Vertical Moisture Barrier Update

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Damages from expansive soils in the United States exceed $10 billion a year. The challenge has been addressed by international conferences, universities, research institutes, and federal, state, and local organizations. The concept of minimizing volumetric change by minimizing moisture change led to the use of a vertical moisture barrier. The Texas Department of Transportation (TxDOT) first used a vertical fabric moisture barrier on a ½-mi section of Interstate 410 with a fabric bid price of $20/lineal-ft. The latest TxDOT project has 14 mi of these barriers, at a cost of $6/lineal-ft. Nineteen vertical fabric barrier projects are reported. Annual maintenance costs have been reduced, and repeated resurfacings are no longer necessary. Vertical moisture barriers can minimize these destructive movements.

Expansive soils seem to exist worldwide. In the United States, damages from expansive soils exceed $10 billion a year. In this country, federal, state, and local agencies; universities; and the armed forces have funded projects to study the problem (*1*).

Studies have found that expansive soils have volumetric changes related to moisture changes. Earlier, monitoring of a ponding project discovered the zone of activity in which the significant moisture changes in a clay were taking place. This activity was also found in a study of several U.S. locations (*2*). If these moisture changes could be minimized, then the volumetric changes that cause pavement distortion could similarly be minimized. In the late 1970s the Texas Department of Transportation (TxDOT) installed its first geomembrane to minimize moisture changes in expansive soils.

The first TxDOT field test with a waterproofed fabric involved 600 ft of the San Antonio Urban Systems Project. The most recent project on Interstate 45 involved 285,000 of lineal-ft vertically placed fabric bid at $6/ft, totaling almost $1.5 million. More than a decade of results are assessed. It should be noted when the vertical moisture barrier is effective as well as when it is not. When it is not effective, a postmortem is in order.

TEXAS CASE HISTORIES

The geomembrane, which is an impervious engineering fabric, was first used in Texas on General McMullen Drive, a San Antonio arterial street that TxDOT reconstructed to control expansive soils. On that project a DuPont-donated fabric was placed horizontally on the subgrade. The initial profilometer, Dynaflect, and photologging test results indicated positive impacts on reducing the destructive actions of the expansive clays. This successful procedure encouraged the inclusion of the deep vertical fabric moisture barrier (DVFMB) in the rehabilitation of Interstate Loop 410 on San Antonio's west side in the Valley High interchange area. Table 1 shows data relating to this and other Texas case histories.

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I-410

I-410 was the first DVFMB project (Figure 1) on the Texas highway system. The fabric was placed vertically, because the existing pavement was to remain in place. The original construction on this project was a hot-mix asphaltic concrete pavement (HMAC) over a flexible base and an expansive clay subgrade. The profile of the mainlanes on this four-lane divided highway varied from a natural ground level to a 20-ft cut section. The mainlane pavements were severely distorted by the swelling clays.

The 6-mi rehabilitation project plans called for the placement of 4,978 lineal-ft of geomembrane, 8 ft deep along both shoulders of the northbound lane. The fabric bid price of $20 lineal-ft was to include the geomembrane costs, placing, backfilling the trench sand backfill, and disposing of the trench excavation. The project's low bid came from the Austin Bridge Company, at $3,696,257 for work that was primarily a HMAC overlay. A backhoe was used to excavate the trench. The specified depth evolved from an earlier ponding project for which the activity zone of these clays varied from six to eight ft. The depth also complied with the manufacturer's standard width of 3 m, while permitting a 2-ft lap to the paved shoulder. The backhoe operation led to the sliding and caving of the trench walls. A subcontractor used sliding shoring pulled by a backhoe. Placement of a Typar T-063, and ethyl vinyl acetate (EVA)–coated geomembrane fabric, averaged 600 ft/day.

Testing began upon project completion in 1979. Profilometer readings, reduced to serviceability indexes (SIs), photologging, and moisture sensors were used. It was observed that the fabric-protected northbound lane had the higher SIs (an SI of 5 being smoothest, decreasing values indicating rougher surface), less pavement cracking, and less moisture change under the pavement than the adjacent southbound lane that was used as the control section (Figure 2). A 1986 widening project included the placement of fabric in the southbound lane, which resulted in the loss of the control section.

I-37, San Antonio

I-37 in southeast San Antonio had been suffering extreme pavement distortion (*1*). The 2-mi reinforced concrete pavement section between Hackberry Street and Pecan Valley Drive required a minimum of $50,000 of asphalt overlays almost every 6 months. After the favorable results from the

TABLE 1 Comparison of 19 Texas Vertical Moisture Barrier Projects

Highway	Location (in Texas)	Geomembrane LF	Geomembrane Bid $/LF	Contract Bid (in 1000's)	Year	Performance
IH 410	San Antonio	4,978	20.00	3,686	1978	Good
IH 37	San Antonio	21,483*	21.00*	5,275	1980	Good
IH 10	San Antonio	24,745*	15.00*	4,232	1983	Good
US 281	San Antonio	4,705*	3.18*	253	1983	Good
IH 30	Greenville	2,000	10.00**	3,248	1984	?
IH 10	Hudspeth County	50,098	13.28	10,600	1984	Good
IH 10	Culberson/Jeff Davis Counties	40,442	19.95	5,100	1985	Good
IH 10	Bexar County	131,200	13.00	7,530	1985	Good
SH 97	Atascosa County (Charlotte)	5,600	10.00	1,102	1986	Not Good
FM 465	Guadalupe County	3,100	10.00***	78	1986	Not Good
FM 725	Guadalupe County	6,840	20.00	162	1986	Not Good
IH 10	Guadalupe Co. (Santa Clara Creek)	12,000	15.00	845	1987	Good
US 87	San Antonio	45,000	13.50	1,629	1987	Good
IH 10	Guadalupe County	14,000	11.42	2,321	1988	Good
IH 10/US 90	Guadalupe County	52,800	11.00	2,402	1988	Good
FM 1516	Bexar County (East)	14,400	10.00	1,874	1989	Good
IH 635	Irving	3,638	15.80	8,800	1989	?
US 84	Snyder	46,000	10.50	3,406	1990	Good
IH 45	Waxahachie	285,140	6.00	18,000	1990	Under Construction

*Bid at square yard.
**Bid at square yard plus stab. cap/c.y.
***Geomembrane supplied by state.

Loop 410 section, a DVFMB was included in the 1980 rehabilitation contract. The 1968 construction of the freeway mainlanes started in a depressed section about 20 ft below natural grade. The subgrade was an active expansive clay. The base above it was cement-stabilized, with a reinforced concrete pavement. Soon after construction the pavement distortion began, as did the asphalt levelups.

The rehabilitation plans included creating positive drainage from the centerline median, asphalt levelup seal, 8-ft DVFMB (Figure 3), and a HMAC pavement. The low bidder was the Killian House Company at $5,275,238, with a DVFMB bid price of $21/yd² for the estimated quantity of 21,483 yd². The Loop 410 subcontractor excavated for the fabric with a trenching machine using a side boom to convey the excavated material to a dump truck. Typar T-063 was placed at a daily goal of 600 lineal-ft, set by the subcontractor and usually accomplished by 1:00 p.m.

Monitoring followed the completion of work. Moisture sensors indicated greater variation outside the fabric than inside

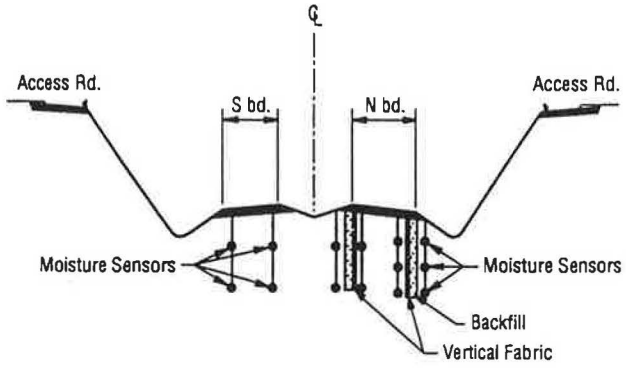

FIGURE 1 I-410 section.

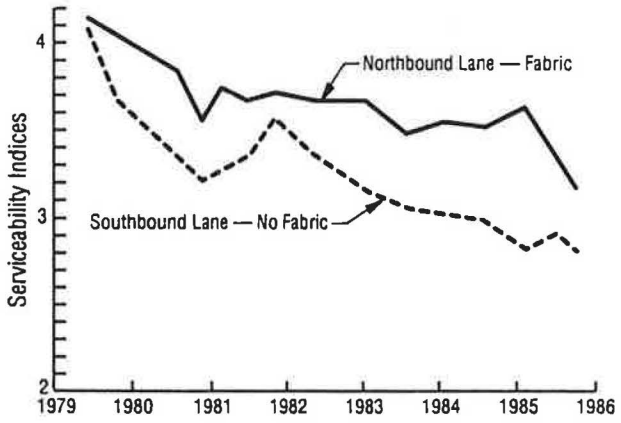

FIGURE 2 I-410 SIs.

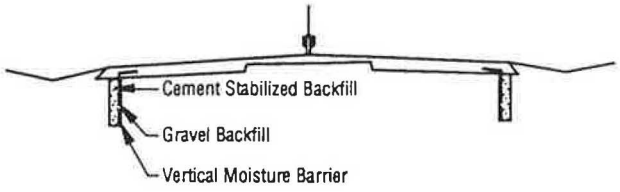

FIGURE 3 I-37 section.

the protected subgrade. Profilometer readings indicated higher SIs on the protected section than on the adjacent control segments. This changed when the north control was rehabilitated. North control SIs then were higher than the fabric-protected section, which remained higher than the south control (Figure 4). Profilometer readings in late 1990 indicated a drop in those SIs recorded on the north control and the fabric sections. It was not possible to determine the south control values because of a reporting variation. Through 1990 no rehabilitation or maintenance work was needed on the fabric section pavement. This was viewed as a tremendous improvement. The 1991 report indicated that two small sections required rotomilling (R. E. Magers, unpublished data).

I-10, Pine and Amanda Streets

I-10 between Pine and Amanda Streets on San Antonio's east side was constructed in the late 1960s. Its reinforced concrete pavement was placed above a cement stabilized base. The subgrade was a swelling clay with plasticity indexes (PIs) from 35 to 55 and liquid limits (LLs) from 65 to 76. Distortion began to appear in the pavement soon after construction was completed. Annual maintenance work to maintain a safe riding surface was performed. In 1983, a $4,232,000 rehabilitation contract was awarded that included 24,745 yd² of geomembrane. The fabric was to be placed 8 ft deep along the shoulders of both mainlanes.

The Dean Word Company was the successful low bidder and elected to use Mirafi MCF 500 and 140N geomembranes that met TxDOT specifications. Its DVFMB bid price was $15/yd². A trenching machine was used for excavation with a frame to direct the fabric into the trench and a conveyor boom to direct the excavated material to waiting dump trucks. Sliding developed in the trench walls, and the excavation was moved farther from the paved shoulder. The additional distance was covered with a geomembrane that received ultraviolet protection from a subgrade cover. The daily rate of placement was 250 lineal-ft.

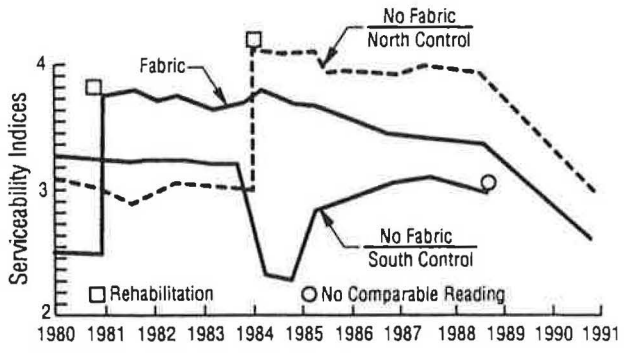

FIGURE 4 I-37 SIs.

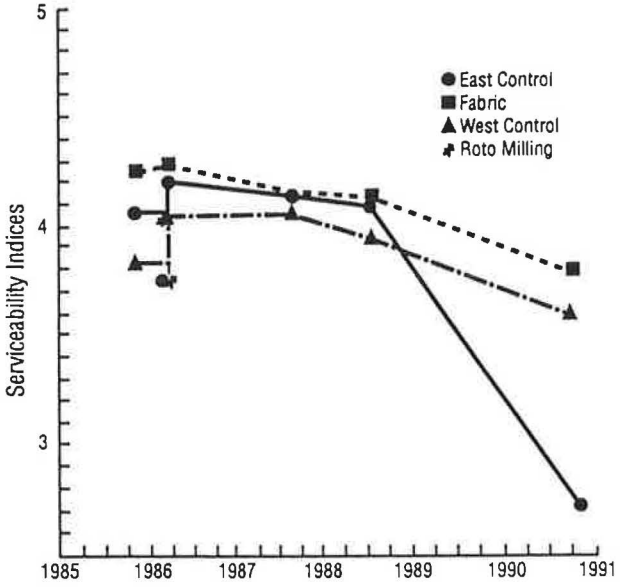

FIGURE 5 I-10 Pine to Amanda SIs.

Profilometer readings, beginning in 1986, proved that the fabric sections had the higher SIs (Figure 5). There has been a decline in these values. The resident engineer reports that no maintenance has been required on the pavement in the past 6 years: "It's made a believer out of me. The fabric section is doing good" (R. E. Magers, unpublished data).

US-281, MacAllister Freeway

The MacAllister Freeway, San Antonio's North Expressway (US-281), was constructed in the 1970s. Its southbound mainlane, just inside I-410 on the city's north side, began to experience pavement distortion. The freeway's divided highway section had a reinforced concrete pavement over a cement-stabilized base. The clays beneath the southbound lanes section, generally below natural ground, had PIs from 25 to 58 and LLs from 47 to 80. The adjacent northbound lane, of similar construction, initially escaped the pavement distortion. It was used as the control section in the testing following the 1983 rehabilitation contract.

The contract called for a HMAC levelup of the southbound lane pavement and the placement of a DVFMB 8 ft deep along its inside and outside shoulders. Creaco was the low bidder at $253,000; it chose a Mirafi MCF 560 geomembrane, bid at $3.40/yd² with an estimated quantity of 4,705 yd². A backhoe was used for excavation and, since the subgrade was very stable, no sliding or caving took place. Following construction, profilometer and photologging baseline records were made. Initial SI values indicated that the fabric-protected section had a smoother ride than the adjacent northbound lane that served as the control section (Figure 6). This section also had less pavement cracking than the control section, whose SIs dropped so low in 1987 that it was rehabilitated, but without fabric. Its SI values then exceeded those

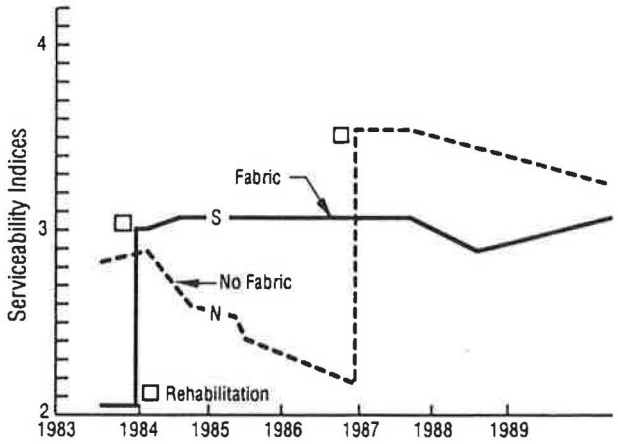

FIGURE 6 US-281 SIs.

of the southbound lane. The 1990 readings indicated a drop in the northbound lane values, whereas the fabric-protected southbound lane values generally held constant (G. K. Hewitt, unpublished data).

I-30, Greenville

I-30 in the Greenville area of northeast Texas was constructed in the 1950s. It has a 10-in. concrete pavement over 6 in. of cement-stabilized roadbed. The subgrade has PIs from 34 to 70 and LLs from 55 to 98. Over the years, the pavement has received asphaltic overlays that varied from 6 to 22 in. In 1984, 10-mi rehabilitation project bid at $3,248,000 included four 1,000-ft barrier test sections. The eastbound lane received fabric 6 and 8 ft deep, a lime slurry, and a lime slurry with fly ash sections. The adjacent westbound lane served as the control section. Native soil with a 2-ft cap of one-sack concrete was used as the backfill material of the fabric section.

The contractor bid the fabric at $10/yd^2 with the stabilized cap at $6.27/yd^3. This reduced to a roadway centerline fabric cost of $27.17. Placement rate of the fabric averaged 1,000 ft/day. The lime was placed in three staggered rows, parallel to the roadway centerline and spaced at 1-ft intervals. The lime bid was $12.73/centerline-ft. Initial moisture readings indicated increased moisture change in the fabric sections compared to the lime slurry sections. Barrier sections initially had lower SI values than the adjacent control sections. Excavation revealed that the lime slurries did not create a continuous curtain. Studies are continuing under the direction of R. L. Lytton of Texas A&M University.

I-10, Hudspeth County

In 1984 I-10 about 75 mi east of El Paso in Hudspeth County had a $10,600,000 rehabilitation project that included DVFMB. In a four-lane divided rural freeway built in the 1960s, planners recognized the presence of expansive clays. A 5-ft undercut of finished subgrade elevations was to remove suspected bentonitic clay. A low-PI inorganic material replaced the clay, and pipe underdrains with sand backfill were installed. The finished section included flexible base and HMAC pavement. The roadway surface remained stable for several years, than began to distort.

Remedial work included 50,098 lineal-ft of DuPont Typar 3358 EVA-coated geomembrane DVFMBs along both shoulders of the east- and westbound lanes. The plans called for a sand backfill with an 18-in. cement-stabilized cap. The contractor's bid for the fabric, placement, and backfilling was $13.28/lineal-ft. A Vermeer 800 trencher was used with a conveyor belt to carry the excavated material to a dump truck. Placement averaged 500 ft/day. Caving that included some shoulder loss occurred during trenching. It was thought that this took place generally in areas in which sand-backfill underdrains were located. Two field changes converted the backfill to gravel and then modified the gradation. The sand backfill apparently created problems in securing the fabric to the shoulders, causing wrinkling and undesirable air pockets.

Early SI readings indicated higher values for the control sections without the fabric. The soil profile indicated an intrusion of a highly plastic brown clay extending 600 ft into the fabric area and reaching to within 2 ft of finished subgrade elevation, along with 200 ft of bentonitic clay and gravel. These materials provided instability that the geomembrane could not control. Psychrometers had also been placed in the test areas. The results of early tests indicated that moisture changes were less inside the fabric area than outside (A. Bazan and R. R. Ellison, unpublished data).

I-10 Culberson and Jeff Davis Counties

I-10 in Culberson and Jeff Davis counties in West Texas had a 48-mi $5,100,000 rehabilitation contract awarded in 1985 (*1*). The four-lane divided highway had a flexible pavement with an asphaltic concrete surface. The work on the rehabilitation contract primarily involved a shoulder joint seal, an asphalt rubber seal coat, and an asphaltic concrete overlay. The work in Jeff Davis County, east of Kent, had 40,442 lineal-ft of DVFMB bid at $19.95/lineal-ft. The fabric was placed along both shoulders of the east- and westbound mainlanes to a depth of 8 ft. A gravel backfill provided the top 18 in. with a cement-stabilized base.

The contractor selected a Phillips Petromat MB nonwoven polypropylene with a polystyrene backing meeting TxDOT specifications. The trench excavation was done with a backhoe. Average daily production was 400 lineal-ft with a 1-day maximum of 1,000 lineal-ft. The presence of bentonitic clay was noted, along with rock and boulders. Sometimes the fabric was reported to be curled up, since the 8-ft depth could not be reached because of the boulders. Considerably less fabric might have been specified had further preconstruction soil profile testing been conducted.

The project was completed in October 1986. Reports through 1990 indicated that the DVFMB sections looked good and required no maintenance work. In 1991, problems started to occur. Field investigations revealed that some of the distorted areas, particularly those with considerable levelups, were well outside the DVFMB areas. In other cases of pavement swells, the fabric had been omitted due to construction traffic-handling problems (M. Jaso and K. Osborne, unpublished data).

I-10, Bexar County

I-10 in eastern Bexar County, between Loop 410, Ackerman Road, and Cibolo Creek, was constructed in the early 1960s (*1*). Upon completion, the four-lane divided freeway was described as the smoothest-riding road in the district. It had a HMAC pavement over flexible base, a foundation course, and a 6-in. lime-treated subgrade. Beneath that pavement section lay expansive clays. Soon the pavements began to distort, and reports indicate annual pavement maintenance costs of $100,000 to $200,000 on the 13-mi section.

In 1985, a rehabilitation contract was awarded that included 131,200 lineal-ft of DVFMB. The fabric was placed 8 ft deep along both shoulders of both mainlanes. The backfill was to be limestone screenings, with a 1-ft cement-stabilized base cap. The Dean Word Company was the low bidder at $7,530,000; its price for the DVFMB was $13/lineal-ft. It was TxDOT's first DVFMB contract for more than $1,000,000. A trencher was again used with the frame for the fabric placement and a conveyor handled the excavated material. Average daily rate of fabric placement was 900 lineal-ft, with a 1-day high of 2,195 lineal-ft. Difficulty in securing limestone screenings led to the use of limestone scalping, which was a finer-grade material. Shoulder cracking and depressions developed, from 1 to 6 in. deep, 2 to 6 ft in length, and up to 4 ft into the shoulder. Thorough investigation, including nondestructive methods, located voids in the backfill.

A contract was awarded to Olmos Equipment Company to place a flowable backfill of portland cement, fly ash, sand, and water (*3*). Its work in 1989 was at bid prices of $3.25/hole and $7/yd^3 for the pumped material. The pavement has served well since 1985; the shoulders are also doing well. Through 1990, no roadway maintenance work was necessary. In 1991 two small sections, 150 ft long, required levelup—"a great improvement" (D. R. Stein, Jr., unpublished data).

SH-97, Charlotte

SH-97 near Charlotte, Texas, between Pleasanton and Jourdanton, had a rehabilitation contract awarded in 1986 that included a DVFMB. The rural two-lane highway had a flexible base and an asphalt surface. It had been suffering from severe pavement distortion and cracking. The subsoils were known to be expansive clays. The contract included a HMAC levelup, seal coat, and surfacing, along with 5,600 lineal-ft of DVFMB.

The Brannan Paving Company was the low bidder at $1,102,000, and the geomembrane price was $10/lineal-ft, including all the material and related work. Brannan chose a DuPont geomembrane and used a Vermeer T-600C trencher. A gravel backfill was used; an average rate of placement was 700 lineal-ft/day.

The pavement began cracking again shortly after project completion. Investigation revealed similar cracking in a nearby school building, as well as nearby roads and curbs. Considerable faulting in the vicinity was thought to contribute to these damages. The DVFMB apparently has not helped the problem. SH-97 has since received several crack-sealing treatments (G. Clement and A. Farrer, unpublished data).

FM-465 and FM-725, Guadalupe County

FM-465 and FM-72 are two-lane rural highways in Guadalupe County that had rehabilitation work in 1986. The Dean Company was the low bidder on both. It used 580 LF DuPont Type T-063 from state supplies, on FM-465 bid at $10/lineal-ft, and 6,840 lineal-ft Phillips fabric 725 bid at $20/lineal-ft. Both projects reverted to a "roller-coaster" pavement ride, leading to the thought that the fabric was not placed deep enough (D. R. Stein, Jr., unpublished data).

I-10, Guadalupe County

Three projects were awarded in 1987 and 1988 in Guadalupe County east of San Antonio. The Dean Ward Company did the work on two of them: at Santa Clara Creek and from there to Seguin, which included part of US-90. A Remag fabric was used on the first project: 12,000 lineal-ft bid at $15/linear-ft and 52,800 lineal-ft of Phillips fabric at $11/lineal-ft a 5.9 mi project from Santa Clara Creek to Seguin. Zumwalt was the low bidder on the project from Cibolo Creek at the Guadalupe Bexar County line to Santa Clara Creek: 4.1 mi long, 14,000 lineal-ft of Remag fabries, bid at $11.12/lineal-ft. No maintenance work has been required on these projects (D. R. Stein, Jr., unpublished data).

US-87, San Antonio

US-87 in southeast San Antonio crosses an area of black gumbo clay—excellent for cotton cultivation, but not for a distortion-free pavement. The existing pavement section was a four-lane divided highway with a 40-ft median, with 6 in. of lime-stabilized subgrade, two 6-in. courses of flexible base, an asphalt seal coat, and HMAC paving. In 1987, the 8-mi widening and rehabilitation project included 45,000 lineal-ft of DVFMB at a cost of $4,232,000. The fabric was placed 8 ft deep along the inside and outside shoulders of both mainlanes. The contractor bid $13.50/lineal-ft for the fabric, its placement, trench excavation and backfilling, with 2½ ft of cement-stabilized base at the top. The contractor used a DuPont Typar EVA-coated polypropylene fabric. A trencher was used for the excavation, and at an 800-ft average daily rate, no special problems were observed during construction. A 1991 report indicated the section was performing well, and, in a change from previous recurring maintenance problems, none has existed since the contract was completed (R. E. Magers, unpublished data).

FM-1516, Bexar County

FM-1516 in eastern Bexar County, outside San Antonio's city limits, is a two-lane rural highway with a flexible pavement. It is built over the expansive soils that have caused considerable pavement distortion. In February 1989, a rehabilitation contract was awarded that extended from I-10 on the south to FM-78 on the north.

The low bidder was the Heath Construction Company, at $1,874.664. The work included 14,400 lineal-ft on DVFMB

on the 3.5-mi project. A Phillips fiber was chosen, and the backfill material specified was a graded aggregate. The contractor's bid price for the DVFMB was $10 lineal-ft. The excavation, placement, and backfilling were subcontracted. A trenching machine was used with a maximum daily production of 1,028 lineal-ft. Work was completed April 1990. The 1991 conclusion was that the pavement was "not doing too badly" (D. R. Stein, Jr., unpublished data).

I-635, Irving

I-635 is an Interstate loop in the Dallas area in Irving, Texas. It underpasses MacArthur Boulevard, a section that was included in a 1989 rehabilitation and widening project. The loop designers recognized the potentially destructive impacts of the Eagle Ford shale on which I-635 is built. The existing pavement is reinforced concrete over 8 in. of cement-stabilized select material with 4 ft of special subgrade replacement with a PI of 20 or less. The underpass area is a cut section about 20 ft below natural ground and has exhibited considerable movement in the past.

The 1989 contract totaling $8.8 million was awarded to Austin Paving Company and included their bid price of $15.80/lineal-ft for 3,638 lineal-ft of DVFMB, its placement, and backfilling. The project specification called for a washed-gravel backfill with 12 in. of cement-stabilized base at the top of the trench. Placement of the Phillips Petromat fabric was completed in early 1991. There seems to be some movement taking place, indicating that possibly the fabric was not placed deep enough (J. Freeman, unpublished data).

US-84, Snyder

US-84 is a four-lane divided highway that extends north of Snyder in west central Texas. The original construction included approximately 14 in. of flexible base, 6 in. of asphalt-stabilized base, and surfacing. The subgrade was a red clay with PIs in excess of 50. A $3,406,000 rehabilitation contract was let in early 1990 that included 46,000 lineal-ft of DVFMB. The fabric was to be placed 8 ft deep along both shoulders of both mainlanes. A gravel backfill (a grade 3 concrete aggregate) was specified with a 1-ft cap of two-sack cement-stabilized base. The Price Construction Company, the contract low bidder, had $10.50/lineal-ft for the geomembrane, its placement, and backfilling. Caprock Equipment, a subcontractor, placed the Philips fabric using a Vermeer trencher with the conveyor attachment to handle the excavation.

During placement, some caving was experienced in areas where the clay had jointed water-bearing lenses. The caving lessened when the backfilling was kept closer to the placement operation. Problems arose with the backfills; settling of the cement-stabilized base cap occurred, requiring additional material. The daily rate of DVFMB placement averaged 1,000 to 1,500 lineal-ft with a 1-day high of 2,500 lineal-ft. Work was completed in 1990. No roadway problems have developed to date; the previous roller-coaster ride has not reappeared (M. Tayler and A. Wimmer, unpublished data).

I-45, Waxahachie

I-45 near Waxahachie is part of the major surface transportation link between Dallas and Houston. Its 16.3-mi rehabilitation contract in December 1990 included 285,140 lineal-ft of DFVMB. It may be described as the latest and greatest of the DFVMBs to date, or the "Mother of DVFMBs." The rehabilitation reused an existing multilane divided highway with an estimated 800,000 yd^2 of 12- and 13-in. reinforced concrete pavement—the total cost: $18 million. The DVFMB bid by the contract winner, Champagne Webber Company of Houston, was $6/lineal-ft for an estimated cost of $1,710,840.

A minimum two-sack portland cement mix base was designated for the top portion of the trench. The backfill in the lower part of the trench was to be graded aggregate or a sand approved by the engineer. The fabric was to be placed 8 ft deep and lapped over the paved shoulders. Payment covered the entire cost of materials, placement, backfilling, and disposal of the excavated material (H. Coppedge, J. Blain, and H. Stanford, unpublished data).

CONCLUSION

DVFMB can be placed vertically, and the reduction in required maintenance expenditures on several major projects after its placement indicates its effectiveness. Reduction of bid prices for this work from $20/lineal-ft in early projects to $6/lineal-ft recently gives further indication of its economic viability. Some of the challenges are indicated by the increase in the number of DVFMB projects in Texas, now 19 (Table 1); the increase in their size from ½ mi on I-410 to more than 50 mi on I-45; and their distribution across the state from northeast to far west.

The DVFMB sections generally had the higher SI readings. Pavement ride quality as measured by profilometer testing does decrease with the passage of time. A contributing factor could be the pavement surface itself, as shown in studies by others. If the geomembrane could be used horizontally, perhaps this could be mitigated. Other pavement failures due to axle loads, base, and pavement deterioration must be considered.

The backfill material for the DVFMB trench can pose significant problems. Base screenings and the subsequent repair work raise the question of the need for a coarse material for the backfill.

Other apparent and real failures, such as the question of inadequate depth, need postmortem searches. In some instances, it is found that the DVFMB was not used. In other instances soil profiles indicate the need for additional investigation in the planning phase. As time passes, the elements of maintaining records and ensuring comparability of results become very important. In the majority of the results, the vertical fabric moisture barriers give substantial indications of reducing the destructive impacts of expansive soils on highway pavements. As George Sowers observed in a recent article, "Communications between engineers, clients, contractors and the public are essential to translate expectations and

plans into successful projects. Without communications the best engineering is futile" (*4*).

ACKNOWLEDGMENTS

The authors acknowledge the help of Kathleen Jones, Mike Gray, Lyn Antoniotti, G. K. Hewitt, Rebecca Grado, C. T. Flores, R. L. Lytton, M. Picornell, J. P. Underwood, A. G. Clement, Ace Farrer, R. E. Magers, D. R. Stein, R. L. Barnhart, R. R. Ellison, J. R. McDonald, R. P. Black, Tom Schlegel, D. Gay, Al Bazan, John Blain, Harold Coppedge, Harold Stanford, Michael Taylor, Henry Hardy, Joe Freeman, J. Nixon, Alvin Wimmer, Maribel Jaso, Kendall Osborne, Dan Daloger, and Douglas Honeycutt.

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Publication of this paper sponsored by Committee on Environmental Factors Except Frost.