Evaluation of Nonwoven Geotextile Versus Lime-Treated Subgrade in Atoka County, Oklahoma

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The use of chemically stabilized subgrades in routine maintenance and new construction of roadways represents an expensive way to address the problem of stabilization and separation from base materials. In 1984 a nonwoven Supac 8NP was installed on secondary state highway SH-131 in Atoka County, Oklahoma, to investigate a more cost-effective means of separation and stabilization. Roadway performance of the geotextile test sections was compared with the traditionally used 610-mm (24-in.) lime-stabilized subgrade control sections, as both the geotextile and the stabilized subgrade were covered by the same pavement structural section. Also evaluated was geotextile survivability and performance after the rigors of construction, the stress of traffic, and aging. Roadway history, fabric and soil sampling and testing, road conditions, and estimation of fabric durability are examined. Geotextile durability is determined by removing the fabric from the roadway and testing the exhumed samples. Data are compared with the original, unaged samples.

According to the 1974 National Highway Needs Report, federal-aid highways are deteriorating at a rate of 50 percent faster than they are being rebuilt. Today this percentage could be much higher. It is therefore imperative that more efficient and effective highway construction and reconstruction technologies be developed. Although Oklahoma has an excellent system of highways, better, more durable roadway systems are being investigated. One promising development is the use of geotextiles for separation and stabilization.

Incorporation of a geotextile in the pavement design can improve performance and service life. Geotextiles are cost-effective alternatives to stabilization methods such as demucking, placement of thick structural fill, lime stabilization, or other expensive manipulation operations. All roadway systems, whether temporary or permanent, derive their strength and support from the subgrade. The misconception in layered roadway designs, such as AASHTO pavement design, is that respective layers of various pavement components will remain "as placed or constructed" over the existing subgrade throughout the service life of the pavement. Because of changes in load and environmental factors, however, pavement system failures do occur at the aggregate base subgrade contact point. This is a result of the intrusion of low-strength subgrade material into the aggregate base and base material into the subgrade. The intermixing of two dissimilar materials causes a net reduction in the effective thickness of the base and initiates a progressive failure mechanism, resulting in the need for continual road maintenance. A study conducted by Hicks et al. (*1*) clearly shows that a base contamination of as little as 10 percent subgrade soil fines can destroy the structural strength of the base layer.

Traditional solutions to this contamination problem include using a well-graded base, which helps choke off the migration of fines but is less strong and not free draining; stabilizing the subgrade to limit its migration; or stabilizing the base stone to make it less affected by fines migration. A better solution is the placement of geotextiles as a separation and stabilization layer between the subgrade and overlying base, preventing base contamination due to subgrade intrusion into the subbase or base. Use of a geotextile for separation and stabilization has been proven technically effective and is a widely used alternative. Work done by Barenburg et al. (*2*) clearly showed that incorporation of a geotextile could significantly improve the stability of the roadway system or would allow the system to be constructed with a thinner structural section and still achieve the same performance level. One reason thinner sections can be used is that the AASHTO methodology, which evolved over time based on performance, actually compensates for base thickness loss due to contamination, and a geotextile eliminates this contamination (*3*). The other reason that geotextiles allow the use of a thinner structural section is the stabilizing effect the geotextile has on the subgrade.

This paper discusses the work done to evaluate and compare a nonwoven needle-punched polypropylene geotextile, Supac 8NP, with 610 mm (24 in.) of in-place lime-stabilized subgrade. The durability of the geotextile and the performance of both sections were monitored over a period of 9 years. Durability is defined as the geotextile's resistance to damage due to initial installation and construction and other mechanical and chemical factors during the service life. Polyester fabric was intentionally not installed because of its chemical incompatibility with lime on the construction site.

The durability of the lime-treated subgrade material was not evaluated.

PURPOSE

The purpose of the study was to compare the relative performance of Supac 8NP, a nonwoven needle-punched polypropylene geotextile, nominal weight 271 g/m^2 (8 oz/yd^2), with lime-treated subgrade soil. Long-term performance questions were also addressed by examining the long-term durability of the geotextile section. Specifically, would the less expensive geotextile system placed over a highly plastic clayey subgrade be equivalent to 24 in. of

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lime-treated subgrade? The same road base and surface treatment were applied over both the lime-stabilized and the geotextile-stabilized section to allow a fair comparison.

PROJECT LOCATION

The project is located on secondary highway SH-131, 0.8 km (0.5 mi) east of the town of Wardville, extending east to US-69 in northern Atoka County, Oklahoma. Two traditionally used lime-treated sections, one on each end of the Supac 8NP section, were selected as the control. The geotextile section was 183 m (600 ft) long by the full width of the roadway. Both lime sections used a layer of lime-stabilized subgrade 610 mm (24 in.) thick. The project was built by Honegger Construction Company of Oklahoma City, Oklahoma, as a part of the Oklahoma Department of Transportation (ODOT) project SAP-3(168).

SITE CONDITIONS

The subgrade soils were of poor quality with low bearing capacity. The site has a perched water table at a depth of approximately 0.6 m (2 ft) to 0.9 m (3 ft) during winter and spring. Soil classification and mechanical analysis data for the site are given in Table 1. According to ODOT guidelines, these soils require special treatment to increase the subgrade strength and prevent local and general damage to the pavement system. Originally the project was set up to require lime treatment for subgrade support to the pavement because of poor soil conditions. The project was modified to include Supac 8NP as part of an experiment.

CONSTRUCTION

Lime Treatment Section

Approximately 2 mi of the 8.5-km (5.27 mi) project were treated with quicklime. The modification was based on subgrade soil properties and the Oklahoma subgrade index (OSI). The OSI is used to determine whether a subgrade requires any modification, and is calculated from the liquid limit, plasticity index, and percentage passing the No. 200 sieve. As a rule of thumb any subgrade with an OSI of 15 or more requires lime treatment in order to carry the design load. More than 40 percent of the soils exceeded 15 OSI on the project.

The lime-treated areas were constructed according to ODOT Standard Specifications 706.02 and 307. The treated subgrade was placed and compacted in three lifts of 8 in. each. Lime quantities were estimated at 58 kg/m^2 (108 lb/yd^2) for the 610-mm (24-in.) layer. The concentration of the lime incorporated into the treated subgrade was approximately 5 percent. Figure 1 shows a cross-section of the lime-treated area.

Fabric Treatments

Supac 8NP, a nonwoven geotextile, with a width of 3.81 m (12.5 ft), was placed over the existing subgrade. An initial 3.81-m

TABLE 1 Soil Classification, Physical and Mechanical Analysis

AASHTO Soil Group	Station	Subgrade Soil Classification	Depth (in)	Liquid Limit(%)	Plasticity Index	Physical & Mech. Analysis: Percent Passing No.10	No.40	No.200	OSI[b]
ORIGINAL SUBGRADE SOIL - 1983									
A-6(13)	176+00	Silty Clay	0-6	34	19	98[a]	95	81.4	14
A-6(16)	Underlay	" "	6-12	36	20	100	97	84.8	15
A-6(17)	"	" "	12-18	37	22	100	96	82.4	16
A-6(16)	"	" "	18-24	37	20	100	97	85.2	15
A-2-6(0)	178+00	Sandy Clay and Gravel	0-6	26	12	57[a]	38	24.6	4
A-7-6(20)	Underlay	Silty Clay	6-12	43	28	94[a]	92	78.6	20
A-7-6(23)	"	" "	12-18	47	31	95[a]	90	78.5	22
A-7-6(27)	"	" "	18-24	49	32	100	97	84.7	23
SUBGRADE SOIL UNDER VARIOUS SECTIONS - 1993									
A-4(1)[c]	177+50	Silty Clayey Sand	0-6	32	5	78[a]	58	38.2	2
A-4(0)[c]	-	" " "	6-24	NP	NP	84[a]	64	42.4	0
A-7-6(19)	Below Lime Treatment	" " "	24-36	49	27	95[a]	87	72.3	21
A-7-6(21)	195+16	Lean Clay w/Sand	0-6	46	28	96[a]	95	79.0	20
A-7-6(37)	-	Fat Clay	6-24	58	37	100	99	90.6	27
A-7-6(42)	-	" "	24-36	63	43	100	99	98.8	30
A-6(1)[c]	227+95	Clayey Sand	0-6	38	12	77[a]	73	62.7	5
A-7-5(2)[c]	-	" "	6-24	47	12	91[a]	47	21.8	13
A-7-6(34)	Below Lime Treatment	Fat Clay	24-36	59	32	99[a]	81	68.3	24

[a]Percent Passing 1-inch Sieve
[b]Oklahoma Subgrade Index
[c]Lime Treated Sections

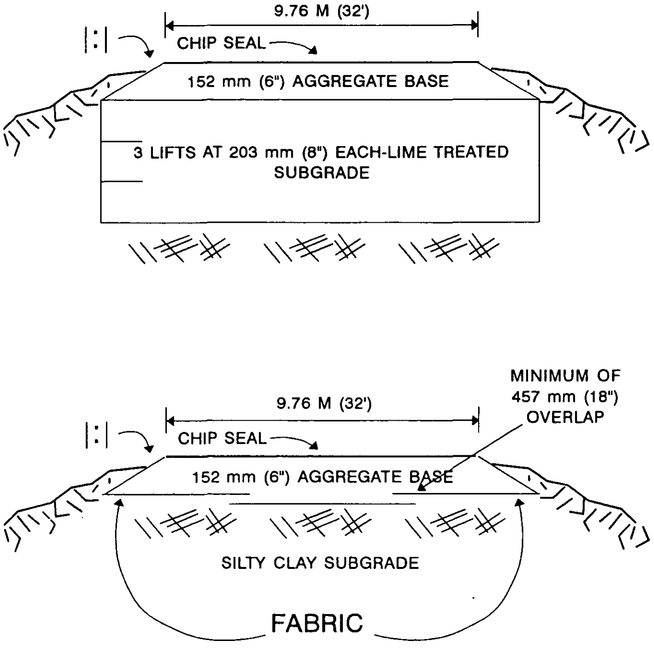

FIGURE 1 Typical cross-section of pavement.

(12.5-ft) roll was placed along the centerline of the roadway and two additional rolls were overlapped along either side. The overlap ranged from 457 mm (18 in.) to 610 mm (24 in.), providing a minimum effective width of 9.8 m (32 ft). The geotextile design cross-section is also shown in Figure 1.

The 183-m (600-ft) length of geotextile was installed by hand and took a six-man crew less than an hour. No special tools or equipment were necessary for the installation.

Pavement Structure

The same pavement structure was placed over the lime-treated and the geotextile-covered sections. Six inches of aggregate base, Type A (based on ODOT Standard Specification, 1976, Section 303) was placed by dump trucks. The aggregate was backdumped, placed in two layers, and compacted to 100 percent density per AASHTO T-180. Construction traffic did not tear or abrade the geotextile.

The surface of the aggreagate base wsa primed with 1.0 L/m^2 (0.22 gal/yd^2) of SS-1 emulsion. The primed surface then received a single bituminous surface treatment (chip seal). A CRS-2 emulsion tack coat was applied at a rate of 1.7 L/m^2 (0.38 gal/yd^2). It was followed by 16 kg/m^2 (30 lb/yd^2) of 16-mm (5/8-in.) cover aggregate and pneumatic rollers.

Exhuming of Geotextile

The following procedure was followed to exhume the geotextile. Since the roadway was kept open during removal of fabric, one lane of the test section was closed and traffic was diverted to the other lane by flag persons.

An approximate outline of the section to be removed was marked. With the help of a jackhammer the outer edges of the section were penetrated to the aggregate base. The backhoe operator cautiously removed the pavement and some aggregate base. The remaining aggregates were removed with pick and shovel to within 25 to 50 mm (1 to 2 in.) of the geotextile. The final layer of aggregate was removed by hand. Approximately 1 yd^2 of the geotextile was then cut and removed from the subgrade. The subgrade and base aggregate nearest to the fabric were visually inspected for contamination or slurry buildup underneath. No base contamination or slurry material was found. Samples of the subgrade soil were brought back to the laboratory from both sections, and test results are given in Table 1 for comparison with the original test data. The digout section was backfilled with a full-depth asphalt patch after another piece of geotextile was installed. The exhumed fabric sample showed no damage upon initial observation except two approximately 1-mm holes. The samples were brought back to the Phillips Fibers testing laboratory to determine mechanical loss in strength compared with original samples. The comparative strength properties of virgin samples and of samples removed in 1989 and 1993 are presented in Table 2.

Cost Analysis

Table 3 gives a summary of the materials and in-place 1984 costs for the project. The Supac fabric (geotextile) was furnished for free by Phillips Fibers Corporation. However, Supac 8NP fabric

TABLE 2 Supac 8NP Physical Properties

PROPERTY	TEST PROCEDURE	VIRGIN[a] SAMPLE	1988 (After 4 YRS)	1993 (After 9 YRS)
Tensile Strength, KN (lb)	ASTM D-4632	0.89 (200)	1.04 (234[b])	1.0 (199[b])
Elongation, %	ASTM D-4632	50	62	67
Puncture Strength, KN (lb)	ASTM D-4833	0.50 (125)	0.75 (170)	0.7 (158)
Mullen Burst, KPa, (psi)	ASTM D-3786	2618 (380)	3714 (539)	3259 (473)
Coeff. of Perm., cm/sec.	ASTM D-4491	0.4	–[c]	–[c]
Permittivity, sec^{-1}	ASTM D-4491	1.0	"	"
AOS	ASTM D-4751	7.0	"	"

[a]minimum average roll values, weakest principal direction
[b]the value is in the weakest direction
[c]hydraulic properties were not tested due to soil residue in the exhumed geotextile

TABLE 3 Pavement Layer Cost, 1984

Layer	Cost ($/m²)
Aggregate Base, 152 mm (6") Thick	3.56
Prime Coat	0.27
Tack Coat	0.32
Cover Aggregate No. 3 (5/8")	0.39
Total	4.55

costs were $1.39/m² ($1.17/yd²). Today the cost of Supac is less, making it an even more cost-effective option. The installation cost was estimated to be $0.12/m² ($0.10/yd²), bringing the total installed geotextile cost to $1.51/m² ($1.27/yd²).

The installed bid price for 610-mm-thick (24-in.-thick) lime-treated subgrade was $12.77/m² ($10.73/yd²). The total cost for the pavement construction, including a 6-in.-thick base, prime, and surface treatment was $4.53/m² ($3.81/yd²). Table 3 gives detailed pavement costs.

DISCUSSION OF RESULTS

To determine the durability and performance of geotextile, the following data were evaluated: soil sampling and testing results, fabric sampling and testing results, roadway conditions, ride quality, roadway maintenance history, and review of the pavement design that is based on Benkelman beam deflection measurements. Observations were made on the conditions of the exhumed geotextile samples, subgrade beneath the fabric, and base above the fabric. In combination this information provides adequate backup to characterize performance and durability.

Pavement performance and pavement deterioration were examined first. In 1986 the lime-treated sections experienced extensive pothole damage and underwent repairs. This was reportedly due to a wet spring in 1985. There was only one isolated pothole in the geotextile-stabilized section. In 1988 1½-in.-thick ODOT Type C hot-mix asphalt concrete was placed on the entire roadway even though the geotextile section had almost no pavement distress.

To evaluate the rideability, tests were conducted with the Mays ridometer in February 1993. The average pavement serviceability index (PSI) for the entire project was 3.7. The Supac section individually had a PSI of 3.6. According to ODOT, roadway repairs are usually required when the PSI is 2.5 or less. When the pavement was visually examined and evaluated, the lime-treated control section and the fabric section showed no visible differences.

The Benkelman beam deflection measurements were made in June 1993 and compared with 1984 test data, which were developed after the construction of the project. The 1993 deflection measurements were made after an early morning rainfall. The average deflections in 1993 were somewhat higher than in 1984 for both sections. Review of the deflection data shows that the geotextile-stabilized section is more flexible than the lime-stabilized subgrade section. Supac in this application is functioning as a separation and stabilization fabric by providing a barrier against intermixing of subgrade and base aggregates while letting the moisture seep through. The 610-mm-thick (24-in.-thick) lime-treated section is providing a beam effect due to higher stiffness; that is why the Benkelman beam deflection measurements are lower in these sections. However in 1985 the lime-treated section developed many potholes even though deflection data already indicated adequate roadway strength. Similarly 1984 data for the section show moderate deflection and yet no potholes.

The 6-in. pavement structure placed over the fabric is a limited section. Although it has performed well, this structural section could be increased significantly and the cost benefit of the geotextile section would still be evident. Increasing the structural section over the fabric would produce a road that would show less deflection, which, as can be seen, may have little relevance to actual road performance.

The Mays ridometer data and visual inspection of both the control and Supac sections clearly show that these sections have equivalent performance. Review of the 1984 and 1993 overlay design based on deflections indicates that the fabric section requires strengthening while the lime-treated sections require no strengthening. However in 1988 the 1½-in. overlay was placed due to potholes in lime-treated section. This clearly shows that input parameters need to be modified for the design of an overlay that is based on deflection data. Stiffness is not always an indicator of stronger properties or performance characteristics. As shown in this case, a slightly forgiving subgrade can provide better performance, although according to the design based on deflection data the nonwoven section would need strengthening to carry design loads.

Durability of Fabric

The nonwoven geotextile polypropylene did not show any loss of strength. Instead it showed some gain in mechanical properties. This finding agrees with the work done by Brorsson et al. (*4*) of the Swedish National Road Administration. That study also showed that after 10 years, nonwoven needle-punched polypropylene geotextiles kept their original strength fairly unchanged while the thermally bonded nonwoven geotextiles lost approximately 50 percent of their original strength. These data also agree with other work done by Phillips Fibers Corporation to evaluate the life expectancy of Supac (*5*). The virgin data shown in Table 2 represent the "minimum average roll values" in the weakest principal direction, and test data for exhumed samples are the actual test data for field samples. Another good indication of the excellent durability characteristics of Supac is the percent of elongation. Generally in the degradation process the fabric loses elongation properties and strength. Review of the elongation data shows no change in elongation properties compared with the unused samples. To further evaluate the chemical durability of the polypropylene resin, infrared analysis shows that no oxidation of the geotextile occurred. The infrared data show that there is no change in the molecular weights of three samples tested (i.e., virgin material) and the fabrics exhumed in 1988 and 1993.

Performance

Although subgrade soils were fat clays, which are known to hold moisture and are prone to pumping, none of these problems was observed below the nonwoven geotextile section. In comparing overall project conditions (including no potholes in the fabric section compared with the lime-treated control, surface conditions as good as control, and same current PSI) it is clear that the geotextile section has performed its separation and stabilization function

TABLE 4 Cost Analysis, 1984

Type of Treatment	Treatment Cost/M²	Pavement Layers Cost/M²	Total Cost/M²
Supac 8NP Fabric	$ 1.52	$4.55	$ 6.07
Lime - 610 mm (24") Thick	$12.82	$4.55	$17.38

Calculated per mile cost of subgrade treatment and pavement layers, 7.32 M (24 ft) wide.

Supac 8NP fabric..........................$ 71,526
Lime Treatment - 610 mm (24") thick........$204,723

for the past 9 years. From a pavement life-cycle analysis it is clear that the geotextile section required less maintenance and should continue to show a longer pavement life due to its long-term establishment of a separation and stabilization layer, compared with the lime-stabilized system, which will continue to break down over time.

Cost-Effectiveness

The cost of the lime-treated section was $11.26/m² ($9.46/yd²) higher than the geotextile section. Table 4 presents a cost analysis. After 6 months, the lime-treated section pavement surface failed due to severe spring weather conditions and required 38 mm (1½ in.) of additional overlay. The geotextile section did not need the additional overlay, but because it was in the middle of the lime-treated sections it received the same overlay treatment. Had the fabric section been left unpaved, which might not have been practical, the cost-benefit ratio would have been much higher. The approximate additional cost was $2.97/m² ($2.50/yd²) for an overlay plus the maintenance cost of repairing potholes before an overlay. These additional costs are not included in the table.

CONCLUSIONS

- The Supac 8NP nonwoven needle-punched polypropylene geotextile did not lose any strength properties during 9 years of service life.
- Based on infrared test data, there is no chemical degradation or change in molecular weight of the polypropylene resin in the geotextile.
- Supac 8NP performed its intended function of separation and stabilization.
- Actual pavement performance, based on PSI data and visual inspection of the control and Supac sections, is the same for all practical purposes; that is, the basic performance of the Supac 8NP section is equivalent to that of the 24-in. lime-treated subgrade.
- There is a strong need to develop new design methods based on Benkelman beam deflection measuring devices for designing geotextile-incorporated pavements.
- Significant savings in both construction and maintenance costs can be realized by incorporating a geotextile in road design. Geotextiles bring down the life-cycle cost of pavements.

REFERENCES

1. Hicks, R., and B. Jorenby. Base Course Contamination Limits. Presented at The 65th Annual Meeting of the Transportation Research Board, Washington, D.C., 1986.
2. Barenburg et al. *Evaluation of Soil-Aggregate Systems with Mirafi Fabric.* University of Illinois, Urbana.
3. *Interim Guide for Design of Pavement Structures,* Washington, D.C.
4. Brorsson et al. Long-Term Properties of Geotextiles and their Function as a Separator In Road Construction. *Proc., 3rd International Conference on Geotextiles,* Vienna, Austria, 1986.
5. *Stabilization Design Guide.* Phillips Fibers Corporation.