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Department of Transportation

RESEARCH PROJECT NO. 90-063
EVALUATION OF RUBBER-MODIFIED
ASPHALTIC CONCRETE

FINAL REPORT
SEPTEMBER 1998

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PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF CONSTRUCTION AND MATERIALS
ENGINEERING TECHNOLOGY AND INFORMATION DIVISION

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The effective disposal of waste tires has become an increasing problem that will grow if something is not done to alleviate this problem. With this concern in mind, legislation has been passed to encourage the public and private sector to find ways to reuse tires.

Other States DOT's have been incorporating waste tire rubber into many different asphaltic materials, primarily as a crack sealant. Some have experimented with adding ground tire rubber to asphaltic mixes in hope that it will solve the dilemma of growing waste tires and produce improved road surfaces.

This report evaluated rubber-modified asphaltic concrete mix using the wet process in comparison to the Department's standard ID-2 bituminous wearing mix. The wet process pre-blends the ground rubber into the liquid asphalt and then adds the rubber-modified asphalt to the aggregate. The control mix and the rubber-modified asphalt mix were compared over a performance period of 5 years, and the rubber-modified asphalt mix results were unfavorable. The rubber-modified asphaltic mix showed enhanced signs of wear and cracking, while the standard ID-2 mix showed normal wear and minor cracking. Therefore at this time, utilizing waste tires in rubber-modified asphalt concrete using the wet process is not recommended for use by the Department as an alternate roadway mix.

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CONDUCTED BY:
THE PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
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September 1998

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Metric Conversion Factors*

To Convert From:	To:	Multiply By:
	Length	
foot (ft)	meter (m)	0.3048
inch (in)	millimeter (mm)	25.4
yard (yd)	meter (m)	0.9144
mile (statute)	kilometer (km)	1.609
	Area	
square foot (ft^2)	square meter (m^2)	0.0929
square inch (in^2)	square centimeter (cm^2)	6.451
square yard (yd^2)	square meter (m^2)	0.8361
	Volume	
cubic foot (ft^3)	cubic meter (m^3)	0.02832
cubic yard (yd^3)	cubic meter (m^3)	0.00315
gallon (U.S. liquid)	cubic meter (m^3)	0.004546
ounce (U.S. liquid)	cubic centimeter (cm^3)	29.57
	Mass	
ounce-mass (avdp)	gram (g)	28.35
pound-mass (avdp)	kilogram (kg)	0.4536
ton (metric)	kilogram (kg)	1000
ton (short, 2000 lbm)	kilogram (kg)	907.2
	Density	
pound-mass/cubic foot	kilogram/cubic meter (kg/m^3)	16.02
mass/cubic yard	kilogram/cubic meter (kg/m^3)	0.5933
pound-mass/gallon(U.S.)**	kilogram/cubic meter (kg/m^3)	119.8
pound-mass/gallon(Can.)*	kilogram/cubic meter (kg/m^3)	99.78
	Temperature	
deg Celsius (°C)	kelvin (°K)	$t^{\circ}K = (t^{\circ}C + 273.15)$
deg Fahrenheit (°F)	kelvin (°K)	$t^{\circ}K = (t^{\circ}F + 459.67) / 1.8$
deg Fahrenheit (°F)	deg Celsius (°C)	$t^{\circ}C = (t^{\circ}F - 32) / 1.8$

ABSTRACT

The effective disposal of waste tires has become an increasing problem that will continue to grow if something is not done to alleviate this problem. With this concern in mind, legislation has been passed to encourage the public and private sector to find ways to reuse waste tires.

Other States DOT's have been incorporating waste tire rubber into many different asphaltic materials, primarily as a crack sealant. Some have experimented with adding crumb rubber to asphalt mixes in hope that it will solve the dilemma of growing waste tires and produce improved road surfaces.

This report evaluated a rubber-modified asphaltic concrete mix using the wet process in comparison to the Department's standard ID-2 bituminous wearing mix. The wet process pre-blends the ground rubber into the liquid asphalt and then adds the rubber-modified asphalt to the aggregate. The control mix and the rubber-modified asphalt mix were compared over a performance period of 5 years, and the rubber-modified asphalt mix results were unfavorable. The rubber-modified asphaltic mix showed enhanced signs of wear and cracking while the standard ID-2 mix showed normal wear and minor cracking. Therefore at this time, utilizing waste tires in rubber-modified asphalt concrete using the wet process is not recommended for use by the Department as an alternate roadway mix.

INTRODUCTION

Throughout the nation, the effective disposal of waste tires has been an increasing problem. Mountains of tires exist in almost every community across the nation and the problem will steadily grow with the passage of time. The Pennsylvania Legislature has drafted legislation to control the storage of, and the disposal of, waste tires. This legislation is directed at regulating the storage and disposal of waste tires, but also encourages beneficial uses of the tires.

Other State DOT's have already been incorporating waste tire rubber into many different asphaltic materials, primarily as a crack sealant. Some have experimented with adding crumb rubber into asphaltic concrete mixes in hope that it will solve the dilemma of growing waste tires and induce improved road surfaces. When adding the waste tire crumb rubber to the asphaltic material there are two different processes of mixing. The dry process adds the crumb rubber at the plant by introducing it directly into the hot aggregate in the pugmill or drum dryer. The wet process pre-blends the crumb rubber into the liquid asphalt using special equipment and then adds the combined liquid to the aggregate. Both methods have been previously utilized by other States.

The purpose of this report was to evaluate rubber-modified asphaltic concrete using the wet process in comparison to a standard ID-2 bituminous wearing course of the Department's. The rubber-modified asphaltic concrete and the control were compared over a performance period of 5 years.

CONSTRUCTION SUMMARY

In 1991, the Department constructed a test site beginning at the Westmoreland-Fayette county line at Scottsdale and continuing approximately 4 miles SW on SR 0819 in Fayette County (see Figure 1 page 2). The paving operation included base repair, shoulder seal coat, and an overlay of a Bituminous Wearing Course, ID-2, Bituminous Leveling Course, SRL-M. As a comparison the bituminous wearing course mix had two variations one with a crumb rubber modifier (experimental) and one without the crumb rubber (control).

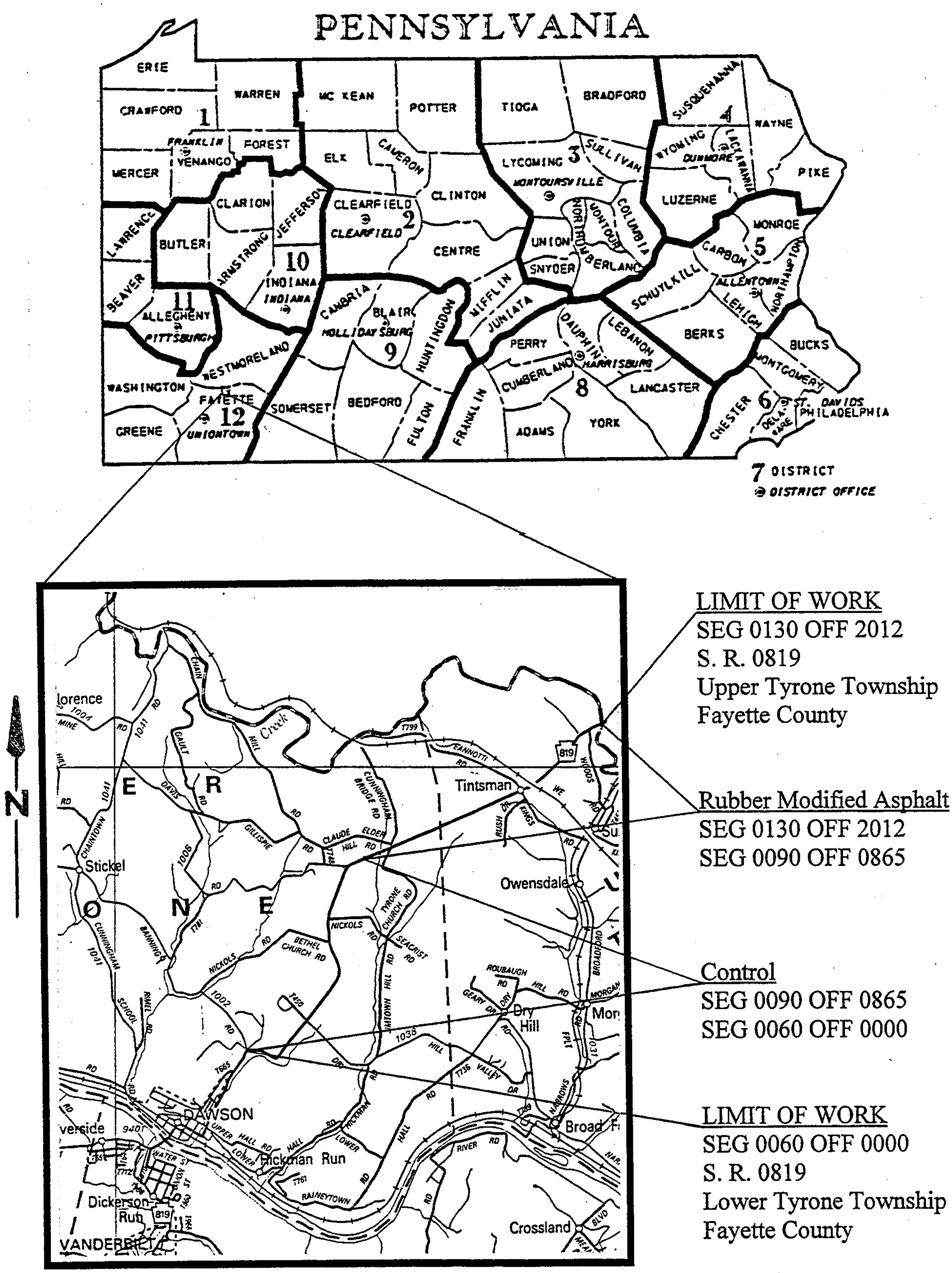

FIGURE 1: Location Map of SR 0819 Fayette County

The crumb rubber mix and the control mix were placed as a one and one-half (1½) inch depth overlay on the existing pavement, each section approximately 2 miles in length. The same base liquid asphalt was used for the crumb rubber section and the control section. The existing roadway consisted of a 14 to 16 foot wide concrete pavement widened with BCBC. The widening was paved with a binder and the shoulder was paved with a selected material.

No samples were taken during the mix design process. All samples were taken during construction. Loose box samples and pavement cores were taken of the experimental mix (rubber-modified asphaltic concrete) and of the control mix (standard ID-2) to evaluate the materials properties. Special attention was paid to the stability and the density achieved, as well as monitoring the gradation and asphalt content of the mixes.

For this evaluation 2,213 tons of rubber-modified asphaltic concrete material was placed in two days. The Department used the wet process for this material therefore the liquid binder contained the crumb-rubber modifier. The crumb-rubber modified asphalt liquid binder was approximately 137 tons (6.2% by weight of the total mix). The asphalt liquid binder contained approximately 13.7 tons of the crumb rubber (10% by weight of the liquid binder). The percentage of crumb-rubber (10%) used was based on manufactures and national experience. Using less than 10% in the liquid binder would have made the use of crumb-rubber negligible.

COST ANALYSIS SUMMARY

The objective of this experiment was to compare the rubber-modified asphaltic concrete with the more commonly used ID-2 wearing surface. The cost per ton of the ID-2 wearing surface was $28.06. In comparison, the cost of the rubber-modified asphalt was $44.91 per ton. In this case 2,213 tons of the crumb rubber-modified asphalt concrete was used, resulting in a total cost of $99,385.83, if the common ID-2 would have been used the cost would have been $62,096.78. The cost of the rubber-modified asphaltic concrete was 60% greater than the standard ID-2 bituminous wearing course used as a control.

PERFORMANCE SUMMARY

Site investigations were performed yearly to determine the quality of the roadway surface of the rubber-modified asphaltic concrete and the standard ID-2 bituminous wearing course. Initially the crumb rubber asphalt was performing satisfactorily when compared to the control. The first indication of additional cracking was reported in May of 1993. In February and March of 1994, there were significant, visible differences between the control and the rubber-modified asphaltic concrete. The rubber-modified section was found to contain large longitudinal cracks and noticeable raveling (see photos 3-6 pages 7-8). District 12-0 had sealed the cracks in the rubber-modified section by the next inspection in May of 1995. In May of 1995 additional photos were taken of the cracks that had continued to develop in the rubber-modified asphalt (see photo 8 page 9). The rubber-modified section continued to exhibit more raveling and longitudinal cracking as compared to the control.

It appears the crumb-rubber modifier that was added to the asphalt, resulted in the asphalt binder becoming stiffer. This stiffness resulted in poor performance relative to fatigue (longitudinal cracking) and low temperature (transverse cracking). In comparison, the unmodified asphalt binder used as the control did not exhibit this cracking, suggesting that the base liquid asphalt had suitable intermediate and low temperature properties to resist the longitudinal and transverse cracking.

DISCUSSION

The Department is currently in the process of implementing SHRP performance-graded binder specifications and is evaluating a proprietary chemically treated crumb rubber modified product in both the wet and dry process. In the long run it is envisioned that how a specific producer meets the performance grading requirements of the SHRP specification will be "blind" to the user, such that crumb rubber may be a viable alternative. It is important that the Department assess the performance of such mixes to determine their long-term viability.

Additionally, in reaction to previous ISTEA Section 1038 requirements, the Department, like other state DOT's, initiated a program to utilize tires in asphalt mixes. The Department chose to put crumb rubber in base course mixes by the dry process at 1% of the total mix. This increased mix cost by approximately 17%. However, since the ISTEA requirements have been rescinded, the Department has decided not to mandate placement of additional crumb rubber base course mixes due to the additional cost.

CONCLUSION AND RECOMMENDATIONS

The problem of the disposal or storage of, waste tires is a very serious problem that needs to be addressed quickly and efficiently. Using the waste tires in asphalt mixes would solve part of this problem. However, the performance of the rubber-modified asphaltic concrete was found unsatisfactory in comparison to the Departments standard ID-2 wearing course. In addition, the cost of the rubber-modified concrete was considerably larger than the ID-2 surface. The Department encountered no improvements with the rubber-modified asphaltic concrete when compared to the ID-2 surface. Therefore, this particular procedure for utilizing waste tires in rubber-modified asphalt concrete is not recommended for use by the Department as an alternate roadway mix at this time.

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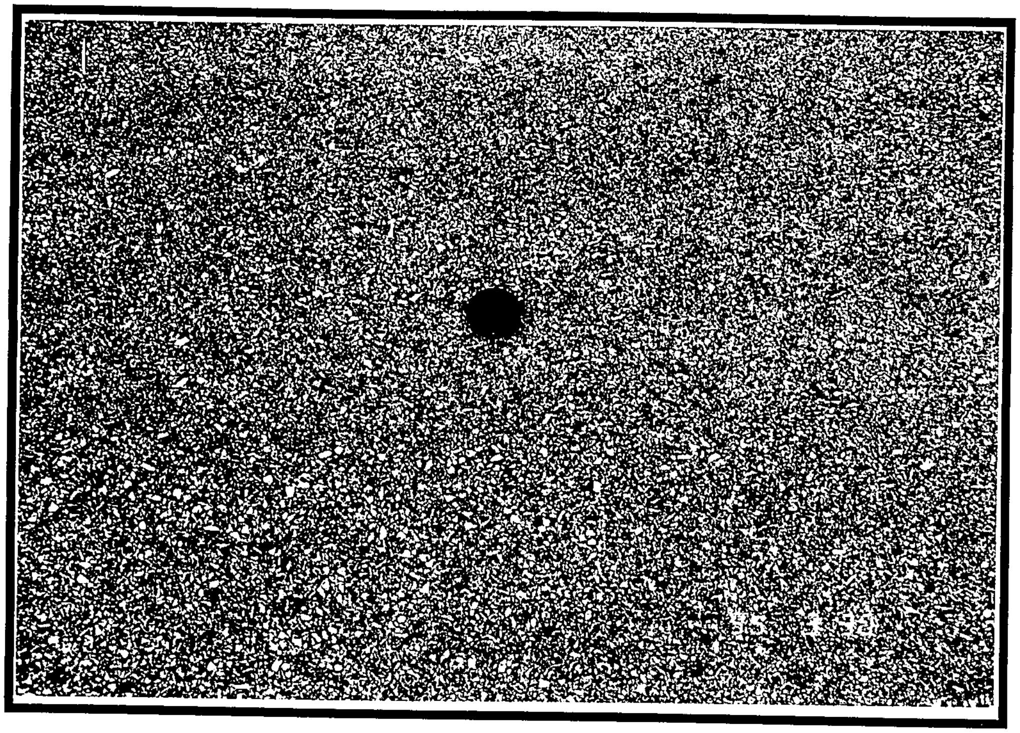

Photo No. 1 Close-up of control pavement
March, 1994

Photo No. 2 Looking south at control section
March, 1994

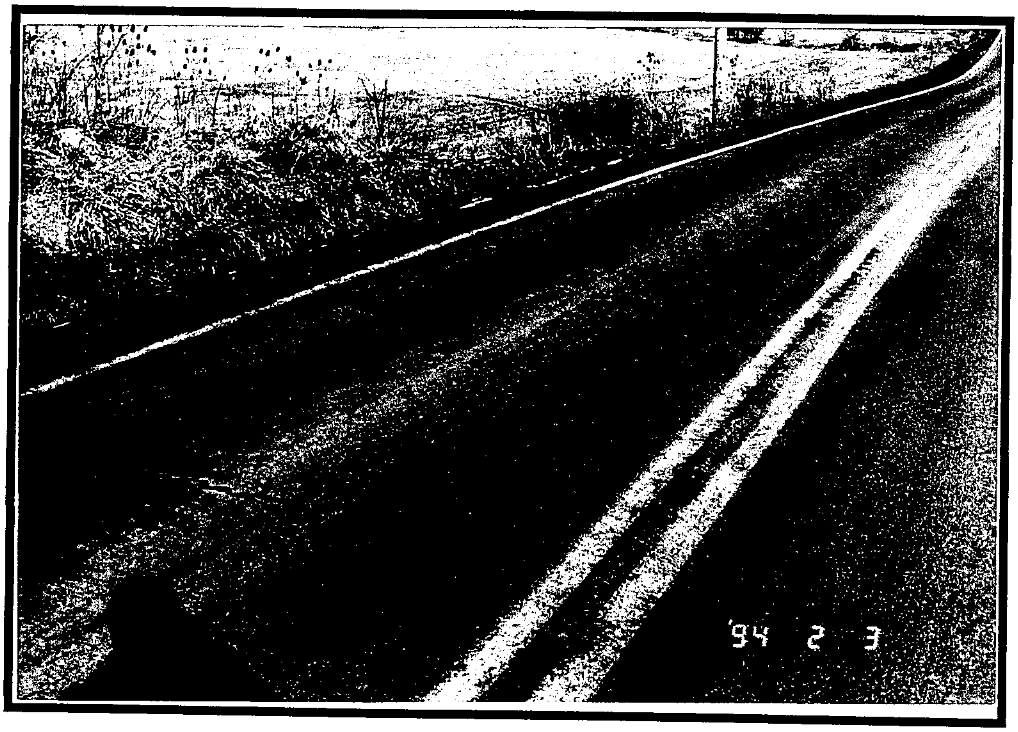

Photo No. 3 Cracks in rubber-modified asphalt
February, 1994

Photo No. 4 Cracks in rubber-modified asphalt
March, 1994

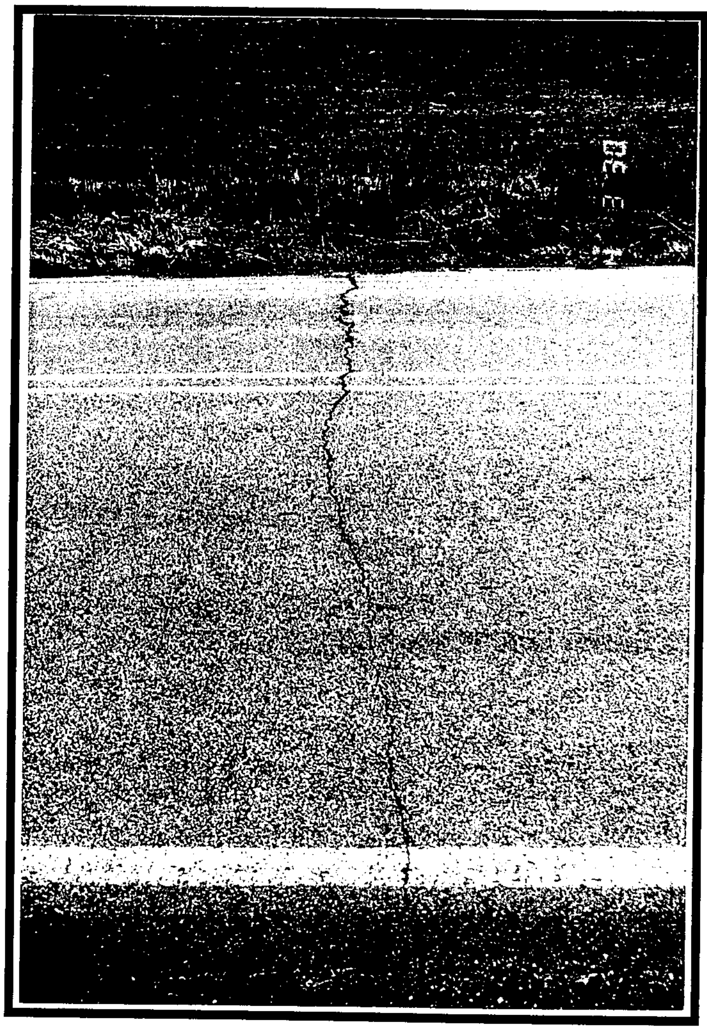

Photo No. 5
Cracks in rubber-modified asphalt
March, 1994

Photo No. 6
Cracks in rubber-modified asphalt
May, 1994

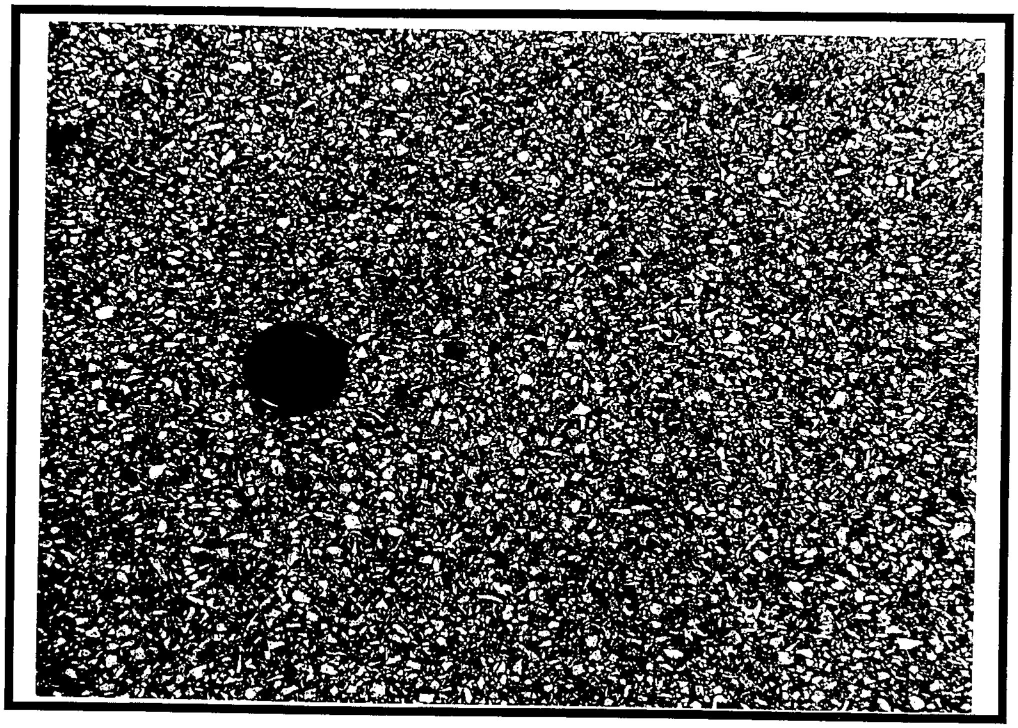

Photo No. 7 Close-up of control pavement
May, 1995

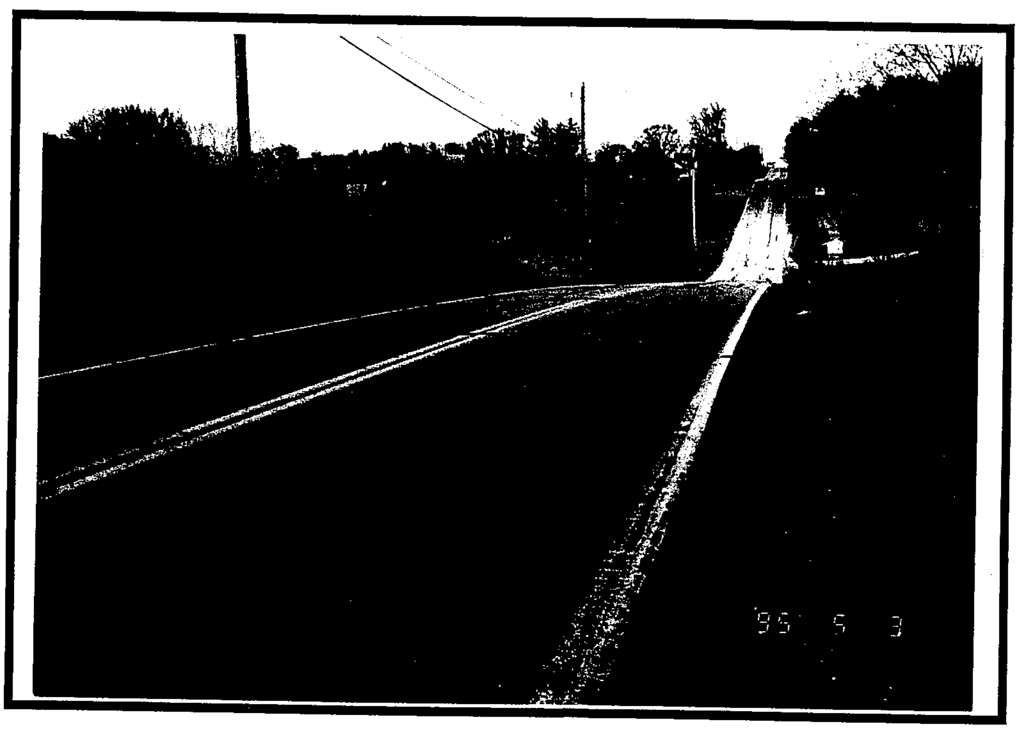

Photo No. 8 Sealed cracks in rubber-modified asphalt
May, 1995

Appendix A
Job Mix
Formula Reports

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Experimental
ID-2 Wearing 10% Rubber 91-9
Job Mix Formula Report

AGGREGATE AND AC PRODUCER	LOCATION	SPEC.	TYPE	%	SP. GR.
Coolspring Stone Supply	Map 26A	#10	A	33.4	2.637
Coolspring Stone Supply	Map 26A	#8	A	46.1	2.639
Dravo Basic Materials	DRA 04A	N Sand	A	14.3	2.566
Rouse Rubber Industries	Vicksburg, MS	Rubber	GF-80	0.62	1.15
Ashland/Boswell/Coastal/Amoco	Floreffe/D'burg/ Charl/Balt.	AC	20	5.58	1.03

Type:__________ Pen:________ Visc. @ 140 F:________ Visc. @275 F:________ Mix Temp.: SRL-H

Job Mix Formula and Design

Bit.	AC	Rubber	1½	1	½	3/8	4	8	16	30	50	100	200
Upper	6.28				100	100	71	48	36	28	22	16	9
Design	5.58	0.62			100	93	63	42	30	22	16	10	6
Lower	4.88				100	85	55	36	24	16	10	4	3

Mix Characteristics

Theor. Density	Lab Density	Bitumen % by Wt.	Rubber % by Wt.	Pass No. 8	Pass ½"	Stability	Flow	Percent by Volume		
								Voids	VFA	VMA
2.450	2.357	5.58	0.62	42	100	2640	14.3	3.7	78.0	16.4

Hot Bins

Bin	2½	2	1½	1	3/4	1/2	3/8	4	8	16	30	50	100	200	Hot Blend %
1						100	100	100	93	71	52	31	24	14	42
2						100	88	36	5						58
3															
4															
5															
Comb															100

Batch Composition

	AC Rubber Blend	Bin No. 1	Bin No. 2	Bin No. 3	Bin No. 4	Bin No. 5
Per Cent	6.2	39.4	54.4			

Control
ID-2 Wearing 91-15
Job Mix Formula Report

AGGREGATE AND AC PRODUCER	LOCATION	SPEC.	TYPE	%	SP. GR.
Coolspring Stone Supply	Map 26A	#10	A	33.4	2.637
Coolspring Stone Supply	Map 26A	#8	A	46.1	2.639
Dravo Basic Materials	DRA 04A	Type A	Sand	14.3	2.566
Ashland/Boswell Tri State	Floreffe/Dravosburg/ Warrenton				
Lake/United/Coastal	Springdale/Warren/ Charleroi	AC	20	6.2	1.03

Type: AC-20 Pen: ** Visc. @ 140 F: ** Visc. @275 F: ** Mix Temp.: ** SRL-?
**As per affidavit from refinery

Job Mix Formula and Design

Bit.	AC	2	1½	1	½	3/8	4	8	16	30	50	100	200
Upper	6.9				100	100	71	48	36	28	22	16	9
Design	6.2				100	93	63	42	30	22	16	10	6
Lower	5.5				100	85	55	36	24	16	10	4	3

Mix Characteristics

Theor. Density	Lab Density	Bitumen % by Wt.	Filler % by Wt.	Pass No. 8	Pass ½"	Stability	Flow	Percent by Volume		
								Voids	VFA	VMA
2.418	2.342	6.2	-----	42	100	2177	11.7	3.0	82.0	16.4

Hot Bins

Bin	2½	2	1½	1	3/4	1/2	3/8	4	8	16	30	50	100	200	Hot Blend %
1						100	100	100	93	71	52.4	31	23.8	14.3	42
2						100	87.9	36.2	5.0						58
3															
4															
5															
Comb						100	93	63	42	30	22	13	10	6	100

Batch Composition

	Bitumen	Bin No. 1	Bin No. 2	Bin No. 3	Bin No. 4	Bin No. 5
Per Cent	6.2	39.4	54.4			

ID-2 Binder 91-2
Job Mix Formula Report

AGGREGATE AND A.C. PRODUCER	LOCATION	SPEC.	TYPE	%	SP. GR.
Coolspring Stone Supply	Map 26A	#57	A	67.6	2.654
Coolspring Stone Supply	Map 26A	#10	A	27.8	2.637
	DRA 04A				
Ashland/Boswell Tri State	Floreffe/Dravosburg/ Warrenton				
Lake/United/Coastal	Springdale/Warren/ Charleroi	AC	20	4.6	1.03

Type: AC-20 Pen: ** Visc. @ 140 F: ** Visc. @275 F: ** Mix Temp.: **
**As per affidavit from refinery

Job Mix Formula and Design

Bit.	AC	2	1½	1	½	3/8	4	8	16	30	50	100	200
Upper	5.4		100	100	70		40	31	24	20	17	12	7
Design	4.6		100	97	62		32	25	18	14	11	6	4
Lower	3.8		100	89	54		24	19	12	8	5	1	1

Mix Characteristics

Theor. Density	Lab Density	Bitumen % by Wt.	Filler % by Wt.	Pass No. 8	Pass ½"	Stability	Flow	Percent by Volume		
								Voids	VFA	VMA
2.488	2.394	4.6	-----	25	62	2187	11.9	3.7	72.6	13.5

EFF 4.2

Hot Bins

Bin	2½	2	1½	1	3/4	1/2	3/8	4	8	16	30	50	100	200	Hot Blend %
1			100	100		100		100	88.4	67.2	52.2	41.0	22.4	14.9	26.8
2			100	100		95		17.4	4.0						21.6
3			100	94.2		28.4		3.0	0.8						51.6
4															
5															
Comb			100	97		62		32	25	18	14	11	6	4	100

Batch Composition

	Bitumen	Bin No. 1	Bin No. 2	Bin No. 3	Bin No. 4	Bin No. 5
Per Cent	4.6	25.6	20.6	49.2		

BCBC 91-22
Job Mix Formula Report

AGGREGATE AND A.C. PRODUCER	LOCATION	SPEC.	TYPE	%	SP. GR.
Coolspring Stone Supply	Map 26A	#57	A	67.8	2.654
Coolspring Stone Supply	Map 26A	#10	A	27.8	2.637
Ashland/Boswell Tri State	Floreffe/Dravosburg/ Warrenton				
Lake/United/Coastal	Springdale/Warren/ Charleroi	AC	20	4.4	1.03

Type: AC-20 Pen: ** Visc. @ 140 F: ** Visc. @275 F: ** Mix Temp.: **
**As per affidavit from refinery

Job Mix Formula and Design

Bit.	AC	2	1½	1	½	3/8	4	8	16	30	50	100	200
Upper	5.2		100	100		70		38		24	18	10	
Design	4.4		100	93		50		25		14	11	6	
Lower	3.6		95	52		36		16		8	6	4	

Mix Characteristics

Theor. Density	Lab Density	Bitumen % by Wt.	Filler % by Wt.	Pass No. 8	Pass ½"	Stability	Flow	Percent by Volume		
								Voids	VFA	VMA
2.497	2.392	4.4	-----	25		2008	11.6	4.0	68.3	13.9

Hot Bins

Bin	2½	2	1½	1	3/4	1/2	3/8	4	8	16	30	50	100	200	Hot Blend %
1			100		100		100		88.4		52.2	41.0	22.4		26.8
2			100		100		56		4						21.6
3			100		86.4		21.5		0.8						51.6
4															
5															
Comb			100		93		50		25		14	11	6		100

Batch Composition

	Bitumen	Bin No. 1	Bin No. 2	Bin No. 3	Bin No. 4	Bin No. 5
Per Cent	4.4	25.6	20.6	49.3		