Permanent Road Stabilization: Low-Cost Pavement Structures and Lightweight Geotextiles

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Greenville County, South Carolina, constructs permanent paved surfaces on approximately 20 mi of existing gravel roads each year. The county engineer sought to protect his new low-cost pavement from premature degradation and more frequent maintenance by including an appropriate geotextile as a separator between the subgrade and the pavement structure. The physical properties required to make the geotextile an effective long-term separator include both strength properties, which resist the forces of coarse aggregate being pushed into the subgrade, and hydraulic properties, which prevent the pumping of fine soils up into the coarse base aggregate while still allowing for pore water pressure dissipation from the subgrade. The geotextile strength and hydraulic properties necessary to survive construction and to provide long-term filtration and separation between the subgrade and the base aggregate are evaluated by testing of exhumed geotextile samples and visual pavement condition surveys for a trial installation.

The geotextile acts as an effective long-term separator by resisting the forces of coarse aggregate being pushed into the subgrade, and by preventing the pumping of fine soils up into the coarse base aggregate while still allowing for pore water pressure dissipation from the subgrade.

A trial installation was made on a >8,000-ft low-volume county road. The purpose of the trial was to determine necessary geotextile material properties and to assess the relative performance of different pavement cross sections with and without geotextiles.

In order to assess the ability of the geotextile to survive construction, numerous samples were exhumed from beneath the two pavement types after the stone base had been completely spread and compacted, but before the surface course was constructed. Testing indicated that, under comparable conditions, like-weight woven and nonwoven geotextiles exhibit virtually the same degree of construction survivability in terms of percent strength retained. Additionally, the grade on which the installation was made has a significant influence on geotextile survivability.

The long-term performance of the installation was determined through periodic inspections of the road surface. The road surface condition was characterized and ratings were entered into the county's pavement management system (PMS) for various segments of the road. The PMS then dictates the timing of the maintenance of the various road segments. This procedure allows for the assessment of the ability to extend maintenance schedules when geotextiles are used with low-cost pavement structures. The cost savings associated with extending maintenance schedules can then be compared to the nominal additional cost of including a geotextle.

INSTALLATION LAYOUT

Stockton Road in southern Greenville County, South Carolina, was selected for this trial installation because it had been surfaced with aggregate twice in the preceding 18 months and was once again in need of additional surfacing. This was a clear indication that the road subgrade was unstable when saturated and could benefit from the installation of a stabilization geotextile.

The full length of the road, approximately 8,100 ft, was surfaced with pavement sections as shown in Figure 1 and presented in Table 1. The following cross sections were used on approximately one-third of the road each:

- 1-in. triple treatment surface course over 3-in. compacted-stone base,
- 1½-in. asphaltic concrete (AC) surface course over 3-in. compacted-stone base, and
- 2½-in. full-depth AC binder course.

Approximately 500 ft each of three different geotextiles, 4- and 6-ounce-per-square-yard (oz/yd^2) needle-punched nonwoven geotextiles and a 4-oz/yd^2 slit-film woven geotextile, were installed between the subgrade and each pavement section. The remaining footage of the road will act as a control for the long-term evaluation of each pavement section.

Before the placement of the geotextile or pavement systems, the road subgrade was fine graded and surface saturated by water truck, and baseline cone penetration measurements were made.

Properties of stabilization geotextiles are given in Table 2.

SITE DATA COLLECTION AND EVALUATION

In order to facilitate meaningful evaluation of long-term road performance, the following information was obtained during the trial installation:

- Road centerline survey including staking of stations (50-ft intervals);

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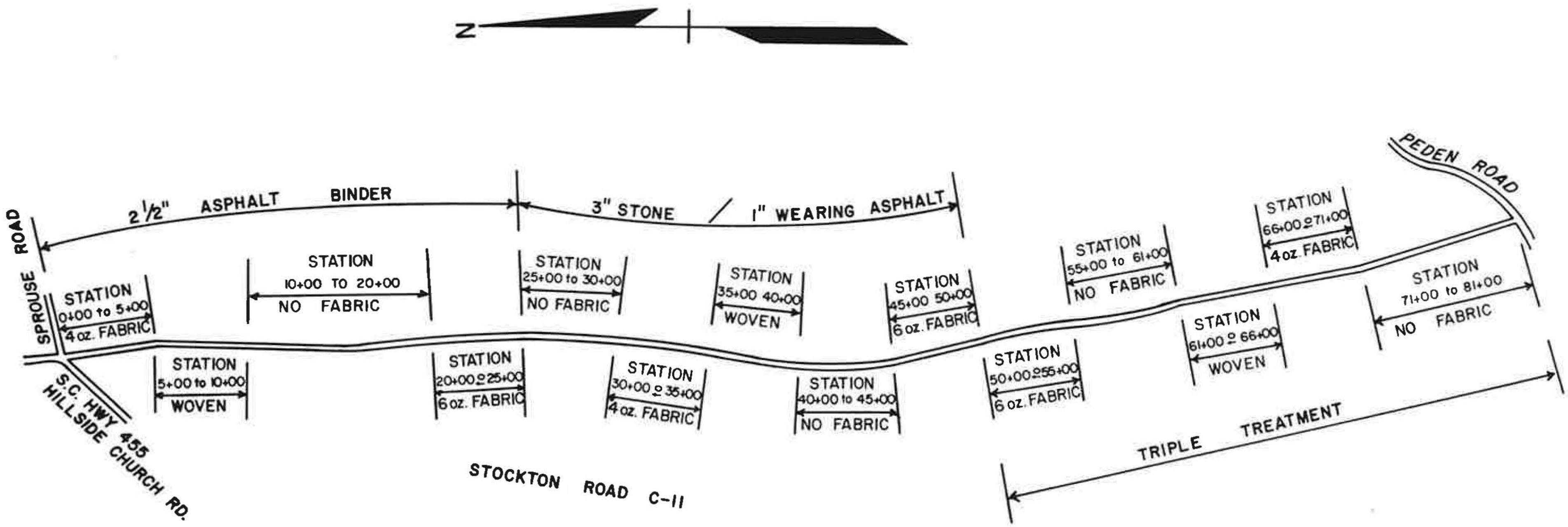

FIGURE 1 Stockton Road experimental paving plan of May 11, 1987.

TABLE 1 STOCKTON ROAD PAVEMENT INSTALLATION

Station to	Station	Stabilization Geotextile	Pavement Section
0+00	5+00	A	2 1/2" Full Depth Asphalt
5+00	10+00	B	2 1/2" Full Depth Asphalt
10+00	20+00	None	2 1/2" Full Depth Asphalt
20+00	25+00	C	2 1/2" Full Depth Asphalt
25+00	30+00	None	1 1/2" Asphalt over 3" Stone Base
30+00	35+25	A	1 1/2" Asphalt over 3" Stone Base
35+25	40+25	B	1 1/2" Asphalt over 3" Stone Base
40+00	45+50	None	1 1/2" Asphalt over 3" Stone Base
45+50	50+00	C	1 1/2" Asphalt over 3" Stone Base
50+00	55+00	C	Triple Treatment over 3" Stone Base
55+00	61+00	None	Triple Treatment over 3" Stone Base
61+00	66+00	B	Triple Treatment over 3" Stone Base
66+00	71+00	A	Triple Treatment over 3" Stone Base
71+00	81+00	None	Triple Treatment over 3" Stone Base

TABLE 2 TYPICAL PROPERTIES OF STABILIZATION GEOTEXTILES

Construction	ASTM Method	A PET Continuous Filament Needlepunched Nonwoven	B PP Silt Film Woven	C PET Continuous Filament Needlepunched Nonwoven
Weight, oz/sy	D3776	4.2	4.0	6.0
Grab Strength, lbs	D4632	135/110	200/200	205/175
Grab Elongation, %	D4632	70/85	20/18	75/85
Puncture, lbs	D3787	60	80	90
Trapezoid Tear, lbs	D4533	60/50	65/65	80/75
Mullen Burst, psi	D3786	210	385	315
Water Flow Rage, gpm/sf	D4491	140	5	130
A.O.S., sieve size	D4751	70-100	40	70-100

- Centerline plan and profile of roadway, including stations, fabric location and identification, and pavement location and identification; and
- Saturated soil strength as measured using the cone penetrometer index.

The survey revealed two segments of the roadway that would provide conditions significantly different from those of the rest of the road. These two segments involved edge drains with no outlets and steep grades. It was decided to use a heavier nonwoven geotextile in these areas and concentrate the use of the 4-oz/yd^2 geotextiles in the areas of more uniform conditions to facilitate more accurate performance comparisons of the like-weight materials.

Cone penetrometer data indicated that the road subgrade either varied in its stability over its length or, more likely, greater water penetration was achieved in portions of the roadway. Penetrometer readings were consistently in the 150 to 180 range (c = 12 to 15 psi), but from Station 0+00 to Station 57+50 they were achieved at an average penetration depth of less than 1 in. From Station 58+00 to Station 81+00, the average penetration depth was approximately 1¾ in. In either case, the upper zone of the subgrade appeared to be affected by saturation.

GEOTEXTILE INSTALLATION AND ROAD BASE CONSTRUCTION

With the road and edge drains fine graded for proper cross slope and drainage, installation of the geotextile began. The first segment to be constructed involved the construction of the stone base in two 1½-in. compacted lifts followed by a triple-treatment surface course. The thin lifts of base material with a substantial coarse fraction (see Table 3 for base aggregate grain size analysis) were expected to produce a worst-case condition on the geotextiles.

The second segment to be constructed involved the construction of a full 3-in. compacted lift of stone base followed by a 1½-in. AC surface course.

The third constructed segment was a compacted 2½-in. of full-depth AC binder course.

In all three segments, the geotextiles were unrolled and tacked in place using 16-penny nails to prevent them from being disturbed by the wind. Special caution was taken to eliminate any wrinkles in the geotextile in the full-depth segment. Because the geotextile was tacked down, only a nominal 6- to 12-in. overlap was required on the dry, firm subgrade.

Trucks dumping base aggregate were allowed to run and dump directly on the fabric. This procedure was considered a practical acceptance of the typical methods of constructing these low-volume roads as well as providing a worst-case evaluation.

A motor grader spread the aggregate to the desired depths, and an 8-ton steel-wheeled roller provided the compaction of the base material. Geotextile sampling for construction damage was done after the completion of the aggregate base, but before the construction of the surface course.

The third pavement segment was full-depth asphalt binder to a compacted thickness of 2½ in. No sampling was done in this segment, but some field observations were made.

TABLE 3 ROAD BASE AGGREGATE SIEVE ANALYSIS

50+00 to 81+00		25+00 to 50+00	
Sieve #	Percent Passing	Sieve #	Percent Passing
1 1/2	100	1 1/2	100
1	92.5	1	96.9
3/4	79.9	3/4	90.0
1/2	69.7	1/2	76.8
3/8	63.1	3/8	69.2
4	52.7	4	56.7
8	45.7	8	47.8
16	37.9	16	39.0
30	30.0	30	30.5
50	19.5	50	19.6
100	10.7	100	10.7
200	5.7	200	5.5
PAN	--	PAN	--

The only unsatisfactory observations made during the construction of the full-depth segment involved placement of the 2½ in. of hot asphalt on the woven-slit film geotextile. Circular arc–shaped cracks appeared in the pavement as the paver progressed up a modest (<1 percent) grade and once again when paving a somewhat steeper grade. This effect is believed to be a result of slippage of the pavement at the geotextile-pavement interface.

EXHUMING GEOTEXTILE SAMPLES

Geotextile sampling for determination of construction damage was performed following compaction of the aggregate base. The most severe construction loadings were assumed to occur during set-up of the base aggregate and construction of the ensuing surface course was assumed to impose less significant stresses on the geotextiles.

Geotextile sampling was not done in the full-depth asphalt pavement segment. Construction stresses in this segment only involved asphalt trucks running directly on the geotextile, which was similarly done by aggregate trucks in the other two segments, and by paver wheel loads that appeared insignificant.

Samples were initially exhumed by shoveling aggregate off 30- by 30-in. areas every 50 ft and cutting out 18- by 18-in. geotextile samples; 30- by 30-in. patches were then tucked in to repair the sampled area.

After the initial sampling of the first segment, shoveling was restricted to a doughnut around the 18- by 18-in. sample. The sample was then cut and the aggregate was gently rolled off the geotextile. It was hoped that this would minimize abrasion to the fabric caused by the sampling. Subsequently, the first segment was resampled using the doughnut approach. Laboratory results did not indicate that shoveling aggregate off the sample, rather than the doughnut approach, resulted in more abrasion to the geotextile.

All samples were marked with the station number corresponding to the sampling location and a note was made if aggregate depth above the fabric varied significantly from the desired 3 in.

LABORATORY TESTING AND RESULTS

The evaluation of construction damage of the geotextile required laboratory testing of appropriate strength properties to determine the extent of degradation resulting solely from construction-related activities.

It was decided to utilize those strength properties that are often cited in stabilization geotextile specifications but that are independent of fabric orientation. This choice simplified the notation requirements on the exhumed fabrics.

Two nondirectional tests, Mullen burst and puncture, were chosen. These tests are quick and straightforward, and each provides a useful measure of strength loss during construction.

Control samples were cut from the rolls received on site and tested in the laboratory to verify that published data were acceptable for subsequent comparisons.

Ninety-nine field samples were exhumed—22 of each geotextile in Segment 1 and 11 of each geotextile in Segment 2. Most field samples had puncture damage to a minor extent. In order to avoid extreme results, both Mullen burst and puncture tests were set up to intentionally exclude obvious puncture holes. Five Mullen burst and five puncture tests were run on each sample and the results were averaged.

As could be expected, the results were widely scattered, but when averaged for each sample and for each location, and when two samples were exhumed from the same location, the results appeared consistent.

As presented in Table 4, the 4-oz/yd^2 fabrics used in the low-survivability conditions performed similarly in terms of percent strength retained. The slit-film woven geotextile appeared to be somewhat less susceptible to reduction in puncture strength though just slightly more sensitive to Mullen burst strength reduction than the nonwoven needle-punched geotextile. The differences seem relatively insignificant and do not appear to be grounds for differentiating between the two geotextiles for purposes of construction survivability. Four-ounce-per-square-yard geotextiles are more susceptible to puncture than to abrasion under these base aggregate lifts. Although a relatively small percentage of strength reduction was apparent, puncture holes were apparent in nearly every sample.

TABLE 4 GEOTEXTILE STRENGTH RETAINED AT LOW-SURVIVABILITY CONDITIONS*

	4 oz/sy Continuous Filament Needlepunched		4 oz/sy Slit Film	
	NONWOVEN		WOVEN	
	Mullen Burst %	Puncture %	Mullen Burst %	Puncture %
Triple treatment over 3" Base	80	80	77	100
1 1/2" Asphalt Surface over 3" Base	100+	100+	93	100+

*Heavy construction equipment operating on firm, dry, well draining subgrade. Road grades are flat to slight.

TABLE 5 GEOTEXTILE STRENGTH RETAINED AT MODERATE-SURVIVABILITY CONDITIONS*

	6 oz/sy Continuouse Filament Needlepunched Nonwoven	
	Mullen Burst %	Puncture %
Triple treatment over 3" Base	57	73
1 1/2" Asphalt Surface over 3" Base	77	79

*Heavy construction equipment operating on poorly drained subgrade. Road grades are moderate to steep.

Table 5 presents interesting insight into the need for a more durable geotextile when more demanding survivability conditions are experienced. The 6-oz/yd² needlepunched, nonwoven geotextile experienced approximately 20 and 40 percent strength loss in the two pavement segments built using aggregate base. These data indicate the importance of considering road grade and drainage when assessing survivability conditions and that this geotextile may not have been durable enough for the given moderate survivability conditions.

Under both low- and moderate-survivability conditions (see Tables 4 and 5), the allowance of extraordinarily thin compacted lifts of base course, as was allowed in the triple-treatment segment of Stockton Road, should elevate the applicable geotextile survivability conditions one level (i.e., from low to moderate).

CONSTRUCTION SURVIVABILITY OBSERVATIONS AND RECOMMENDATIONS

Satisfactory performance of the roadway depends on the ability of the geotextile to survive construction without a significant reduction in the physical properties that are necessary to provide long-term separation and filtration. With retained strength as a guide, the following observations concern the construction survivability of geotextiles in low-cost, low-volume pavement structures:

- Like-weight woven-slit film and nonwoven needlepunched geotextiles exhibit the same degree of construction survivability, in terms of retained strength, under like conditions.
- The required level of survivability must include an assessment of lift thickness of base aggregate and roadway grade, as well as saturated subgrade strength and construction vehicle loading.
- 4-oz/yd² geotextiles of all types are too light weight to resist localized puncturing when thin base course lifts are used.

Table 6 presents survivability conditions and suggested appropriate geotextile mass per unit area.

MONITORING PAVEMENT PERFORMANCE

In order to characterize the relative long-term performance of the various pavement sections, it was necessary to periodically inspect the road surface to track degradation. Two independent visual inspection programs were initiated. The first

TABLE 6 GEOTEXTILE SPECIFICATIONS FOR CONSTRUCTION SURVIVABILITY IN LOW-COST, LOW-VOLUME ROADS*

Survivability Level	Subgrade Conditions	Base Course Thickness **	Geotextile Mass/Unit Area
Low	Dry, firm, flat	> 6"compacted	4 oz/sy
Moderate	Water sensitive, flat	> 3-4" compacted	6 oz/sy
High	Water sensitive, grade > 2%	> 3-4" compacted	8 oz/sy

* These recommendations incorporate the allowance for construction vehicles to run directly on the fabric during aggregate base construction. These recommendations expect minor puncture damage to the geotextile. The resulting greater sensitivity to pumping is not considered critical in low volume installations. Required survivability should be increased for higher volume roads to protect against puncture damage to the geotextile.

** For base course lifts less than 3", required survivability should be increased one level (i.e. low to moderate).

program involved qualitative evaluation of the surface on a quarterly and then a semiannual basis. The second program included quantitative assessments of the pavement surface on two different occasions.

The quantitative assessments were entered into a computerized pavement management system that could then project the long-term performance of each pavement segment. The qualitative surface observations were used to validate the quantitative assessments and are presented in Table 7.

PAVEMENT CONDITION EVALUATION

Greenville County used the American Public Works Association's Micro Paver Software for Pavement Management. This program was developed by the U.S. Army Corps of Engineers, Civil Engineering Research Laboratories. The basic data entered on the various pavement sections rely on surface distresses. Their quantity and severity establish the overall quality of a pavement. The pavement condition index (PCI) is established on a ranking scale from 0 to 100. The various qualitative descriptions and the relationship to the PCI numbers are presented in Table 8. In addition, the various types of distresses identified in the pavement evaluation for a PCI determination are noted at the bottom of Table 8. Each of the 19 distresses associated with asphalt pavements relates to a deduction value from the top-rank value of 100. Pavement condition information is entered into and weighting, deduction, and projecting calculations are expeditiously handled through the computer software program. A pavement is assumed to be allowed to deteriorate to a PCI of 40 before resurfacing or other rehabilitative work would be required. Pavements exposed to traffic loads and volumes significantly greater than those experienced by the low-volume roads being addressed should be maintained at some greater level. The action level is established by local preference.

TECHNICIAN TRAINING

Obviously, the key to a reliable pavement management program is the determination of the PCI value. This value relates directly to the interpretation of the road surface by the personnel conducting the evaluation. The engineering technicians conducting these evaluations went through several days of extensive classroom training followed by field visits to all types of pavement in order to get thoroughly acquainted with the various types of distresses and their severity levels. A continual cross check on work performance is made to ensure the overall quality and dependability of the program. All teams are trained such that on any given pavement section, the final PCI of that section does not vary over a range of more than five points. The results of PCI evaluations on various segments on Stockton Road are presented in Table 9.

The PCI rankings of the pavement excluded distresses that are not related to the overall structural performance of the pavement. Sample units without areas damaged by construction, utility work, and other localized distresses were intentionally selected. Sample units within each test section contained approximately 2,600 ft^2. The sample units selected were typical of the pavement within each section.

PROJECTING RATE OF DETERIORATION

Micro Paver uses a fourth-degree equation to simulate the PCI deterioration curve. Attempts were made to generate unique pavement performance curve data characteristic of Greenville County roads using PCI data that are available on all 1,390 mi of roadway within the county's inventory. The 3-in. stone base under a triple-treatment surface has long been the locally accepted standard. Samples were exhumed from numerous pavements to correlate PCI values and residual base thickness. Surface-treated pavements having PCI values of less than 20 demonstrated the near-total loss of stone-base materials. Stone-base material thicknesses ranged from 0 to 2 in. maximum, with the norm being approximately 1 in. It had been hoped that these older pavements could be used to establish a historical record of pavement performance and to generate a specific PCI deterioration curve. But a satisfactory correlation has not yet been found, and therefore a general form of the equation is being used to develop a family of curves to project pavement life (see Figure 2). An appropriate curve was then selected from the family of curves that best fit the limited performance data (PCI) through the first 2½ years. When test sections allowed, multiple sampling units were evaluated and the average PCI value was used to determine performance. Subsequent sampling of the roadway may alter the form of the general deterioration curves.

TRAFFIC VOLUMES

Before the installation of the pavements, Stockton Road served five homes. The estimated average daily traffic (ADT) was less than 50 vehicles per day (vpd). Lacking traffic count data, the general allowance of 10 vpd, per household, was used. The current actual traffic counts indicate usage at station 0+00 to be 300 vpd with 5 percent truck traffic. At the terminus of the project (Station 81+00), the traffic count is 300 vpd with 5 percent truck traffic. The road currently serves 17 residences. The paving of this roadway has had a drastic impact on the development of the area. This rural area is well removed from any area showing development trends.

PAVEMENT PERFORMANCE

As discussed earlier, geotextile/pavement sections were laid out to facilitate accurate comparisons. The 4-oz/yd^2 slit-film fabrics under full-depth asphalt developed cracking patterns 3 months after installation. These cracks have grown consistently worse with time. At the transition Station 25+00, the 6-oz/yd^2 fabric clearly demonstrated its ability to transmit subsurface water. At the downgradient edge, no underdrainage was provided. The alligator cracking noted at this location was attributed to subgrade deterioration caused by failure to install an adequate underdrain to remove water carried through the fabric. The same conditions prevailed at Station 55+00 under the triple-treatment surface.

FULL-DEPTH ASPHALT

Figure 3 shows the projected lives of the various pavement sections using 2½ in. of full-depth asphalt. In terms of pave-

TABLE 7 PAVEMENT PERFORMANCE AND OBSERVED SURFACE CONDITION

	2 1/2" Full Depth Asphalt					1 1/2" Asphalt over 3" Stone Base				Triple Treatment Over 3" Stone Base				
Date of Visual Inspection	4 oz/sy NW 0+00 to 5+00	4 oz/sy SF 5+00 to 10+00	Control 10+00 to 20+00	6 oz/sy NW 20+00 to 25+00	Control 25+00 to 30+00	4 oz/sy NW 30+00 to 35+25	4 oz/sy SF 35+25 to 40+25	Control 40+25 to 45+50	6 oz/sy NW 45+50 to 50+00	6 oz/sy NW 50+00 to 55+00	Control 55+00 to 61+00	4 oz/sy SF 61+00 to 66+00	4 oz/sy NW 66+00 to 71+00	Control 71+00 to 81+00
July 1, 1987	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction	Complete Construction
Oct. 7, 1987	Smooth, Crack-free	Substantial Slippage Cracking	Smooth Crack-free Some Raveling	Smooth, Crack-free	Smooth, Crack-free	Smooth, Crack-free	Smooth, Crack-free	Smooth, Crack-free	Smooth, Crack-free	Coarse Crack-free Slight Fines Migration	Coarse Crack-free Slight Fines Migration	Coarse Crack-free Slight Fines Migration	Coarse Crack-free Slight Fines Migration	Coarse Crack-free Slight Fines Migration
Jan. 8, 1988	Same	More Cracking	Same	Significant Hair line Cracking (Poor Drainge)	Same	Same	Same	Intermittent Transverse Cracks	Same	Same	Alligator Cracking on Steep, Grade (Wet Subgrade)	Same	Same	Same
April 18, 1988	Same	More Cracking	Same	More Hairline Cracking	Same	Same	Same	More Transverse Cracking	Same	Alligator Cracking Propagating from Control Section	Further Alligator Cracking	Same	Same	Same

TABLE 7 (*continued on next page*)

TABLE 7 (*continued*)

July 25, 1988	Same	Cracks have con- nected Alligator Patterns	Slight Trans- inverse and Long- tudinal Cracking	More Hairline Cracking	Slight Trans- verse and Long- tudinal Cracking	Same	Slight Longitu- dinal Cracking	More Trans- verse Cracking	Same	More Alligator Cracking	Severe Alligator Cracking	Same	Same	Slight Alligator and Longitu- dinal Cracking
Feb. 15, 1989	Same	Extensive Alligator Cracking Repress- ing Into Large Block Cracking	Repaired Ravelling Intermit- tent Trans- verse and minor Long. Cracking	Hairlines are now Signifi- cant Pattern of Trans- verse and Long Cracks	More Trans- verse and Long tudinal Cracking	Few Minor Longitu- dinal Cracks	Slight Longitu- dinal Cracking	Intermit- tent Block Cracking	Same	More Alligator Cracking	Alligator Cracking Removed and patched	Same	Same	More Alligator and Longitu- dinal Cracking
July 21, 1989	Minor Trans- verse Crack	Most Severe Alligator Patched, Blocks becoming Alligator	Intermit- tent Cracking Beginning to Block	Alligator Cracking Developin from tran verse & Longi- tudinal	Large Block Cracking Develop- ing	Minor Cracks Appear to have healed in hot Weather	Most Cracks Appear to have healed in hot Weather	Increas- ing Inter- mittent Block Cracking	Minor Longitu- dinal Crack	Alligator Cracking Stabili- zed	Continued Alligator around Asphalt Patch	Same	Same	Severe Alligator Cracking Patched, Additional Alligator Cracks

TABLE 8 PAVING CONDITION AND PCI RANK

Pavement Condition	PCI Rank
Excellent	100
Very Good	85
Good	70
Fair	55
Poor	40
Very Poor	25
Failed	10
	0

ASPHALT PAVEMENTS
DISTRESS TYPES

1.	Alligator Cracking	*10.	Long & Trans Cracking
2.	Bleeding	11.	Patching & Util Cut Patching
3.	Block Cracking	12.	Polished Aggregate
*4.	Bumps and Sags	*13.	Potholes
5.	Corrugation	14.	Railroad Crossing
6.	Depression	15.	Rutting
*7.	Edge Cracking	16.	Shoving
*8.	Jt. Reflection Cracking	17.	Slippage Cracking
*9.	Lane/Shoulder Drop Off	18.	Swell
		19.	Weathering & Raveling

* All Distresses are Measured in Square Feet Except Distresses 4, 7, 8, 9, and 10 which are Measured in Linear Feet; Distress 13 is Measured in Number of Potholes.

ment life for the 2½-in. thickness of asphaltic binder, the performance of the 4-oz/yd^2 nonwoven fabric appeared to have a significant impact on pavement life. The slit-film material itself, as well as the problems associated with placing asphalt on its relatively slick surface, clearly proved to be a detriment to a full-depth asphalt pavement. The pavement section incorporating the 6-oz/yd^2 fabric performed unsatisfactorily. This result suggests that heavier-weight fabrics may be too spongy beneath full-depth asphalt or that lack of drainage, which was evident in this section, leads to poor performance.

ASPHALT OVER BASE COURSE

The predicted PCI values for the 1.5-in. asphaltic wearing course over the 3-in. stone base contained far less deviation than the other types of pavements and are shown in Figure 4. The 4-oz/yd^2 woven and nonwoven fabrics performed equally as well in this installation, whereas the 6-oz/yd^2 fabric performed slightly better.

TRIPLE TREATMENT OVER BASE COURSE

Figure 5 shows the projected lives of pavement sections using triple treatment over base course. Where triple treatment was provided over the 3-in. stone base, pavement life was only estimated at 7.6 years. This life is the lowest anticipated life of any of the designs used. Again, the 6-oz/yd^2 fabric installed under adverse conditions performed at a level less than anticipated; however, its performance under adverse conditions still exceeded the life of the pavement in the control sections. The 4-oz/yd^2 nonwoven fabric appeared to outperform the slit-film material. The triple treatment produces a relatively rough, coarse surface texture that is somewhat difficult to evaluate.

COMPARING PAVEMENT TYPES

Despite the effort to provide a pavement that would have a projected life of 15 years, all sections performed below expectations by showing a rather rapid decrease in quality during the first 2 years. Figure 6 shows the relative performance of the three basic pavement designs under the control conditions. The best overall performance was achieved by using a 3-in. stone base, with a 1½-in.-thick asphalt surfacing overlay. The full-depth asphalt binder material, which was expected to have equal performance characteristics, showed <9 years of projected pavement life. The porosity of the binder material may have had an impact on the rapid initial deterioration. Had

TABLE 9 PAVEMENT PERFORMANCE DETERMINED BY PAVEMENT MANAGEMENT SYSTEM USING APSA-MICROPAVER PCI AND PROJECTED PAVEMENT LIFE

	2 1/2" Full Depth Asphalt			1 1/2" Asphalt over 3" Stone Base						Triple Treatment Over 3" Stone Base				
Date of Inspection	4 oz/sy NW 0+00 to 5+00	4 oz/sy SF 5+00 to 10+00	Control 10+00 to 20+00	6 oz/sy NW 20+00 to 25+00	Control 25+00 to 30+00	4 oz/sy NW 30+00 to 35+25	4 oz/sy SF 35+25 to 40+25	Control 40+25 to 45+50	6 oz/sy NW 45+50 to 50+00	6 oz/sy NW 50+00 to 55+00	Control 55+00 to 61+00	4 oz/sy SF 61+00 to 66+00	4 oz/sy NW 66+00 to 71+00	Control 71+00 to 81+00
PCI July 1989	80	74	81									78	85	
PCI February 1990	85		76	69	84	86¦80	85¦87	85	87	70	66			67¦72
Projected Pavement Life (Yr)	10.2	7.8	8.9	7.3	11.4	11.9	11.9	11.4	12.5	7.8	7.8	8.3	8.9	7.8
Distress * Types	Light Alligator Edge Cracking	Low to Medium Block Cracking, Light Edge Cracking	Light Block Cracking, Light L&T Cracking, Edge Cracking	Light Alligator Edge, L & T Cracking	Light Block, Edge & L & T Cracking	Light to Medium Edge Cracking, Light Alligator and L&T Cracking	Light Block Cracking, Edge Cracking, L & T Cracking	Light Block Cracking, Edge Cracking, L & T Cracking	Light Edge Cracking, L & T Cracking	Light Edge Cracking, Light Rutting, Raveling	Light Bumps, Edge Cracking, Rutting, Raveling	Light Bumps, Edge Cracking	Light Rutting, Raveling	Light Bumps, Light Rutting, Raveling

* L & T indicates longitudinal and transverse cracking.

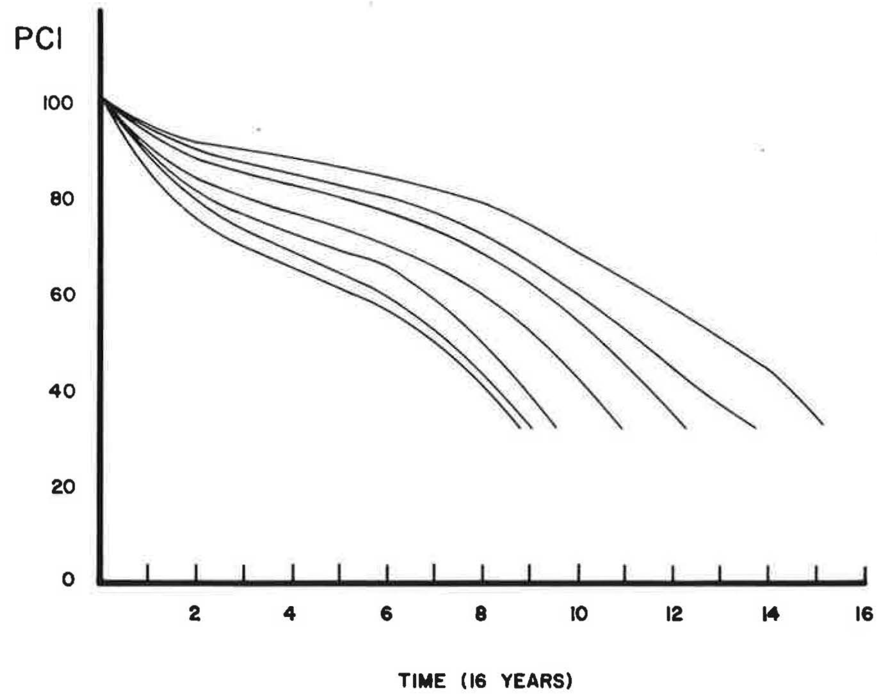

FIGURE 2 Predicted PCI family of curves.

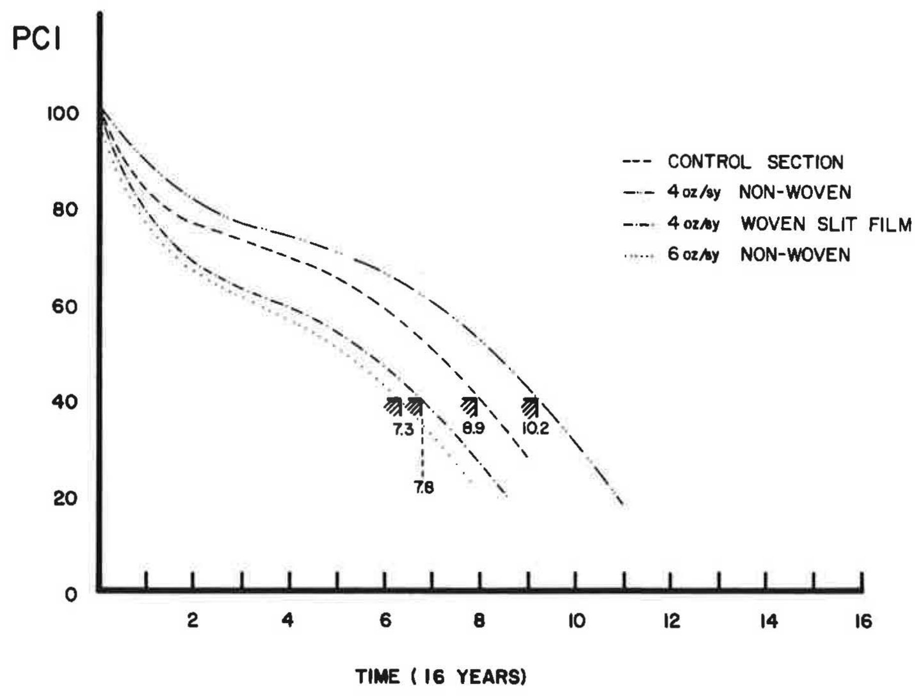

FIGURE 3 Predicted PCI curve for 2½-in. asphalt binder pavement.

the asphalt binder material performed better as an initial paving surface, it would have been a more desirable structural base for future overlays.

Although triple treatment provides an all-weather surface and protects the subgrade from moisture-related failures, overall it performs poorly as a structural material. Being the most flexible of the three designs, the rutting currently observed will likely continue and develop significant problems.

Figure 7 shows predicted PCI curves for pavements using 4-oz/yd^2 nonwoven fabrics.

COST ASSESSMENT

During the construction of the pavement section, various aspects were performed by Road and Bridge Department personnel.

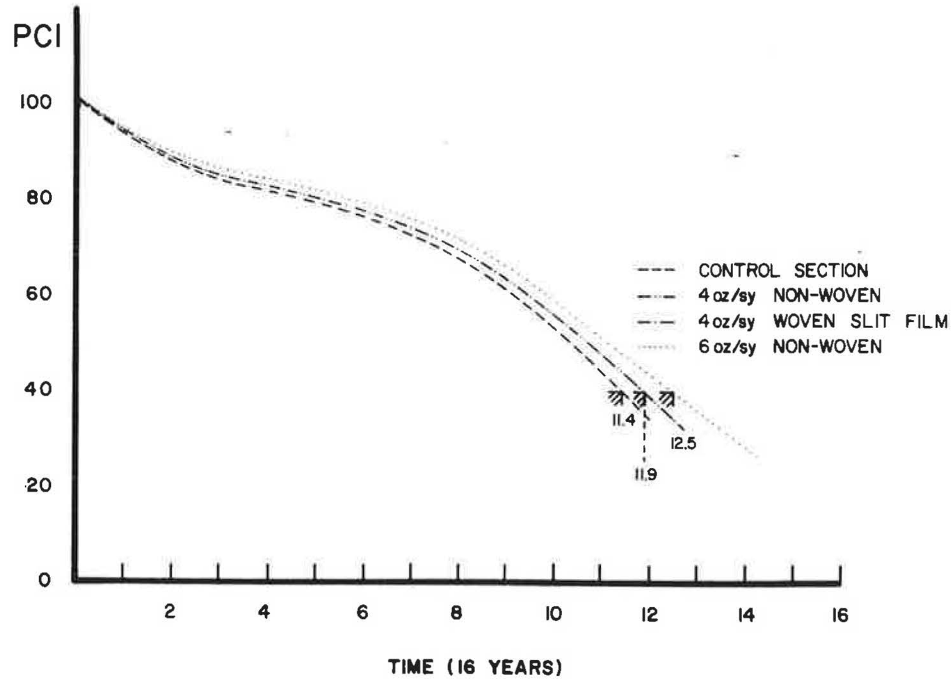

FIGURE 4 Predicted PCI curve for 1½-in. asphalt wearing course over 3-in. stone base.

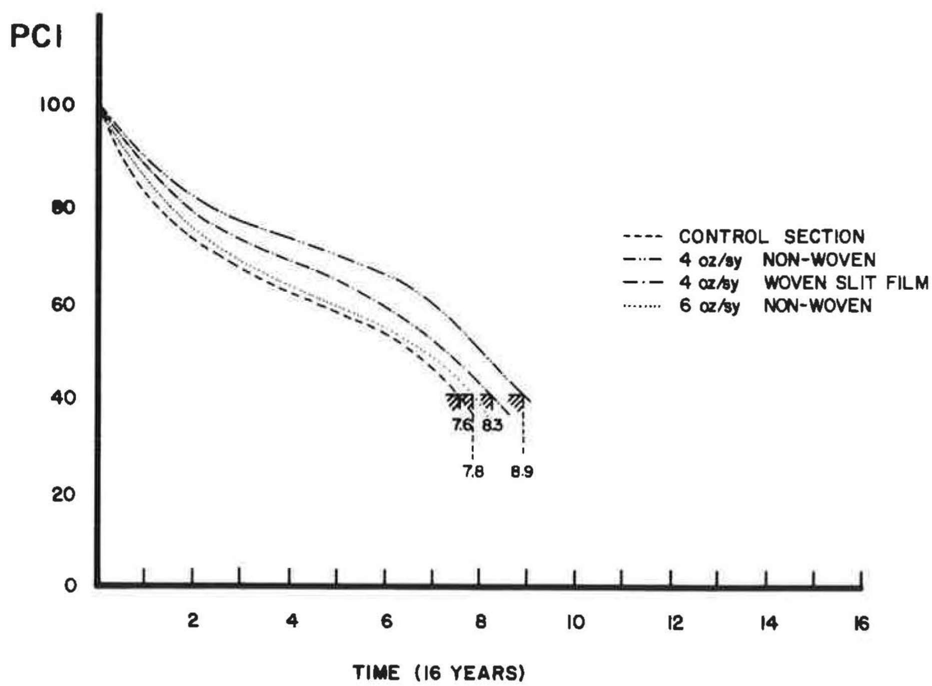

FIGURE 5 Predicted PCI curve for triple treatment over 3-in. stone base.

Costs associated with all labor, equipment, and materials were tracked using the county's work management system. The use of county-owned equipment was charged against the project on the basis of monthly rental rates for equipment. The costs of contracted services have been 10 to 15 percent lower than the unit cost for various work items performed by county personnel with equipment charges included. Table 10 presents the costs of constructing the pavements used in this test. Comparable contracted prices for similar installations are currently being experienced. All hot-laid asphalt materials, as well as the fabric and base under these materials, were placed in conjunction with the county's annual resurfacing program by a private contractor. Table 10 indicates that the actual thicknesses of applied surfacing material was 1.3 in., slightly less than the expected 1.5 in. The full-depth binder materials averaged 0.1 in. thicker than specified.

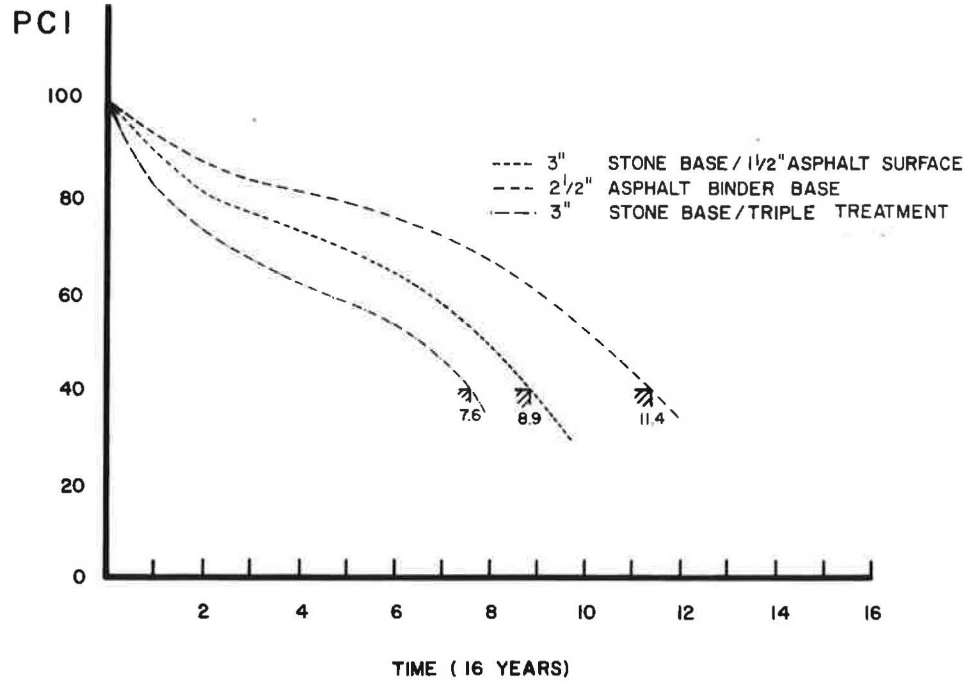

FIGURE 6 Predicted PCI curve for control pavement sections.

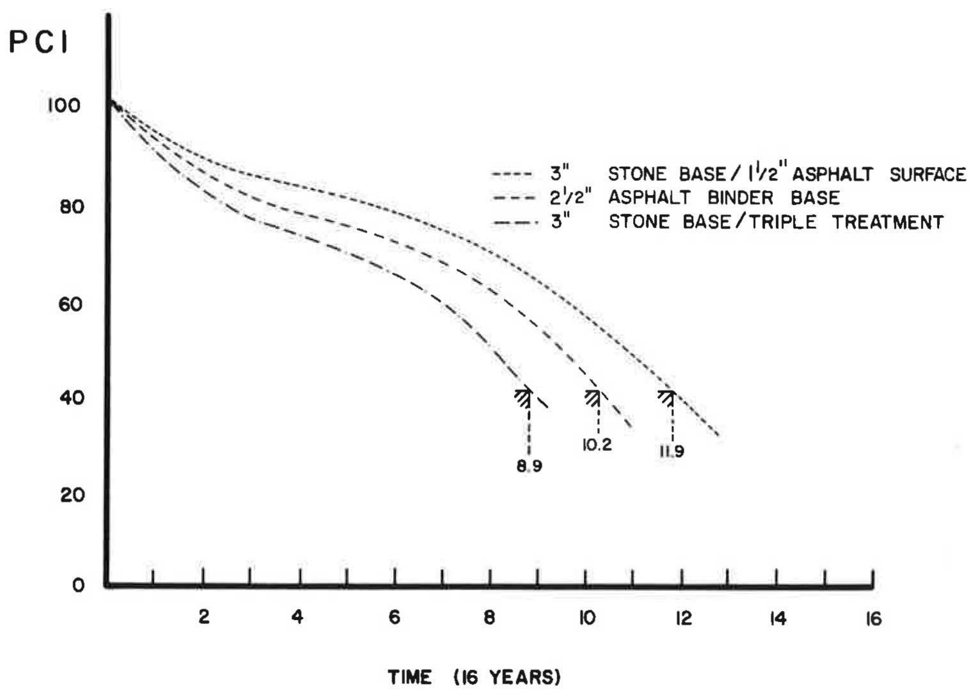

FIGURE 7 Predicted PCI curve for pavements using 4-oz/yd² nonwoven fabrics.

EQUIVALENT UNIFORM ANNUAL COSTS

In order to account for varying pavement lives when comparing pavement alternatives, an annual cost comparison technique was chosen. The equivalent uniform annual costs (EUACs) were calculated for each pavement test section using pavement lives projected by the general deterioration curves. The assumptions include an interest rate of 7.5 percent and a restoration cost of \$1.78/yd² to provide an asphaltic overlay once the PCI had deteriorated to 40. EUAC equations are described elsewhere (*1*, p. 104).

Table 11 presents the EUAC values for the various pavements installed for this project. The 2½-in. full-depth binder control pavements demonstrated annual costs slightly less than

TABLE 10 STOCKTON ROAD, GREENVILLE COUNTY, SOUTH CAROLINA, ROAD SURFACING COST DATA

I. 2-1/2 FULL DEPTH BINDER (by contractor)

	FABRIC	FABRIC MATERIAL	ASPHALT(1.3" actual)	TOTAL SQUARE YARD
	$	$	$	$
w/ 4 oz/sy NW	.06	.40	3.50	3.96
w/ 6 oz/sy NW	.06	.55	3.50	4.11
w/ 4 oz/sy WSF	.06	.40	3.50	3.96
None	-	-	3.50	3.50

II. 1-1/2 ASPHALT SURFACE OVER 3" BASE (by contractor)

	FABRIC	FABRIC MATERIAL	BASE	ASPHALT(1.3" actual)	TOTAL SQUARE YARD
	$	$	$	$	$
w/ 4 oz/sy NW	.06	.40	2.29	1.78	4.53
w/ 6 oz/sy NW	.06	.55	2.29	1.78	4.68
w/ 4 oz/sy WSF	.06	.40	2.29	1.78	4.53
None	-	-	2.29	1.78	4.07

III. TRIPLE TREATMENT OVER 3" BASE

	FABRIC		BASE			TRIPLE TREATMENT			TOTAL
	LABOR	MATERIAL	LABOR	MATERIAL	EQUIPMENT	MATERIAL	LABOR	EQUIPMENT	SQUARE YARD
	$	$	$	$	$	$	$	$	
w/ 4 oz/sy NW	.06	.40	.23	1.94	.49	------1.80------		.85	5.77
w/ 6 oz/sy NW	.06	.55	.23	1.94	.49	------1.80------		.85	5.92
w/ 4 oz/sy WSF	.06	.40	.23	1.94	.49	------1.80------		.85	5.77
None	-	-	.23	1.94	.49	------1.80------		.85	5.31

TABLE 11 STOCKTON ROAD, GREENVILLE COUNTY, SOUTH CAROLINA, ROAD SURFACING COST DATA—EUAC

	INITIAL COSTS $/SY	PAVING LIFE (YEARS)	EQUIVALENT UNIFORM ANNUAL COST $/SY
I. 2-1/2 FULL DEPTH BINDER (by contractor)			
4 oz/sy Non-woven	3.96	10.2	0.419
6 oz/sy Non-woven	4.11	7.3	0.500
Woven/Silt Film	3.96	7.8	0.473
Control/No Fabric	3.50	8.9	0.410
II. 1-1/2 ASPHALT SURFACE OVER 3" BASE (by contractor)			
4 oz/sy Non-woven	4.53	11.9	0.438
6 oz/sy Non-woven	4.68	12.5	0.442
Woven/Silt Film	4.53	11.9	0.438
Control/No Fabric	4.07	11.4	0.409
III. TRIPLE TREATMENT OVER 3" BASE			
4 oz/sy Non-woven	5.77	8.9	0.581
6 oz/sy Non-woven	5.92	7.8	0.620
Woven/Silt Film	5.77	8.3	0.595
Control/No Fabric	5.31	7.6	0.580

the pavement section where 4-oz/yd² nonwoven fabric was used. The 4-oz/yd² woven slit-film materials were not suitable for use under full-depth pavement.

For the pavement section constructed of 1½-in. asphaltic wearing surface over a 3-in. stone base, the annual costs for installations using fabric run slightly higher. This seems to indicate that, provided the stability of the subgrade is maintained, the presence of fabric at the interface may not be critical to overall pavement performance. After long-term performance can be monitored, it will be seen if the presence of a fabric increases pavement life by providing protection of the subgrade through its drainage characteristics.

The performance of triple treatment over the 3-in. stone base demonstrated a near-equal cost benefit for using 4-oz/yd² fabrics.

CONCLUSION

Geotextiles provide general stability and drainage properties that may increase the quality of a pavement section. Little is known about low-volume pavement design using geotextiles. Principles of reduction in aggregate base depths to offset costs of paving fabrics are not applicable to thin designs.

In most cases, life cycle costs for pavement with fabric were somewhat greater than the costs associated with the control sections that did not use fabrics. Local conditions still warrant the evaluation of life cycle costs associated with any project because the construction costs will vary with the locality.

Low-volume pavement designs are susceptible to accelerated deterioration. When average daily traffic is less than 500 vpd, the pavement life is significantly impacted by any increases in truck traffic. The presence of fabrics may reduce the susceptibility to rapid deterioration.

Fabric use in low-volume pavements should be regarded as a tool to maximize performance of paving materials. It is expected that the use of fabric guarantees performance of base materials at their maximum structural coefficient levels. Yet, the long-term benefits may not be seen until pavements approach 5 to 7 years of age. At these ages, the mixing of the subgrade and base materials are normally expected to begin. The retention of the subgrade and base material interface, together with the ability of the fabric to channel water out of the road section may warrant fabric installation. Fabrics may or may not enhance initial pavement performance, but as subsequent overlays are placed, fabrics continue to protect base courses from fouling and therefore will likely enhance future pavement performance.

In conclusion, the short-term results of using fabric in low-volume pavement designs is inconclusive. Future evaluations are expected to show that careful selection of appropriate fabric weights to ensure construction survivability is critical to pavement performance. Also, when engineering fabrics are used, appropriate interceptor drains must be provided at downgradient terminal fabric edges to channel water out of the pavement structure. Many questions remain regarding long-term performance of these test sections. Most notably, will fabrics prevent accelerated deterioration as cracking patterns allow water to pass through the pavement and base material to the detriment of the subgrade?

REFERENCE

1. D. G. Newman. *Engineering Economic Analysis*. Engineering Press, 1977.