EVALUATION OF GROUND AND RECLAIMED TIRE RUBBER IN BITUMINOUS RESURFACING MIXTURES

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SUMMARY

Eight experimental rubber asphalt test sections along with eight comparable control sections, were constructed in 1978 and 1979 on M 46 in Saginaw County. Condition surveys were made before construction and throughout a five-year evaluation period to determine effectiveness in reducing rutting and reflective cracking. Laboratory tests were also performed to measure tensile strength, resilient modulus, and other structural parameters of both the experimental and control section mixtures.

INTRODUCTION

Rehabilitating the Michigan highway system involves resurfacing many miles of roadway with bituminous mixtures each year for the purpose of providing a smooth, continuous water-resistant surface over existing pavements constructed of either asphalt or portland cement concretes. However, cracks and joints in the old pavement soon 'reflect' through the new bituminous surfacing, allowing water penetration which generally shortens pavement life.

Several procedures have been tried over the years to reduce reflective cracking including the use of separation courses, bond-breaking layers, breaking of the old concrete into pieces, and increasing the thickness of the asphaltic overlay to as much as 5 or 6 in. Some of these methods, alone or in combination, have been effective—with the more effective methods involving thick layers of separation and overlay materials—but all are expensive. Large quantities of aggregates and asphalts are required for thicker construction and could create problems in connection with structure and guardrail clearances. Rubberized asphaltic overlays of normal thickness (1 to 2 in., generally) have also been tried on a limited basis using both latex formulations and ground reclaimed tire rubber.

Laboratory studies have recently been reported which indicate that the use of scrap rubber has improved the performance of asphalt surfaces with respect to low temperature flexibility, skid resistance, fatigue life as well as a reduced tendency for bleeding and flushing (1, 2). Both field and laboratory experience indicate that normal paving mixtures require approximately 5 percent rubber (based on the amount of asphalt cement) for optimum results. Two types of scrap rubber are generally considered for this use; ground 'reclaimed' or 'devulcanized' rubber and ground rubber crumb (3). Reclaimed rubber has been subjected to heat and chemical treatment in an attempt to devulcanize or return it to a plastic state. Ground rubber crumb on the other hand is simply scrap rubber ground and sieved to the desired sizes.

The literature indicates that reclaimed rubber can be added to either hot asphalt cement or to hot aggregate in the pug mill. Ground rubber,

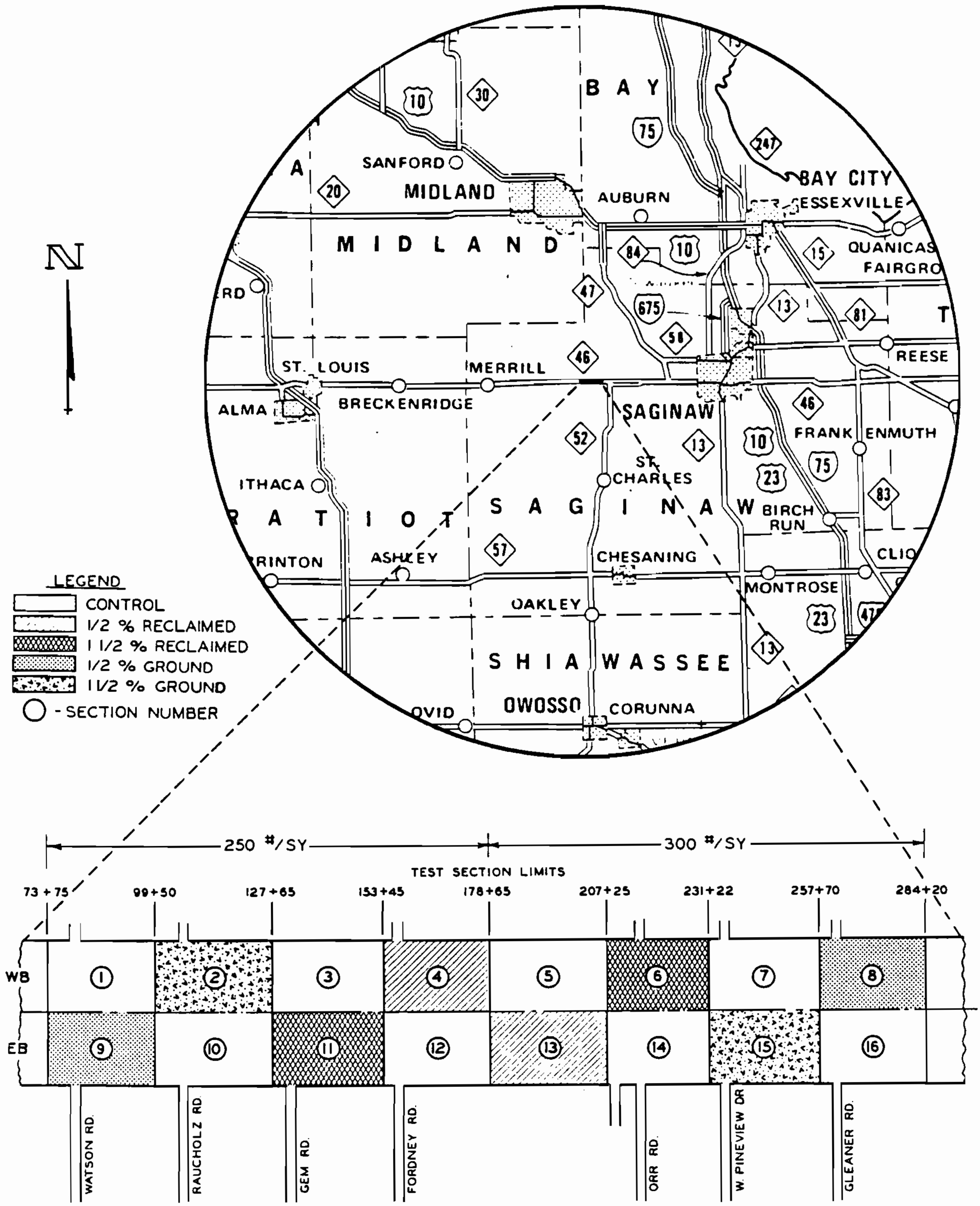


Figure 1. Diagram of experimental sections of the rubber-asphalt overlay evaluation on M-46 in Saginaw County, showing application rates and rubber content of test sections.

however, has generally been added to only the hot asphalt cement to make a rubberized binder prior to blending with aggregates. The effectiveness of both types of rubber, when used as a resilient filler, has been measured in the laboratory (1). Little or no difference was observed between the two types of rubber but both showed improvement in physical characteristics when compared with non-rubber control mixtures. As a resilient filler the ground rubber is blended with the hot mixture in the pug mill.

The purpose of this study is to evaluate the effectiveness of ground crumb and reclaimed tire rubber in asphalt mixes for reducing reflective cracking and increasing the life of pavement overlays.

CONSTRUCTION OF TEST SECTIONS

Sixteen test and control sections were constructed on M 46 in Saginaw County as shown in Figure 1. The sections were a portion of a project involving a two-course bituminous resurfacing placed over a jointed concrete pavement which had previously been overlayed with the overlay badly rutted. In addition to rutting the old surface was cracked over each joint.

Prior to construction, laboratory mix designs were prepared using materials from the project for the three mixtures; conventional, ground rubber crumb, and reclaimed rubber. Aggregate gradations were the same for all mixes as shown in Table 1. The two types of tire rubber were incorporated in the mixes at two percentage levels, 1/2 percent and 1-1/2 percent, requiring separate Marshall mix designs for each as well as a design for the conventional paving mixture for the control sections. Marshall mix design results for the three mixtures are summarized in Table 2.

TABLE 1
PROJECT MIX
DESIGN GRADATION

Sieve Size	Percent Passing
3/4"	100.0
1/2"	97.5
3/8"	88.2
#4	69.1
#8	54.5
#16	42.7
#30	32.0
#50	18.7
#100	9.5
#200	6.5

Paving of the leveling course was completed in the fall of 1978 with the top course applied in the summer of 1979.

Ground rubber mixtures were prepared in the contractor's batch plant. Ground tire rubber crumb in 50-lb bags was added to the aggregate in the pug mill immediately prior to the addition of the asphalt cement. The rubber-aggregate blend was then dry mixed for 10 seconds, the asphalt cement added and then mixed for an additional 45 seconds. Low melt (200 F) polyethylene bags were used and batch weights set so that whole numbers of unopened bags could be put into the pug mill.

Reclaimed tire rubber was premixed with heated asphalt cement in a heated storage tank then pumped into the batch plant weigh bucket in the normal manner. Because of difficulties in attaining sufficiently high asphalt temperatures prior to blending, the rubberized asphalt accumulated in the weigh bucket. Two batches of conventional mix were than made which cleared the weigh bucket before production of reclaimed rubber mix could be resumed.

TABLE 2
MARSHALL MIX DESIGN INFORMATION FOR CONTROL, GROUND RUBBER, AND RECLAIMED RUBBER TEST SECTIONS

	Control	Ground Rubber Crumb	Reclaimed Rubber
Optimum Asphalt Content, %	6.15	6.08	5.69
Stability, lbs	2435	2002	3637
Flow	13.0	11.9	12.04
Air Voids	2.92	2.99	2.99
V.M.A.	17.09	16.84	16.11
Void Filled with Asphalt	82.92	82.27	81.28
Density, pcf	147.7	146.1	147.8

EVALUATION PROCEDURE

Evaluation was based on the performance of eight pairs of test and control sections during a five-year period. Supplementing the field evaluation measurements were laboratory tests to measure physical characteristics of the experimental and control mixtures. The test and control sections, each approximately 1/2 mile long, were constructed to include two levels of each of the rubber additives at two different overlay thicknesses as shown in Figure 1. During construction, samples of the mixture were obtained from the test sections and the following measurements were made in the laboratory:

1) Unit weight
2) Marshall stability and flow
3) Resilient modulus
4) Indirect tensile strength

Field evaluation measurements included rut depths, condition surveys (primarily cracking), and friction levels. Initial field measurements and observations were made within six months after construction, then were continued yearly throughout the evaluation.

RESULTS

Field performance evaluation was based on reflective cracking, rut depths, friction levels, and overall condition at the end of the evaluation period.

Analysis of reflective cracking was based on the Cracking Index* for each section after three years of service, expressed as a percentage of the Cracking Index measured prior to resurfacing (4). Cracking Index ratios for test and control section pairs, shown in Figure 2, demonstrate no overall benefit from either type of rubber. Only section 13, when compared with section 5, shows a lower ratio of cracking while sections 2 and 15 (1-1/2 percent ground rubber) show greatly increased crack reflection.

Final rut depth measurements made at the end of the evaluation period show a general reduction in rutting for the rubber sections (Fig. 3). Rutting comparisons were made by pairing sections in the eastbound lanes and in the westbound lanes in order to account for traffic differences, since all sections in the eastbound lane experienced less rutting. Results shown in Figure 4 indicate that there was more traffic in the westbound lane than in the eastbound lane. With the exceptions of sections 7 and 11, the rubber asphalt sections reduced rutting as compared with sections paved with the conventional mixture. Considering the westbound lane, rutting was reduced by 21 percent in sections containing the ground rubber mixture but only by eight percent in sections with the reclaimed rubber. Similar reductions were achieved in the sections in the eastbound lane. Average final rut depth measurements are tabulated below and are also included in Figure 3.

	Final Rut Depths, in.	
	Westbound	Eastbound
Control	0.131	0.050
Ground	0.104	0.033
Reclaimed	0.121	0.046

Pavement Friction Numbers, FN, were nearly equal for the three surfacing mixtures as shown below.

	Friction Number	
	Average	Standard Deviation
Control	43	2.1
Ground	43	2.5
Reclaimed	42	2.0

*Cracking Index is defined as the number of transverse cracks across the full pavement width plus one-half of the number of cracks extending one-half the width in a 500-ft section of two-lane roadway.

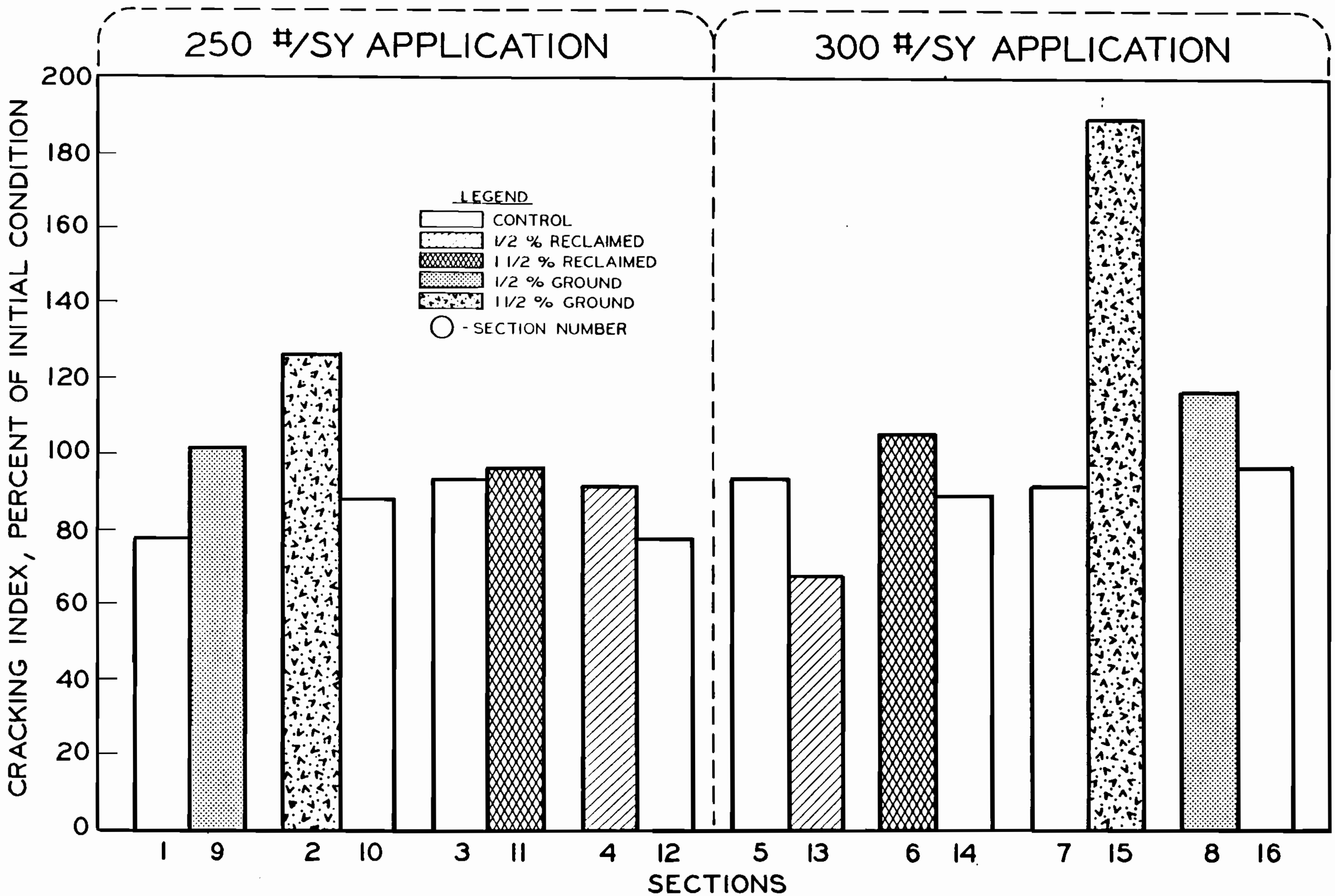


Figure 2. Cracking index ratios for test sections and comparable control sections of conventional mixture.

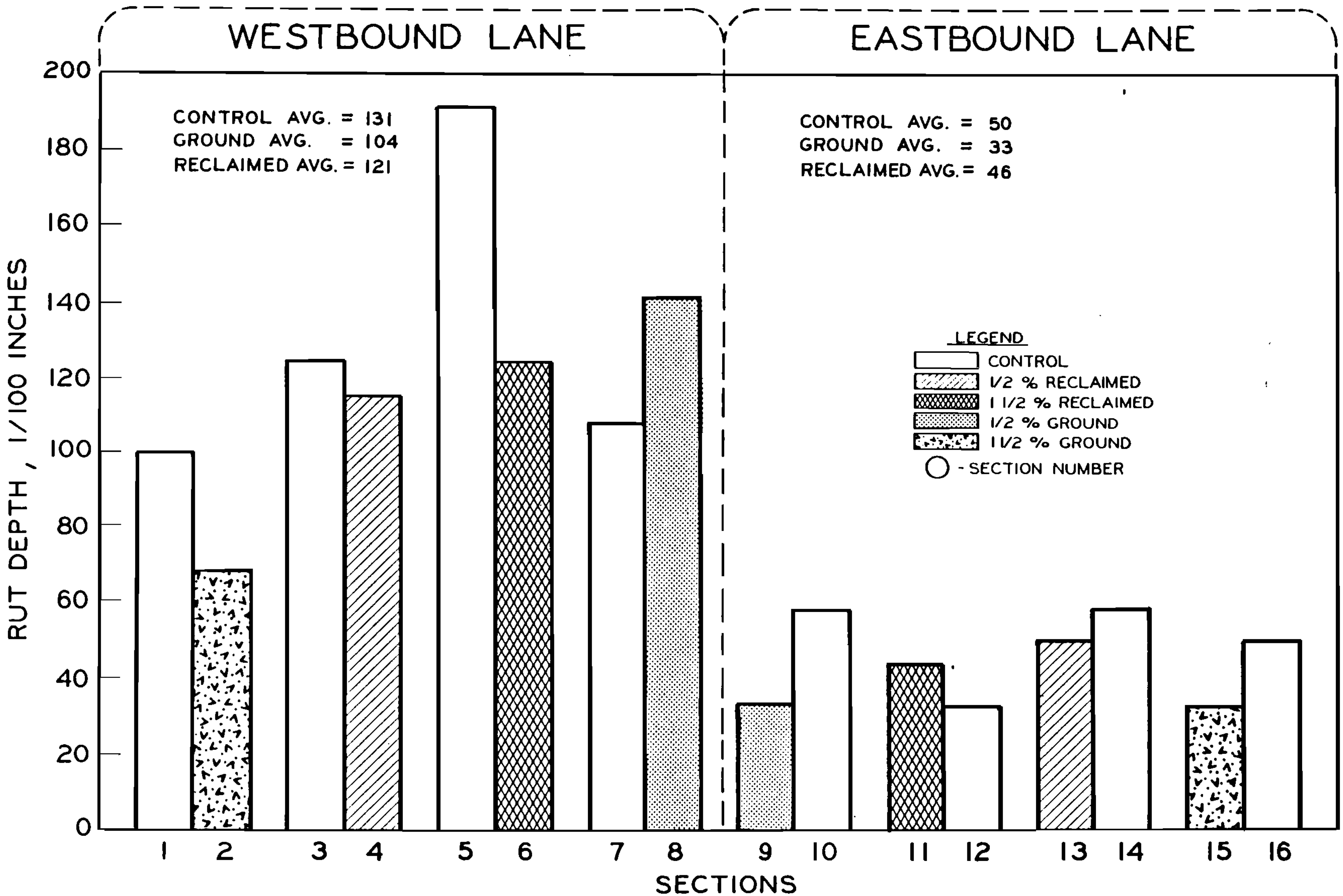
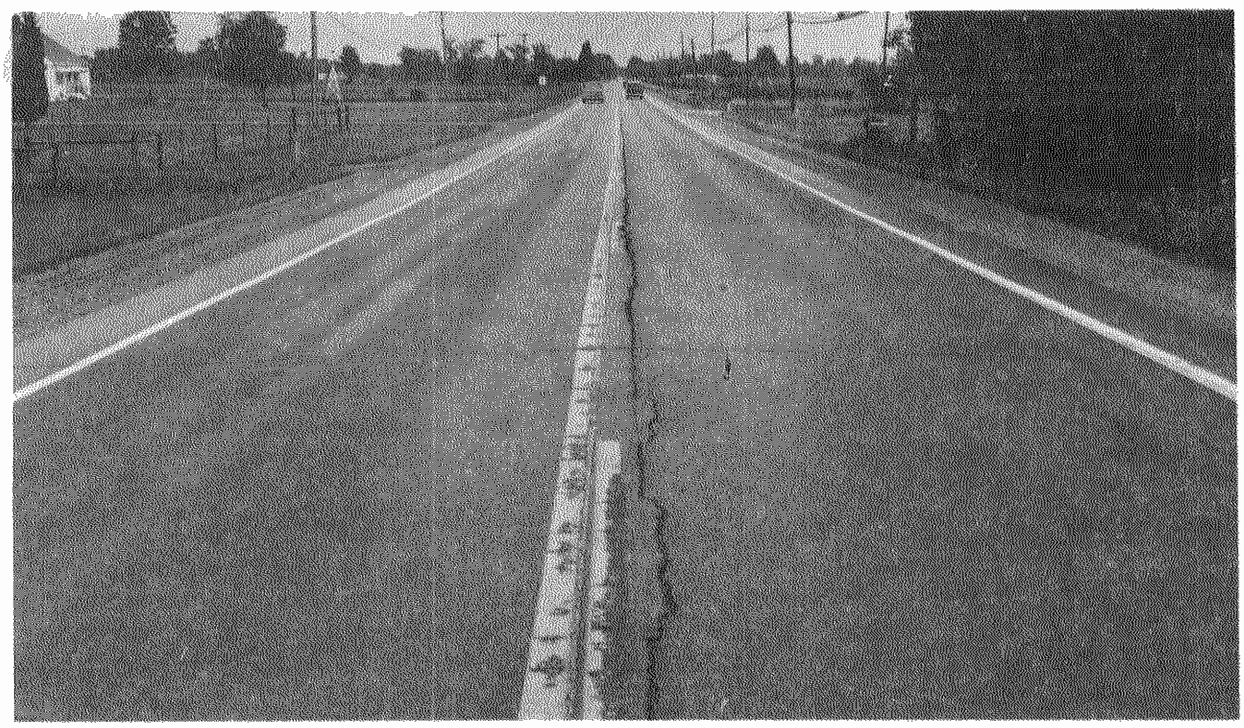


Figure 3. Final rut-depth measurements for test sections and comparable control sections.

Control section 7 in left lane. Ground rubber mix, 1-1/2 percent, in right lane, section 15.



Control section 3 in left lane. Reclaimed rubber mix, 1-1/2 percent, in right lane, section 11.

Figure 4. Condition of the experimental rubber-asphalt and control sections at the end of the evaluation.

In addition to the evaluation tests and measurements previously described, field inspections were performed periodically. During these inspections it became obvious that the 1-1/2 percent ground rubber sections (sections 2 and 15) were disintegrating and required frequent maintenance patching. Figure 4 shows the condition of the 1-1/2 percent rubber sections as compared with the adjacent control section at the end of the evaluation.

Laboratory test results are summarized in Table 3 showing indirect tensile strength, tensile strain at failure and resilient modulus. There does not seem to be any relationship between these test values and field performance except perhaps in sections 2 and 15, the 1-1/2 percent ground rubber sections. Tensile strengths and resilient modulus values were lower for sections 2 and 15 than for the other materials.

TABLE 3
STRUCTURAL PROPERTIES OF RUBBER ASPHALT MIXTURES AS MEASURED IN THE LABORATORY

Property	Mixture				
	Control	Reclaimed		Ground	
		1/2%	1-1/2%	1/2%	1-1/2%
Indirect Tensile Strength	165	130	126	169	115
Tensile Strain at Failure	.0078	.0088	.0105	.0079	.0081
Resilient Modulus (.1 sec. 72 F)	822,000	625,000	548,000	820,000	442,000

CONCLUSIONS

Even though extensive laboratory testing was performed on the experimental and control mixes, the in-service performance of the test sections provided the only significant comparative results. Reclaimed rubber, which required premixing with hot asphalt cement, was the most troublesome during plant operations; the required 400+ F asphalt temperature in the blending tank was difficult to achieve as was adequate mixing. Specific conclusions resulting from this study are as follows:

1) Mixing rubber with hot asphalt cement requires direct mechanical mixing along with temperatures well above 400 F to avoid agglomeration in the tank and clogging of pumps and delivery system.

2) The 1-1/2 percent ground rubber mixture performed poorly in terms of reflective cracking and surface disintegration.

3) No overall reduction in reflective cracking was achieved with any of the rubber mixtures.

4) Some reduction in rutting was obtained with all the rubber mixtures with the 1-1/2 percent ground rubber mixes being more beneficial than the other mixes in reducing rutting.

5) There was no significant difference in pavement friction values measured for the several mixtures used in the project.

RECOMMENDATIONS

Based on the results of this evaluation it is recommended that tire rubber (either ground or reclaimed) not be added to bituminous paving mixtures. Before considering future projects involving rubber additions it is recommended that benefit-cost evaluations be performed on the candidate mixtures. The benefit-cost evaluation should be performed in the laboratory in conjunction with the mix design and would involve the measurement of strength and stiffness retained by the mixture after simulated environmental exposure.

It is further recommended that the effects of tire rubber on mix properties after several recyclings be assessed before further projects are initiated.

REFERENCES

1. McRae, J. L., and LaGrone, B. D., "Effect of Modified Reclaimed Rubber and Ground Vulcanized Rubber on the Physical Properties of Bituminous Pavements as Evaluated by the Gyratory Testing Machines," Highway Research Record No. 361, pp. 14-19, 1971.

2. Stephens, J. E., and Mokrzewski, S. A., "The Effect of Reclaimed Rubber on Bituminous Paving Mixtures," School of Engineering, University of Connecticut, March 1974.

3. "Those Amazing Rubber Roads," Rubber World, March 1967.

4. Haas, R. C. G., "A Method for Designing Asphalt Pavements to Minimize Low-Temperature Shrinkage Cracking," The Asphalt Institute, Research Report 73-1 (RR-73-1), January 1973.