FINAL REPORT

EVALUATION OF ASPHALT RUBBER STRESS-ABSORBING MEMBRANE

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

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ABSTRACT

This report describes the construction and evaluation of a stress-absorbing membrane (SAM) using a liquid asphalt binder containing ground tire rubber. Approximately 10 lane-km of SAM and 4 lane-km of control surface treatment for comparison were constructed in 1992.

There was excessive loss of coarse aggregate under traffic on the SAM section, resulting in broken windshields. Although aggregate loss was significant, friction values were generally satisfactory. SAM was effective in keeping cracks of the underlying surface sealed. Because it appears difficult to determine and use the proper amount of binder to prevent aggregate loss and bleeding, the authors recommend that SAMs not be pursued further as a method of surface treatment in Virginia.

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INTRODUCTION

During the past 10 to 15 years, the quality of Virginia's surface treatments has improved significantly. This improvement is a result of (1) the adoption of the "flakiness index" design method that is used to determine asphalt and aggregate quantities, (2) payment for aggregate by the area covered to eliminate the application of excessive aggregate, and (3) the use of modified seal surface treatments to eliminate problems of aggregate loss under traffic. Even with these improvements, Virginia continues to look for ways to improve surface treatments. A type of chip seal surface treatment using asphalt rubber binder provided the potential for improved service life.

During the 1960s, McDonald developed an asphalt rubber binder. The binder has been used in a surface treatment commonly known as a stress-absorbing membrane (SAM). This name was assigned because the binder provides elasticity that absorbs the stresses developed from movement of underlying cracks and helps prevent reflection cracks in the new surface. The binder is composed of approximately 80 percent asphalt cement and 20 percent ground tire rubber from old tires. Asphalt rubber is claimed to be very resistant to cracking and to provide an effective seal to prevent water damage to underlying layers and aging of the binder. This material has been used extensively in Arizona[1] and California.[2] In Phoenix, Arizona, it helped retard primary reflection cracking for 15 years. Also, there was a reduction in damage claims for broken windshields in California. One of the environmental benefits of using asphalt rubber is that old tires can be used rather than being placed in landfills. The question remains whether SAMs are cost-effective since the initial cost is considerably more than that of surface treatments using conventional binders.

In 1989, the Virginia General Assembly passed legislation requiring the Department of Waste Management to develop a plan to use and dispose of old tires. In addition, the federal Intermodal Surface Transportation Efficiency Act (ISTEA) passed in 1991 required states to use rubber in asphalt. This latter legislation has been rescinded.

In 1989, the Virginia Transportation Research Council (VTRC) worked with the Suffolk District of the Virginia Department of Transportation (VDOT) in placing an asphalt rubber SAM as a modified seal surface treatment on Route 301 in Greenville County just north of Emporia.

The modified seal consisted of a layer of asphalt rubber binder, a layer of coarse aggregate, and a layer of fine aggregate. Excessive bleeding occurred on the test section, which was attributed to the combination of a bleeding condition of the existing pavement and the heavy asphalt rubber application rate of approximately 2.7 l/m^2 (0.60 gal/yd^2). This application rate was in the mid-range of rate recommended by International Surfacing, Inc.[3] Since it was experimental, SAM was much more expensive than conventional treatments. Because of its less than satisfactory performance, no further work with this material was attempted for a few years.

In 1992, test sections were installed and evaluated in VDOT's Bristol District. The installation included a test section of asphalt-rubber SAM and two control sections: a modified seal surface treatment and a conventional surface treatment. Two types of control treatments were used because these treatments were commonly used in various locations of the state and it was desirable to know how SAM compared to both treatments. This report describes the installation, test results, and performance of the test and control sections.

PURPOSE AND SCOPE

The purpose of this study was to evaluate a test section of SAM surface treatment using an asphalt rubber binder. Two control sections using a conventional surface treatment and a modified single seal treatment were also evaluated.

Since it appeared that the use of ground tire rubber would be mandated, this second trial of SAM was conducted although the original trial had poor results. This trial indicated whether SAM could be constructed under normal conditions and yielded 4-year performance information.

METHODOLOGY

The asphalt rubber test section (SAM) and the control surface treatments using CRS-2L, which is latex modified, were evaluated by placing field test sections and observing their performance over 4 years. Construction was also observed, and data were collected on the equipment, materials, construction techniques, ambient and asphalt temperatures, and problems encountered during construction.

Description of Test Sections

The test and control sections were placed on Route 11 in Wythe County from 31.23 km (19.40 milepost) to 38.41 km (23.16 milepost) (see Figure 1). Figure 2 shows the layers of the SAM and control sections. Both control treatments, conventional and modified single seal, are used extensively in Virginia. The conventional treatment consisted of a single layer of CRS-2L binder followed by a layer of coarse aggregate. The modified single seal consisted of a layer of

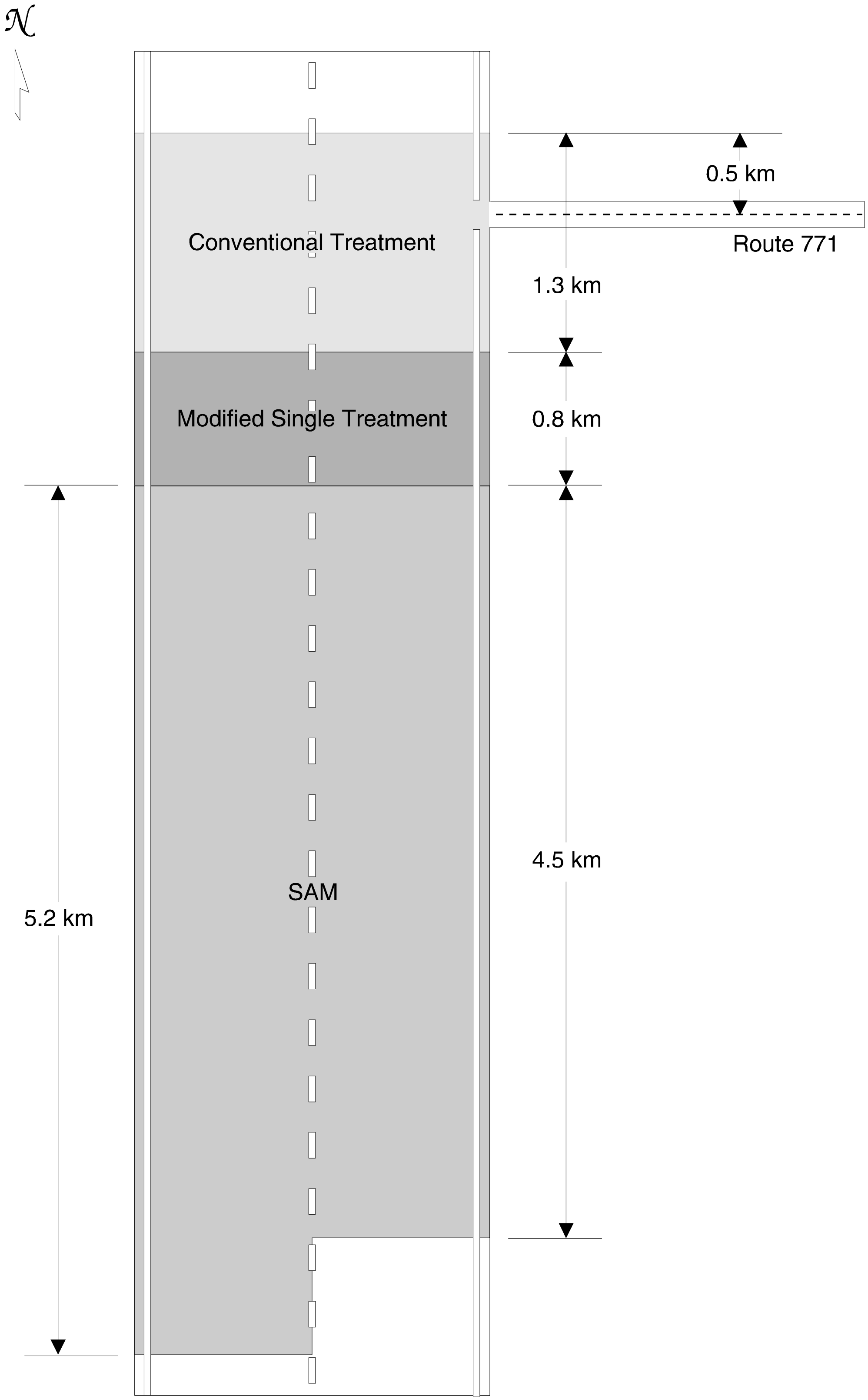

Figure 1. Test Sections

CRS-2L followed by a layer of coarse aggregate, another layer of CRS-2L, and a final layer of fine aggregate (No. 9).

Design and Construction Application Rates

The quantities of asphalt and aggregate to be used on the control sections were initially estimated from past design rates for that aggregate. However, the quantities were verified with the flakiness index design test described in the 1979 asphalt emulsion manual[4-6] published by the Asphalt Institute.

During construction, the application rates for the asphalt rubber binder, CRS-2L asphalt emulsion, and aggregate were checked to ensure that the correct quantities were being applied. The rates were determined by measuring the amount of binder sprayed on 0.093 m^2 (1.0 ft^2) metal plates placed on the pavement before the distributor and aggregate spreader passed. The application rates are shown in Table 1. The rate of application for the SAM binder was much lower than the recommended rate used on the earlier test section placed in 1989 because of the bleeding problems with that test section.

Table 1. Application Rates of Materials

Treatment Type	Asphalt Type	Aggregate Type	Asphalt Quantities l/m^2/(gal/yd^2)	Aggregate Quantities kg/m^2/(lb/yd^2)
SAM	AR Binder	No. 8-P	1.6/0.36	9.2/17.0
SAM	None	No. 9		5.4/10.0
Conventional	CRS-2L	No. 8-P	1.3/0.28	9.2/17.0
Modified Seal	CRS-2L	No. 8-P	0.77/0.17	8.1/15.0
Modified Seal	CRS-2L	No. 9	0.68/0.15	5.4/10.0

Materials

The SAM asphalt rubber binder had 84 percent AC-20 asphalt cement from Bristol Asphalt Products, Inc., Bristol, Virginia; 15 percent ground tire rubber from Baker Rubber Co., South Bend, Indiana (see Table 2); and 1 percent ground tennis ball production waste. The styrene-butadiene latex modified emulsion, CRS-2L (2.5 percent latex), used for the conventional and modified seals was supplied by Ultrapave (see Table 2 for binder specifications). Salem Stone Co., Sylvatus, Virginia, supplied the No. 8-P aggregate and American Limestone Co. in Abingdon, Virginia, supplied the No. 9 aggregate (see Table 3 for aggregate gradations).

Table 2. Gradation of Ground Tire Rubber

Sieve Size	Percent Passing
No. 8	100
No. 10	95-100
No. 30	0-10
No. 50	0-5

Table 3. VDOT CRS-2L Specifications

Tests	Min.	Max.
Viscosity, Saybolt Furol, 53° C (122°F), sec	100	400
Storage Stability Test, 24 hr, %	---	1.0
Classification Test	Passes	---
Particle Charge Test	Positive	---
Sieve Test, 20 mesh, %	---	0.2
Distillation Oil Distillate, by volume of emulsion, % Residue, %	 --- 65	 3.0 ---
Tests on Residue from Distillation Penetration, 25°C (77°F), 100 g, 5 sec Ductility, 25°C (77°F), 5 cm/min, cm Softening Point, -18°C (°F) Elastic Recovery: % Recovery = $\frac{20 - E}{20} \times 100$ where E is elongation in cm	 100 100 100 50	 250

Construction

The experimental and control sections were constructed on May 11 and 12, 1992. The asphalt rubber binder was blended and applied by Able Bituminous Contractors, Inc., of Riverside, Rhode Island. The No. 8-P cover aggregate for the SAM and control sections was placed by W & L Construction and Paving Co., Chilhowie, Virginia. Although the treatments were placed in May, the air temperature was always higher than 16°C (60°F) and construction never started until a surface temperature of 21°C (70°F) was reached (except for one shady location where the sun never reached the pavement and the surface temperature never exceeded 13°C ([54°F]).

A special blending unit was used by Able Bituminous Contractors, Inc., to blend the AC-20 asphalt and the ground rubber. The heating and blending of the asphalt and rubber were done near the job site in the blending unit shown in Figure 3.

Figure 3. Asphalt Rubber Blending Unit

The asphalt rubber binder was sprayed with a 22,800-l (6,000-gal) capacity distributor that was designed and built especially for Able Bituminous Contractors, Inc. Three distributor loads of the asphalt rubber were used for SAM.

The original application rate of the asphalt rubber was set at 0.96 l/m^2 (0.30 gal/yd^2) to minimize the chance of bleeding. However, the light application in the beginning did not appear satisfactory, and the application rate was raised to 1.12 l/m^2 (0.35 gal/yd^2). As shown in Table 4, the average asphalt rubber application rate for the test section was 1.15 l/m^2 (0.36 gal/yd^2), which was slightly higher than the target.

Application temperatures for the asphalt rubber were recommended to be between 143 and 218^{o}C (290 and 425^{o}F). Since the ambient temperature was cool and the contractor did not have any experience applying the material at the low application rates desired, the contractor recommended a minimum application temperature of 183^{o}C (360^{o}F) to minimize any potential application problems. Table 5 shows the asphalt temperature of each load used.

In addition to the asphalt rubber and No. 8-P aggregate, approximately 3.0 kg/m^2 (8.0 lb/yd^2) of No. 9 choke aggregate was spread on SAM to prevent aggregate pickup. Traffic was not allowed on SAM until after the final application of No. 9 material. This traffic control practice was also employed with the modified seal surface treatment and the conventional surface

Table 4. Aggregate Gradations

Sieve	Percent Passing		
	No. 8-P Spec	**No. 8-P Used**	**No. 9**
12.5 mm	100	100	100
9.5 mm	92 $\pm$ 8	93.5	92 $\pm$ 8
4.75 mm	5-30	34.0	25 $\pm$ 15
2.36 mm	Max. 5	5.4	----
1.18 mm	---	---	Max. 10

Table 5. Application Temperature of Asphalt Rubber

Load Number	Temperature ^{o}C (^{o}F)
1	193 (380)
2	186 (363)
3	199 (390)

treatment. Traffic was not allowed on any section for 1 hour, and then traffic was controlled with a pilot vehicle while the adjacent lane was treated.

During construction, the chip spreader always placed the No. 8-P aggregate within 30 seconds from the time the binder was sprayed to ensure that the binder did not cool too much before the aggregate was placed. A rubber tired roller followed by a steel wheel roller were used to embed the aggregate. After the No. 9 aggregate was placed, the rolling order was reversed.

Problems During and After Construction

A representative of Able Bituminous Contractors, Inc., had developed a special nozzle to spray the rubberized asphalt mixture at the specified low rate. Although the nozzle was somewhat successful, clogging was a continual problem that often caused nonuniformity. As can be seen in Figure 4, severe streaking occurred when the asphalt rubber was sprayed through the small-diameter nozzles.

Table 3 shows that the No. 8-P aggregate did not meet the specifications. There was also a requirement that limited the amount of -75 µm (No. 200) material to 1.5 percent as determined by washed gradation. The aggregate had a heavy dust film coating, and although a dry gradation was inadvertently performed, it would have probably failed the washed gradation requirements for -75 µm (No. 200) material. The dusty aggregate combined with the low application rate of

Figure 4. Streaking Caused by Use of Small-Diameter Nozzles

the asphalt binder produced an opportunity for aggregate loss. A subsequent review of the literature revealed specifications that require clean aggregate[3] and others that suggested precoating aggregate with a thin asphalt film[7] to overcome aggregate loss.

When the road was released to traffic, a large number of broken windshields were reported on the SAM test section for 2 weeks. There were no problems with broken windshields on the control sections. In addition, dust was quite bad on all sections.

RESULTS

Performance Evaluations

Prior to placement of the test and control sections, a pretreatment pavement evaluation was done by VTRC personnel and Bristol District materials personnel to determine pavement distresses. The evaluation included a survey of the cracks, pavement distresses, and overall condition of the pavement.

The entire section of road was severely aged, with cracks ranging in width from 6.4 mm (1/4 in) to 16.0 mm (5/8 in). However, on the north end of the project where the two control sections were placed, the cracking was less frequent and not severe. Because of the overall extensive cracking, VDOT maintenance personnel attempted to patch the cracks that exceeded 6.6 mm (1/4 in) during the week of May 4, 1992. However, because of inclement weather, many of the severe cracks were not repaired, and some failed because of poor curing conditions. The cracks on the north end were repaired successfully. It was not feasible to locate the sections in such a manner that all sections had the same types of distresses. Although this situation could be perceived as providing an unfair comparison between the test and control sections, the investigators felt that the experiment would still provide useful information about the problems experienced in the 1989 test. In addition, it provided the ultimate test for SAM since its performance was supposed to be superior to that of the control treatments. Satisfactory performance under these severe conditions would be reason for use for this material in the future.

Pavement performance evaluations were conducted periodically on the test and control sections beginning in July 1992. The results of these surveys are shown in Table 6. These evaluations were subjective, but the opinions concerning pavement distress were a consensus of several experienced individuals. Stone loss is expressed as a percentage of the stone that was dislodged by traffic and thrown to the side of the road. Cracking and bleeding are expressed as percentages of the total pavement area affected.

Table 6. Distress Survey Results

Date	% Stone Lost			% Pavement Area With Cracking			% Pavement Area With Bleeding		
	1*	2*	3*	1	2	3	1	2	3
7/16/92	18	0	0	0	0	0	25	0	0
8/18/92	18	0	0	0	0	0	25	0	0
10/19/92	25	0	0	1	0	0	40	0	0
1/26/93	30	0	0	1	0	0	45	0	0
5/17/93	40	0	0	1	0	0	45	0	0
8/16/93	40	0	0	3	0	0	50	0	0
2/28/94	40	0	0	5	0	0	50	0	0
12/12/95	40	0	0	5	5	5	50	0	0
7/10/96	50	0	0	6	5	5	50	0	0

1--SAM Surface Treatment; 2--CRS-2L Modified Single Seal Surface Treatment; 3--CRS-2L Conventional Surface Treatment.

There was no stone loss and no bleeding on the control sections. There was significant bleeding on the SAM section because of stone loss. Although the bleeding and stone loss gradually progressed as evidenced by the distress surveys, there were no further reports of broken windshields after the initial post-construction period. The final amount of cracking was approximately the same for all treatments. Since the surface on which SAM was placed had more cracking than the other sections, it was more successful at preventing the cracks from reflecting through the treatment. Although it was successful, SAM could not prevent the reflection cracks as originally hoped. Except for the appearance of stone loss and a bleeding surface on SAM, the overall performance of the pavement structure in all sections was good.

Friction Tests

Because much of the stone was whipped off the SAM test section by traffic, the investigators decided to conduct friction tests because of potential safety problems. The friction test results are shown in Table 7.

Table 7. Friction Test Results for Each Section

	Rubberized		Modified Single Seal		Conventional	
Date	**NBL**	**SBL**	**NBL**	**SBL**	**NBL**	**SBL**
	Average/Range		**Average/Range**		**Average/Range**	
7/92	50/29-59	48-29-56	51/41-54	50/43-55	50/46-56	52/47-55
6/93	39/19-53	44/18-52	44/42-47	39/27-48	48/41-54	50/41-54
6/94	30/14-51	35/16-49	42/39-44	38/33-42	45/36-50	47/39-50
6/95	29/13-50	33/16-48	40/36-41	36/32-40	41/32-48	42/37-49

The average friction numbers with the bald tire for all three sections were satisfactory (>20), but some of the numbers for SAM were low. These low friction numbers represented the 61-m (200-ft) section of road that was in the shaded area, which lost excessive stone and bled. Because the section was short and involved no turning movements of traffic, it was not considered to be a hazard. It was also reported in Texas that bleeding asphalt rubber chip seals still retained adequate friction resistance.[8]

Cost-Effectiveness

The cost of SAM was about double that of the conventional and single modified treatments. The costs were \$1.20/m^2 (\$1.00/yd^2 for SAM, \$0.60/ m^2 (\$0.50/ yd^2) for the conventional treatment, and \$0.67/ m^2 (\$0.56/ yd^2) for the modified single seal treatment. These first costs are close to those reported in a Texas report[8] and NCHRP synthesis[9] and indicate that a SAM would have to last approximately twice as long as a normal treatment to be cost-effective.

DISCUSSION

Problems encountered during construction were different from those associated with the earlier project in VDOT's Suffolk District. Bleeding occurred because of excessive stone loss, not because of applying too much binder, which happened on the Suffolk project. Although bleeding occurred, the friction numbers were satisfactory.

One cause of lost stone was that it was coated with excessive fines. The asphalt rubber binder is a viscous material that tends not to flow through the dust coating and form a tight bond with the large aggregate particles. The CRS-2L used on the control sections was more likely to penetrate the dust coating and coat the aggregate particles well to form a good bond. The literature[7] indicates that it may be necessary to precoat the aggregate with binder to ensure stone retention, which would result in higher costs. To try to prevent the bleeding that had occurred in the earlier project, the binder application rate was set lower than that recommended by industry. The lower application rate also possibly caused stone loss. The correct application rate that would result in neither bleeding nor stone loss may be hard to achieve under routine conditions.

Another negative aspect of stone loss was broken windshields and inconvenience to the highway users. Phoenix, Arizona, discontinued use of SAM because of the public outcry against its use.[7]

A positive aspect of SAM was its ability to keep cracks sealed to prevent the entrance of surface water. Although many cracks of the underlying surface were evidenced by the depressed appearance, they remained sealed.

The initial cost of SAM is considerably more than the initial cost of treatments currently used in Virginia. The service life of SAM would have to be much longer than that of current treatments to be cost-effective. An attempt will be made to monitor the age at which the different treatments need to be resurfaced to determine an accurate comparison of effectiveness.

CONCLUSIONS

- SAM is effective in keeping cracks of the old surface sealed.

- Although SAM is slightly more effective at preventing reflection cracks, the excessive loss of coarse aggregate under traffic results in broken windshields.

- Conventional treatments are better than SAM, primarily because of the aggregate-loss problem.

- Friction values for SAM are generally satisfactory, although stone is lost and the asphalt rubber is exposed.

- It appears to be difficult to use the proper amount of asphalt rubber binder that will result in neither aggregate loss nor bleeding.

RECOMMENDATION

- SAMs should not be pursued further as a method of surface treatment in Virginia.

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