Geogrids as a Rehabilitation Remedy for Asphaltic Concrete Pavements

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Rutting and shoving of asphaltic concrete pavements extend from streets in front of the White House across the country. Frequent practice has been to remove and replace the pavement. Rotomilling the displaced material, relaying it, and overlaying the lanes is another remedy. On multilane highways, overlaying both lanes with asphaltic concrete is frequently done. Studies have indicated that the outside lanes receive several more equivalent axle loads than the inside lanes. This is reflected by their increased distress and rutting. The Texas State Department of Highways and Public Transportation's El Paso District is testing a different solution. The outside lane was provided with additional reinforcement using geogrids on a rehabilitation project on Interstate Highway 10. Sections received various quantities of asphaltic concrete overlays. The rotomilled geogrid sections failed. The other sections including another geogrid are serving well.

Rutting and shoving of asphalt concrete pavements extend from the streets in front of the White House across the country. Frequent practice has been to remove and replace the offending pavement. Rotomilling the displaced material, relaying it, and overlaying the lanes with more asphaltic concrete is another remedy. Common practice on multilane highways is to overlay the lanes with another course of asphaltic concrete. Recent studies on the Interstate system indicated that the outside lanes received two to six times the single-axle equivalent loads as the inside ones; yet rehabilitation projects often add another course of asphaltic concrete to both lanes. The Texas State Department of Highways and Public Transportation (SDHPT) El Paso District 24 sought another solution. The first step was a literature search.

LITERATURE SEARCH

Reinforcement of flexible pavement structures using various material has existed for many years. In the 1930s cotton was used. Later, the material of choice was reinforcing steel. In 1980 with the introduction of a new type of high-strength polymer geogrid known as Tensar, another option became available. In 1983, Halim et al. (*1*) presented results of cooperative laboratory testing by Canada's Royal Military College, the Ontario Ministry of Transportation, and Waterloo University. They concluded that substantial savings of asphalt paving thickness, double the number of load repetitions to failure, plus fatigue cracking reduction could be achieved using the geogrid.

Kennepohl and Kamel (*2*) reviewed the many attempts to reinforce asphaltic concrete. Efforts to increase longevity and satisfactory performance were suffering from asphalt's lower ultimate tensile strengths compared with its compressive strengths. Reinforcement is desired to increase the tensile strength, provide longer fatigue life, and reduce material cost. The geogrids provided a recommended solution to strengthening asphaltic pavement structures. Geogrids were seen as offering considerable potential in pavement design processes.

Brown (*3*) reported investigation of permanent deformation development and reflective cracking in asphalt pavements using an AR-1 geogrid. Responses showed the geogrid significantly increased rutting resistance. The manufacturer published a manual in January 1985 (*4*). Placement methods on asphalt, concrete, and granular material methods for dealing with faults are clearly explained.

Kennepohl et al. (*5*) presented results of full-scale test models at Canada's Royal Military College and the University of Waterloo showing that the geogrid-reinforced sections carried three times the number of loads before reaching 1-in. rut depth, compared with the unreinforced ones.

Lytton (*6*) tested asphalt beams with and without geogrid. The tests were conducted at varying temperatures, crack openings, load cycles, overlay thicknesses, and with and without crack seals. The tests indicated that an overlay with a geogrid and a seal coat will last four times longer than a nonreinforced overlay. It was observed that as the daily temperature range increases, the days of overlay life decrease. Brown (*7*) found that placing an AR-1 at the bottom of an asphalt base increases the layer life by a factor of 10. The report concluded that where rutting is a problem, geogrid reinforcement should be considered as a solution.

Though geogrids are manufactured by others, Tensar reports were the only ones found in this search.

BACKGROUND

After the literature search and discussions, SDHPT planned an experimental rehabilitation project on Interstate Highway 10 in Hudspeth County 25 mi east of El Paso. The average daily traffic (ADT) on this four-lane divided highway with heavy truck volumes was 8,000 vehicles per day (vpd). Several sections would receive geogrid reinforcement in the outside lanes along with overlays of asphaltic concrete pavement (ACP). Other sections would receive varying quantities of ACP. The existing section was built as a four-lane divided highway on 6 in. of soil cement, 6 in. of flexible base, 3 in. of asphalt-stabilized base, and an ACP of 165 lb/yd^2. A safety shoulder widening project added 3 in. of asphalt-stabilized base and 165 lb/yd^2 ACP (Figure 1).

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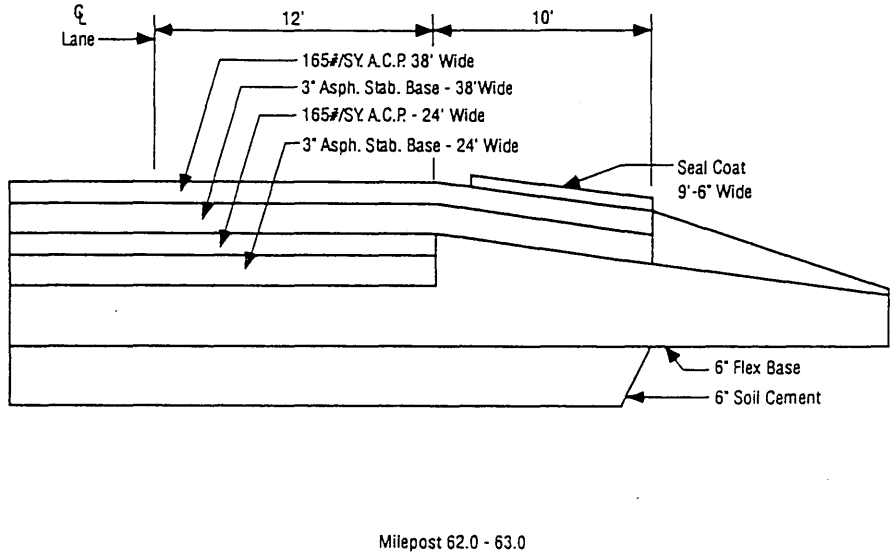

FIGURE 1 Existing section.

The first mile of the new section would receive 110 lb/yd² ACP with a shoulder seal. The second mile would have 220 lb/yd² with shoulder seals. The third mile would have ½-mi sections where the geogrids would be placed in the outside lanes. The first half included salvaging and replacing approximately 4½ in. of material in the outside travel lane, a width of 12 ft. The material was to be stockpiled and a geogrid, an SS-I or equal, placed at the 4½-in. depth. The milled material was to be placed and compacted on top of the grid in two equal lifts. A seal coat would be applied on the outside lane, and an ACP overlay of 165 lb/yd² would cover the existing pavement width, with a shoulder seal to finish the operation (Figure 2). The next ½ mi had an AR-1 geogrid or equal on the outside lane's existing pavement with a seal coat followed by a 165 lb/yd² overlay and a shoulder seal (Figure 3).

FHWA recommended the addition of a fourth mile to the project. The first ½ mi would salvage and replace the 4½-in. depth of material in the outside lane, return the milled material compacted in two lifts, seal it, and place 165 lb/yd² ACP (Figure 4). The final ½ mi would have a seal coat on the outside travel lane, 165 lb/yd² of ACP, and the shoulder seals (Figure 5).

The estimated cost of the project bid items totaled $615,438 (Tables 1 and 2). Bids were opened May 5, 1988. The Yantis Corporation was the apparent low bidder for $656,978.

CONSTRUCTION

From June 13 to 24, 1988, a Bomag recycler rotomilled the first 1,300 ft of the eastbound outside travel lane that was to

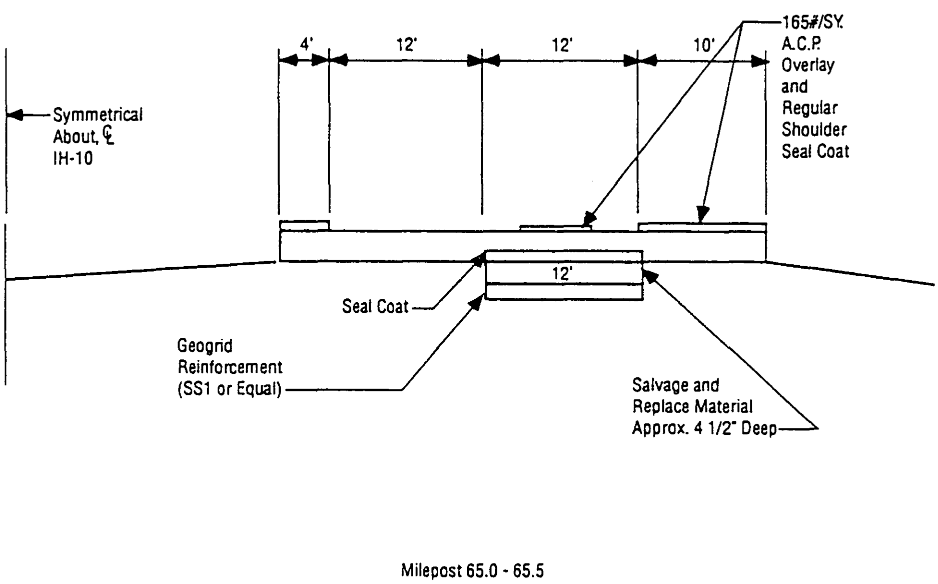

FIGURE 2 First half of third 1-mi section.

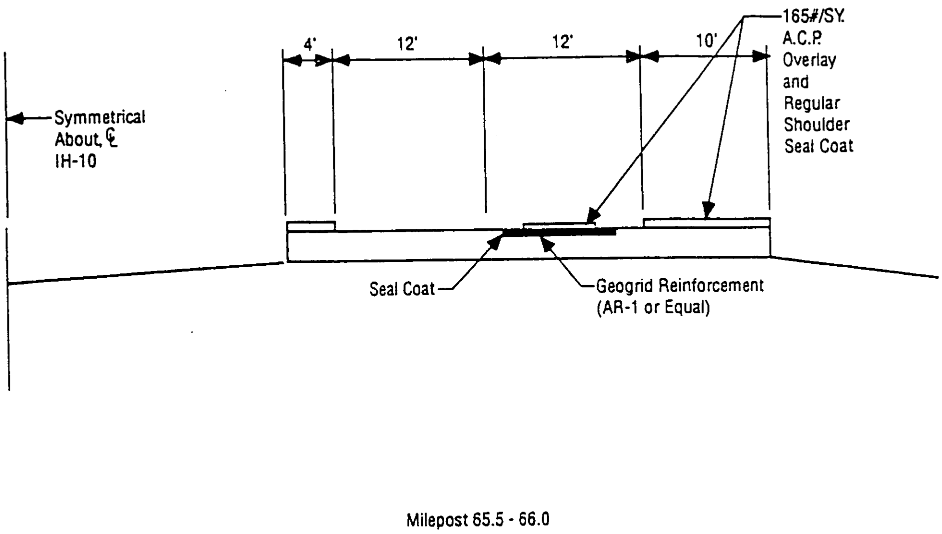

FIGURE 3 Second half of third 1-mi section.

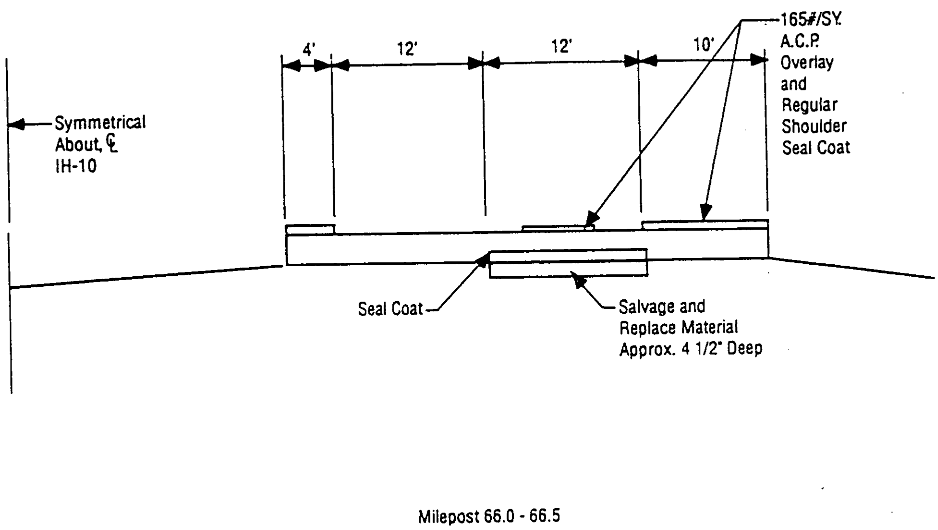

FIGURE 4 First half of fourth 1-mi section.

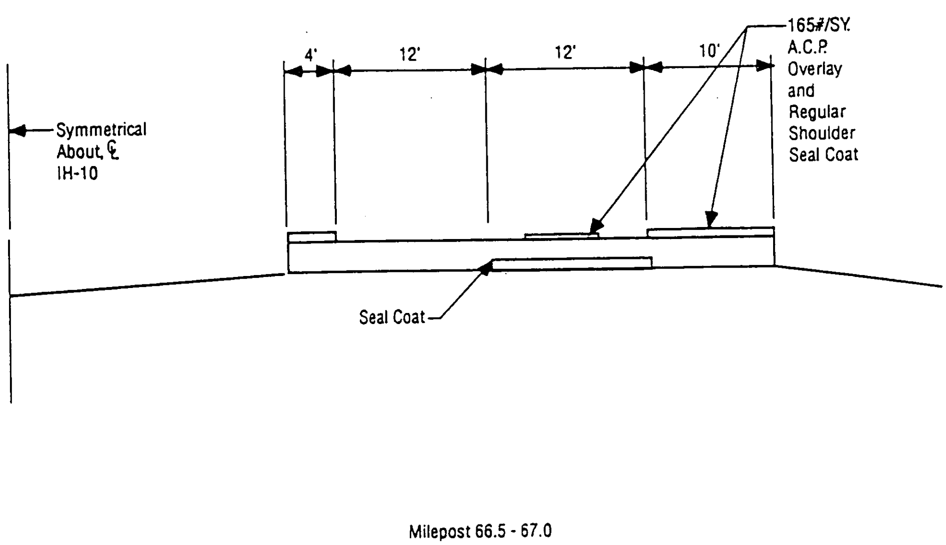

FIGURE 5 Second half of fourth 1-mi section.

TABLE 1 IH-10 Geogrids Estimates

Item	Rate	Estimated Quantity	Bid	Total
Asphaltic Concrete				
Aggregate Type D (ton)	Varies	13,930	31.70	$441,581
Asphalt (ton)		810	31.70	25,677
Seal Coat				
Aggregate Type B Gr 3 PreCoat (G)	1/110 SY[a]	657	40.0	26,280
Asphalt AC 3, 5, 10 gal.	0.35/SY	39,424	1.00	39,424
Geogrid				
AR-1		7,040	3.50	24,640
SS-1		7,040	2.50	17,600
Salvaging and Replacing Base (SY)		14,080	2.80	39,424

[a]Seal Coat Rates
Aggregate - 1/110 SY Travel Lanes - 1 CY/100 SY Shoulder
Asphalt - 0.35 Gal/SY Travel Lanes - 0.45 Gal/SY

TABLE 2 Costs

Rate	Cost/Square Yard ($)	
110 LB/SY	1.74	
220 LB/SY	3.48	
165 LB/SY	2.65	
AR-1	3.50	
165 LB/SY	2.65	= $6.15
SS-1	2.50	
165 LB/SY	2.65	= $7.95
Rotomilled	2.80	
Seal Coat		
0.35 Gal/SY @ 1	0.35	
1 CY/110 SY @ 40/CY	0.36	
	0.71	

receive the geogrid. This was followed by similar sections on the east- and westbound lanes. The milled material was windrowed on the adjacent paved shoulder.

The Tensar geogrid fabric, an SS-1, was placed on the eastbound lane beginning June 30. The geogrid corporation personnel were present, and procedures outlined in its publication for installation were followed. Tensioning bars were placed through both ends of the geogrid roll. The beginning of the roll was nailed to the surface with a 22-caliber power hammer. At the other end, a chain connected the tensioning bar to a Dynamometer, a come-along, and then to a pickup truck. The truck supplied most of the required tension to the geogrid. The geogrid was nailed at the far end and at intermediate points to secure the tension that had been achieved.

After the grid placement, a maintainer, a water truck, a pneumatic roller, and a vibratory roller were used to place the milled material in two equal lifts and compact it. The material was in a very tight condition. Seal coating of the milled material began on June 30. The seal was not sticking to the replaced milled material. On completion of the seal coat operation, placement of the ACP began. The trucks delivering the ACP and the asphalt paving machine caused considerable amounts of the seal coat to pull up as they passed over it. Later, large sections of the ACP became loose on the eastbound rotomilled sections. By July 14, the condition of these pavement sections was considered severe and hazardous to the traveling public. Traffic was detoured off the sections. A field change was prepared to provide a safe solution for the traffic. The rotomilled material was removed along with the geogrid, the seal coat, and the ACP. In their place, 4½ in. of black base, topped by an AR-1, a seal coat, and 165 lb/yd^2 of ACP, was placed. On the FHWA section, the same work was done, except no geogrid was added.

The field change included three new bid items: (*a*) removal of existing base and/or asphalt surfacing, (*b*) asphalt (AC) base, and (*c*) asphalt (TY C). The field change provided negotiated prices for the new items and for increased quantities at the original bid prices for asphalt (TY D), asphalt (AC), barricades, signs and traffic handling, and geogrid reinforcing (TY AR-1). The field change indicated a net overrun of $178,033.

Work began on the field change items on July 15, on the eastbound lane and then on the westbound lanes. The contractor during this period continued work on other contact items. With the geogrid representative present, the AR-1 was placed on the existing pavement and tensioned as required. Seal coat was applied over the AR-1, followed by the ACP over the full pavement width. The shoulder seal completed that phase of the rehabilitation. Where the geogrid was too close to the finish surface, it popped through the ACP. These faults were easily remedied. The ACP over the fault was removed, approximate 6-in. squares were cut in the geogrid, and the geogrid was then nailed back in place, followed by the addition of ACP and compaction. These areas have behaved well for more than 3 years after the remedial efforts.

The rehabilitation project was completed on August 12, 1988. The final estimate totaled $812,277.51, a $155,299 increase from the low bid.

OBSERVATIONS AND DISCUSSION

This project is part of the annual highway performance monitoring system (HPMS) and the pavement evaluation study (PES). Profilometer readings, part of these studies, are taken in a moving vehicle and computer-reduced to serviceability indices. A perfectly smooth pavement would result in a serviceability index (SI) of 5. Descending SIs indicate an increasingly rough pavement. The outside lanes in both directions on this project were measured. Generally between 1983 and 1986, before the treatment, eastbound lane (EBL) SIs decreased (Table 3). No westbound lane (WBL) readings are on record in 1986, but the trend from 1983 to 1984 was down. With the rehabilitation work in summer 1988, SIs trended upward; however, the readings in December 1990 reflected a downward movement to levels below those registered in 1983 (Table 4). On both the EBL and WBL, the 110-lb/yd^2 overlay section had the better SIs. The AR-I section secured to the existing pavement, followed by the 165 lb/yd^2 and the black base, with the 165-lb/yd^2 segments, were close behind.

The PES also provided evaluations of rutting and raveling/patching. This information is provided in 2-mi sections, which creates some interpretative challenges since the geogrid test sections were in ½-mi lengths (Tables 5 and 6).

The rutting tabulation (Table 5) shows three number sets for each test. They indicate the area damaged by the rut. The first number set indicates a rutted area of 1 to 25 percent, the second 26 to 50 percent, and the third more than 50 percent. Within each set, the number 1 indicates a rut depth of ½ to 1 in., and the number 2 a rut depth in excess of 1 in. Between 1983 and 1987, there was a general increase in rut areas and depth. After the rehabilitation project, rutting indicated a slight decrease in the first survey in December 1988. The 1990 results indicate an increase in rutting and its depths. On both lanes, it appears that between MPs 64 and 66 the rutting condition was the least bad. Between these MPs were the 220 lb/yd^2 overlay and the geogrid test sections. At the other ends were the 1-mi sections where no work was done. The AR-1 geogrid section was within the least-rutted area.

TABLE 3 IH-10 Serviceability Indices, Eastbound Lane

Treatment 6-7/88	Milepost	12/83	10/84	12/86	12/88	12/89	12/90
	62.0						
		4.1	4.0	3.6	3.9	3.3	3.4
No Work	62.5						
		4.3	4.2	3.9	4.3	3.3	3.6
	63.0						
		4.6	4.4	4.2	4.7	4.2	4.1
110 LB Overlay	63.5						
		4.5	4.4	4.3	4.6	4.6	4.0
	64.0						
		4.4	4.5	4.2	4.6	4.6	3.9
220 LB Overlay	64.5						
		4.5	4.5	4.4	3.9	4.0	3.1
	65.0						
Black Base/AR-1 165 LB Overlay		4.5	4.6	4.5	4.0	3.3	3.4
	65.5						
AR-1 +165 LB Overlay		4.5	4.5	4.0	4.1	4.3	3.8
	66.0						
Black Base 165 LB Overlay		4.5	4.5	4.2	4.2	4.3	4.0
	66.5						
165 LB Overlay		4.4	4.5	4.2	4.2	4.4	3.5
	67.0						

TABLE 4 IH-10 Serviceability Indices, Westbound Lane

Treatment 6-7/88	Milepost	12/83	10/84	12/86	12/88	12/89	12/90
	61.0						2.7
	62.0						
		4.1	4.1	N/A	3.9	2.9	3.1
No Work	62.5						
		4.4	3.8		3.9	3.8	2.9
	63.0						
		4.2	4.0		4.3	4.2	3.5
110 LB Overlay	63.5						
		4.5	4.1		4.2	4.3	4.0
	64.0						
		4.5	4.2		4.0	3.9	3.7
220 LB Overlay	64.5						
		4.5	4.2		4.0	3.9	3.4
	65.0						
Black Base/AR-1 165 LB Overlay		4.3	4.1		4.1	4.1	3.5
	65.5						
AR-1 +165 LB Overlay		4.5	3.9		4.3	4.4	3.9
	66.0						
Black Base 165 LB Overlay		4.6	4.3		4.1	4.3	3.9
	66.5						
165 LB Overlay		4.4	4.4		4.2	3.9	3.5
	67.0						

TABLE 5 IH-10 Geogrids—Rutting, Percent Area

Milepost	83	84	85	86	87	88	89	90
Eastbound Lane								
62-64	0-0-0	0-1-0	2-0-0	N/A	0-2-0	2-0-0	1-0-0	0-0-1
64-66	0-0-0	0-0-0	1-0-0	N/A	0-0-1	0-0-0	1-0-0	1-0-0
66-68	0-0-0	0-0-0	0-1-0	N/A	2-0-0	0-2-0	0-2-0	0-0-1
Westbound Lane								
62-64	0-0-0	0-0-1	1-0-0	0-1-0	0-1-0	0-0-1	2-0-0	0-1-0
64-66	0-0-0	0-0-1	1-0-0	0-1-0	0-1-0	0-0-0	2-0-0	0-1-0
66-68	0-0-0	0-0-1	0-1-0	1-0-0	0-1-0	0-0-1	0-2-0	0-2-0

Percent Area		Depth
Key 1	1-25	1/2"-1" = 1
Key 2	26-50	>1" = 2
Key 3	>50	

Rutting and shoving of IH-10 ACPs in El Paso and Hudspeth counties continued to cause concern. In late 1990, it was decided to make further investigation readings transversely of the pavement section at ¼-mi intervals. The Barnhart bar permitted these quick, accurate, and safe measurements.

This latest survey and the average end area calculations provide additional material to evaluate the effectiveness of the geogrid project. The EBL provides the most apparent values (Table 7). The 110-lb/yd² overlay and the AR-1 section secured to the existing pavement with the 165 lb/yd² had the low rutting values.

A letter from the geogrid producers, received after project bid opening, suggested that a spreader box or asphalt paver be used to place the milled material on the roadway. Concern was raised that a grader or similar equipment could damage the grid in the placement operation. They later noted that

TABLE 6 IH-10 Geogrid—Raveling/Patching

Milepost	83	84	85	86	87	88	89	90
Eastbound Lane								
62-64	0-0-0	0-0-0	2-0-0	N/A	0-0-0	0-0-0	0-0-0	0-0-0
64-66	0-0-0	0-0-0	1-0-0	N/A	0-0-0	0-0-0	0-0-0	0-0-0
66-68	0-0-0	0-0-0	0-1-0	N/A	0-0-0	0-0-0	0-0-0	0-0-0
Westbound Lane								
62-64	0-0-0	1-0-0	1-0-0	1-0-0	1-0-0	1-0-0	1-0-0	1-0-0
64-66	0-0-0	0-0-0	1-0-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0
66-68	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0

Percent Area
Key 1 1-25
Key 2 26-50
Key 3 >50

TABLE 7 IH-10 Geogrids

Milepost	Cross Reference to Figures	Action	Average End Area (Sq. Ft.) Eastbound Lane	Average End Area (Sq. Ft.) Westbound Lane
62.00	3	No Work	0.41	0.10
62.25	-	No Work	0.00	0.15
62.50	-	No Work	0.09	0.08
62.75	-	No Work	0.53	0.04
63.00	4	110 LB/SY	0.09	0.00
63.25	-	110 LB/SY	0.00	0.00
63.50	-	110 LB/SY	0.01	0.00
63.75	-	110 LB/SY	0.05	0.00
64.00	5	220 LB/SY	0.00	0.00
64.25	-	220 LB/SY	0.03	0.00
64.50	-	220 LB/SY	0.09	0.04
64.75	-	220 LB/SY	0.03	0.13
65.00	6	BB/AR-1/165 LB/SY	0.13	0.05
65.25	-	BB/AR-1/165 LB/SY	0.10	0.0
65.50	7	AR-1/165 LB/SY	0.00	0.00
65.75	-	AR-1/165 LB/SY	0.02	0.02
66.00	8	BB/165 LB/SY	0.07	0.01
66.25	-	BB/165 LB/SY	0.03	0.00
66.50	9	165 LB/SY	0.07	0.00
66.75	-	165 LB/SY	0.00	0.06
67.00	-	No Work	0.00	0.01
67.25	-			
67.50	-			
67.75	-			

the milled material was not binding and that compaction results were viewed as unsatisfactory. Additional observation stated the geogrid rolls are manufactured in straight sections. Placing the geogrid on a horizontal curve can cause wrinkling, as experienced on this project, but could be remedied by additional tacking of the material to the support surface.

OTHER STATES' EXPERIENCES

Additional information on geogrid experiences was received from three other states. The Maine Department of Transportation's Research and Development Section reported using these materials since 1976 (*8*). In June 1984, AR-1 Tensar geogrid and a Bates "terra firma" were used where both lanes were rutted, drainage of the silty subgrade was poor, and the road was frequently closed during thaw conditions. A 1988 report indicated that the test sections were generally in good condition. Some signs of rutting were noted in the northbound lane right wheelpath in the Bates area.

The Minnesota Department of Transportation reported on three January 1985 geofabric tests (*9*). Two used Glasgrid on TH 20 and TH 95, and both had installation problems. The third test involved a Tensar. No paving problems were experienced, but the missing protection from the seal coat areas was considered a potential cause of concern. The report observed that Tensar did not seem suited for large-scale projects, because the tensioning operation did not have appropriate equipment, and the use of the strain gauges caused delays.

The New Mexico State Highway and Transportation Department (NMSHT) reported on four geogrid projects in intradepartment correspondence. Two used Glasgrid and two used Tensar AR-1 placed on State Road 44 near Nageezi in October 1985. A slight advantage could be seen for the geogrid. The second NMSHT Tensar project was on ramp on the Frontier interchange of Interstate 40 near Santa Rosa. The project manager concluded that the operation, done in July 1988, was a success but took too long.

Three other reports of early geogrid placements were received and offered encouragement on the use of the material (*10–12*).

The failure of the rotomilled section led to a thorough review by Wood et al. (*13*). Addition of virgin aggregates appears to be a standard practice. Water was considered important to cold in-place recycling (CIR). All have constraints of no rain or immediate forecast of rain. PennDOT recommends a double surface treatment for a pavement with an ADT of 1,500 or less, a hot mix wearing surface for ADTs of 1,501 to 3,000, and no CIR with ADTs over 3,000 or with heavy truck traffic. The states that used CIR consider it promising. Mix design, field control, and when the roadway is ready for traffic are considered major problems. Cost savings are reported.

Rotomilling has been the subject of many other studies and reports. One by Kennedy et al. (*14*) summarizes major considerations. Basic failure causes were aggregates, and the resulting aggregate/asphalt combinations were highly susceptible to moisture damage, ineffective antistripping and "over-asphalted" pavement sections.

CONCLUSION

The concept of strengthening existing ACPs that are experiencing rutting and shoving is a worthwhile goal. This Interstate Highway 10 rehabilitation project compared the results of a variety of overlay quantities including sections using two types of geogrids in the distressed outside lanes. The first cost of the rehabilitation indicated the 110-lb/yd^2 overlay was the least expensive. Tests indicated that it performed as well as or better than any other combination used.

The geogrid was placed beneath the rotomilled material that was relaid without additives or heat in the section that failed shortly after traffic used that lane. The SS-1 grid is heat sensitive, requiring insulation from a seal coat. It is believed that the geogrid was not a factor in the section failing. The reuse of rotomilled material has many potential advantages. However, there are many documented projects that failed despite intensive prior testing, use of additives, and other rehabilitative measures.

The AR-1 geogrid with greater heat resistance capabilities functioned well. This conclusion is based on a review of the SIs and the end areas. It can be viewed as one way to strengthen an existing ACP suffering distress. If only one lane suffers distress, rather than adding material to all adjacent lanes, this may provide a long-term economic and environmental solution. Over decades, ACPs have been reinforced with a variety of materials. The polypropylene geogrid, after a decade of testing in the laboratory and field, holds great promise. It could provide long life of project economies when incorporated into construction of new roadways. Geogrids are seen as possible enhancements to the construction and rehabilitation of ACPs in an economical and conservationist effort.

ACKNOWLEDGMENTS

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