PB99-100208

REPORT FHWA/NY/SR-94/114

Membranes for Pavement/Shoulder Joints

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SPECIAL REPORT 114

ENGINEERING RESEARCH AND DEVELOPMENT BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION

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MEMBRANES FOR PAVEMENT/SHOULDER JOINTS

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Final Report on Research Project 199-1
Conducted in Cooperation With
The U.S. Department of Transportation
Federal Highway Administration

Special Report 114
December 1994

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New York State Department of Transportation
State Campus, Albany, New York 12232

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA/NY/SR-94/114	2. PB99-100208	3. Recipient's Catalog No.
4. Title and Subtitle MEMBRANES FOR PAVEMENT/SHOULDER JOINTS		5. Report Date December 1994
		6. Performing Organization Code
7. Author(s) Dan E. McAuliffe and Luis Julian Bendana		8. Performing Organization Report No. Special Report 114
9. Performing Organization Name and Address Engineering Research and Development Bureau New York State Department of Transportation State Campus, Albany, New York 12232		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Offices of Research, Development & Technology HRD-10 Federal Highway Administration U.S. Department of Transportation Washington, DC 20590		13. Type of Report and Period Covered Research Project 199-1 Final Report
		14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Admininistration. Study Title: Membranes for Pavement/Shoulder Joints.

16. Abstract

Shoulder drop-off on overlaid rigid pavements with asphalt concrete shoulders beneath the overlay is believed to be caused by water infiltration through the reflective crack over the old longitudinal shoulder joint. The study reported here was initiated to determine the effectiveness of 1) geotextile membranes placed over this longitudinal pavement/shoulder joint before overlaying, or 2) a saw-and-seal joint in the overlay over that joint, in reducing such water infiltration and thus preventing or minimizing the shoulder drop-off. Drop-offs are considered safe for all drivers when less than 37 mm, and safe for most drivers from 37 to 51 mm. In this study, all drop-off readings were 7 mm or less, with most being 4 mm or less. This shows that to date the test sections, although differing statistically from the control sections, are functionally the same.

17. Key Words overlays, longitudinal joints, shoulders drop-off, membranes, geotextiles, saw-and-seal joints, reflective cracking	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages vi + 13	22. Price

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CONTENTS

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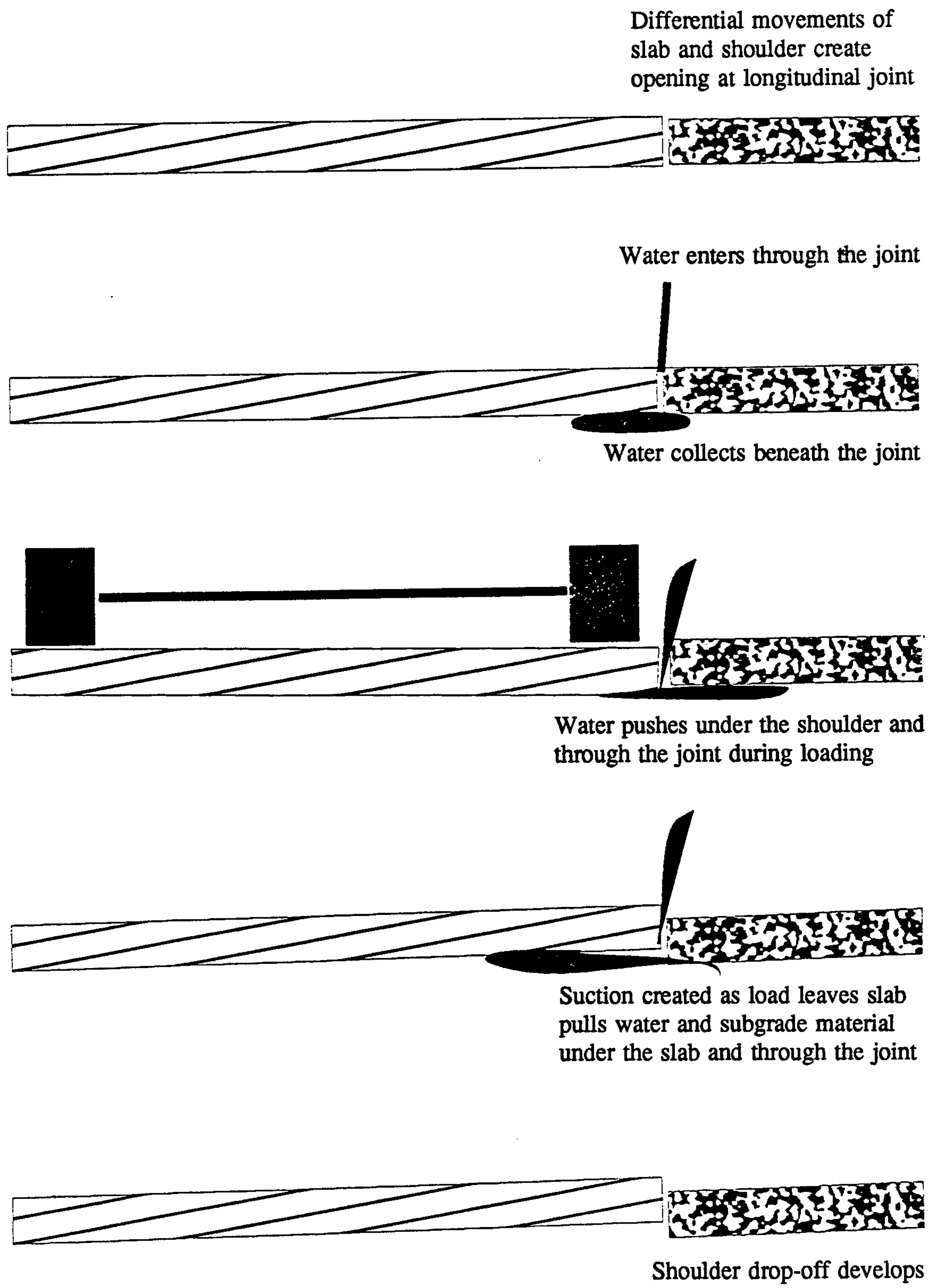
Figure 1. Drop-off mechanism.



I. INTRODUCTION

A. Background

In 1993, the New York State Department of Transportation adopted The New York State Thickness Design Manual for New and Reconstructed Pavements (1). In this manual, rigid pavement is required to have tied, full-depth, portland-cement-concrete shoulders over a 100 mm layer of cement or asphalt permeable base, with continuous edge drains and outlets. Before 1993, however, the New York State Highway Design Manual (2) specified a 100 mm flexible shoulder in a typical rigid-pavement cross-section. As a result, New York has about 5,000 centerline km of concrete pavement and another 10,000 centerline km of resurfaced concrete pavement, most having flexible shoulders and thus a significant potential for shoulder "drop-off." The mechanism producing the drop-off resembles that causing faulting (Fig. 1), which has been described as follows (3):

1. Daily temperature changes and/or moisture gradients cause curling of rigid slabs, and voids form at the bottom of the slab/shoulder joint.

2. Differences in material properties between the flexible shoulder and rigid pavement slab, along with seasonal temperature changes, produce differential movement and thus separation along the slab/shoulder joint.

3. Also, drag forces occurring with untied shoulders tend to open the slab/shoulder joint.

4. After this joint opens, water enters and accumulates in the voids.

5. Passage of a heavy vehicle deflects the concrete slab and water is forced under the shoulder.

6. After the load passes, the slab rebounds and a vacuum forms. Some material is pulled under the concrete slab and some is pumped through the joint, loosening the shoulder and reducing bearing capacity.

7. Repetition of this action causes reduction in elevation of the flexible shoulder, called shoulder "drop-off."

When the pavement is overlaid, problems continue as surface water enters through the reflective cracks that develop over the longitudinal shoulder joint. During plowing operations, material also is sometimes scraped off the shoulder while it is in a heaved position. Periodically, maintenance crews attempt to seal these joints, but differential horizontal and vertical movements of the slab and shoulder make these efforts futile. In addition to sealing the longitudinal joints, maintenance crews periodically "wedge" the shoulder, applying a strip of asphalt along the longitudinal pavement edge to bring it back to grade. A procedure to retard water penetration thus may increase overlay service life, reduce maintenance costs, and improve safety.

Since the process causing shoulder drop-off requires water, preventing it from entering the joint should reduce the occurrence of drop-off. In this project, two methods were tried -- 1) membranes applied to cover the shoulder joint before placing the overlay, and 2) sawing-and-sealing the overlay above the shoulder joint.

B. Study Objectives

The intent of the investigation reported here was to determine 1) if either membranes or sawing-and-sealing can effectively prevent water from infiltrating into the shoulder joint, 2) relative effectiveness of these two procedures in eliminating shoulder drop-off, and 3) their cost-effectiveness.

II. INVESTIGATION

This work consisted of preventing water infiltration by 1) adding a strip membrane over the longitudinal shoulder joint before applying the overlay, or 2) sawing-and-sealing the longitudinal shoulder joint after applying the overlay. If either method proved effective, maintenance crews would be free to perform other tasks, and useful lives of overlays would be lengthened, resulting in savings of both expenditures and lives by ensuring safer, more durable roads. In addition to membranes, several factors were considered: variations both among the membranes tested and within test sites, and methods of data collection.

A. Test Sites

The first of the three sites was on I-87 in Saratoga County, placed in 1987. The other two were on I-81 in Broome County north of Binghamton, the southern contract placed in 1988 and the northern in 1990. Engineering Research personnel placed the I-87 membranes, and a paving contractor those on I-81. Sites were chosen to minimize variation among sections, all having rigid pavements with asphalt shoulders and a history of shoulder drop-off and heaving. Finally, they were to be long enough to allow installation of 150 m test sections and adjoining 150 m control sections with little or no change in alignment. All three sites met these criteria.

B. Membranes Tested

These were selected on the basis of material properties, composition, and method of application. In all, manufacturers submitted seven membranes, each installed in separate sections -- 1) one with a two-part binder (primer and sealer), 2) another with a single primer coat, 3) a third with a single tack coat, and 4) four membranes with adhesive backings. Table 1 lists membrane manufacturers and describes application methods. Manufacturers claimed that membranes placed over the shoulder joint before overlaying (Fig. 2) would prevent water infiltration through the joint. Table 2 lists lengths and sequence of membranes installed at each site. In addition to the membranes, four saw-and-seal sections were included in the experiment.

C. Saw-and-Seal

To control overlay cracking over underlying joints, the process known as "saw-and-seal" has been used, involving the following steps:

Table 1. Membranes tested.

Product	Application Method	Manufacturer
Roadglas	Binder Course (primer) Second Binder Course (sealer)	Owens-Corning Fiberglass Corporation
Paveglas	Primer Coat	Royston Laboratories, Incorporated
Paveprep	Tack Coat	Paveprep Corporation
Petrotac	Adhesive Backing	Phillips Fibers Corporation
Polyguard	Adhesive Backing	Polyguard Products Incorporated
Royston 108	Adhesive Backing	Royston Laboratories, Incorporated
Tapecoat M860	Adhesive Backing	Tapecoat Company

Table 2. Summary of test sections*.

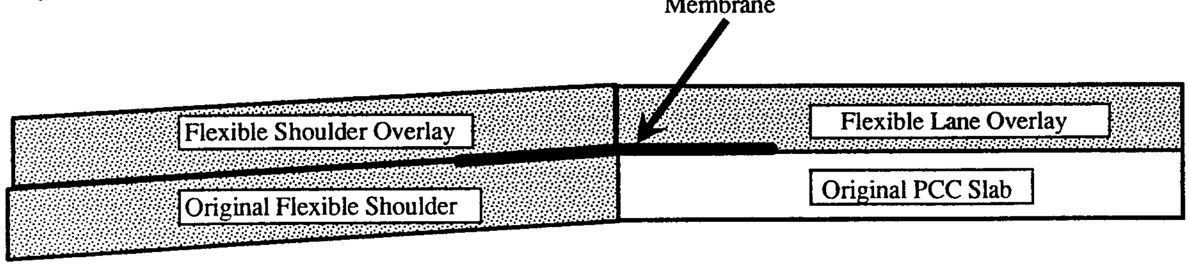
I-87 Site (Placed: 1987)		I-81 North Site (Placed: 1990)				I-81 South Site (Placed: 1988)			
		Northbound		Southbound		Northbound		Southbound	
Treatment	Length (m)	Treatment	Length (m)	Treatment	Length (m)	Treatment	Length (m)		Length (m)
Petrotac	152	Control	86	Control	2	Control	207	Control	16
Control	172	Saw-and-Seal	155	Tapecoat	153	Petrotac	122	Saw-and-Seal	123
Roadglas	166	Control	95	Control	153	Control	244	Control	121
Control	168			Royston 108	153	Royston 108	123	Polyguard	117
Royston 108	157	Control	81	Control	5	Control	123	Control	129
Paveglas	152	Paveglas	149			Saw-and-Seal	122	Paveprep	123
Control	167	Control	105	Control	8	Control	6	Control	120
				Saw-and-Seal	154			Paveglas	125
Control	20	Control	5	Control	305			Control	59
Paveprep	140	Paveprep	153	Polyguard	152				
Control	161	Control	275	Control	6				
Polyguard	153	Petrotac	154						
Control	166	Control	9						

* Spaces represent unmonitored sections.

Table 3. Summary of measurements.

Location	Drop-off Measurements	Distress Surveys	Cores
I-87 Site	11	6	1
I-81 North Site NB	5	3	8
I-81 North Site SB	5	3	0
I-81 South Site NB	9	5	6
I-81 South Site SB	9	5	8

Figure 2. Membrane placement.



1. Make a sawcut 35 mm into the overlay, directly above the slab/shoulder joint beneath that overlay.

2. Remove any debris from the sawcut, using water or compressed air.

3. Fill the sawcut with an approved asphalt sealer.

The sawcut is made directly over the joint, and the overlay pavement thus should crack beneath the cut and above the underlying joint, minimizing or eliminating uncontrolled cracking at or near the joint. With the cracking controlled and already sealed, water infiltration is prevented.

Sawing-and-sealing has been very successful in controlling transverse cracking over contraction joints in overlaid rigid pavements (4). It was hoped that this would be equally successful here. The main problem with this process is making sure the sawcut is aligned directly over the underlying joint. When misaligned, this process is ineffective in controlling cracking.

D. Data Collection

Three types of data were collected, as summarized in Table 3:

1. Shoulder drop-off was measured using a straight beam (Fig. 3) with its head placed at the shoulder joint and its foot adjusted over the shoulder until the beam was level. Leveling was accomplished using a bar attached to the beam end with a clamp. Distances from the bottom of the beam to the shoulder surface were measured 152, 762, 1372, and 1981 mm from the longitudinal pavement-shoulder joint. To compare shoulder movement in the test and control sections, readings were taken twice a year, in spring (May or June) and again in late fall or early winter (November or December).

2. Cracking was surveyed once a year, usually in May, measuring cracking at the shoulder joint in units of meter/meter (crack length/lane length). Distress surveys were necessary to detect when cracking occurred in each section, so that cores might be taken.

3. Pavements were cored to determine if membranes remained intact after the pavement cracked. At least two cores were removed in each test section.

E. Data Analysis

1. Multiple Regression (5,6)

This technique uses the least-squares method to relate one or more independent variable(s) to one dependent variable at a given reliability level -- for this study, 95-percent reliability was used. The result is a model that is the "best-fit" of a line through the given data. In other words, the program searches for the combination of regression variables that

Figure 3. Apparatus for shoulder drop-off measurements.

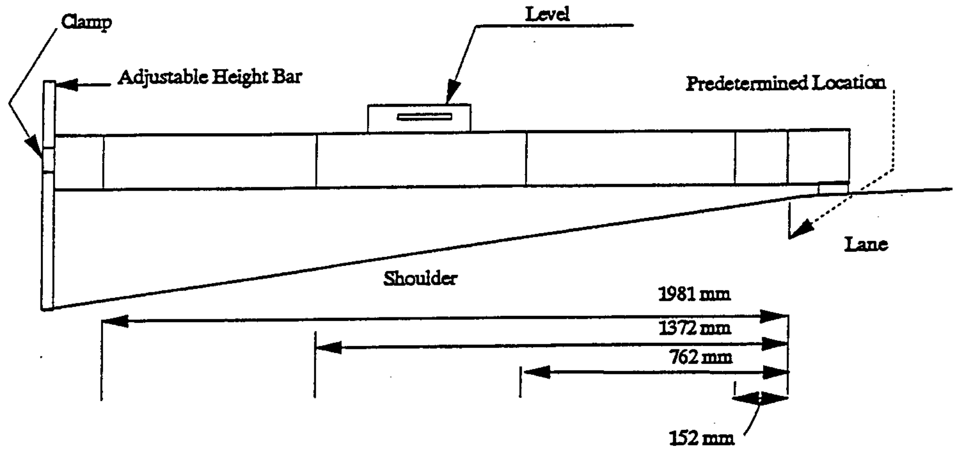


Table 4. Summary of regression variables.

Variable*	Reason for Inclusion in Regression Analysis
Age	Determine if drop-off increases as overlay ages
Season	Determine if seasonal effects (e.g., washouts and heaves) increase drop-off
Time-Season	Determine if magnitude of seasonal effects change as overlays age
Position Within Section	Account for variations in overlay performance due to variations in substructure materials (Subgrade and subbase)
Treatment	Determine if treatment affects overlay performance
Average Drop-Off	Show how measured drop-off changes with time

*All variables are independent except "average drop-off" (dependent).

statistically describe shoulder performance. Besides computing the regression model, the residuals also had to be analyzed to assure that the relationship could be modeled as linear.

2. <u>Regression Variables</u>

For all sections, the variables examined were 1) age, 2) season, 3) position (joint number) within the section, 4) average reading at a given age, and 5) a composite variable created by combining season and age. Influence of each variable on drop-off was found by performing a multiple-regression analysis. First, all variables were entered into the model. Then all statistically significant variables were retained, and the regression analysis was run again. ("Statgraphics" output for each section is available to interested readers.)

The dependent variable in this analysis was the average drop-off measurement -- the amount of shoulder movement at any given age. All other variables were independent. Age was included to measure how drop-off changes as the overlay ages. Season was included to determine if seasonal temperature variations could account for any of the drop-off measured. The composite variable age-season was used to determine if variations in seasonal effects changed with age. Finally, treatment was included to determine if variations in performance existed between test and control sections. Table 4 summarizes the regression variables used.

III. RESULTS AND DISCUSSION

A. Overlay Age

The first consideration in the data analysis was overlay age. The oldest examined was placed in 1987, making it 6 years old. Past experience has shown that overlays generally last 15 years or more, suggesting that the period in service may have been insufficient to show effects of the treatments.

B. Performance of Test Sections

It should be noted that no drop-off or heave was apparent at any site. The following notes are based on statistical differences in drop-off measurements found using the methods described earlier.

1. I-87 Site

   Treatments applied here were Petrotac, Roadglas, Royston, Paveglas, Paveprep, and Polyguard. At this site most variables were found to be statistically significant, but of the treatments only Paveprep was not statistically significant. The others (although significant) were functionally the same as adjoining control sections.

2. I-81 Northbound North Site

   The treatments applied here were Paveglas, Paveprep, Petrotac, and saw-and-seal. No single variable appeared to affect performance of all sections. None of the treatments were statistically significant, showing that to date they have had no effect on performance.

3. I-81 Southbound North Site

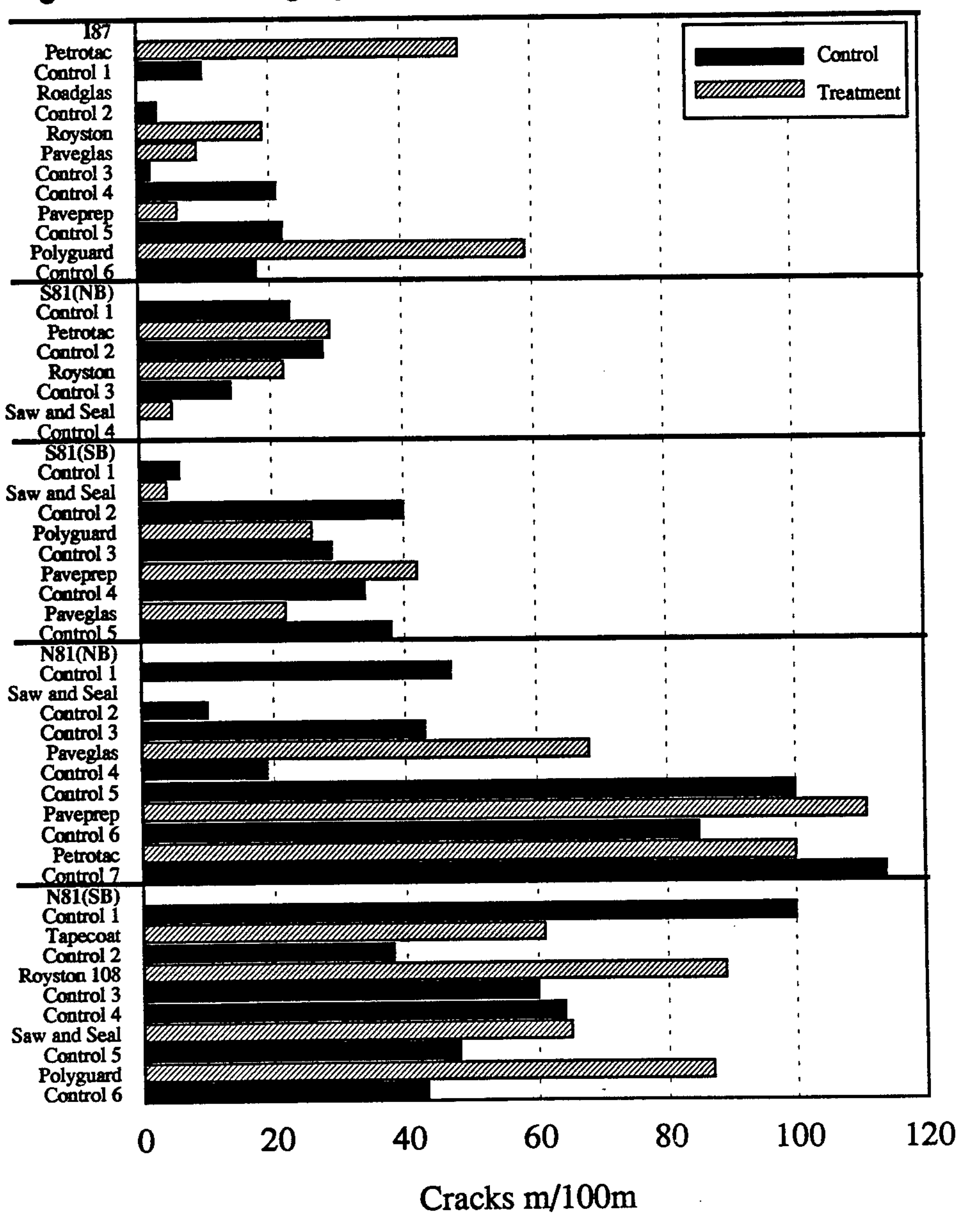
   Treatments applied here were Tapecoat, Royston, Polyguard, and saw-and-seal. For this section, seasonal change in readings accounted for most of the difference in drop-off measurements. Tapecoat and Polyguard treatments were statistically significant, but their effects were minor and acted to increase drop-off.

Table 5. Summary of statistically significant differences.

Treatment	I-87 Site	I-81North Site Northbound	I-81North Site Southbound	I-81 South Site Northbound	I-81 South Site Southbound
Roadglas	Increased faulting	- -	- -	- -	- -
Paveglas	Increased faulting	No difference	- -	- -	Increased faulting
Paveprep	No difference	No difference	- -	- -	No difference
Petrotac	Increased faulting	No difference	- -	Increased faulting	- -
Polyguard	Increased faulting	- -	Increased faulting	- -	Decreased faulting
Royston 108	Increased faulting	- -	No difference	Increased faulting	- -
Tapecoat	- -	- -	Increased faulting	- -	- -
Saw-and-Seal	- -	No difference	No difference	Decreased faulting	No difference

Note:
1) No test sections differed functionally from neighboring control sections as of May 1993,
2) Dashes denote treatment installed.

Figure 4. Cracking by test site.



4. I-81 Northbound South Site

Treatments applied here were Petrotac, Royston, and saw-and-seal. Here little difference was found between test and control sections, and the effect of the treatments (even when statistically significant) was minor compared to that of other variables. Again, sections with treatments had statistically greater drop-offs than those without.

5. I-81 Southbound South Site

Treatments applied here were Polyguard, Paveprep, Paveglas, and saw-and-seal. Here again, there was little difference between test and control sections, and the effect of the treatments (even when statistically significant) was minor compared to that of other variables.

Statistically, all treatments except one Polyguard section and one saw-and-seal section performed the same or worse than adjoining control sections (Table 5). Drop-off is considered safe for all drivers when it is less than 37 mm and safe for most drivers from 37 to 51 mm (7). In this study, all readings were 7 mm or less, with most 4 mm or less. This shows that to date the test sections, although differing statistically from the control sections, are functionally the same. Measurements in sections showing increased or decreased drop-off had smaller variation than measurements in adjacent sections, but these drop-offs were still in the same range. This suggests that the differences were due to smaller sample sizes in these test sections, not to the treatments.

C. Cracking

This was monitored because pavements were to be cored after the overlay had cracked at the longitudinal shoulder joint, to determine if membranes were still intact. Manufacturers had made no claims concerning membrane effects on reflective cracking, but since cracking data were being collected, they were analyzed to determine what effect, if any, membranes had on reflective cracking. Figure 4 shows reflective cracking in all test and control sections. No relationships were found between reflective cracking and membrane placement. Saw-and-seal sections, however, did show less cracking, the only exception being on southbound pavement at the I-81 north site, where the sawing-and-sealing was believed to be misaligned over the underlying joint.

D. Coring

Pavement cores showed that all membranes but Petrotac remained intact. It was not possible to determine if Petrotac had ripped before or during coring, but since it is similar in composition to the others, it is believed that it too was still intact before coring.

IV. SUMMARY AND RECOMMENDATIONS

The statistical analysis showed that as of May 1993, test and control sections performed similarly after up to 6 years of service. None of the seven membranes were found to have consistently affected overlay performance. When they were found to have altered performance statistically, magnitude of change was so slight that they still had no functional effect -- measured faulting in test and control sections was less than 7 mm, which is considered safe for all drivers (7). Paveprep was the only membrane not statistically significant in any section. The one saw-and-seal section that had less shoulder drop-off had only slightly less than the adjoining control sections, and the treatment may actually have had no real effect. Further examination of drop-off data revealed that even though treatment sections showed significant differences, their performance was still in the same range as the adjacent control sections, with no actual difference between control and test sections. It is recommended that monitoring continue for the rest of the overlay's useful life for full understanding of what effects (if any) the treatments have had on overlay performance.

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