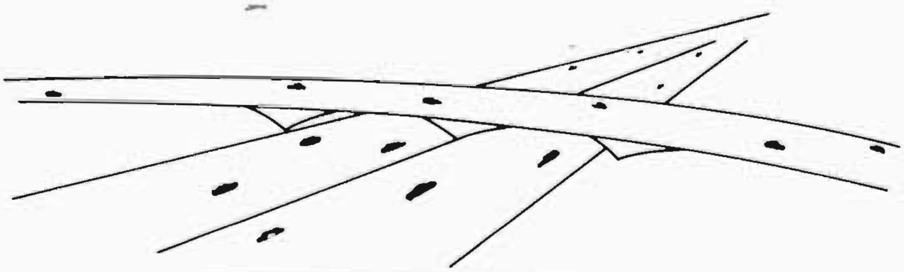

DEPARTMENTAL RESEARCH

Report Number 187-9

HORIZONTAL PLACEMENT OF A GEOTEXTILE ON A SUBGRADE TO CONTROL A SWELLING SOIL

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

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16. Abstract

Geotextiles may control swelling soils that cause considerable damage to America's highways. In 1980, expansive soils caused an estimated $7 to $9 billion damage in the United States, half occurring on roads, streets and highways. The Texas State Department of Highways and Public Transportation (SDHPT) conducted field testing of early generation fabrics on a San Antonio project. The fabrics were placed on an active subgrade with a high potential vertical rise using adjacent roadway sections as controls. Five years of testing with field elevations, dynaflect observations, photologging, and profilometer measurements computerized to serviceability indices give strong indications that fabrics contribute to reduced movement, increased strength, reduced pavement cracking, and generally smoother riding characteristics.

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HORIZONTAL PLACEMENT OF A GEOTEXTILE ON A SUBGRADE TO CONTROL A SWELLING SOIL

by

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District 15

Texas State Department of Highways and Public Transportation

Study No. 1-10-77-187
Report No. 187-9

February, 1983

DEDICATION

This report is dedicated to John Nixon, Engineer of Research for the State Department of Highways and Public Transportation, for his many years of service to the people of this state and for his guidance, concerns, and affording opportunity to the author of this paper.

The material contained in this report is experimental in nature and is published for informational purposes only. Any discrepancies with official views or policies of the DHT should be discussed with the appropriate Austin Division prior to implementation of the procedures or results.

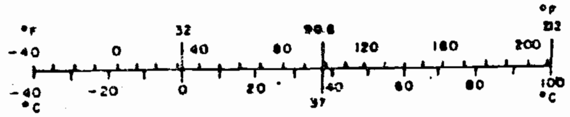
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

Swelling soils caused an estimated $7 to $9 billion damage in the United States in 1980 (Ref. 1). Fifty percent of the damage occurred to highways. Texas is one of 20 states impacted by these expansive and destructive subgrades, at a cost to its roadway system probably exceeding $200 million. These damages can be seen on many facilities. On highways and streets they are frequently reflected in distorted, twisted, bumpy, rough riding, unsafe pavements.

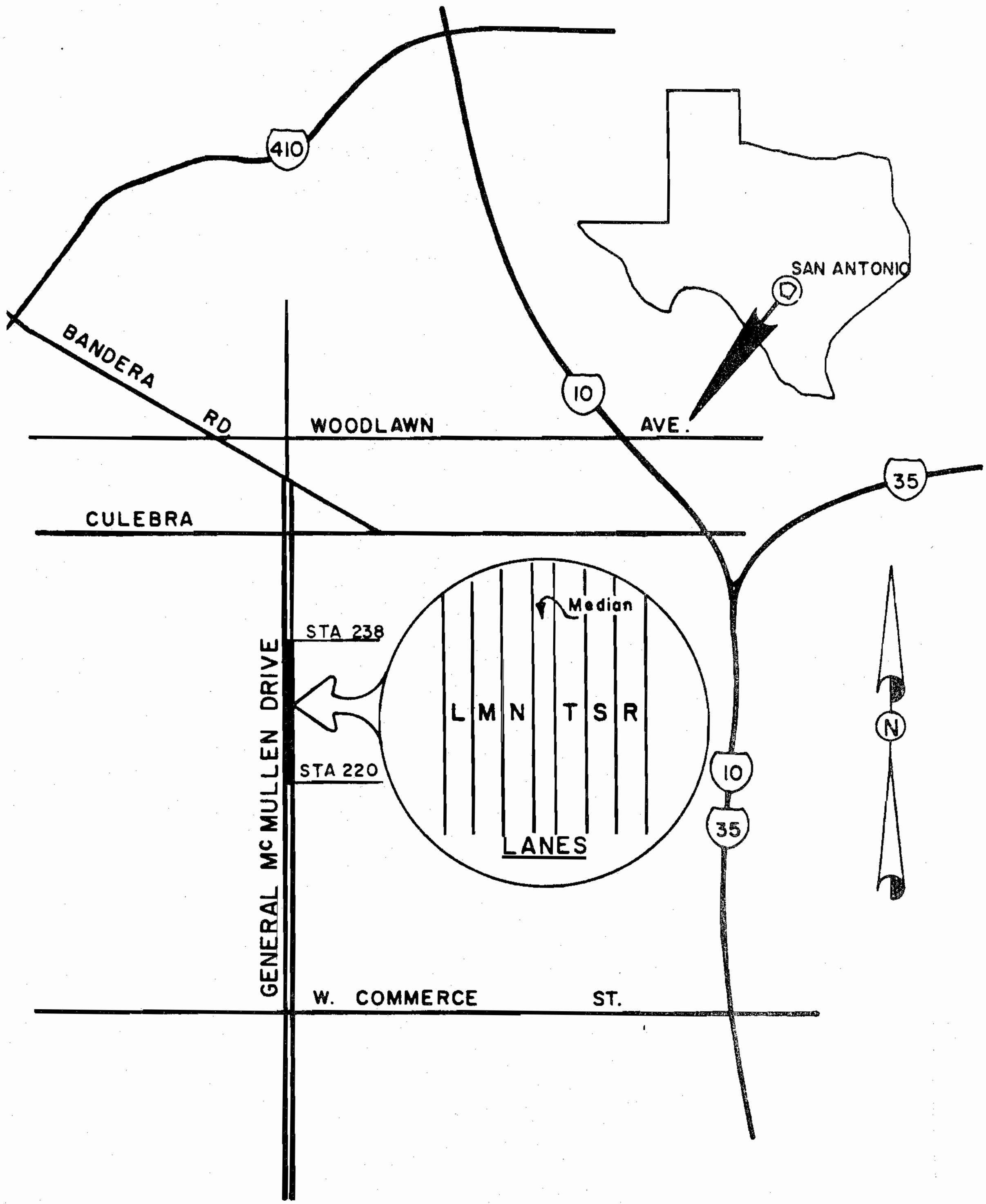
The State Department of Highways and Public Transportation has sought to solve this problem for decades. They have worked cooper-atively with Texas Transportation Institute (at Texas A & M University) and the Center for Transportation Research (at the University of Texas) in an effort to reduce the destruction and continuing dollar drain. A wide variety of state and federal agencies, the Transportation Research Board and governments around the world have sought solutions to expansive soil problems, resulting in many tests and reports. Many of these techniques have been tried in Texas, including soil selection, removal of the existing subgrade, ponding, chemical stabilization, deep sand backfilled underdrains, and fabrics (Refs. 2, 3, 4, & 5).

The San Antonio project, in South Central Texas, has a coated spunbonded polypropylene fabric placed on an active clay subgrade. Monitoring this work since 1977 has provided results that indicate the potential value of the horizontal placement of coated fabric on an expansive soil.

PROJECT HISTORY

San Antonio is a rapidly growing city with considerable expansive soils. General McMullen Drive, a major arterial street in southwest San Antonio, reflected the destructiveness of the swelling clays (Fig. 1).

FIGURE 1



410
BANDERA RD
WOODLAWN AVE.
CULEBRA
10
35
SAN ANTONIO
STA 238
STA 220
GENERAL McMULLEN DRIVE
Median
L M N T S R
LANES
N
10
35
W. COMMERCE ST.

The roadway pavement was cracked, distorted, and uneven. The concrete median, sidewalks and curbs also reflected these irregular movements.

The City Council selected General McMullen Drive, from West Commerce Street to Culebra Road, as an urgently needed major street repair not on the State Highway System, but eligible for Urban System Funding. The SDHPT accepted the project and prepared plans for its reconstruction.

The Bexar County soils map prepared by the U.S. Department of Agriculture, Soil Conservation Service and the Texas Agriculture Experimental Station, indicated that this street crossed the Louisville-Houston Black Terrace Association, a deep calcareous clay soil in an old alluvium (Fig. 2). In the General McMullen test area, the soil types include the Houston black clay series, deep dark gray to black and calcareous. It is structurally weak with a very fine blocky conformation. Subsurface layers tend to be a lighter color that crack when dry and swell when wet. Drainage in these soils is slow to rapid on the surface, while internally it ranges from slow to none. Rainfall is rapidly absorbed when the soil is dry and cracked, but practically all of it runs off after the clay's point of water saturation has been reached. The soil survey's engineering interpretation section indicates this material makes very poor road subbase or fill.

The SDHPT drilled test holes in December 1973 at three project locations. At engineer's station 194, the clays varied from tan to brown to a depth of 14 ft. where a 3-ft. layer of sand and gravel was found above a brownish clay at 17 ft. At station 224+50, the clays extended to 16 ft. with a strata of sandy water-bearing clay with gravel from 7 to 12 ft. At station 238+50 the black, marly clays extended from the surface to 4 ft., a 2-ft. layer of clayey gravel, then brown and shaley clay to 21 ft. Atterburg limits indicated plasticity indices from 11 to 47 and liquid limits from 26 to 72. Using the McDowell method, potential vertical rise (PVR), was calculated: 2.5 in. at station 194, 4.5 in. at station 224+50, and 3.25 in. at station 238 (Fig. 3).

FIGURE 2

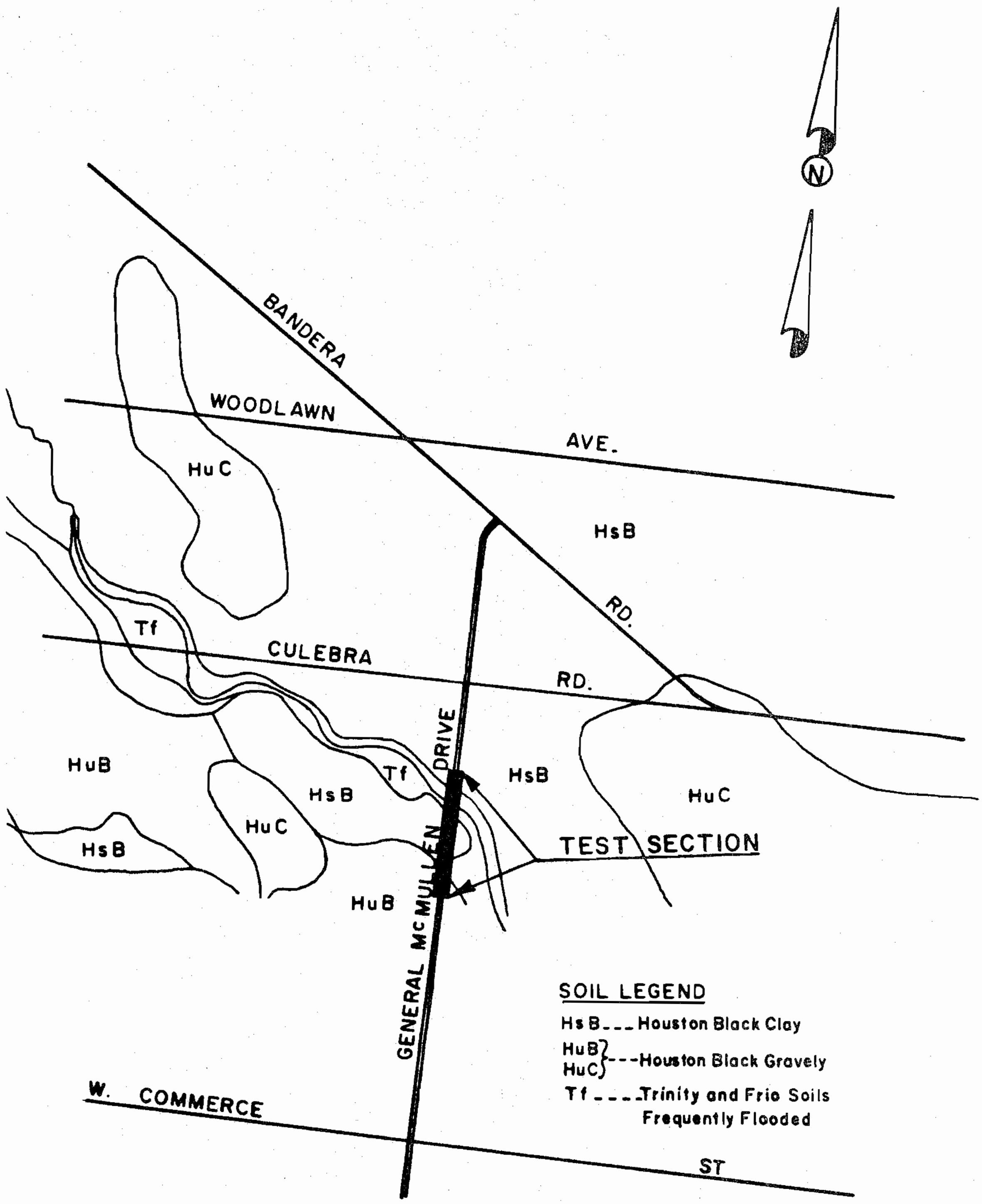
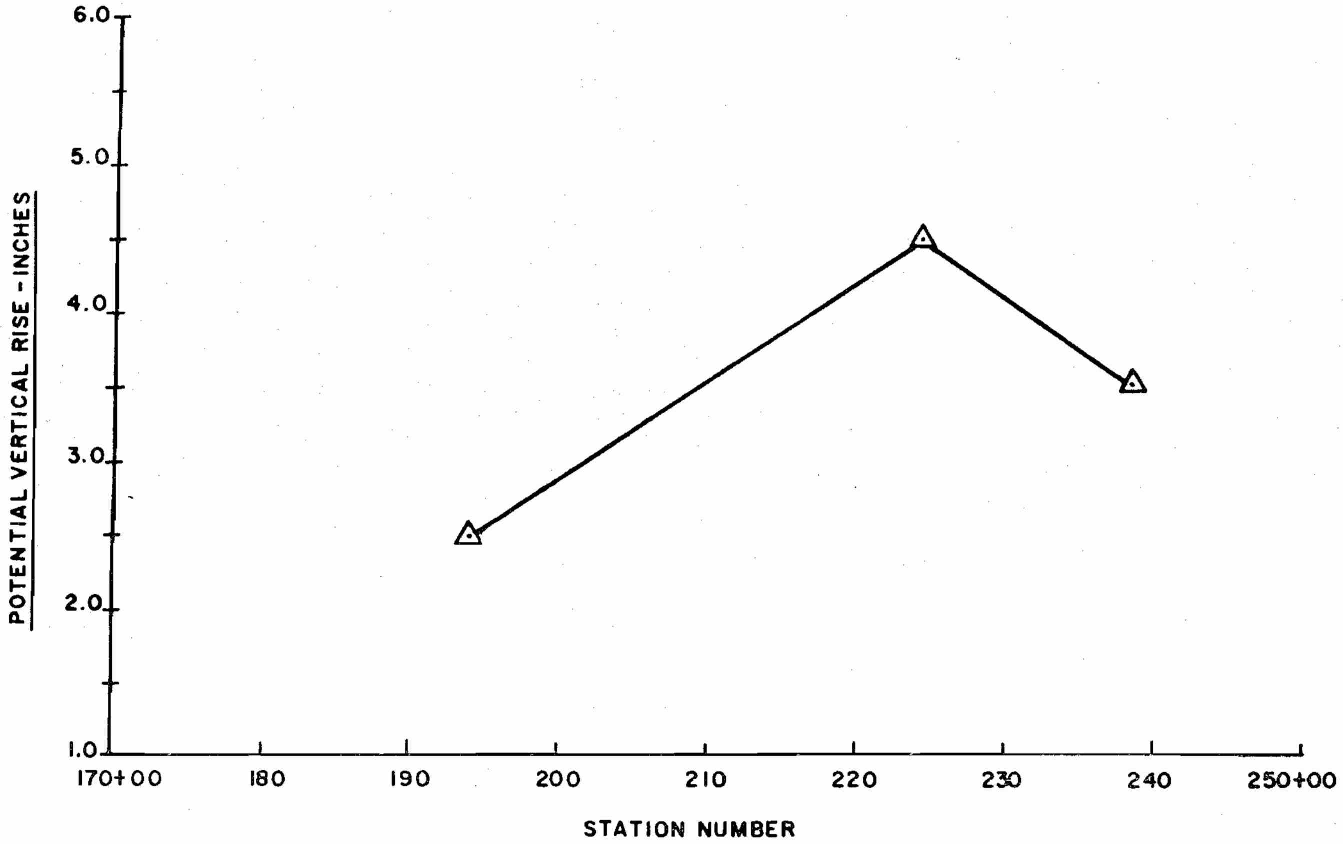

BANDERA
WOODLAWN
AVE.
RD.
CULEBRA
RD.
DRIVE
GENERAL McMULLEN
W. COMMERCE
ST
HuC
HsB
Tf
HuB
HsB
Tf
HsB
HuC
HuC
HsB
HuB
TEST SECTION
N
SOIL LEGEND
HsB---Houston Black Clay
HuB, HuC---Houston Black Gravely
Tf----Trinity and Frio Soils Frequently Flooded

FIGURE 3

CALCULATED POTENTIAL VERTICAL RISE



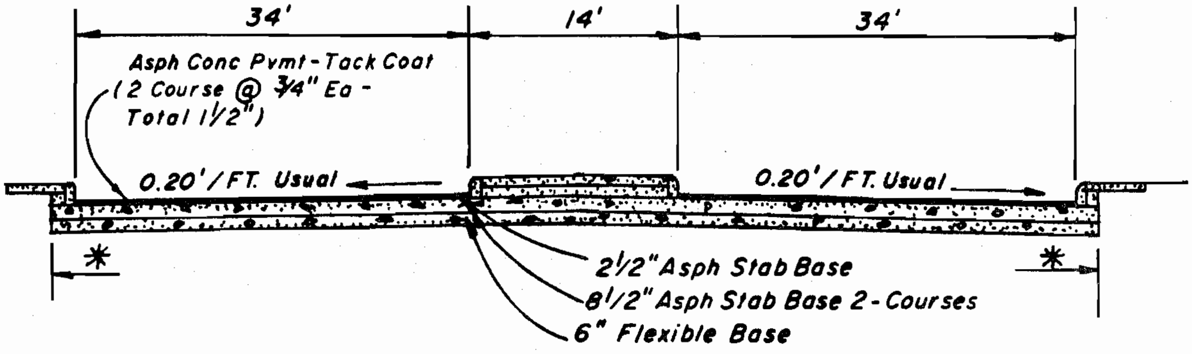
The SDHPT's plans specified the existing city street to be removed in half sections and rebuilt. The typical section had 6 in. of flexible base, 11 in. of black base (8.5 in. in two courses and one 2.5 in.) and a 1.5-in. finish course (Fig. 4). The contract on the 3.2-mi. improvement was awarded to the Kelly Construction Company with a low bid of $1,698,425. They began work in January 1976 and completed the improvement in May 1977. This project was, to the author's knowledge, the first in Texas where a coated fabric was placed on an expansive soil subgrade with the intent of evaluating its effectiveness in controlling swelling clays. The fabrics used were DuPont's coated Typar spun-bonded polypropylene Styles 3353 and 3153 (Table 1). Colorado's tests using the material indicated the coated fabric's potential in controlling the swelling soils' destructive impact on pavements.

CONSTRUCTION PROCEDURES

The contractor began work on the roadway's west side, constructing that half section, removing the existing pavement and building the future southbound lane. The coated fabric, Style 3353, for the west half was placed June 3, 1976 on the subgrade between stations 226 and 232. The coated fabric was delivered in 10 ft. wide rolls and used on a 600 ft. section ultimately 90 ft. wide from subgrade crown to crown. Four and a half roll widths were used. Each roll lapped 1 ft. over the one laid previously, the last one was cut in a half width. All laps were tacked with emulsion. Two full roll lengths covered the section.

The rolls were placed by a six man crew from SDHPT's Southwest Bexar Maintenance Section, since the test section was not a contract item. The emulsion was brought to the job in a portable heater and was placed with a hand hose, on the edge to be lapped. Then the next roll was placed. It took four hours to spread the eight full and two half section rolls. Rear-dumping tractor trailer trucks hauled and unloaded base on the coated Fabric.

FIGURE 4



TYPICAL SECTION
GENERAL McMULLEN DR

* Full Subgrade Width Of Typar Fabric.
Sta 226+00 To Sta 232+00

TABLE I, PHYSICAL PROPERTIES SYTLE 3153 AND STYLE 3353 TYPAR SPUNBONDED POLYPROPYLENE (EXTENSION COATED WITH POLYPROPYLENE)

	STYLE 3153	STYLE 3353
Weight - oz./yd.^{2}	2.4-2.6	4.8-5.1
Thickness - Mils	7-9	17-20
Grab Tensile - lbs.	85	130
Grab Elongation - 5%	67	55
Trapezoidal Tear - lbs.	30	60
Mullen Burst - psi	70	150
Permeability (perms)	3	25
Puncture - lbs./in.^{2}	52	130

Specific Gravity - 0.95

Melting Point - 340° F.

NON-PROPRIETARY DESCRIPTION

A sheet structure composed entirely of randomly dispersed isotactic polypropylene continuous filaments thermally bonded mostly at the crossover points and extrusion coated with polypropylene.

A front-end loader moved some of the base over the lapping sections to secure the sheets and minimize any fabric movement. A maintainer bladed and spread the base. None of the operations visibly tore the fabric. Truck turning tended to pull it and created some air pockets.

On June 14, 1976, following paving the southbound lane and opening it to traffic, the second coated fabric test section was placed. The subgrade was covered with coated fabric from station 226 to 232 with placement from the centerline to the east crown. A roll of Typar Style 3153, lighter than Style 3353, was placed along the east crownline to compare it's effectiveness. The lighter material was overlapped by 4 ft. of the heavier fabric. Subsequent laps were 1 ft. wide. Following the placement of the base, black base and surface courses, testing procedures began.

METHODS OF EVALUATION/TESTING

The SDHPT at residency, district and Austin headquarters cooperated closely with the Center for Transportation Research in conducting and evaluating the coated fabrics' effectiveness on this expansive subgrade. Adjacent 600 ft. roadway sections to the north and south were used as controls for comparison with the coated fabric section.

Elevations were taken by SDHPT on the finished pavement beginning in 1977. The average movement, whether up or down from the first reading, indicated little variation. The control section from stations 220 to 225+75 averaged from .04 ft. (.5 in.) to .08 ft. (1 in.) at the outside crown points; between 233 and 238, all averages were .04 ft. (.5 in.) and on the fabric protected pavement .04 ft. (.5 in.) to .05 ft. (.6 in.). These are minimal and a credit to the Department's design used with the asphalt stabilized bases. The maximum elevation variation occurred at station 221 with a downward movement of -0.19 ft. (2.25 in.) at the east crown. The largest upward movement was +0.14 ft. (1.6 in.) at station 220. In the coated fabric section, the maximum change was -0.10 ft. (1.25 in.) at station 232 with only negligible upward movement. The PVR calculations predicted movements from 2.5 in. to 3.25 in. upward in the control section to 4.5 in. in the fabric protected section. The actual maximum upward movement took place in the control section. The maximum predicted movement has not occurred. The added value of the coated fabric in the most active area must be considered (Table II).

Photologging was used in measuring fabric effectiveness, with testing in 1981 and 1982. The procedure involved taking pictures in each lane, of the entire pavement, with a camera mounted 8 ft. high on a moving vehicle. Each slide, showing a roadway section one lane wide and 8 ft. long, was projected onto a grid screen divided into 100 rectangles. The number of rectangles containing cracks were counted and calculated as a percent of the total.

The percent of area cracked in January 1981 ranged from zero to 1.08% with the maximum cracking occurring in the non-fabric protected sections (Table III). Of the six lanes analyzed in January 1981, four of the coated fabric protected lanes indicated zero percent cracked. On the control sections, two and three lanes had no cracking. Averaging the percent cracking by the photologging process indicated 50 to 250% higher levels on the control non-fabric sections. The highest was 0.59% and 0.38% both on the non-fabric protected section. The lowest average was on the coated fabric section, 0.24%.

In June 1981, maximum cracking again occurred on the control sections, unprotected by the fabrics - 1.8% compared to 1.42% in the treated area. Average cracking was higher in the non-protected sections, 0.71% and 0.43%, compared to the coated fabric's 0.32%. Again, four of the coated fabric lanes had no cracking while this condition existed in three control lanes. In January 1982 photologging, the maximum percent cracking was 1.64% in the non-fabric section and 0.73% over the coated fabric. The averages were 0.59% and 0.27% for the control sections and 0.21% for the coated fabric.

TABLE II, GENERAL MCMULLEN DRIVE
DIFFERENCES IN ELEVATIONS 1977 - 1981

		LEFT		RIGHT	
	Station	L.G.* Outside Edge	L.C.P.* Crown Point	R.C.P.* Crown Point	R.G.* Outside Edge
	220+00	-0.15	+0.14	-0.06	-0.09
CONTROL	221+00	+0.02	-0.05	-0.05	-0.19
	222+00	-0.02	-0.04	-0.05	-0.08
	223+00	-0.03	-0.04	-0.05	-0.05
	224+00	-0.03	-0.04	-0.05	-0.04
	225+00	+0.01	+0.01	-0.05	-0.05
	226+00	-0.04	-0.04	-0.05	-0.04
	227+00	-0.05	-0.07	-0.06	-0.06
FABRIC	228+00	-0.06	-0.05	-0.06	-0.06
	229+00	-0.06	-0.04	-0.04	-0.05
	230+00	-0.04	-0.02	-0.04	-0.04
	231+00	0.00	+0.01	-0.02	-0.04
	232+00	-0.10	-0.07	-0.02	0.00
	233+00	-0.04	-0.04	-0.05	-0.05
CONTROL	234+00	-0.05	-0.05	-0.06	-0.05
	235+00	0.00	-0.03	-0.04	-0.02
	236+00	-0.03	-0.03	-0.02	-0.02
	237+00	-0.09	-0.06	-0.03	-0.03
	238+00	-0.03	-0.03	-0.05	-0.07

* L.G. = Left Gutter

L.C.P. = Left Crown Point

R.G. = Right Gutter

R.C.P. = Right Crown Point

TABLE III, PHOTOLOGGING TESTS PERCENT AREA CRACKED

Date	Section	L	M	N	T	S	R	Average
1-81	Control	1.08	0.97	0.51	0	0	0.98	.59
	Fabric	1.07	0	0	0	0	0.36	.24
	Control	0	1.05	0.69	0	0	0.54	.38
6-81	Control	1.26	1.6	0	0	0	1.4	.71
	Fabric	1.42	0	0	0	0	0.5	.32
	Control	0	1.8	0.1	0	0	0.7	.43
1-82	Control	0.62	1.25	0	0	0	1.64	.59
	Fabric	0.73	0.03	0	0	0	0.52	.21
	Control	0	1.43	0	0	0	0.16	.27
8-82	Control	1.09	1.65	0	0	0	3.93	1.11
	Fabric	1.64	0	0	0	0	0.53	.36
	Control	2.07	0	0	0	0	0.40	.41

August 1982 indicated maximum cracked areas in the south control of 3.93% with an average of 1.11% for its sections. The coated fabric covered sections had a maximum value of 1.64% and an average of 0.36%. The north control pavement had a maximum lane cracking of 2.07% with an average of 0.41%. Both controls had more cracking than the coated fabric section.

A cracked pavement will permit more water to pass into the base and subgrade. The drying with cracking followed by wetting is an essential element in the swelling clay cycle of heaves. It may be that as cracking over expansive clays increases, so will pavement distortion. The trend over a time period shows an increasing percent of cracked area with the inside lanes showing the least amounts.

Dynaflect testing was conducted in August 1973 prior to construction, and in January 1981 and March 1982 after construction. A static tire loading test device was used. At any particular test location, five geophone readings were taken and a curve was plotted. Stiffness coefficients, spreadability and maximum deflection were calculated. The stiffness coefficient separates subgrade values from the pavement's total section. The higher the number, the greater the strength. The preconstruction subgrade values showed a uniformity. In March 1982 the coated fabric protected section subgrade value was slightly lower than the adjacent ones. Pavement values for the coated fabric protected section appeared to be slightly higher (Table IV). Maximum deflection was calculated by multiplying geophone number one values by 22.5 to simulate the movement produced by an 18 kip load, and this reflects subgrade value properties. These tests in January 1981 and March 1982 indicated the subgrade under the coated fabric protected section had greater deflection in five of six cases and was possibly weaker (Table V). This may be related to its PVR, its greater expansive capabilities, or the holding of moisture under the material. Spreadability was calculated by summing the five geophone readings and dividing the sum by five times the geophone number one reading.

TABLE IV, STIFFNESS COEFFICIENTS

	Subgrade		Pavement	
Date:	8-73*	3-82	8-73*	3-82
North Control	0.20	0.20	0.60	0.95
Fabric	0.20	0.18	0.72	1.09
South Control	0.21	0.20	0.65	0.98

*Prior to Reconstruction

TABLE V, MAXIMUM DEFLECTIONS

Date:	1-81	3-82	1-81	3-82	1-81	3-82
Southbound Lanes	L		M		N	
Control	.015	.023	.017	.017	.022	.016
Fabric	.018	.022	.015	.017	.023	.019
Control	.012	.016	.013	.014	.016	.013
Northbound Lanes	T		S		R	
Control	.013	.015	.015	.015	.018	.020
Fabric	.019	.021	.019	.020	.025	.026
Control	.017	.017	.015	.017	.020	.023

The higher the value, the stiffer the pavement structure. In the January 1981 and March 1982 tests, the coated fabric sections showed the greatest (Table VI). The outside pavement lanes have developed a weaker pavement structure than the interior ones. This was expected since traffic was considered to be concentrated on the outside lanes.

The higher average stiffness coefficients on the total coated fabric protected section's pavement structure and its higher spreadability indices was significant from its placement on the most active and weaker subgrade section. This substantiated the effectiveness of coated fabrics as strengtheners of total pavement structure reported in studies (Refs. 6, 7 & 8).

Serviceability indices (SI) were developed from profilometer readings taken in July and December 1981 and June 1982. The computer program rated sections on a scale of 0 to 5 with the highest number indicating the smoothest riding surface. In July 1981, the coated fabric protected sections had higher SI's than the control sections in five of the six readings. The coated fabric section indices ranged from 3.86 to 2.64 while the control sections ranged from 4.14 to 2.17 (Table VII). In December 1981 and June 1982, the coated fabric sections showed higher values in four of six locations. In these latest measurements, the coated fabric sections ranged from 3.84 to 2.61 and the control sections from 4.13 to 1.95. SI's decreased with the passage of time in 14 of 18 cases. With the higher PVR in the coated fabric protected section, it was expected to have the rougher ride and lower SI, but this did not usually develop.

TABLE VI, SPREADABILITY INDICES

Dates:	1-81	3-82	1-81	3-82	1-81	3-82
Southbound Lanes	L		M		N	
Control	81	74	79	79	76	80
Fabric	86	78	83	83	83	83
Control	81	75	79	79	74	80
Northbound Lanes	T		S		R	
Control	79	79	79	80	80	76
Fabric	84	82	84	82	84	77
Control	80	81	82	81	80	73

TABLE VII, SERVICEABILITY INDICES

	Outside			Center			Inside		
	7-81	12-81	6-82	7-81	12-81	6-82	7-81	12-81	6-82
Northbound Lanes									
South Control	2.75	1.73	1.95	3.67	3.54	3.25	3.85	4.11	4.13
Fabric Section	3.63	3.62	3.58	3.86	3.72	3.59	3.41	3.30	3.33
North Control	2.17	2.81	2.92	3.69	3.68	3.67	4.14	3.88	3.87
Southbound Lanes									
South Control	2.32	1.95	2.16	3.09	3.01	2.94	3.41	3.34	3.31
Fabric Section	2.64	2.58	2.61	3.83	3.81	3.84	3.86	3.84	3.75
North Control	-	2.70	2.60	3.68	3.61	3.64	3.61	3.53	3.56

SUMMARY

Preconstruction testing, the Atterburg limits, a maximum plasticity index of 47, and potential vertical rise (a maximum of 4.5 in.) confirmed what the eye perceived. Expansive clays had severely distorted the existing pavement. Following reconstruction which included a fabric section, testing programs continued. Elevations showed a maximum rise of 1.625 in. and a maximum fall of .5 in. on the non-fabric protected control section. Movements in general were minimal. Photologging, measuring the percent area cracked, showed a maximum of 3.93% in the control section. Average percent cracking in each of the four test periods showed the fabric protected sections with the least amounts. Stiffness coefficients (from dynaflect testing) were lower for the fabric protected subgrade compared to the adjacent areas - 0.18 and 0.20 respectively. The pavement measurements showed higher values for the fabric section as did the maximum deflection, in 9 of 12 cases. Spreadability indices, between 74 and 86, similarly had higher values in the fabric areas. This pattern was repeated with the serviceability indices, a measure of the profilometer's ability to indicate a quality of ride. Of the perfect 5.0, values ranged from a low of 1.73 to a high of 4.14, both on control non-fabric covered subgrades. On four of the last six tests, the fabric protected section provided the smoother ride despite its placement on the potentially most active area.

CONCLUSION

The coated fabric was placed over the more active clay subgrade. Vertical pavement movement has usually been minimal throughout and not reached the estimated PVR. Maximum elevation changes took place on the non-fabric covered sections. Comparing photologging, dynaflect and profilometer results, the coated fabric pavement indicated less cracking, a stronger pavement system rating on a weaker subgrade, and better profilometer readings than the adjacent control sections. Evaluating the lighter coated fabric against the heavier one doesn't seem feasible due to the small width considered. The coated fabric's use is viewed with guarded optimism. It may provide substantial contributions to minimizing losses of pavement systems. Expanded use and observation seems justified.

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