11. Peak Load Supported by Specimens during Overlay Test.

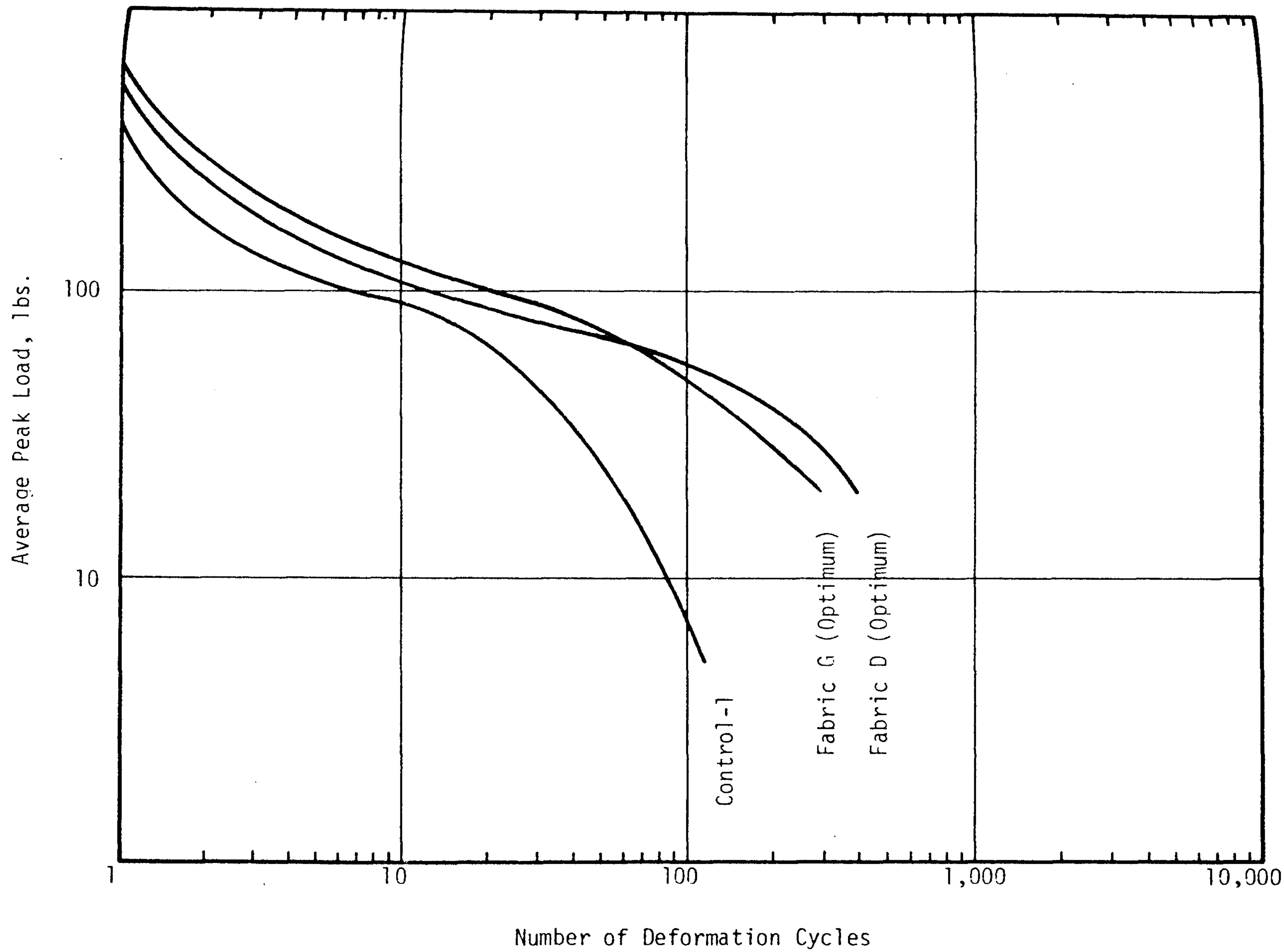

Figure 12. Peak Load Supported by "Retested" Specimens during Overlay Test.

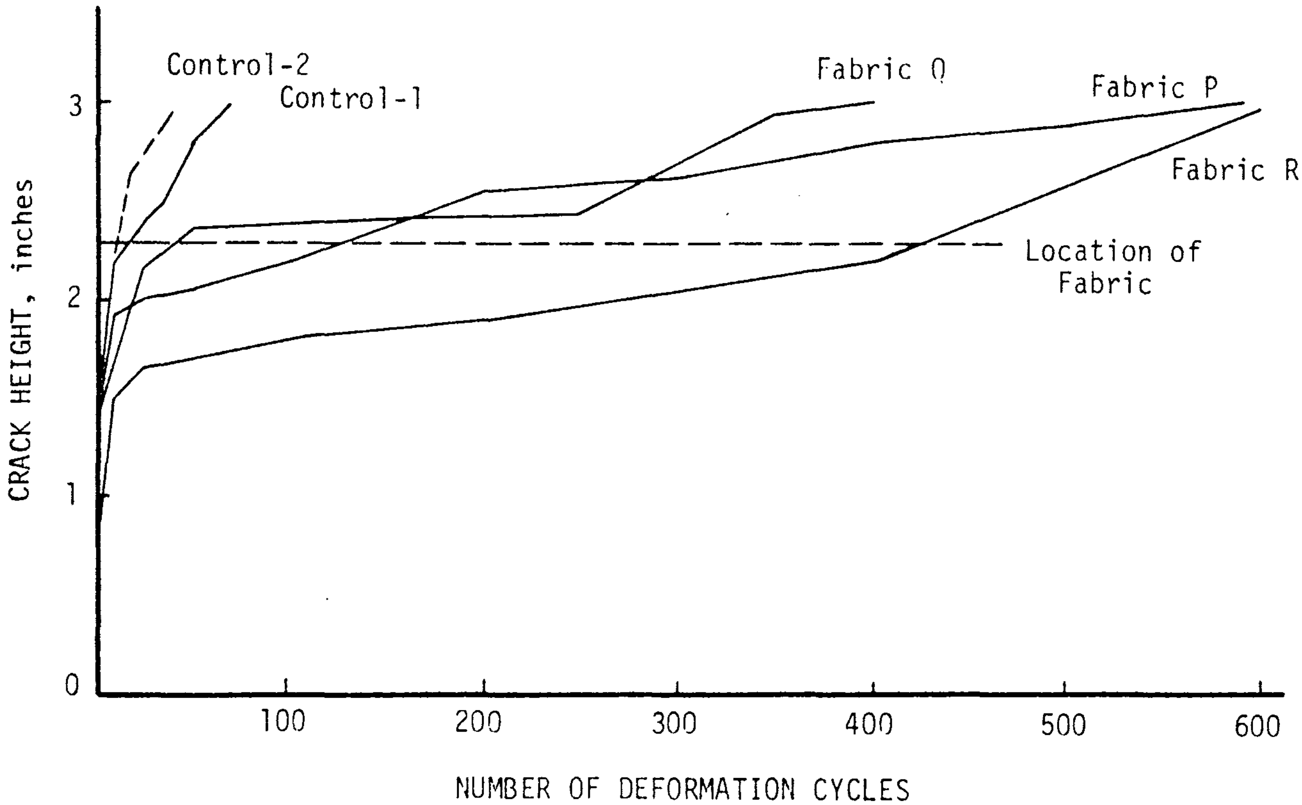

Figure 13. Average Crack Height versus Number of Deformation Cycles for Fabrics P, Q and R.

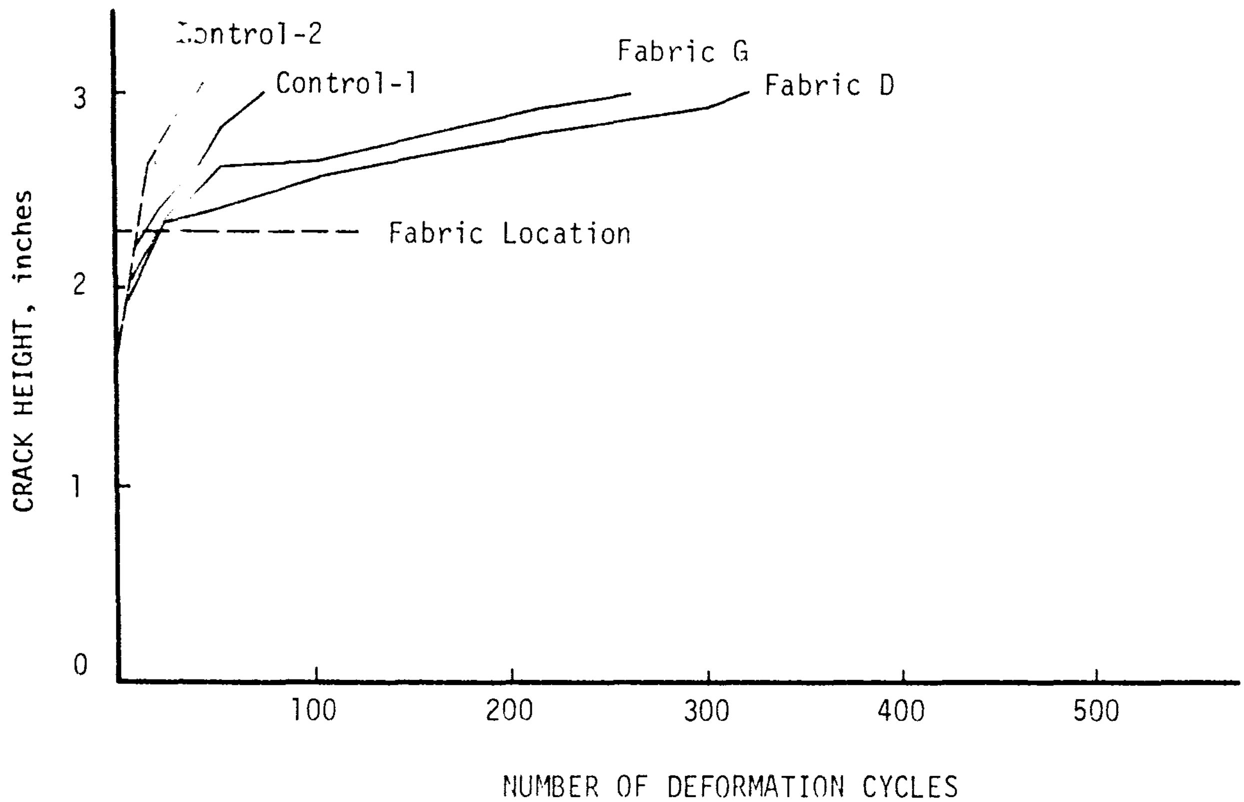

Figure 14. Average Crack Height versus Number of Deformation Cycles for Fabrics D and G.

Direct Tension Tests

To determine the effects of Fabrics P, Q and R on the tensile properties of asphalt concrete, uniaxial tensile tests were performed at a constant displacement rate of two inches per minute (5.1 cm/min) and a temperature of 68°F (20°C).

Specimens were prepared using the laboratory standard gravel and asphalt cement mixed at 300°F (150°C) and molded at 250°F (121°C). The first step was to mold a 2 x 3 x 15-inch (50 x 75 x 375 mm) beam using the modified soil-test Model CN-425 kneading compactor with a 3 x 4-inch (75 x 100 mm) tamping foot applying 35 tamps on each of the two 1-inch layers. After the first 1-inch layer was compacted, the appropriate quantity of asphalt cement tack coat was uniformly distributed over the top surface, a 3 x 15-inch (75 x 375 mm) piece of fabric was applied, and lastly, a second 1-inch layer was compacted. Following extrusion from the mold, the beams were allowed to cool to room temperature. Each beam was cut in half longitudinally, then each half was sawed into three pieces and trimmed to ultimately produce test specimens approximately 1.5 x 1.5 x 5-inches (38 x 38 x 135 mm) with a strip of fabric near the center. Three repetitions of the uniaxial tensile test were performed on each type of test specimen.

Direct tension test results for individual test specimens are given in Table A2, Appendix A. A statistical summary of the test results is given in Table 10. It appears that, under these test conditions, a little extra asphalt will improve tensile properties of asphalt concrete as much as an asphalt-soaked layer of fabric designed particularly to reduce reflection cracking. The Control-1 specimens with a tack coat

Table 10. Statistical Summary of Direct Tension Test Results.

Fabric	Statistic*	Tensile Strength, psi	Ten. Strain @ Failure, in/in x 10^{-6}	Secant Modulus, psi
P (0.19 gal/ yd^2 Tack)	Mean	87	4,351	20,600
	Std Dev	13	709	3,935
	Coef Var	15%	16%	19%
Q (0.19 gal/ yd^2 Tack)	Mean	58	5,186	12,800
	Std Dev	6	1,473	3,834
	Coef Var	11%	28%	19%
R (0.19 gal/ yd^2 Tack)	Mean	105	4,426	23,300
	Std Dev	7	127	2,146
	Coef Var	6%	3%	9%
Control-1 (0.05 Tack at Interface)	Mean	106	4,423	26,600
	Std Dev	17	1,088	9,205
	Coef Var	16%	26%	35%

and no fabric exhibited lower total air voids and significantly better tensile properties than the Control-2 specimens (3) which had no tack. Furthermore, earlier direct tensile tests (3) showed improved tensile properties with increased asphalt tack when a fabric was employed.

In an attempt to produce specimens with a narrow range in air voids, the compaction procedures followed in the preparation of these specimens were identical to those described in References 3 and 4. It is difficult to produce specimens with similar air voids when using different fabrics and tack rates; therefore, values of stress and strain at failure were plotted as a function of air void content (Figure A1 and A2, Appendix A). A linear regression had been determined in Reference 3. This linear relationship was used to "normalize" the stress and strain data or, that is, estimate the value of stress and strain that would have been obtained if all specimens contained a similar quantity of air voids. Histograms showing the normalized values of stress and strain for several fabrics tested in this program are shown in Figures 15 and 16.

When standard deviations are considered, the normalized tensile strengths of Control-1 and Control-2 specimens are about the same. This is to be expected since the only difference in these two types of specimens is that Control-1 specimens contain additional asphalt which filled more voids and the normalizing process nullified this difference.

The normalized tensile strengths of specimens containing Fabrics P and R are about equal to those of the control specimens and exceeded only by the tensile strengths of specimens containing Fabrics A and G (when only optimum tack is considered) (Figure 15). Figure 16 shows

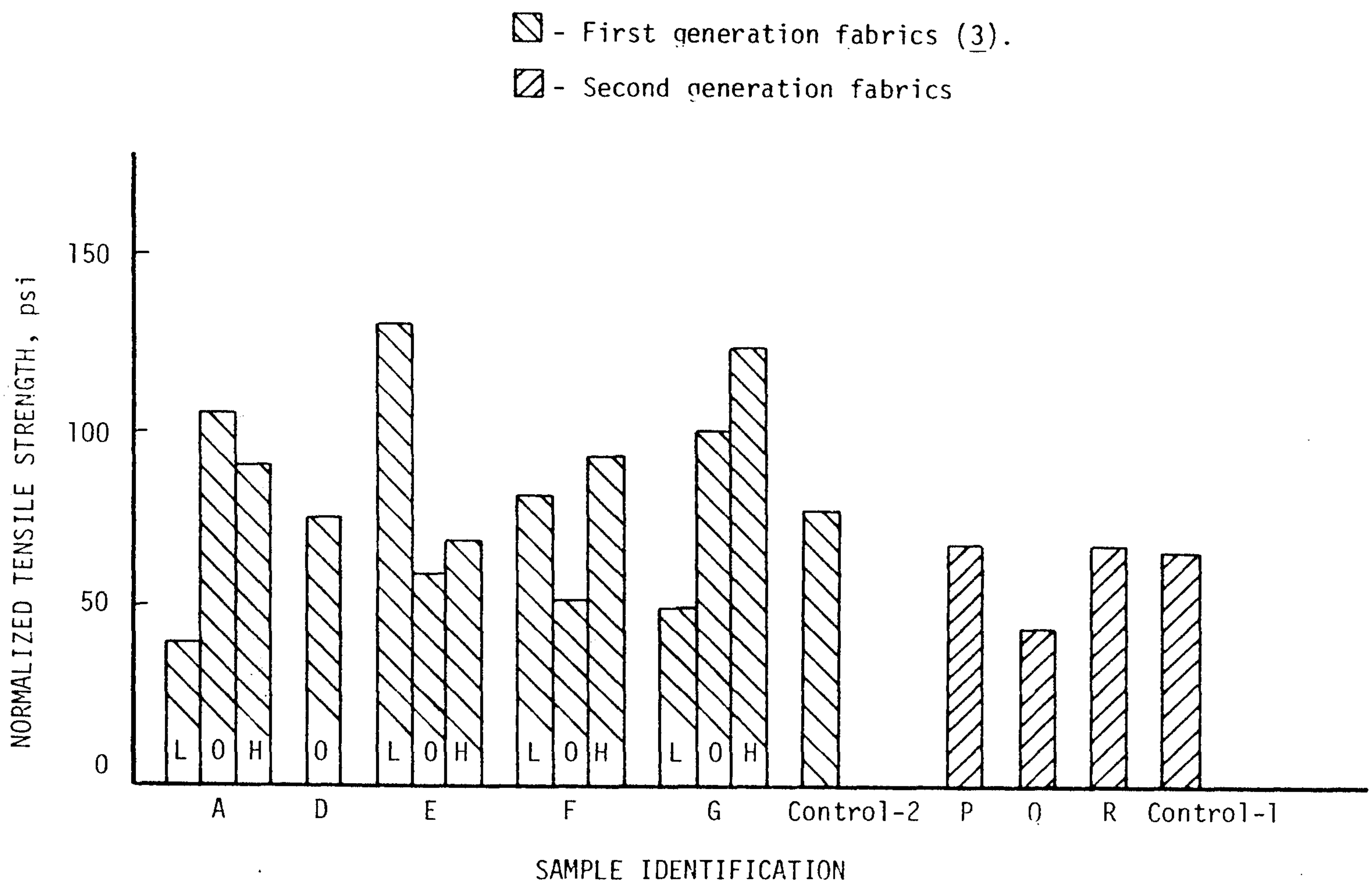

Figure 15. Normalized Average Tensile Strength of Test Specimens.

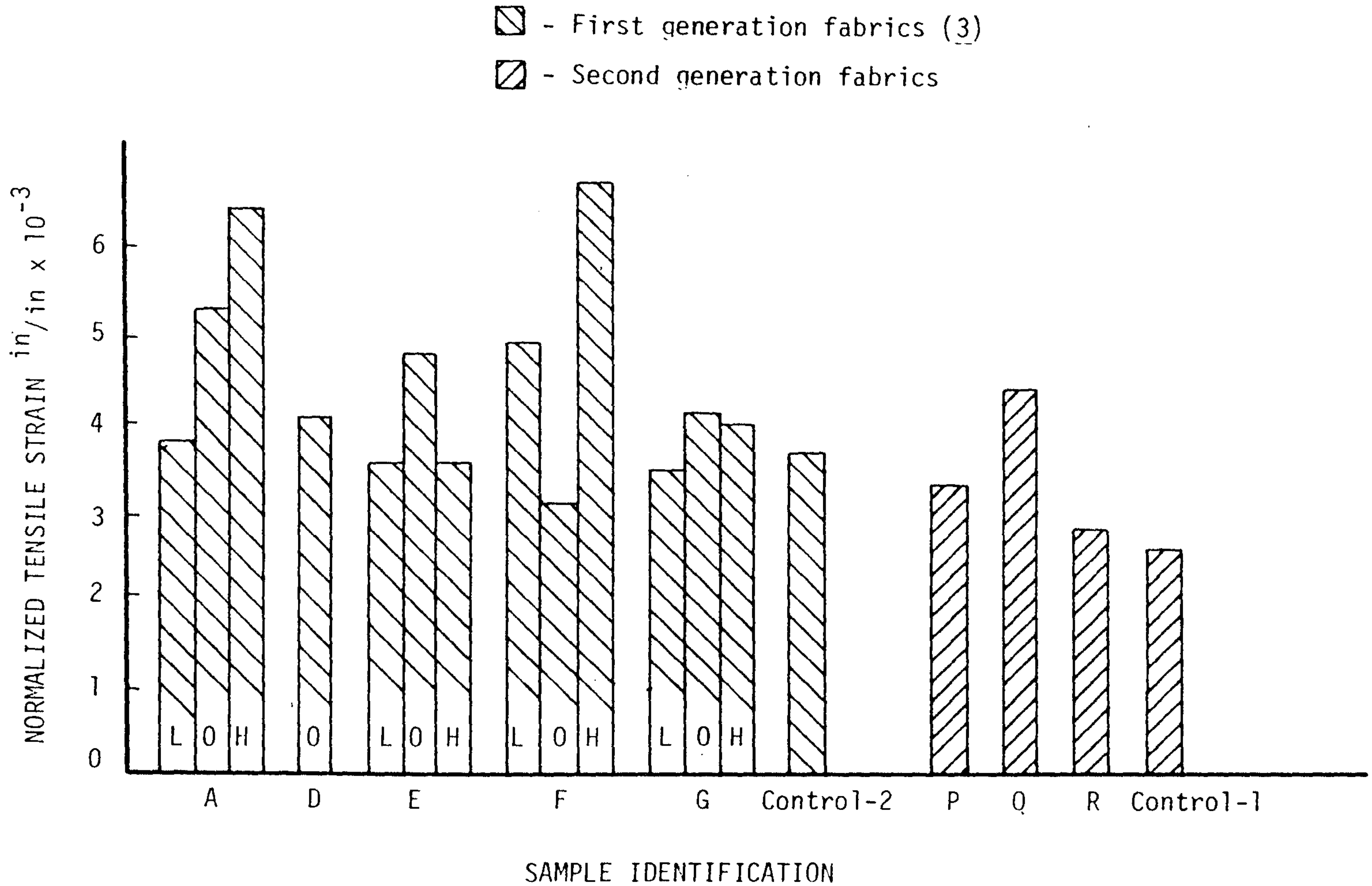

Figure 16. Normalized Average Ultimate Tensile Strain of Test Specimens.

that most of the specimens containing fabric allowed more strain prior to failure than their counterparts containing no fabric. Fabrics P and R appear to perform satisfactorily from the standpoint of tensile properties measured by the uniaxial tensile test.

Conclusions from Laboratory Tests

The following conclusions are based on the laboratory test results reported herein as compared to related research (1, 2, 3 and 4) reported previously.

1. Most of the fabrics tested did not shrink significantly when placed unrestrained in 250°F asphalt for up to 30 minutes. Most of these fabrics, however, exhibited significant shrinkage when placed unrestrained in 300°F asphalt for longer than one minute. Fabric R does not show significant shrinkage under any circumstances tested. (Note: significant linear shrinkage is considered to be that which is greater than 5 percent or that which occurs over a period longer than 15 minutes. These fabric characteristics have been associated with overlay cracking during or shortly after construction (3).

2. Shear strength (as measured in the laboratory) of asphalt concrete at a fabric interlayer increases with asphalt tack rate and decreases with increasing temperature. Fabrics will cause a decrease in interfacial shear strength at lower temperatures where shear strength is already more than adequate. Shear strength is influenced by properties of the fabric such as surface texture, thickness, porosity and fuzziness. Overall, Fabrics P and R resulted in higher

shear strengths than most of the fabrics tested.

3. Fatigue performance of asphalt concrete containing a fabric is influenced by fabric characteristics such as surface texture, porosity, and asphalt holding capacity. Thick fabrics hold more asphalt which improves their performance as a stress relieving interlayer (thus, fatigue performance). Fatigue performance of thin fabrics is more sensitive to asphalt tack application rate. Fabrics P and R give acceptable fatigue performance.

4. Fabrics significantly reduce the growth rate of reflection cracks in asphalt concrete test specimens. Fabrics remain intact after complete rupture of the asphalt concrete. Reflected cracks are often offset from the original crack and may appear as 2 or more smaller cracks which, in the field, would probably allow less surface water to penetrate to the base. The smaller cracks would most likely be more easily "healed" by the kneading action of traffic in warm weather. Specimens containing Fabrics P and R exhibited resistance to reflection cracking that is superior to any other specimens tested at optimum asphalt content.

5. In the uniaxial tensile test, ultimate tensile stress may be either increased or decreased by the use of fabrics. Ultimate tensile strain usually increases when fabrics are employed. Initial tangent modulus is improved by the use of fabrics (3, 4) which indicates that an asphalt-soaked layer of fabric will favorably influence the tensile properties of asphalt concrete, particularly at very small strains. This appears to be advantageous from a pavement performance standpoint. Generally, tensile strength of specimens containing Fabrics P and R are comparable to the tensile strength of the other specimens tested.

FIELD EVALUATIONS

A portion of the research program was devoted to a study of the performance of pavement interlayer systems. Selected literature was reviewed and field visits made to selected states and field test sites. The states visited were Arizona, California, Colorado, Georgia and Utah. Test sections were evaluated in Arizona and Utah. The purpose of the visits was to establish the relative performance of fabrics as compared to control sections and other interlayer systems, establish relative performance among types of fabrics and to establish a data base for future evaluations of pavement sections containing new Mirafi fabrics.

Selection of Test Sites

Table 11 formed the basis for selection of those states and regions of the country for visits. Test sections placed on both asphalt concrete and portland cement concrete were desired. In addition, a spectrum of distress types and climate conditions were desired. The states of Arizona, California, Colorado, Georgia and Utah were selected as they offered the desired variables plus research organizations which collected detailed data on a number of sections. Sections in Kansas, Minnesota and Texas do not have enough age to produce meaningful results, therefore, these field visits were deleted.

Table 12 shows locations of the new generation Mirafi fabric installations. Installations at Holbrook, Phoenix and Scottsdale, Arizona; Monticello, Utah; and Denver Colorado were visited and evaluations were performed.

Table 11. National Test Site Selection Matrix.

Type of Pavement	Type of Pavement Distress or Design	Climatic Area			
		Dry No F-T	Wet No F-T	Dry F-T	Wet F-T
Flexible	Alligator	*California	*Georgia	*	*
	Transverse	*Texas		*California	*Minnesota
	Longitudinal and Transverse	*Texas California		*Kansas Monticello, Utah Holbrook, Arizona	
Rigid**	Jointed Non-Reinforced	*California	*Georgia	*Holbrook, Arizona	
	Jointed Reinforced	*North Carolina		*	*
	Continuously Reinforced	*	*	*	*

F-T - Area of Subgrade Freeze-Thaw

*Pavement distress or design located in climatic area

**Type of distress should also be considered (faulting, spalling, etc.).

Table 12. Location of Second Generation Mirafi Fabrics*.

Fabric	Location	Variables at Site: More Than One Fabric	Variables at Site: Asphalt-Rubber Included
900X-N	Decator, Illinois	No	No
	Salisbury, N. C.	No	No
	Albany, New York	Yes	No
	Syracuse, New York	Yes	No
	Monticello, Utah	Yes	Yes
	Charlotte, N. C.	Yes	No
	Phoenix, Arizona	No	No
900X-A	Charlotte, N. C.	Yes	No
	Harrisburg, N. C.	Yes	No
	Holbrook, Arizona	Yes	Yes
	Los Alamos, N. M.	Yes	No
	Denver, Colorado	Yes	Yes
	Tremonton, Utah	No	No
	Boise, Idaho	No	No

*Data furnished by Mirafi Inc.

Method of Evaluation

Reports from state Departments of Transportation were obtained during the visits. Data from the reports have been summarized in Table 13. As expected a uniform method of preconstruction, construction and post construction evaluation was not used; however, sufficient information was usually available to make subjective comparisons among the sections.

In an attempt to provide guidelines for evaluation of test sections, an information gathering form was developed and is contained in Appendix B. The engineer should not be expected to supply all the data requested as the form is quite extensive. It is important that basic preconstruction, construction and post construction data be collected in as uniform a manner as possible.

Field Performance

A minimum of 3 ~~to 5~~ or more years is required to collect relative performance information. Many of the sections evaluated and all of those with the new generation Mirafi fabrics did not have the required age for meaningful comparisons. A summary of the more important conclusions that can be noted upon a careful review of data in Table 13 is given below.

Table 14 lists those sections where fabrics have provided a limited performance improvement. Table 15 lists sections where fabrics provide no distinct performance improvements. Table 16 is a listing of test sections that compare types of fabrics. Those sections which exhibit

Table 13. Summary of State Field Trials.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Arizona	Scottsdale Indian School Road Scottsdale to Miller Section placed March 81 (8)	AC	Petromat + 1 1/4" AC	Some wrinkles when placing end of roll	• After 9 months no distress in any of sections	Cracks in old pavement exceeding 1/8 inch filled with slurry Old pavement-block cracking, longitudinal cracking and alligator cracking
			Mirafi 900X-A + 1 1/4" AC	Roll damp, roll broken, hand laid		
			Control 1 1/4" AC			
	LDS Church Parking Lot Phoenix, AZ Section placed September 80 (8)	chip seal 1970 1 1/2"AC 1962 4" aggregate base 1962	Mirafi 900X-N + 1" AC	Placed by hand	• 1 random reflection crack • 1 longitudinal crack at overlap of fabric • 5-10% reflection cracks after 9 months of service	Small section on parking lot, old pavement longitudinal and transverse cracks, some raveling
			Control 1" AC			
	Business SH 140 Holbrook Section placed September 80 (9)	AC PCC	Mirafi 900X-N + 2 AC + 3/4" OGFC		• After 9 months of service no cracking	Old pavement of AC milled to PCC prior to placing fabric
			Control 2 AC + 3/4" OGFC			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	US 395 Doyle 02-LAS-395 Section placed August 1972 (10, 11)	AC	Stress relieving + 1" AC	Varied thickness of interlayer	After 4 years slightly better than control	Old pavement severe map and block cracking
			Emulsion slurry seal + 1" AC		After 4 years about same as control	
			Petroset fog seal + 1" AC		After 4 years about same as control	
			Petromat + 1" AC	Some wrinkling	After 9 years slightly more cracking than 2.4 AC control	
			Petrolastic crack filled + heavy thick + 1" AC	Cerex was to be used but could not be placed	After 4 years 10% reflection cracking performing better than petromat	
			Control 1" AC		After 4 years 26% reflection cracking	
			Control 2.4" AC		After 9 years less cracking than Petromat + 1" AC	
	SH 36 Susanville 02-LAS-36 Section placed (10)	AC	Reclamite construction seal on overlay		No difference as compared to control	
			Control no construction seal			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	IH 80 COLFAX 03-PLA-80 Section placed July 1974 (10, 11)	3.6 AC 8 CTB 8 Subbase	Petroset fog seal on 2.4" AC			Old pavement longitudinal and transverse cracks
			1.2" OGFC + 1.2" AC		After 24 months small cracks	
			1.2" OGFC + 2.4" AC			
			Petromat + 2.4" AC		After 7 years performing better than 2.4" AC control and almost as good as 3.6" AC control	
			Control 2.4" AC			
			Control 3.6" AC			
	US 101 Pismo Beach 05-SLO-101 Section placed July 1972 (10)	AC	0.7" OGFC + 3.6" AC			Old pavement longitudinal and transverse cracks
			Control 3.6" AC			
		PCC	0.7" OGFC + 3.6" AC			
			Control 3.6 " AC			
	SH 43 Bakersfield 06-KER-43 Section placed September 1972 (10, 11)	AC	Heater scarification 3/4" inch + rejuvenation agent + 1" AC			Old pavement longitudinal and transverse cracks
			Control 1" AC			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	US 1 Long Beach 07-LA-01 Section placed January 1973 (10, 11)	PCC	Stone dust + 2.4" AC			Old pavement cracks and joints
			Petromat strips + 1.2" AC		Failed within one year	
			Petromat strips + 2.4" AC		After 6.5 years minimal hairline transverse and longitudinal cracking	
			Control 2.4" AC			
	IH 15 Riverside 08-RIV-15 Section placed September 1972 (10)	AC	Petromat + 1" AC	Some wrinkling moved under trucks and laydown machine	After 42 months better than control section but cracks have reflected	Old pavement alligator cracking
			Petromat + 1" AC + 3.2" AC		After 42 months no cracking	
			Control 1" AC			
			Control 1" AC + 3.2" AC		After 42 months no cracking	

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	SH 78 Vista 11-SD-78 Section placed December 1972 (10)	4" AC	Petromat + 1" AC		After 42 months minimal amount of cracking	Old pavement alligator cracking
			Petromat + 1" AC + Petroset construction seal			
			Petroset construction seal on 1" AC			
			Reclamite construction seal on 1" AC			
			Control 1" AC		After 42 months alligator cracks have reflected	
	SH 115 Brawley 11-IMP-115 Section placed August 1974 (10, 11)	AC	Petromat + 1.2" AC		After 6 years excellent condition	Old pavement alligator cracking
			Petromat + 2.4" AC		After 6 years fair condition	
			Sahuaro asphalt-rubber		After 2 years some wheel track cracks	
			Control 2.4" AC		After 6 years excellent condition	
			Control 4.2" AC		After 6 years excellent condition	
	SH 74 Capistrano 07-ORA-74 Section placed September 1977	AC	Petromat + 1.2" AC		After 2 years extensive longitudinal and transverse cracking	Old pavement very weak No condition survey prior to construction
			Control 2" AC			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	SH 11 Pasadena 07-LA-11 Section placed June 1977 (12)	AC	Petromat + 2" AC		After 27 months one small crack	
			Control 2" AC		After 27 months no cracks	
	SH 2 Westwood Camden to Sepulveda Section placed November 1977 (12)		Petromat + 2.4" AC		After 21 months no cracks	
			Control 2.4" AC		After 21 months no cracks	
	SH 47 Long Beach 07-LA-47 Section placed June 1976 (12)		Petromat + 2" AC		After 39 months excellent performance	No condition survey prior to construction
			Control 2" AC		After 39 months excellent performance	
	SH 7 07-LA-7 Section placed March 76 (12)		Petromat + 1.2" AC St. John Street		After 41 months less than 10% reflection cracks	
			0.7" AC + Petromat + 1.2" AC		After 41 months one hairline crack	
			Control			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	SH 46 Paso Robles 05-SLO-46 Section placed February 1977 (12)		Petromat + 3" AC		After 3 years no distress in any sections	No condition survey prior to construction
			Petromat + 4.2" AC			
			Petromat + 5.4" AC			
			Control 4.2" AC			
	US 101 Gilroy 04-SCL-101 Section placed July 1976 (12)		Petromat + 1.8" AC		After 30 months no distress in any sections After 4 years all sections in excellent condition	No condition survey prior construction
			Petromat + 2.4" AC			
			Control 3.6" AC			
	US 395 09-MNO-395 Section placed September 1979 (12)		Petromat + 2.4" AC			
			Control 2.4" AC			
	SH 17 Fremont 04-ALA-17 Section placed 1978 (12)	PCC	Petromat + variable thickness AC		After 2 years no cracking Bleeding evident at spot locations	Some rocking slabs Large number of sections

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	US 101 Petaluma 04-MRN, Son-101 Section placed September 1978 (12)		1.2" AC + Petromat + 1.2" OGFC		After 1 year no cracking in any section	
			1.2" AC + Fibretex + 1.2" AC + 1.2" OGFC	Some tearing and disintegrating under distributer tires		
			1.2" AC + Mirafi 140 + 1.2" AC + 1.2" OGFC	Extensive wrinkling		
			1.2" AC + Bidim C-22 + 1.2" AC + 1.2" OGFC			
			1.2" AC + Bidim C-34 + 1.2" AC + 1.2" OGFC	Slight wrinling		
			Bituthene tape + 1.2" AC + 1.2" OGFC	Some slippage of mix over tapes during rolling		
			Varistrate tape + + 1.2" AC + 1.2" AC + 1.2" OGFC (4 types of tapes)	Numerous wrinkles some slippage of mix over tape during rolling, some cracking over tape		
			1.2" AC + Petromat + 2.4" AC + 1.2" OGFC			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	SH 12 Rio Vista 10-SLO-12 Section placed August 1978 (12)		Petromat + 1" OGFC		After 24 months 1 small transverse crack, 2 small ravelled areas	Old pavement hair-line wheel path alligator crack-ing Poor construction practices used
			Bidim C-22 + 1" OGFC		After 24 months no cracking and no raveling	
			Bidim C-34 + 1" OGFC		After 24 months 3 longitudinal wheel path cracks	
			AR-4000 Heavy tack + 1" OGFC		After 24 months 8 transverse cracks and 3 bleed-ing spots	
			Control 1" OGFC		Extensive alli-gator cracks and scattered trans-verse and longi-tudinal cracks	
	IH 80 Richmond 04-CC-80 Section placed October 1980 (12)					
	IH 505 Winters 03-YOL-505 Section placed September 1980 (12)					

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
California	SH 395 Winters 03-YOL-505 Section placed September 1980 (12)		1.2" AC + Petromat + 1.2" AC		After 12 months no cracking	
			Control 2.4" AC			
	SH 49, SH 20 Grass Valley Section placed May 1979 (12)	AC CTB	Petromat + 1.2" AC			
			Bidim C-22 + 1.2" AC			
			Bidim C-34 + 1.2" AC			
			Slurry seal			
			Asphalt-rubber			
			Control 1.2" AC			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Colorado	US 36 near Broomfield Sections placed September 1981 (13)		Protecto-wrap on joints and cracks + leveling course + 1 1/2" AC	Piece picked-up by wheels of distributer, maintainer nicked fabric, fabric shoved or rolled at several locations during AC laydown	After 6 months the shoulder joint cracked outside edge of fabric, no centerline joint cracking, transverse joints cracked	Leveling course laid with maintainer
			Bituthene on joints and cracking + leveling course + 1 1/2" AC	Fabric shoved or rolled at several locations during AC placement	After 6 months 29% of shoulder joint has cracked no centerline joint cracking, 2% transverse joints cracked	
			Polygard on joints and cracks + leveling course + 1 1/2" AC	Fabric bunched-up under maintainer	After 6 months no cracking	
			Control section		After 6 months no centerline joint cracking, no cracking at shoulder joint, no transverse cracking	

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Colorado	Parker Road Sections placed September 1980 (14)	2" AC 1964 gravel base-1937 ADT=17,500 on 4 lanes 4% trucks	Bituthene on cracks + 1 1/2" AC + 1 1/2" AC	Fabrics buckled under truck braking action	After 6 months no cracking or performance problems	
			Bidim C-22 + 1 1/2" AC + 1 1/2" AC	Some fabric alignment problems; some delamination in any sections due to haul trucks		
			Mirafi 900X-A + 2" AC + 1 1/2" AC			
			Mirafi 140S + 2" AC + 1 1/2" AC	Some delamination due to haul trucks, some alignment problems		
			Petromat + 2" AC + 2" AC			
			Duraglass + 2" AC + 2" AC	Installed by hand, fabric broke while being unrolled, some delamination due to haul trucks		
			Control section 3 1/2" AC			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Colorado	SH 58 From US 6 to Jefferson Co. Sections placed July 1979 (15)		Petromat + 1 1/2" AC			After 21 months no comparison of treatment effectiveness can be made, some cracking in test sections
		AC	Sawed old AC + Petromat + 1 1/2" AC			
			Petromat + 1 1/2" AC + sawed overlay		After 21 months no cracking	
			Sawed old AC + 1 1/2" AC			
			Control 1 1/2" AC			

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Colorado	I 70 Clifton to Cameo Section placed October 1971 (16)	3" AC 1963 4" BASE 1963 6-17" BASE 1963	Spray application of Asphalt rejuvenating agent + leveling course + 2" AC	Spot heavy applications of rejuvenating agent	After 5 years 96% reflection cracking	Prior to overlay longitudinal cracks 41 ft/1000 sq.ft.^{2} Alligator cracking 36 ft^2/1000 sq.ft.^{2} For reducing reflective cracking petromat, slurry seal and rubberized asphalt
			Petromat + leveling course + 2 1/2" AC (Cracks poured prior to placing fiber)	Paver pick up of fabric	After 5 years no reflection cracking flushing in wheel paths	
			Emulsion slurry + leveling course + 2" AC	Problems with aggregate graduation	After 5 years 29% reflection cracking	
			Squeegee seal + leveling course + 2" AC	Cracks not filled properly substitute aggregate uses	After 5 years 87% reflection cracking	
			Heater scarification + rejuvenative agent + leveling course + 2" AC	5/8 to 3/4 inch scarification	After 5 years 100% reflection cracking, good performance for 2 years	
			5/8" plant mixed seal + 2" AC		After 5 years 48% reflection cracking, bleeding after 3 years	
			Emulsion crack pouring + leveling course + 2" AC		After 5 years 80% reflection cracking	
			2-inch neoprene rubberized asphalt concrete		After 5 years no cracking, 35% reflection cracking where no leveling course used	

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Colorado	I 70 (cont.) (16)		Petroset fog seal on overlay + leveling course + 2" AC		Flushed immediately, 1/2 inch plant mixed seal placed immediately, flushed and overlaid again in 1974, after 5 years 21% reflection cracks	
			Control section leveling course + 2" AC			
	I 70 Near Empire Section placed June 1972 (16)		Cerex + 2" AC	Placed in strips and continuous	After 4 years 11% reflective cracks where strips used and 25% cracks where continuous sections used	Small test section 2-100 FT sections
			Control section 2" AC		After 4 years 6% reflective cracks	
	I 25 Belleview to county line road (Denver) Section placed August 1975 (16)	PCC	Petromat + 1 1/2" AC	Placed on PCC-shoulder joint (strips used)	After 1 year no reflective cracks	
			Control 1 1/2" AC		After 1 year no reflective cracks	

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Colorado	I 25 South Downing Street (Denver) Section placed March 1976 (16, 17)	PCC	0-1 1/2" leveling AC + Mirafi strips + 1 1/2" AC		After 44 months 50% reflective cracking	Fabric section slightly better performance for first two winters, joints reflected no cracks in old slabs
			0-1 1/2" leveling AC + Mirafi + 1 1/2" AC		After 44 months 48% reflective cracking	
			Control - 0-1 1/2" leveling AC + 1 1/2" AC		After 44 months 54% reflective cracking	
	SH 50 Kannah Creek to Grand Junction Section placed August 1977 (18)	AC ADT=7900	Sahuaro asphalt-rubber + 1 1/2" AC (Cracks filled)		After 32 months 35% reflective cracking	Old pavement alligator and longitudinal not transverse block cracking Asphalt-rubber used for crack pouring Permeability tests indicate interlayers do not provide waterproofing Interlayers reduce alligator reflective cracking but not thermal cracks
			Sahuaro asphalt-rubber + 1 1/2" AC (Cracks not filled)		After 32 months 37% reflective cracking	
			ARCO asphalt-rubber + 1 1/2" AC (Cracks not filled)		After 32 months 50% reflective cracking	
			Petromat + 1 1/2" AC (Cracks not filled)		After 32 months 33% reflective cracking	
			Control 1 1/2" AC (Cracks filled)		After 32 months 42% reflective cracking	
			Control 1 1/2" AC (Cracks not filled)		After 32 months 54% reflective cracking	

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Colorado	SH 26 West Alameda Avenue I 25 to South Irving St. (Denver) Section placed August 1977 (19)	5-6 1/2" AC 6" PCC ADT=28,000 5 lanes	Petromat + 1 1/2" AC		After 31 months 45% reflective cracking in PCC and 67% in AC	Old pavement widening project with alligator cracking in widened AC section Cracks filled with asphalt-rubber
			Sahuaro asphalt-rubber + 1 1/2" AC		After 31 months 59% reflective cracking in PCC and 53% in AC	
			Control 1 1/2" AC		After 31 months 74% reflective cracking in PCC and 79% in AC	

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Georgia	IH 85 Gwinnett County (30 miles north of Atlanta) Section placed July 1976 (20, 21)	30 ft. undowelled joints	.75" AC + Petromat + 2" AC		After 52 months 79% reflection cracking, 4 crack severity	
		9" PCC 1964	.75" AC + Petromat + 4" AC		After 52 months 23% reflection cracking, 1 crack severity	
		3" cutback asphalt stabilized 1964	.75" AC + Petromat + 6" AC		After 52 months 7% reflection cracking, 1 crack severity	
		5" soil aggregate 1964	.75" AC + Mirafi + 2" AC		After 52 months 90% reflection cracking, 6 crack severity	
		ADT=20,000 on 4 lanes	.75" AC + Mirafi + 4" AC		After 52 months 35% reflection cracking, 2 crack severity	
			.75" AC + Mirafi + 6" AC		After 52 months 1% reflection cracking, 1 crack severity	
			Bituthene strips + 75" AC + 2" AC	Mixed shoved during rolling	After 52 months 61% reflection cracking, 2 crack severity	
			Bituthene strips + .75" AC + 4" AC		After 52 months 26% reflection cracking, 1 crack severity	
			Bituthene strips + .75" AC + 6" AC		After 52 months 0% reflection cracking, 0 crack severity	

* Estimate of severity of crack on 10 point scale - 10 worst condition

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Georgia	IH 85 (cont.) (20, 21)		Arkansas Base + 2.5" AC + 1" AC		After 52 months 10% reflection cracking, 2 crack severity	
			Control - 2" AC with edge drain		After 52 months 96% reflection cracking, 6 crack severity	
			Control - 4" AC with edge drain		After 52 months 82% reflection cracking, 7 crack severity	
			Control - 6" AC with edge drain		After 52 months 40% reflection cracking, 3 crack severity	
			Control - 2" AC with edge drain		After 52 months 99% reflection cracking, 6 crack severity	
			Control - 4" AC with edge drain		After 52 months 64% reflection cracking, 4 crack severity	
			Control - 6" AC with edge drain		After 52 months 10% reflection cracking, 1 crack severity	
	IH 85 Troup County Section placed July 1979 (22)	PCC jointed	Polygard + 2" AC 9% rubber	No problems	No cracks after 1.5 years in any sections	
			Polygard + 4" AC	No problems		
			Heavy duty Bitu-thene + 2" AC	No problems		
			Heavy duty Bitu-thene 4" AC	No problems		

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Georgia	IH 85 (cont.) (22)		Protector-wrap + 2" AC	Tracks separated fabric		
			Protector-wrap + 4" AC	Tracks separated fabric		
			8" oz Petromat strips + 2" AC	Some strips pulled-up by trucks		
			Control Polygard + 2" AC			
			Control Polygard 9% rubber + 4" AC			
	US 129 Hall county Section placed 1974 (23)	AC 1957	Glass fiber + 2" AC		After 3 years hairline cracks over severely distressed areas base did not pump	Old pavement excessive cracking and raveling
			ARCO asphalt-rubber chip seal + 2" AC		After 3 years hairline cracks, base did not pump	Placed by maintainance forces
			Asphalt-cement chip seal + 2" AC		After 3 years hairline cracks, base pumped	
			Rubber emulsion chip seal + 2" AC		After 3 years cracks appeared, base pumped	
			RS 2C emulsion chip seal + 2" AC		After 3 years cracks reflected, base pumped	
			Petromat + 2" AC		After 3 years few cracks, base did not pump	

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance*	Comments
Georgia	US 129 (cont.) (23)		Control 2" AC		After 3 years, reflection cracks, only section over PCC pavement	
	SR 20 Cherokee Section placed 1976 (21, 24)		Asphalt-rubber + 1" AC		After 5 years Slight alligator cracking 2% area Slight longitudinal cracking/100 FT no transverse cracks	Old pavement distress different in control sections versus test sections After 5 years ranking of sections, asphalt-rubber, Bidim C-28, Petromat, Mirafi, Bidim C-22
			Petromat + 1" AC		After 5 years Slight alligator cracking 2% area Slight longitudinal cracking 100-200FT Slight transverse cracking 5-9	
			Mirafi + 1" AC		Section overlaid because of excessive slippage and alligator cracking	
			Bidim C-22 + 1" AC		After 5 years most of section overlaid because of slippage failures	

* Longitudinal cracking FT per station
Transverse cracking Number per station

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance*	Comments
Georgia	SR 20 (cont.) (21, 24)		Bidim C-28 + 1" AC (Heavy tack)		After 5 years No alligator cracking Slight longitudinal cracking 100-200FT Slight transverse cracking 1-4	
			Bidim C-28 + 1" AC (light tack)		After 5 years Moderate alligator cracking 2% area Slight longitudinal cracking 1-4 Slight transverse cracking 100FT	
			Sahuaro asphalt-rubber + 1" AC		After 5 years No cracking, some base failure	
			Control 1" AC		After 5 years Moderate alligator cracking 7% area no longitudinal cracking, no transverse cracking	
	IH 85 North of Gwinnett Project Section placed 1974 (21)		Petromat		After 7 years No difference in performance but, cracks in petromat section not as severe	
			Glass fibers			
			Control			

* Longitudinal cracking FT per station
Transverse cracking Number per station

Table 13. Continued.

State	Location of Project	Description of Old Pavement	Experimental Features	Construction Problems	Performance	Comments
Utah	SH 666 Near Monticello Section placed 1980 (25)	AC	3/4" AC + Mirafi 900X-N + 2" AC		After 9 months of service slight alligator cracking 5% area	Old pavement extensive rutting, patching alligator cracking and transverse cracking Order of sections by amount of cracking, Mirafi, petromat, asphalt-rubber, control Hot mix segregation sand seal present on some sections
			3/4" AC asphalt-rubber + 2" AC		After 9 months of service, slight alligator cracking 1% area	
			3/4" AC + Petromat + 2" AC		After 9 months of service slight alligator cracking 2% area	
			Control 3/4" AC + 2" AC		After 9 months of service no cracking	

Table 14. Test Sections Where Fabrics Provide Limited Performance Improvements.

State	Location of Project	Old Pavement	Months Age	Remarks
California	SH 43, Bakersfield	AC	48	For thin overlay only
	IH 15 Riverside	AC	42	
	SH 78 Vista	AC	42	
	SH 12, Rio Vista	AC	24	
Colorado	I 70 Clifton	AC	60	
	SH 50, Kannah	AC	32	Alligator cracking only not transverse
	SH 26, Alameda	PCC	31	
Georgia	IH 85, Gwinnett Co.	PCC	52	
	US 129, Hall Co.	AC	36	

Table 15. Test Sections Where Fabrics Provide No Distinct Performance Improvement.

State	Location of Project	Old Pavement	Age, Months
California	US 395, Doyle	AC	48
	SH 36, Susanville	AC	
	IH 80, Colfax	AC	84
	US 1, Long Beach	AC,PCC	78
	SH 115, Brawley	AC	72
	SH 74, Capistrano	AC	24
	SH 11, Pasadena	AC	27
	SH 2, Westwood	AC	21
	SH 47, Long Beach		39
	SH 7		41
	SH 46, Paso Robles		36
	US 101, Gilroy		48
	SH 17, Fremont		24
Colorado	I 70, Empire	PCC	48
	I 25, Downing	PCC	44
	SH 58	AC	21
Georgia	SR 20, Cherokee		60
	IH 85		84
Utah	SH 666, Monticello	AC	9

Table 16. Test Sections Which Compare Types of Fabrics.

State	Location of Project	Old Pavement	Age, Months	Mirafi Fabric Included
Arizona	Scottsdale		9	900X-A
California	US 101, Petaluma		12	140
	SH 12, Rio Vista		24	No
	SH 49, Grass Valley	AC	12	No
Colorado	US 36, Broomfield	PCC	6	No
	Parker Road	AC	6	900X-A
Georgia	IH 85, Gwinnett Co.	PCC	52	140
	IH 85, Troup Co.	PCC	18	
	US 129, Hall Co.	AC	36	
	SR 20		60	140
	IH 85			No
Utah	SH 666, Monticello		9	900X-N

improved performance should be compared on a life cycle basis with the control sections. Maintenance costs would have to be included in the analysis.

Available field data on those sections which contain Mirafi fabrics and other fabrics for comparison purposes are listed in Table 16. Mirafi 900X-N is also included on test sections at a parking lot at a LDS Church in Phoenix and at Holbrook, Arizona.

Table 17 is a partial list of fabrics and other similar materials which are used as interlayers. All of these materials were not observed in service in highway pavements. This list is included here merely to illustrate the variety of products on the market.

Conclusions from Field Evaluations

When fabrics are used as interlayers, a "clear cut" performance advantage (as compared to control sections) is often not evident. Types of pavements, pavement distress and environmental variables must be carefully selected if fabrics are to be economically employed. Sufficient detailed data are not available which clearly define these conditions.

Field test sections which provide comparisons among fabric types are often of a young age and hence little definitive data is available. Older sections which contain different types of fabrics show small and often insignificant performance differences. Unfortunately, these older sections often contain the "first generation fabrics". Second and third generation fabrics are now being marketed.

Based on observations by the research team, fabrics are most likely

Table 17. Partial List of Manufacturer's of Fabrics, Tapes, Etc., Which are Used as Interlayers.

Material	Manufacturer	Description	Reference
Amopav	Amoco	Non-woven polypropylene	-
Bidim Cerex	Monsanto Company	Non-woven polyester fabric, spunbonded nylon fabric	13, 14
Bituthene	W. R. Grace	Polypropylene fabric with rubberized asphalt backing	12,14
Duraglass	Johns-Mansville	Non-reinforced fiberglass mat	14
Extrudamat	Hercules	Short length polypropylene fibers applied as an asphalt slurry	22
Fibretex	Crown-Zellerbach	Spunbonded polypropylene (5 layers)	12
Glass Fiber	Burlington Glass Co.		23
Mirafi	Mirafi Inc	Non-woven polypropylene and polyethylene	14
Petromat	Phillips Fibers Corp.	Non-woven polypropylene	14
Polygard	Polygard Products	Rubberized asphalt with fabric backing	22
Protecto-wrap	Protecto-wrap Company	Bituminous resin modified with a synthetic resin and reinforced with a fabric	22
Reepav Typar	DuPont		10
Trevira	Hoechst	Spunbonded continuous filament polyester	-
Trutex	True Temper		12
Varistrate	3-M Company		-

to be successful when employed to reduce reflection of fatigue cracks in otherwise structurally sound asphalt concrete pavement material. Fabrics are least likely to be successful when employed to reduce reflection of large transverse cracks or construction joints in portland cement concrete pavements.

DESIGN IMPLICATIONS

Based on observations made during this study and other research (26), it appears that the following guidelines can be used during design and construction to minimize problems and maximize long-term performance of fabrics installed to arrest reflection cracking:

1. Patch potholes, fill cracks larger than one-eighth inch, and eliminate faulting, prior to application of fabric.

2. Fabric should not be unnecessarily exposed to traffic and the elements. Over-exposure can only serve to damage the fabric and thus reduce its effectiveness even though the fabric may not appear to be damaged. Traffic will abrade away fibrous material to varying degrees depending upon the type of fabric. Tires will pinch or wear holes in the fabrics mat at the peaks of the larger aggregate in the old surface. Fabric will be damaged predominately right where it is needed most - in the wheelpaths. Furthermore, from a skid resistance standpoint, a dangerous situation could develop on exposed fabric particularly during periods of wet weather.

Exposure of fabric to prolonged rainfall can adversely affect the fabric-to-pavement bond. In severe cases, isolated areas of fabric may become completely separated from the pavement. A highly textured pavement surface, where there is a large volume of voids between the fabric and pavement surface, will most likely be detrimental to this situation.

3. Fabric should be overlapped at transverse joints with top layer pointed in direction of travel of traffic and/or construction

equipment. Joints should be tacked with the minimum acceptable quantity of emulsified asphalt or hot asphalt cement to avoid disruption by wind or traffic. Adequate overlap of fabrics at transverse joints should be at least one foot; whereas overlap of longitudinal joints can be as little as six-inches. Cutback asphalts should never be used as tack or to secure fabric overlaps. The petroleum-based solvents in cutbacks can damage synthetic fabrics after prolonged exposure.

4. Some wrinkling of fabrics during installation is unavoidable. On a straight section wrinkles (if any) will be typically longitudinal sometimes amplified by action of the pneumatic roller if the fabric is not taut in the transverse direction. On a curved section wrinkles will, of course, be transverse. It is usually recommended that large wrinkles be cut and overlapped to reduce the localized bulkiness of the fabric. Large wrinkles can be a source of premature cracking in the overlay due to compaction without firm support or possibly due to fabric shrinkage (particularly if the fabric shrinks more than about 5 percent upon exposure to the hot overlay) (3).

5. Avoid the use of thin, high void overlays with fabric, particularly on high traffic volume facilities. Thin asphalt concrete overlays are often troublesome. This is particularly true when an overlay less than two inches in thickness is installed over a fabric. In areas of high shear stresses, such as intersections and curves, slippage of the overlay can occur during warm weather

resulting in delamination at the fabric interface and premature failure of the overlay. This problem can be prevented by specifying overlays with adequate thickness, sufficient asphalt tack and otherwise using sound overlay design and construction techniques.

6. The appropriate viscosity grade of asphalt cement to utilize as fabric tack coat for a particular job should be based on the maximum temperature of the overlay at laydown, range of ambient temperatures, solar radiation, traffic volume and weight, and relative magnitude of expected shear forces.

It should be as soft as possible to allow proper functioning of the stress-relieving interlayer while providing adequate adhesion and shear resistance between layers. Grade AC-10 is recommended for moderate temperature environments.

7. Asphalt saturation content of a fabric is dependent upon certain fabric characteristics and should be quantified prior to designing a pavement containing fabric. The proper quantity of asphalt tack is dependent upon fabric properties as well as the condition of the old pavement surface.

8. Fabrics can be of particular value in sections where an increase in pavement thickness is undesirable, such as in curb and gutter sections or below an overpass.

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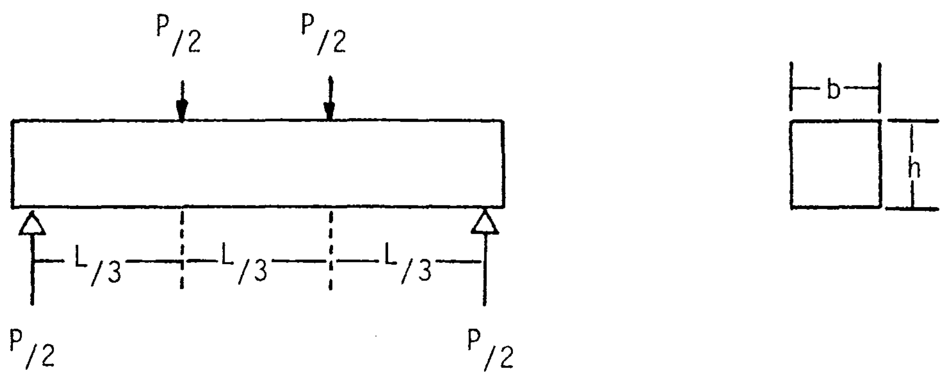
APPENDIX A

LABORATORY TEST DATA

Summary of Formulae

for

Third-Point Loaded Beam (7)



Equation No.

Peak stress in extreme fiber $= \sigma_{max} = \frac{PL}{bh^2}$, psi (D1)

Initial stiffness modulus $= E = \frac{0.213\ PL^3}{W_o\ bh^3} + \frac{0.400\ PL\ (1+\mu)}{W_o\ bh}$,

psi (D2)

Initial bending strain in extreme fiber $= \varepsilon = \frac{\sigma}{E}$, in./in.

(Hooke's Law) (D3)

Total input energy $= U_f = \frac{10.2\ P\ W_o\ N_f}{23}$, in.-lb. (D4)

Maximum energy density $= U_d = \frac{(\sigma_{max})^2}{2E}$, $\frac{\text{in.-lb}}{\text{in.}^3}$ (D5) where:

P = applied load, lbs.

L = tested length of beam, in.

b = width of beam, in.

h = depth of beam, in.

W_0 = center deflection of beam at 200th cycle, in.

μ = Poisson's ratio (assumed 0.35)

N_f = number of cycles to failure

An Explanation of Energy Terms

The total input energy, U_f, is the macroscopic amount of energy (or work) imparted to the specimen during the test (up to failure) by external forces. By contrast, the maximum energy density, U_d, is the microscopic strain energy per unit volume which occurs at a point in the most highly stressed region of the specimen at the peak of any given cycle (7). Total input energy is used herein as a comparative measure of fatigue performance.

Table A1. Results from Individual Flexural Fatigue Test Specimens.

Type Sample	Sample No.	Specific Gravity	Air Voids percent	Input Stress, psi	Bending Strain in/in x 10^{-4}	Cycles to Failure	Stiffness Modulus psi	Total Energy lb-in x 10^3	Max Energy Density psi x 10^{-2}
Fabric P (0.11 gal/yd^2 tack)	P 7	2.31	7.1	100	12.7	3,151	79,000	4,716	0.055
	P 8	2.32	6.6	98	10.8	2,670	94,100	3,207	0.044
	P 9	2.32	6.7	100	8.8	4,337	114,000	4,492	0.038
	P10	2.31	7.0	98	11.4	2,351	86,100	3,087	0.048
	P11	2.31	7.1	100	7.8	4,305	128,300	3,877	0.032
Fabric P (0.19 gal/yd^2 tack)	P 1	2.32	6.5	98	7.3	7,528	137,300	6,490	0.031
	P 2	2.32	5.8	98	6.7	18,184	150,300	14,320	0.028
	P 3	2.32	6.6	96	6.3	10,799	154,300	7,912	0.026
Fabric Q (0.13 gal/yd^2 tack)	Q 7	2.29	7.9	100	17.2	1,712	58,100	3,481	0.074
	Q 8	2.32	6.5	100	12.3	1,150	81,000	5,888	0.053
	Q 9	2.31	6.9	100	13.3	2,501	72,300	3,928	0.057
	Q10	2.31	7.1	98	11.7	2,944	83,600	3,975	0.050
	Q11	2.31	7.2	98	10.4	3,535	94,100	4,246	0.044
Fabric R (0.19 gal/yd^2 tack)	R 1	2.28	8.3	100	9.5	5,882	107,600	6,750	0.041
	R 2	2.32	6.9	98	10.0	7,789	137,300	6,715	0.031
	R 3	2.29	7.7	98	8.9	4,645	112,600	4,880	0.038
	R 4	2.32	6.6	98	6.2	25,687	161,800	18,760	0.026
	R 5	2.32	6.6	98	8.2	3,692	121,200	3,600	0.035
Control-1 (0.05 gal/yd^2 tack)	C 1	2.33	6.1	100	5.2	13,148	195,500	8,310	0.023
	C 2	2.34	5.9	96	4.9	13,942	199,200	7,920	0.020
	C 3	2.33	6.2	98	3.8	13,950	262,400	7,780	0.016
Fabric G (0.20 gal/yd^2 tack)	G 1	2.28	8.4	96	8.9	4,934	110,000	5,064	0.037
	G 2	2.29	8.1	96	5.7	18,890	171,200	12,460	0.024
	G 3	2.30	7.5	96	4.8	15,789	205,500	8,670	0.020

Table A2. Direct Tension Test Results on Individual Specimens.

Fabric	Sample No.	Tensile Strength psi	Ten. Strain @ Failure in/in x 10^{-6}	Secant Modulus, psi	Air Voids percent
P	1	81	0.00533	15,200	6.8
	2	78	0.00398	19,600	
	3	84	0.00455	18,500	
	4	98	0.00477	20,500	
	5	109	0.00422	26,800	
	6	74	0.00326	22,700	
Q	1	56	0.00613	9,100	7.8
	2	-	0.00756	-	
	3	55	0.00446	12,300	
	4	61	0.00398	15,300	
	5	50	0.00533	9,400	
	6	66	0.00366	18,000	
R	1	110	-	-	4.8
	2	111	0.00428	25,800	
	3	98	0.00450	21,900	
	4	100	0.00450	22,300	
Control-1 (0.05 gal/yd^2 tack at interface)	1	109	0.00300	36,400	4.6
	2	93	0.00564	16,400	
	3	128	0.00400	32,000	
	4	92	0.00425	21,600	

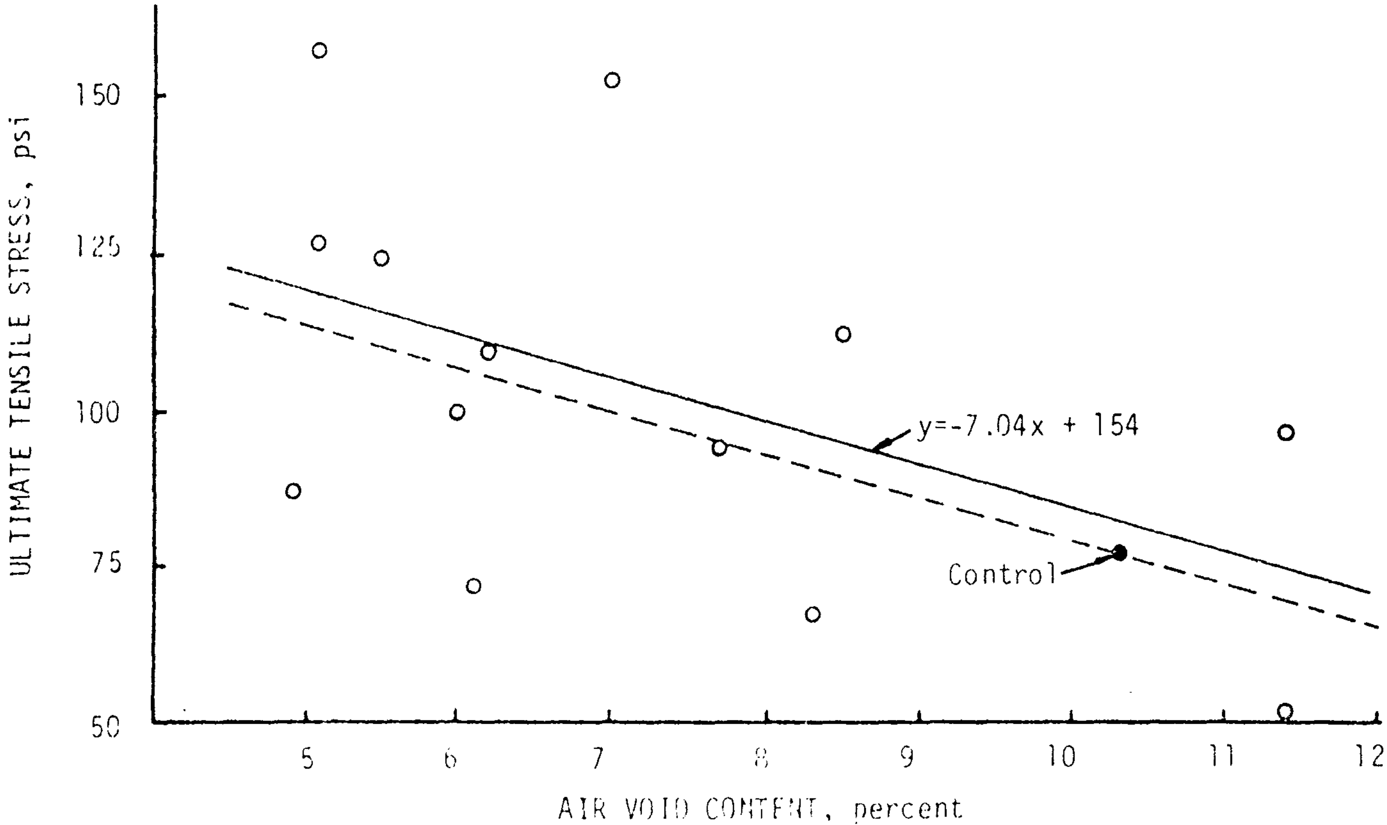


Figure A1. Relationship Between Tensile Strength and Air Voids.

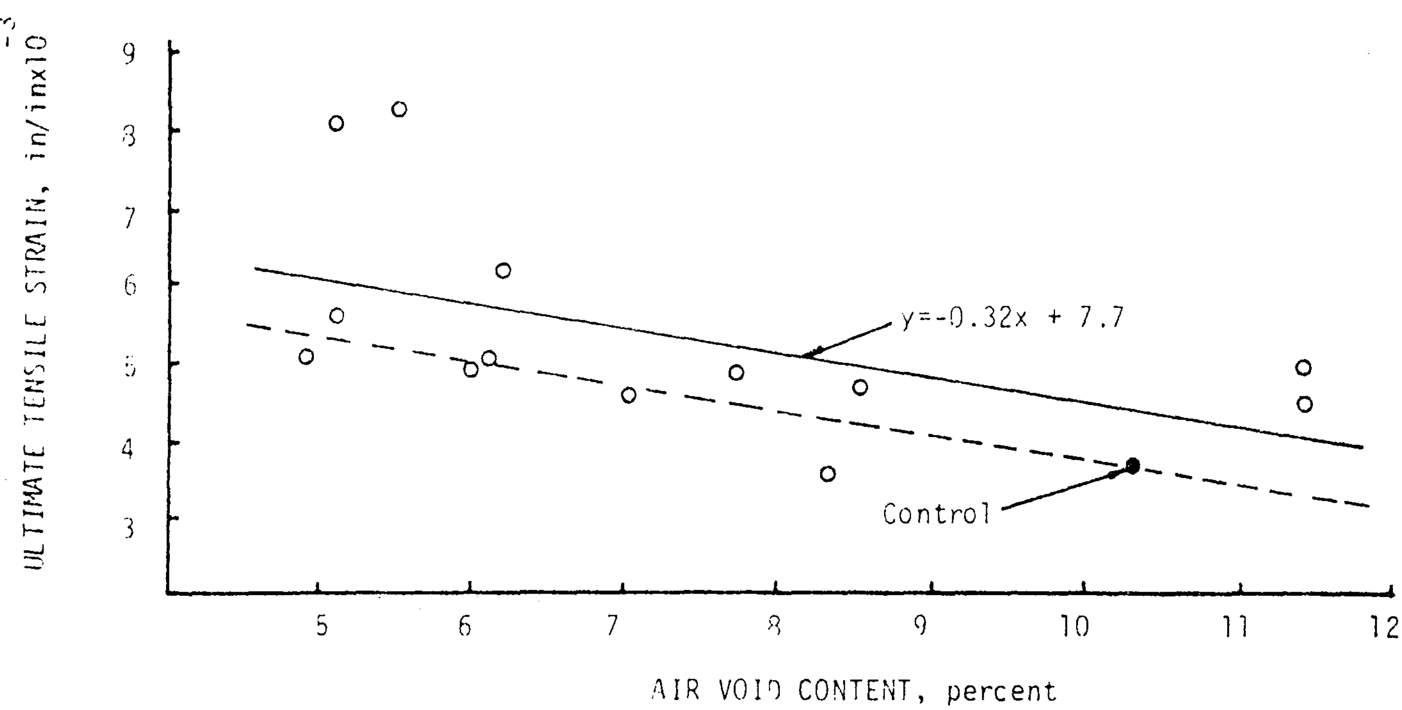


Figure A2. Relationship Between Tensile Strain at Failure and Air Voids.

APPENDIX B

FIELD EVALUATION FORMS

PRECONSTRUCTION INFORMATION

LOCATION

State ____________ County ____________ Highway ____________

Mile Post or Station Limits: From ____________ to ____________

Section Identification No. ____________

Project Contact Individual

Name ____________

Agency ____________

Address ____________

____

____

____

Phone ____________

EXISTING PAVEMENT SECTION

Layer No.	Layer Name	Type of Material	Date of Construction	General Strength and Properties of Materials
Top 1				
2				
3				
4				
5				
6				

OVERLAY SYSTEM

Layer No.	Layer Name	Type of Material	Date of Construction	General Strength and Properties of Materials
1				
2				
3				
4				
5				

PRECONSTRUCTION INFORMATION

NDITION OF OLD PAVEMENT

Condition Survey (Figure 1 or 2, Attachment No. 3)________Pavement Rating Score

Crack Survey (Figure 3)______________________Lineal ft/station
(Attachment No. 3)_____________% Area Cracked (Arizona)

Deflection: Mean______Std. Deviation______Range______No. Readings________
Type of Equipment ______________________________
Temperature _______________Corrected for Temperature__________

Road Roughness: Mean______Std. Deviation______Range______No. Readings________
Type of Equipment ______________________________

Skid Number: Mean______Std. Deviation______Range______No. Readings________

Comments: ______________________________

NVIRONMENTAL (obtain from local weather bureau)

1. Temperature
   a. Yearly Maximum ________________ Minimum ________________
   b. Typical Max. Temp. Drops __________°F/hr) from _______°F to ________°F
      No. per Year ____________
   c. No. of Air Freeze-thaw Cycles per Year ______________
   d. Freeze Index ______________
   e. Average Depth of Frost Penetration ______________

2. Rainfall
   a. Average Annual Rainfall ______________
   b. Average Annual Snow ______________
   c. Average Annual Moisture ______________

3. Monthly Environmental Information

Month	Temperature, °F		Moisture, inch	Month	Temperature, °F		Moisture, inch
	Maximum	Minimum			Maximum	Minimum	
Jan.				July			
Feb.				August			
March				Sept.			
April				October			
May				Nov.			
June				Dec.			

Section Code____

PRECONSTRUCTION INFORMATION

TRAFFIC

Lane	ADT	% in Lane	Eq. 18 kip Axle Loads	% Trucks
All Lanes				
R				
S				
T				
U				
L				
M				
N				
O				

Note: Obtain loadmeter survey data if available.
For definition of lanes, see Reference 1 and Attachment 3.

CONSTRUCTION INFORMATION

EMBRANE OR INTERLAYER TYPE

Conventional Chip Seal____________________

Heater Scarification____________________

Fabric____________________

Asphalt-rubber____________________

Other____________________

HIP SEAL

Asphalt Shot Mean________ gal/yd^2 @ 60°F Std. Deviation__________
Range__________ No. Readings__________

Temperature of Shot__________

Aggregate Quantity__________ lbs/yd^2

Record Asphalt Data on Page__________

Record Aggregate Data on Page__________

EATER-SCARIFICATION

Depth of Scarification Mean__________ inches
Std. Deviation__________
Range__________
No. Readings__________

Temperature of Scarification__________°F

Recycling Agent Used Yes_____ Record Data on Page_____
No_____

Brief Description of Construction Sequence____________________

____

FABRIC

Manufacturer__________ Trade Names__________

Fabric Absorption__________ gal/yd^2 @ 60°F

Tack Coat Quantity Mean__________ gal/yd^2
Std. Deviation__________
Range__________
No. Readings__________
Temperature of Shot_______°F
Fabric Properties__________

Brief Description of Construction Sequence____________________

____

ASPHALT RUBBER

Asphalt-rubber Shot: Mean________gal/yd^2 Std. Deviation__________
Range__________ No. Readings__________

Temperature of Shot______°F Reaction Temperature______°F

Length of Reaction________min.

Time Interval between Mixing and Spraying________hrs.

Aggregate Quantity: Mean________gal/yd^2 Std. Deviation__________
Range__________ No. Readings__________

Record Binder Data on Page 5

Record Aggregate Data on Page 6

Section Code ____

BINDER

ASPHALT CEMENT

Company ____________ Location of Refinery ____________

Grade AC ____________ AR ____________ pen ____________

Original Properties (plot on Figure 6 of Attachment 3)

pen(39.2) ________ pen(77) ________
visc(77) ________ ρ visc(140) ________ ρ visc(275) ________ ρ
Flash Point ________ °F Ring & Ball Softening Point ________ °F

TFOT or RTFOT Properties

pen(39.2) ________ pen(77) ________
visc(77) ________ ρ visc(140) ________ ρ visc(275) ________ ρ
Ductility(77) ________ cm Ring & Ball Softening Point ________ °F

Rostler Parameters: A ______ N ______ A_1 ______ A_2 ______ P ______

ADDITIVE

Company ____________ Location of Source ____________

Grade Designation ____________

Original Properties
visc(140) ________ visc( ) ________ visc( ) ________

Specific Gravity (60°F) ________ Flash Point ________ °F

TFOT or RTFOT Loss on Heating ______ % Viscosity(140) ________

Rostler Parameters: A ______ N ______ A_1 ______ A_2 ______ P ______

RUBBER

Whole Tire ________ % Company ________ Source ________
Chemically Reclaimed ________ % Company ________ Source ________
Natural Rubber Scrap ________ % Company ________ Source ________
Vulcanized Scrap ________ % Company ________ Source ________
Other ________ % Company ________ Source ________

COMPOSITION

Asphalt Cement ________ parts ________ %
Additive A ________ parts ________ %
Additive B ________ parts ________ %
Blended Rubber ________ parts ________ %
Total ________ parts 100 %

Section Code _____

AGGREGATE

GENERAL	A ___ %	B ___ %	C ___ %	D ___ %	Combined
Source Name					
Source Location					
Process(see bottom of page)					
Shape					
Surface Texture					
Geological Description					

GRADATION	Sieve Size		Accumulative Percent Passing			
	________					
Washed?	________					
Yes ____	________					
No ____	________					
	________					
	________					
	No. ________					
	No. ________					
	No. ________					
	No. ________					
	No. 200					

Plot Gradation(s) on Figure 8 of Attachment 3

OTHER PROPERTIES					
Specific Gravity-Apparent					
Bulk					
Bulk(SSD)					
Absorption Capacity					
Loose Unit Weight (lbs/ft^3)					
Sand Equivalent					
LA Abrasion					
Plasticity Index					
Aggregate Precoat Type of Asphalt					
Amount of Asphalt					
Other Properties					

Process: Crushed, Partially Crushed, Washed

Shape: Blocky, Angular, Subrounded, Rounded

Surface Texture: Very Rough, Rough, Smooth, Polished

Section Code _____

ASPHALT CONCRETE OVERLAY MATERIAL

DESIGN

Producer________________________ Site ________________________

Asphalt Cement Content______________% by wt. of aggregate
______________% by wt. of total aggregate

Aggregate Blend ______________% aggregate A
______________% aggregate B
______________% aggregate C
______________% aggregate D

Record Binder Data on Page

Record Aggregate Data on Page

LABORATORY MOLDED MIXTURE PROPERTIES

Hveem Stability______________ Marshall Stability______________lbs

Air Void Content______________ Marshall Flow______________0.01 in

Resilient Modulus, 0.1 sec. Unit Weight______________lbs/ft^3

________°F________psi VMA______________

________°F________psi % Voids Filled______________

________°F________psi

________°F________psi

________°F________psi

Plot data on Figure 7. of Attachment 3

Tensile Properties

Rate of Deformation in/min	Temp. °F	Failure		
		Stress, psi	Strain	Modulus

Creep Data ______________________________

Water Susceptibility______________________________

Other Properties______________________________

POST CONSTRUCTION

PAVEMENT CONDITION

Condition Survey (Figure 1, Attachment No. 3) __________ Pavement Rating Score

Crack Survey (Figure 3) __________ Lineal ft/station

(Attachment No. 3) __________ % Reflected Cracks

Deflection: Mean ____ Std. Deviation ____ Range ____ No. Readings ______
Type of Equipment __________
Temperature __________ Correction for Temperature __________

Road Roughness: Mean ____ Std. Deviation ____ Range ____ No. Readings ______
Type of Equipment __________

Skid Number: Mean ____ Std. Deviation ____ Range ____ No. Readings ______

Comments: __________

____

PROPERTIES OF PAVEMENT CORES

(see test plan Figure 5 of Attachment 3)

Hveem Stability __________ Marshall Stability __________ lbs

Air Void Content __________ Marshall Flow __________ 0.01 in

Resilient Modulus, 0.1 sec. Unit Weight __________ lbs/ft^3

______ °F ______ psi VMA __________

______ °F ______ psi % Voids Filled __________

______ °F ______ psi

______ °F ______ psi

______ °F ______ psi

Plot data on Figure 7

Tensile Properties

Rate of Deformation in/in	Temp. °F	Failure		
		Stress, psi	Strain	Modulus

Creep Data __________

Water Susceptibility __________

Section Code ____

OTHER INFORMATION

SPECIFICATIONS

- Attach Copy of Project Specifications
- Asphalt-rubber Specifications Developed by ____________________
  and Based on Information Supplied by ____________________
- Comments on Needed Improvements in Specifications ____________________

DESIGN METHOD

- Attach Copy of Asphalt-rubber Design Method for Determining Binder and Aggregate Quantities
- If a Design Method was Not Utilized, Who Recommended Quantities?
- Comments on Needed Improvements in Design Methods ____________________

QUALITY CONTROL

- Attach Copy of Quality Control Requirements
- Comments on Needed Improvements in Quality Control ____________________

PRODUCTION

- Type of Interlayer ____________________
- Production Actually Achieved ____________________ yd^2 per day
  ____________________ lane miles per day
- Production Capability ____________________ yd^2 per day
  ____________________ lane miles per day

COST AND ENERGY

- Type of Interlayer ____________________
- Cost ____________ \$ per yd^2 Attach Calculations
- Energy ____________ Btu per yd^2 Attach Calculations

CONSTRUCTION

Sequence of Operations ____________________

Problems ____________________