ASPHALT-RUBBER CONCRETE (ARC) AND RUBBER MODIFIED ASPHALT CONCRETE (METRO RUMAC) EVALUATION

NE 181st Avenue - Troutdale Section
Columbia River Highway (U.S. I-84)

Construction Report

State Funded Project

by

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16. Abstract

This report covers the construction of two test pavements using asphalt concrete modified with tire rubber in September, 1991. The pavements are on a overlay of heavily traveled freeway in the Portland metropolitan area.

One test pavement uses an open-graded asphalt-rubber binder (ISI ARC). This binder was made by blending asphalt with shredded tire rubber. This test pavement is compared to a control pavement of an open-graded Oregon Department of Transportation (ODOT) mix. The other test pavement uses a dense-graded rubber modified asphalt concrete made by a process developed for the Metropolitan Services District of the Portland, Oregon urban area (METRO RUMAC). In this process, crumb rubber was added directly into the mix. This pavement is compared to a control pavement of a dense-graded ODOT mix.

Other than the blending of the asphalt-rubber, the construction of the ISI ARC and the control section were similar, and few problems were encountered.

When the METRO RUMAC was mixed, the system used to add the rubber to the drum was hard to control and monitor. As a result, the rubber content of the mix varied considerably from the desired proportion. This mix was hard to compact to the desired density, and this problem may be linked to variations in the mix's rubber content and/or placement temperature.

After construction, both the ISI ARC and METRO RUMAC test sections had appearances, ride values, deflection reductions, and surface friction values typical of conventional asphalt concrete pavements.

These rubberized mixes need specialized sampling and testing methods to assure that the rubber quality and proportioning were correct.

Both mixes cost substantially more than their conventional counterparts. Most of this increase was due to the costs of the rubber and the addition of the rubber.

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1.0 INTRODUCTION

1.1 Background

The storage and disposal of worn rubber tires are a problem for local governments. Often, tire storage sites are unsightly, a fire hazard, and a breeding ground for pests. In addition, the limited demand for worn tires prevents the rapid depletion of existing stockpiles.

In response to this problem, the 66th Oregon Legislature required the Oregon Department of Transportation (ODOT) to conduct two paving projects using rubber from waste tires. One of these projects, built in 1991, is the subject of this study.

One asphalt-rubber concrete (ARC) test pavement and one rubber modified asphalt concrete (RUMAC) test pavement were built on this project. The ARC test pavement used International Surfacing Incorporated's asphalt-rubber concrete (ISI ARC) in an open-graded wearing course. The "wet" process was used to add tire rubber to the ISI ARC mix. In this method, the tire rubber was blended with the asphalt to make asphalt-rubber binder, which was then mixed with the aggregate to make the ISI ARC.

On the RUMAC test pavement, guidelines developed by CTAK Associates of Portland, Oregon were used. CTAK developed the RUMAC guidelines for the Metropolitan Services District (METRO) of the Portland, Oregon urban area and the Oregon Department of Environmental Quality (DEQ) of the State of Oregon. METRO RUMAC, a dense-graded mix, was used on this project as a wearing course. The "dry" process was used to add rubber to the aggregate. In this system, the tire rubber was mixed with the aggregate before the asphalt binder was added to the mix.

This study is funded by several sources. Most of the funds are from the ODOT; METRO provided funds for the resilient modulus, fatigue, and rutting tests on the RUMAC mixes; and the DEQ paid for and performed the plant opacity tests.

1.2 ODOT ARC and RUMAC Research

Both ISI ARC and METRO RUMAC have not been used previously by the ODOT in Oregon. However, two test sections using ARC and RUMAC mixes were built on US Highway 97 in 1985 near Bend, Oregon [1]. After five years in service, the test section with dense-graded Arm-R-Shield^{R} ARC pavement had better resistance to cracking and weathering than the

2.0 LOCATION, DESIGN, AND MATERIALS

This chapter describes the project location, environment, structural design, materials, suppliers, results of tests on the materials, and mix designs.

2.1 Location, Layout, and Cross Section

The project is located on the Columbia River Highway (US I-84 or Oregon Highway 2) near Troutdale, Oregon, as shown in Figure 2.1. Both ends of the test and control pavement sections are marked on the shoulder with paddles that display the mix type. Within each test and control pavement there are one-half mile long evaluation sections that will be monitored for performance, as shown in Figure 2.2. The evaluation sections in the westbound lanes are marked by paddles saying "Coring Site" on the shoulders at the east ends of the sections, and the evaluation sections in the eastbound lanes are marked by "Coring Site" paddles at their west ends.

Each test pavement abuts a control pavement of the same type of aggregate gradation. The controls are the conventional pavements that the ODOT would normally use. The westbound lanes contain the open-graded ISI ARC test pavement and the open-graded ODOT Class "F" control pavement; these two pavements will be compared to each other. The eastbound lanes have the dense-graded METRO RUMAC test pavement and the dense-graded ODOT Class "B" control pavement; these two pavements will be compared.

As shown in Figure 2.3, the roadway cross section is:

Wearing Course - The wearing course is a single lift overlay of open-graded or dense-graded asphalt concrete with a 2-inch nominal thickness. The experimental and control mixes are in this course.

Inlays - During construction, severely distressed areas were removed by cold planing and replaced with inlays of ODOT Class "B" dense-graded mix at 2-inches nominal thickness.

Old Pavement - The old pavement before the overlay was a 6- to 11-inch thick layer consisting of several asphalt concrete pavements placed since the construction of the Interstate highway in 1953. The condition of the old pavement is discussed in Chapter 5 of this report.

Base - The base is a 9- to 14-inch thick layer of crushed aggregate.

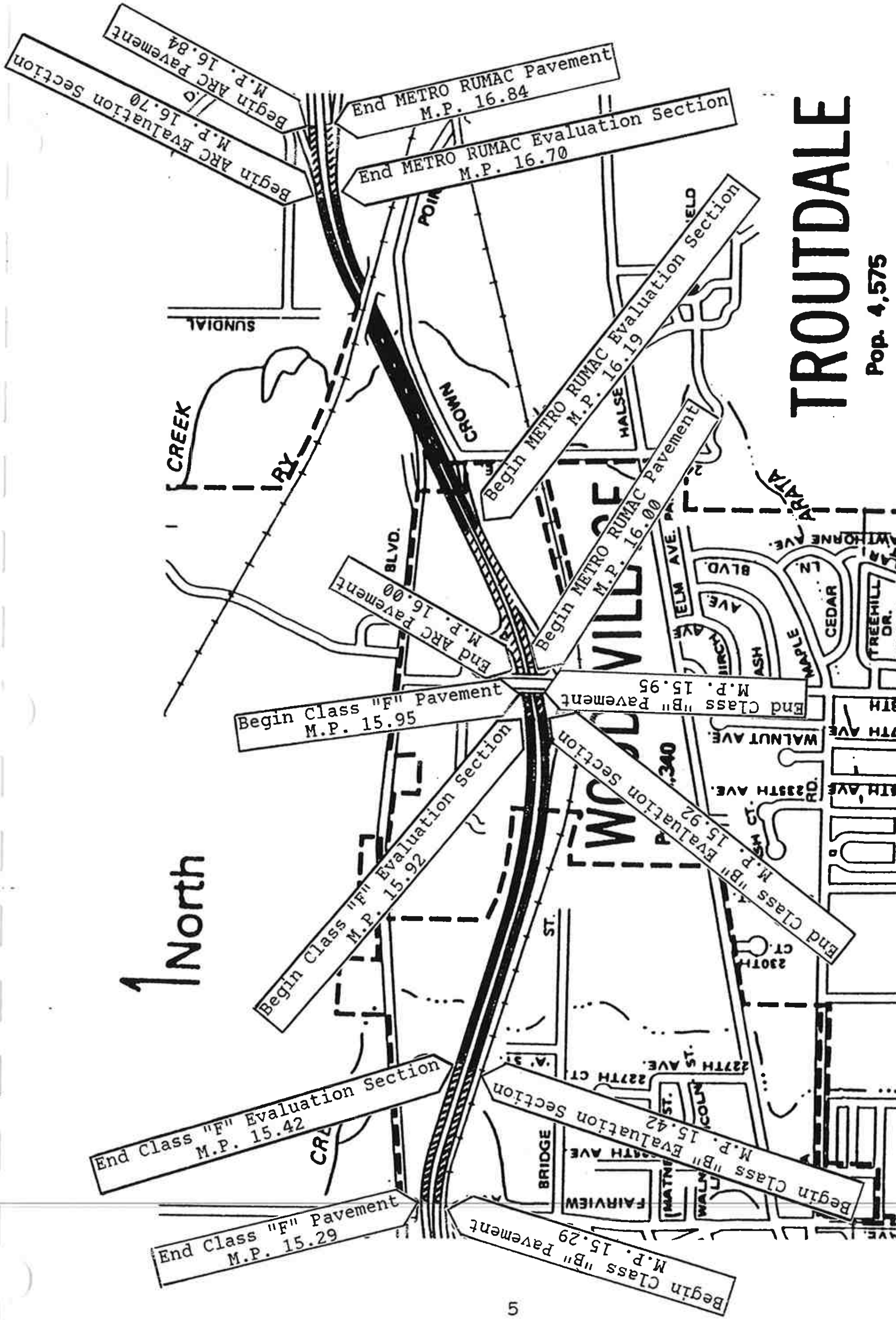


Figure 2.2: Test Pavement Location

Subgrade - The subgrade is loam, sandy soil, alluvial deposits of gravel and cobbles, basalt boulders, and occasional ledges of basalt.

2.2 Environment and Traffic

Both test and control pavements are on a heavily used interstate freeway in the eastern suburbs of the Portland metropolis. This area is in the Willamette Valley climatic region, and it has mild wet winters and moderate dry summers. Most precipitation is rain and the rest is snow. Environment [3] and traffic data are listed in Table 2.1.

2.3 Overlay Design

As this was an ODOT Surface Preservation Project, its main purpose was to provide a functional, rather than structural, improvement to the roadway. Therefore, a structural design was not performed. The layer thicknesses that were used were the minimum required to provide the worn roadway with a smooth and durable wearing surface.

2.4 Materials and Suppliers

Paving material suppliers are listed in Table 2.2. The materials used in the wearing course are described below:

Asphalt Concrete - The ISI ARC, METRO RUMAC, and conventional asphalt concrete mixes were furnished by the contractor.

Binders - ISI's Type II asphalt-rubber binder which is usually specified for mild climates was used in the ISI ARC pavement. The binder contained 80.5% (of total binder weight) Chevron AC-5 asphalt, 19% Atlos 903^R rubber, and .5% Pave Bond Special^R liquid amine anti-stripping additive. The anti-stripping additive was added at the refinery.

The Atlos 903 rubber was buffings produced as a waste product from the recapping of used tires. According to ISI, either crumb rubber processed from whole used tires or tire buffings can be used in their binder. On this project, tire buffings were chosen as they cost less than crumb rubber.

Chevron PBA-5 asphalt with .5% Pave Bond Special anti-stripping additive added at the refinery was used in the Class "F" mixture. Typically, PBA-5 was used for ODOT Class "F" pavements placed in 1991.

Chevron PBA-2 asphalt was used in the METRO RUMAC and Class "B" mixtures. No antistrip agent was added. Typically, PBA-2 was used for ODOT Class "B" pavements placed in 1991.

Tack Coat - Chevron's CSS-1 emulsion was used as a tack coat.

Aggregates - Crushed basalt from the quarry at Watters Concrete, ODOT Source No. 05-15-1, in St. Helens, Oregon was used as an aggregate for all mixes. As a precaution against potential moisture damage, the aggregate for the wearing courses of the ISI ARC section, and the three other sections, were treated with .5% and 1.0% (of total weight of mix) "Snowflake" hydrated lime, respectively. The aggregate in the inlays was not lime treated.

The aggregate used in the METRO RUMAC was blended with 2% (of total weight of mix) crumb rubber processed from whole used car and light truck tires. Although the tire rubber for this project was produced solely by granulation, the specifications allow the finer portions of the crumb rubber to be produced by grinding.

2.5 Results of Tests on Binder, Aggregate and Rubber

This section gives the results of tests on the wearing course's binder, aggregate, and rubber prior to and during production. Most of the tests followed AASHTO, ASTM, and ODOT methods [4, 5, 6]. The sources of the test data are in the footnotes to the tables, and special sampling and test methods are discussed in Chapter 4. The sections of this project's Special Provisions that apply to the ISI ARC and METRO RUMAC and in the Appendix [7].

2.5.1 Binders

Tests were conducted on the binders in three states. The "Original" state was the binder as supplied by the manufacturer, the "Residue" state was the binder after aging in the laboratory oven, and the "Recovered" state was the binder after it was removed in the laboratory from the job mix.

ISI ARC Binder - For the ISI ARC, the suppliers sent representative samples of the AC-5 base asphalt and tire rubber to the laboratory of Western Technologies of Phoenix, Arizona, for the mix design. In the laboratory, the asphalt and rubber were reacted to make the Type II binder for the

Table 2.3a: Binder Test Results - ISI Type II Asphalt Rubber

Test	Method[c]	Test Results[a]	Specifications
Pen @ 39.2°F, 200g, 60s, on Original (dmm)	ASTM D5	43[c], 38[d]	25 (min)
Pen @ 39.2°F, 200g, 60s, on Residue (dmm)	ASTM D5	28[d]	None
Pen Retention @ 39.2°F, (Residue/Original x 100) (%)	ASTM D2872[h]	98[c], 74[d]	75 (min)
Pen @ 77°F, 100g, 5s, on Original (dmm)	ASTM D5	63[c], 68[d]	50 (min) 100 (max)
Cone Pen @ 77°F, 100g, on Original (dmm)	ASTM D217	63[c]	None
Apparent Vis @ 347°F, Spindle 3, 12rpm, on Original (cP)[b]	ASTM 2669	None	1000 (min) 4000 (max)
Haake Vis @ 350°F, #1 Rotor, on Original (cP)[b]	[8]	1500[c] 700 to 1200[e] 1500 to 1900[f] 1900 to 2100[g]	1000 (min) 4000 (max)
Softening Point, on Original (°F)	ASTM D36	128[c], 126[d]	120 (min)
Duct @ 39.2°F, 1cpm, on Original (cm)	ASTM D113	11[c], 15[d]	10 (min)
Duct @ 39.2°F, 1cpm, on Residue (cm)	ASTM D113	15[d]	None
Duct Retention @ 39.2°F, (Residue/Original x 100) (%)	ASTM D2872[h]	127[c], 100[d]	50 (min)
Resilience @ 77°F, Rebound, on Original (%)	ASTM D3407	20[c]	10 (min)

[a]Tested binder was .5% Pave Bond, 19% rubber, and 80.5% AC-5.
[b]Apparent viscosity tests are typically used for determining viscosities in the laboratory and Haake viscosity tests are used in the field. However, for this project Haake viscosity tests were used in place of apparent viscosity tests for both the mix design and construction quality control.
[c]ISI's mix design tests and specified test methods on binder after the rubber was reacted with the base asphalt for 60 minutes @ 350°F.
[d]ODOT check/record tests on binder used in ISI ARC mix.
[e]Range of viscosities from ISI's on-site tests on the twelve loads of binder at 5 minutes reaction time at 350°F.
[f]Range of viscosities from ISI's on-site tests on the twelve loads of binder at 30 minutes reaction time at 350°F.
[g]Range of viscosities from ISI's on-site tests on the twelve loads of binder @ 45 minutes reaction time at 350°F.
[h]ASTM D1754 used to age binder for ISI's mix design, and AASHTO T240 was used to age the ODOT's binder sample.

Table 2.3c: Binder Test Results - PBA-2

Test	Method	Test Results	Specifications
Pen @ 39.2°F, 100g, 5s, on Residue (dmm)	AASHTO T49[f]	2[a], 7[b], 7[d]	None
Pen @ 39.2°F, 200g, 60s, on Residue (dmm)	AASHTO T49[f]	17[a], 26[b], 25[d]	15 (min)
Pen @ 77°F, 100g, 5s, on Residue (dmm)	AASHTO T49[f]	49[a], 51[b], 51[d],	None
Abs Vis @ 140°F, on on Original (P)	AASHTO T202	1550[a], 1460[b], 1525[d]	1100 (min)
Abs Vis @ 140°F, 30cm Hg Vac, on Residue (P)	AASHTO T202[f]	3670[a], 3925[b], 4000[d]	2500 (min) 6000 (max)
Abs Vis @ 140°F, 30cm Hg Vac, on Recovered (P)	AASHTO T202[g]	2740[b,c], 4120[d,e]	None
Abs Vis Ratio (Residue/Original)	AASHTO T202	2.4[a], 2.7[b], 2.6[d]	4.0 (max)
"C" Value	ODOT TM425	55[b,c], 110[d,e]	30 (min)
Kin Vis @ 275°F, on Original (cSt)	AASHTO T201	327[a], 334[b], 343[d]	None
Kin Vis @ 275°F, on Residue (cSt)	AASHTO T201[f]	486[a], 521[b], 535[d]	275 (min)
Duct @ 45°F, 1cm/min, on Residue (cm)	AASHTO T51[f,h]	25+[a], 25+[b], 25+[d]	10 (min)
Duct @ 77°F, 5cm/min, on Residue (cm)	AASHTO T51[f,h]	100+[a], 100+[b], 100+[d]	75 (min)
Flash Point, COC, Original (°F)	AASHTO T48	575[a], 470[b], 515[d]	450 (min)
Solubility in Trichlorethylene, Original (%)	AASHTO T44	99.99[a], 99.98[b], 99.99[d]	99.0 (min)
Loss on Heating, of Residue (%)	AASHTO T47[f]	.58[a], .71[b], .58[d],	None

[a]Acceptance tests on the binder used in mix design for METRO RUMAC and Class "B" mixes.
[b]Average of check/record tests on the binder used in Class "B" mix in inlays.
[c]Viscosity and "C" Value may be artificially high because of excessive duration between sampling and testing.
[d]Average of check/record tests on the binder used in METRO RUMAC mix.
[e]Viscosity and "C" Value may be inaccurate due to rubber particles in the recovered binder.
[f]~~AASHTO T240 used to age asphalt.~~
[g]ODOT TM314 (Modified Abson Procedure) used to recover asphalt.
[h]AASHTO T51 as modified by the Washington DOT (using a special method of applying the release agent).

Table 2.5: Rubber Test Results

a) Rubber Used in ISI ARC

Test	Method	Test Results[a]	Specifications
Dry Gradation,			
% Passing	ASTM C136		
Screen: # 8		100	100
#10		96	95 - 100
#16		58	40 - 60
#30		3	0 - 10
#50		1	0 - 5
#100		.1	-

[a]International Surfacing's test results

b) Rubber Used in METRO RUMAC

Test	Method	Test Results[c]	Specifications
Dry Gradation,			
% Passing	AASHTO T27		
Screen: # 4		100[a], 100[b]	100
# 8		87[a], 90[b]	70 - 100
#16		58[a], 62[b]	40 - 65
#30		32[a], 36[b]	20 - 35
#50		11[a], 10[b]	5 - 15
#100		2[a], .2[b]	
#200		.5[a], .0[b]	
Specific Gravity	ASTM D1817	1.19[a]	1.15 ± .05
Percent of Ash	ASTM D297-36	6.2[a]	8.0 (max)

[a]Acceptance test results.
[b]Check/record test results.
[c]Both tests were made on rubber delivered to the job site.

Consequently, Pave Bond was specified to improve the mix's resistance to stripping.

2.6.2 ODOT's Class "F" Mix Design

This design used an ODOT modified Hveem procedure to determine asphalt content based on void contents, stabilities, and binder film thicknesses [10]. In this design, a 6% target asphalt content was used to give as thick a coating as possible to the aggregate. Based on the results of Index of Retained Strength testing, an anti-stripping agent was required to reduce the potential for moisture damage. Broadband limits, mix design criteria, and design mix properties are listed in Table 2.6b.

2.6.3 BAS Engineering Consultants' METRO RUMAC Mix Design

The original design was provided by BAS Engineering Consultants in Irvine, California. This design used a modified 75-blow Marshall method [11]. Like the ISI ARC design, this design was revised to the standard ODOT format and supplied to the contractor. Broadband limits, mix design criteria, and design mix properties are listed in Table 2.6c.

Besides the addition of crumb rubber, METRO RUMAC mixes typically require 1.1% to 1.2% higher binder contents, as a percentage of total mix weight, than comparable conventional dense-graded mixes; this is based on observations of the METRO RUMAC on this project and two other METRO RUMAC test pavements constructed in the Portland area in 1991.

2.6.4 ODOT's Class "B" Mix Design

This design used the ODOT's modified Hveem method [10]. Broadband limits, mix design criteria, and design mix properties are listed in Table 2.6d.

Table 2.6b: Broadband Limits, Mix Design Criteria, and Design Mix Characteristics at Design Binder Content - Class "F" Mix

Characteristic	Class "F" Mix Design Criteria	Class "F" Design Mix
Gradation (% Passing Screen)		
1-inch	99-100[a]	100[b,c]
3/4-inch	85-96	92
1/2-inch	60-71	66
3/8-inch	-	52
1/4-inch	17-31	26
#10	7-19	10
#40	-	5
#200	1-6	3.1
Binder Content (%)	4-8[a]	6.0
Binder Film Thickness	Sufficient[d]	Thick[d]
Sp. Gr. @ 1st Comp.	None	2.33[e]
Voids @ 1st Comp. (%)	7-11[e]	8.4[e]
Stab. @ 1st Comp.	≥ 26[f]	25[f]
Sp. Gr. @ 2nd Comp.	None	2.39[e]
Voids @ 2nd Comp (%)	≥ 4[e]	6.1[e]
Stab. @ 2nd Comp.	≥ 30[f]	35[f]
"Rice" Max. Sp. Gr.	None	2.544
Voids in Mineral Aggregate (%)	None	18.1
Index of Ret. Strength (%)	≥ 75	72[g], 88[h]

[a]Broadband limits for gradation and binder content. Gradations are % of dry ingredient weight, including 1% lime. Binder contents are % of total mix weight.
[b]Mix design sample at design binder content test results in this column.
[c]Sample includes .5% hydrated lime.
[d]Visual examination based on ODOT mix design procedure [10].
[e]Based on immersed unit weight of unsealed core.
[f]Hveem Stability.
[g]Before addition of Pave Bond antistripping additive.
[h]After addition of Pave Bond.

Table 2.6d: Broadband Limits, Mix Design Criteria, and Design Mix Characteristics at Design Binder Contents - Class "B" Mix

Characteristic	Class "B" Mix Design Criteria	Class "B" Design Mix
Gradation (% Passing Screen)		
1-inch	99-100[a]	100[b,c]
3/4-inch	90-98	95
1/2-inch	75-91	80
3/8-inch	-	72
1/4-inch	50-70	57
#10	21-41	28
#40	8-24	12
#200	2-7	5.0
Binder Content (%)	4-8[a]	5.4
Binder Film Thickness	Sufficient[d]	Thick[d]
Sp. Gr. @ 1st Comp.	None	2.40
Voids @ 1st Comp. (%)	5.5 - 6.5	5.6
Stab. @ 1st Comp.	37[e]	35[e]
Sp. Gr. @ 2nd Comp.	None	2.47
Voids @ 2nd Comp (%)	≥ 2.5	3.2
Stab. @ 2nd Comp.	37[e]	39[e]
Rice Max. Sp. Gr.	None	2.548
Voids in Mineral Aggregate (%)	≥ 14	14.9
Index of Ret. Strength (%)	≥ 75	100
Index of Ret. Resilient Modulus (%)	≥ 70	94

[a]Broadband limits for gradation and binder content. Gradations are % of dry ingredient weight, including 1% lime. Binder contents are % of total mix weight.
[b]Mix design sample values interpolated from briquets with 5.0 and 5.5% binder content.
[c]Sample includes 1% hydrated lime.

3.0 CONSTRUCTION

This chapter describes the construction in September, 1991 of the wearing courses and gives the results of the mix and pavement quality control testing. The test results, test methods, and random measurements of air temperature, road surface temperature prior to paving, wind speed, and other weather data are listed in Table 3.1. AASHTO and ODOT sampling and testing methods were used in most cases [4,6,12]. The sections of the project's Special Provisions that apply to the ISI ARC and METRO RUMAC construction are in the Appendix [7].

3.1 Binder Manufacture and Handling

ISI ARC Binder - The delivery of the base asphalt and the rubber, the blending of the asphalt-rubber, and the pumping of the binder into the plant were the responsibility of ISI. The blending was done near the mix plant and considerable open space was needed for ISI's blending operation. The following were used during asphalt-rubber production:

1) A stock of bagged tire rubber on pallets, and a fork lift.

2) At least one two-trailered tanker truck containing the base asphalt.

3) A large trailer with the asphalt-rubber blending unit.

4) Several transfer trucks.

5) A storage truck.

6) A large trailer mounted pump.

7) Assorted tractors used to pull the trailers and pickups.

According to ISI, Items 1, 2, 3, and at least one transfer truck can be located a short drive away from the plant, if necessary; and Items 5, 6, and at least one transfer truck must be at the mix plant.

To make the asphalt-rubber, the base asphalt was pumped from the tanker into a large tank at the rear of ISI's blending unit by a pump on the unit. In the tank, the asphalt was heated from the 300°F delivery temperature to 400° to 450°F. The bags containing the tire rubber were broken by hand and

Table 3.1b: Job Mix Specifications and Properties - Class "F"

Test	Method	Test Results	Job Mix Specifications
Gradation	AASHTO T11 and T27		
(% Passing Screen):	AASHTO T2		
1-inch		100[a,b]	99-100[b,d]
3/4-inch		94	85-96
1/2-inch		64	60-71
1/4-inch		26	21-31
#10		9	6-14
#40		4	1-9
#200		2.7	1.0-5.0
Binder Content (%)	ODOT TM321		
	ODOT TM322	5.87[c]	5.5-6.5[c]
Moisture Content (%)	ODOT TM311M	.7[c]	.8 (max)[c,f]
Mix Temp. at Discharge (°F)		265-275[e]	253-260[g]
Weather		Clear	None

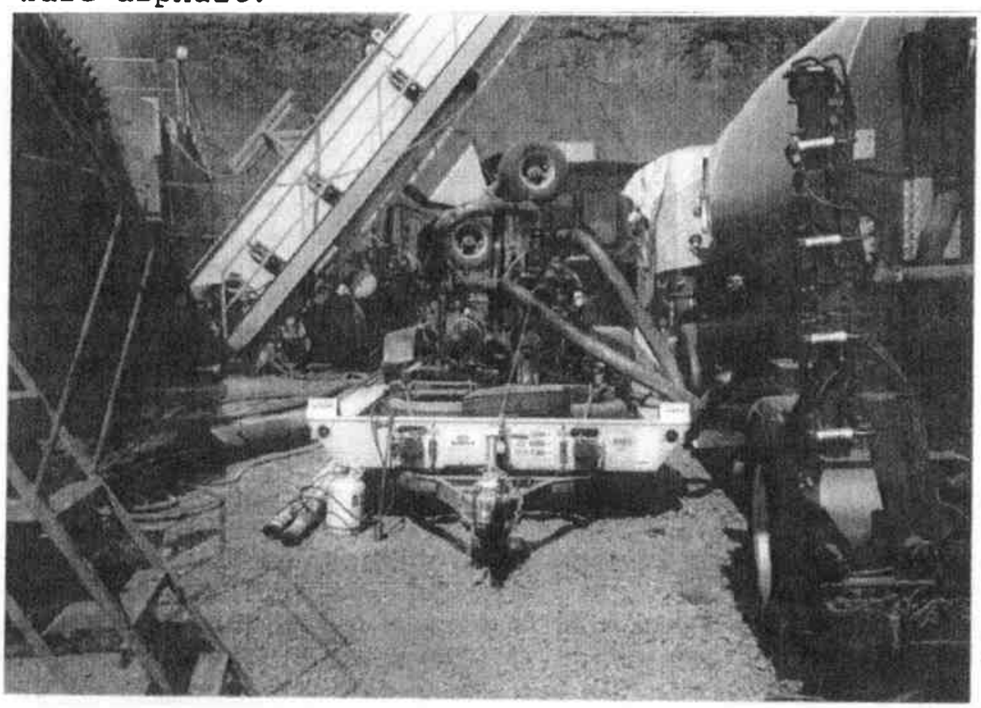
[a]Average of acceptance tests in this column unless noted otherwise.
[b]Percentages of dry ingredient weight including aggregate and 1% hydrated lime.
[c]Percentages of total mix weight.
[d]Narrowband limits in this column unless noted otherwise.
[e]Range of test results.
[f]Specifications in Special Provisions.
[g]Limits in job mix formula.

Table 3.1d: Job Mix Specifications and Properties - Class "B"

Test	Method	Test Results	Job Mix Specifications
Gradation	AASHTO T11 and T27		
(% Passing Screen):	AASHTO T2		
1-inch		100[a,b]	99-100[b,d]
3/4-inch		97	90-98
1/2-inch		78	75-91
1/4-inch		56	52-62
#10		27	24-32
#40		12	8-16
#200		6.4	7.0-3.0
Binder Content (%)	ODOT TM321		
	ODOT TM322	5.48[c]	4.90-5.90[c]
Moisture Content (%)	ODOT TM311M	.4[c]	.8 (max)[c,f]
Compaction (% of Rice)	ODOT TM304		
	ODOT TM306	92.3	91.0 (min)
Mix Temp. at Discharge (°F)		300[e]	295-303[g]
Weather		Clear	None

[a]Average of acceptance tests in this column unless noted otherwise.
[b]Percentages of dry ingredient weight including aggregate and 1% hydrated lime.
[c]Percentages of total mix weight.
[d]Narrowband limits in this column unless noted otherwise.
[e]Random measurements.
[f]Specifications in Special Provisions.
[g]Limits in job mix formula.

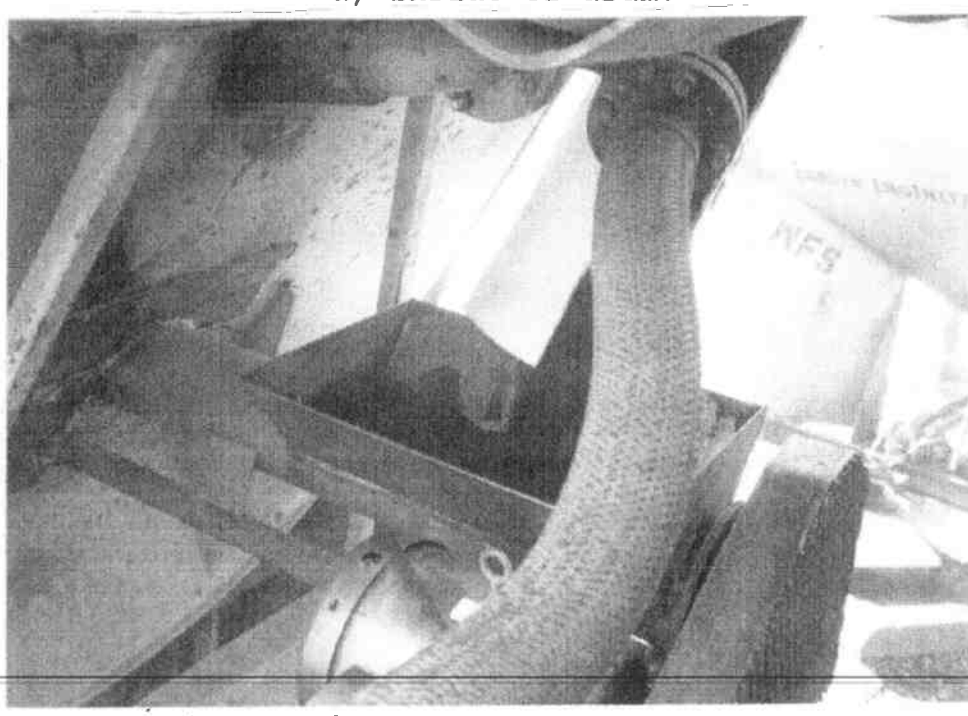
a) Equipment near blending unit. From left to right: transfer truck, blending unit, and tanker with base asphalt.



b) Equipment near drum plant. From left to right: drum, pump, and storage truck.

Figure 3.1: Blending Asphalt-Rubber

a) Inside of drum.



b) Outside end of auger on drum.

Figure 3.2: Mixing METRO RUMAC

Overall, 33 tons of rubber were used in the 1,652 tons of METRO RUMAC mix in three sublots on this project. This amount of rubber gave the mix a nominal rubber content of the desired 2%. However, problems with the rubber feed system caused the rubber content in the individual sublots to vary considerably from the desired percentage.

The first sublot, which was the first 500 tons of mix, had a low rubber content. On the morning of mix production, it appeared that the feed system was not adding enough rubber to the mix. Subsequent calculations indicated that the rubber feed rate was about 1.2% based on the number of bags added to the hopper and the production rate of the plant. It was suspected that blocking up the large hopper in a tilted position affected the feed rate of the system.

The second sublot contained the mix from 500 to 1,000 tons of cumulative production. The feed system was adjusted at the start of the second sublot, and the rubber feed was checked after 600 tons of cumulative production. It was working properly, as 11.5 bags of rubber were added during five minutes production. This was the last adjustment to the feed system that the ODOT witnessed.

The first sublot should have used 10 tons of rubber at a 2% feed rate. But, based on the calculated 1.2% feed rate, 6.3 tons were actually used and 3.7 tons of unused rubber should have been left over from this sublot at the end of the day's production. However, at the end of the day, there was no rubber remaining. Therefore, it can be deduced that the 3.7 tons of rubber that should have been left over from the first sublot was very likely used in the second and/or third sublots. This extra rubber gave one or both of the later sublots excessively high rubber contents.

The METRO RUMAC mix used a slightly finer gradation than the Class "B" mix. This required the contractor to adjust the proportions of aggregate pulled from the bins. The METRO RUMAC mix discharge temperature was 340°F when the plant started in the morning and it soon lowered to 310°F. This, however, was still higher than the temperature range of 295° to 303°F specified in both the METRO RUMAC and Class "B" job mix formulae. These elevated temperatures were used initially to heat the mixing equipment to the mixing temperature. The moisture content of the METRO RUMAC mix averaged .4%, which was below the specified maximum of .8%.

Class "B" - No special equipment or procedures were needed for this conventional mix. The plant discharge temperature was 300°F, which was within the 295° to 303°F limits specified in the job mix formula. The average moisture content was .4%, which was lower than the .8% maximum given in the specifications.

some contractors on other projects sprinkle blotter material composed of sand on fresh ISI ARC to prevent sticking; however, on this project the problem was not serious enough to warrant sanding.

The ISI ARC surface was smooth just after construction and it looked like a typical ODOT open-graded surface, as shown in Figure 3.3a.

Class "F" - This mix was placed and compacted without problems.

METRO RUMAC - The laydown of this mix went smoothly and no special techniques or equipment were needed. This mix had an objectionable odor, as it smelled like burning tires. In the afternoon, placement temperatures in the windrow were 280° to 300°F. Assuming the temperature dropped 5° to 10°F as the mix passed through the paver, the mat temperatures behind the paver would be 270° to 290°F. The mix could have experienced a higher temperature in the morning, as the drum was operated at a higher temperature early in the day. Therefore, the actual laydown temperature range could be within or in excess of the 275° to 285°F specified in the job mix formula.

Breakdown of conventional dense-graded ODOT mixes is usually done by a pneumatic roller. However, for METRO RUMAC these rollers were prohibited by the specifications, as previous experience showed that this mix sticks to these rollers' rubber tires.

Breakdown of the METRO RUMAC was done by four coverages using the DA-50. The coverage used five passes, with static knockdown passes and vibratory comeback passes. This roller could roll right up to the rear of the paver. The operator stated that the material shoved ahead of the roller more than a conventional mix, and that the shoving caused no problems. Intermediate rolling for the first sublot was done by four coverages using the DD-90. For the second and third sublots intermediate rolling was done by five coverages. The first two or three coverages were vibratory and the remaining two were static. Each coverage used five passes. Finish rolling was done by three coverages using the C350B. Each coverage used seven static passes. All rollers used empty drums and were coated with soapy water. No sticking problems were noted, either to the roller wheels or to auto or truck tires.

The contractor had difficulty in reaching the minimum specified density of 94% for the last two of the three sublots. The first sublot compacted to an average of 94%. However, the second and third sublots could only reach average compactions of 91.9% and 87.5%, respectively.

The difficulty in compacting the second and third sublots may be due to excessively high rubber contents and/or lower mix temperatures. As noted in Section 3.2 of this chapter, the desired rubber content was 2%. However, the estimated rubber content of the first sublot was 1.2%, and the rubber content of the second and/or third sublots was deduced to be greater than the desired 2%. In addition, as noted Section 3.2, the mix placed in the first sublot was produced at up to 30°F higher temperatures than the mix in the last two sublots. This hotter mix may have been easier to compact.

The METRO RUMAC pavement looked smooth and dense just after laydown, as shown in Figure 3.3b. It appeared to be slightly denser than a typical ODOT Class "B" pavement.

Class "B" - This pavement was placed and compacted without any problems. Unlike the METRO RUMAC, breakdown was done by four coverages using the C550A pneumatic roller. Each coverage used five passes. Intermediate rolling was done by four coverages using the DD-90, with the first two coverages vibratory and the last two coverages static. Five passes were used for each coverage. Finish rolling was done by two static coverages using the C350B. Seven passes were used for each coverage. All steel wheeled rollers used empty drums covered with soapy water and no sticking was noted, and the contractor achieved 92.3% compaction, which exceeded the required minimum of 91%.

3.5 Plant Exhaust Opacity

The opacity of the exhaust gas from the mix plant's stack was noted during the production of each mix. The exhaust was light tan to white in color, and there was no change in color from mix-to-mix. During the five days of production that observations were made, the opacity gradually increased. Midway through the five day period in which the experimental and control mixes were made, it was noted that the plant opacity exceeded Oregon's allowable limits [13]. The excessive exhaust opacity from this plant may have been due to worn collector bags in the baghouse rather than from the rubberized mixes [13].

3.6 Summary

The blending of the asphalt-rubber for the ISI ARC required specialized blending and pumping equipment which were

4.0 SAMPLING AND TESTING

This chapter describes the special sampling and testing methods needed for the ISI ARC and METRO RUMAC. The sections of the Special Provisions that applied to the ISI ARC and METRO RUMAC are in the Appendix [7].

4.1 ISI ARC Sampling and Testing

4.1.1 Asphalt-Rubber Sampling

The asphalt-rubber on this project was sampled for the complete acceptance test after its 45 minutes reaction time, and the sampling of the binder at the end of its reaction period was important. As seen in the Haake Viscosity test results in Table 2.3a, the viscosity of the asphalt-rubber increased as the reaction time between the asphalt and the rubber lengthened. On this project, the average viscosity after 5 minutes of reaction time was 900 centipoise (cP) which was below the specification's lower limit of 1,000 cP. However, after 30 minutes and 45 minutes of reaction time, the average viscosities were 1,700 cP and 2,025 cP, respectively, which were within the specification limits of 1,000 cP to 4,000 cP. As a result, it was good practice to sample the asphalt-rubber as late in the reaction process as possible. This way, the viscosity of the sample best represented the viscosity of the binder as it entered the mix plant.

4.1.2 Asphalt-Rubber Testing

Apparent viscosity and resilience testing were needed to determine the properties of the asphalt-rubber in the complete acceptance test. These tests could not be done in the ODOT's Materials Laboratory. The apparent viscosity measurement required specialized equipment that the laboratory did not have, such as a Haake or Brookfield viscometer with a heating unit to bring the asphalt-rubber to the testing temperature for viscosity testing, and a ball penetration tool for resilience testing.

The use of ISI ARC requires more testing than the use of a conventional asphalt. In addition to the viscosity tests of the asphalt rubber, ISI conducts tests to assure that the base asphalt properties, rubber characteristics, and rubber content of the asphalt-rubber were within the specification limits. Verifying the properties of the base asphalt would have required additional asphalt acceptance tests. Acceptance and check tests on the rubber gradation and rubber properties would require gradation and miscellaneous testing. Verifying the binder's rubber content would require an inspector to witness the entire asphalt-rubber blending operation. The tests and inspections listed above

Currently, the ODOT uses the nuclear gauge to determine the asphalt content in a mix. However, the nuclear gauge could not be used to measure asphalt content in the rubber modified AC because the asphalt content readings are influenced by the rubber in the mix. To the gauge, the rubber may appear as asphalt, and consequently, the resultant asphalt content readings may be artificially high.

To monitor binder content, the plant was calibrated according to ODOT TM322 and the asphalt content was determined by meter readings and verified by tank stickings using ODOT TM321 [12].

4.2.5 Rubber Content Determination

The rubber content of the mix was determined by dividing the weight of rubber augured into the drum during five minutes production by the weight of mix produced during this interval. The weight of the added rubber was calculated by counting the number of preweighed bags dumped into the auger feed hopper. Details of this system are in Chapter 3 of this report. There are two disadvantages using this method:

1) It would not work if the rubber was not in pre-weighed bags. Rubber for METRO RUMAC can be delivered in bulk.

2) The calibration is only valid for the time interval in which it is made and if the plant is producing mix at the rate that the inspector assumed in his/her calculations. The mix production or rubber introduction rates could easily be changed when the inspector was not present, and even if the inspector is present, it is often impossible to simultaneously watch the mixture production rate meter and the addition of the rubber, as these activities often occur at different parts of the plant.

Although a drum plant was used for this project, these problems could also occur with a batch plant. Solutions may include:

1) If the rubber is delivered in bags to a batch plant, each batch's rubber content can be calculated by dividing the total number of bags added to each batch by the total weight of each batch. One or two people may be needed to continually monitor this process.

2) If the rubber is delivered in bags to a drum plant, the rubber content can be calculated for each sublot by dividing the total number of bags of rubber added to the mix every ten minutes by the total amount of mix produced every ten minutes. One or two people may be needed to keep these records.

3) For batch or drum plants with a continuous mechanical

they would have added significant costs to the ODOT.

Tests normally performed on conventional asphalt were used for the METRO RUMAC binder, except that the METRO RUMAC mix could not be tested for the "C" value. The rubber particles in the recovered binder could clog the capillary tube used for absolute viscosity testing.

The rubber in the METRO RUMAC mix needed special sampling and testing techniques for acceptance tests.

The binder content in the METRO RUMAC could not be measured by extractions or the nuclear asphalt content gage. For this project, the binder content was measured by meter readings and verified by tank stickings.

Monitoring the rubber content of the METRO RUMAC mix was difficult. Strict adherence to the specifications for rubber addition was needed. Constant monitoring by manual observation or an automatic recording device may be helpful on future projects.

5.0 POST-CONSTRUCTION INSPECTION

This chapter presents the results of inspections before and after construction and the results of tests on materials removed from the newly constructed pavements.

5.1 Pavement Evaluation - Visual Inspection

5.1.1 Pre-Construction Visual Inspection

The roadway was visually inspected and ruts were measured several months before the overlay.

This overlay was over a cracked, potholed, and ravelled asphalt concrete surface. The majority of the surface area was covered by maintenance patches of various ages. These patches and the potholes made this road very rough.

There were ruts 1/8 to 1-1/8 inches deep on the old roadway. While many of the sections with deep rutting were inlaid during this project, the new overlay covered areas with ruts up to an inch deep. Most of the deeper rutting was caused by both aggregate loss from the wheeltracks and displacement of the mix due to traffic loadings.

Many areas had severe fatigue cracking and alligator cracking in the wheeltracks. Most of these severely cracked sections were removed and replaced with inlays immediately prior to the overlay. Some areas with light fatigue cracking in the wheelpaths were covered directly by the overlay.

Figure 5.1 shows a typical area prior to the overlay. Most of this surface was an old blade patch. There were 5/8-inch deep ruts in the outer lane and 1-inch deep ruts in the inner lane.

5.1.2 Post-Construction Visual Inspection

The roadway was visually inspected within one week after construction. There was no cracking or visible rutting on any of the test or control pavements. The ISI ARC and Class "F" sections had surface textures typical of ODOT open-graded pavements, and the METRO RUMAC and Class "B" mixes had surface textures similar to typical ODOT dense-graded surfaces.

5.2 Friction

The pavement friction was measured before construction in August 1991 and shortly after construction in November 1991.

expected for thin overlays of rough roadways. Much of the differences in roughness between the sections may be due to the uneven surface of the old roadway.

5.4 Deflections

Deflections were measured several months before construction in April 1991 and several months after construction in February 1992. The test results are listed in Table 5.1b. A KUAB falling weight deflectometer was used.

Before construction, average deflections ranged from 8- to 11-thousandths of an inch; consequently, this roadway was structurally sound and all sections had similar deflections. After the overlay; the average deflections ranged from 6- to 8-thousandths of an inch, with reductions varying from 1- to 3-thousandths of an inch. Consequently, none of the surface treatments significantly decreased deflections, and all four types of surfacing added approximately the same strength to the roadway. A small decrease in deflections is to be expected, as this new surfacing is relatively thin in comparison to the rest of the roadway structure. Also, not all of these strength increases were due to the 2-inch thick overlays, as there were several 2-inch thick inlays scattered throughout each section.

Table 5.1: Pavement Roughness and Deflections

a) Roughness

Date	Average International Roughness Index (IRI)			
	ISI ARC	Class "F"	METRO RUMAC	Class"B"
10/9/91 (Post-Construction)	110	89	81	83

b) Deflections

Date	Average Deflections in Thousandths of an Inch			
	ISI ARC	Class "F"	METRO RUMAC	Class"B"
4/25/91 (Pre-Construction)	11	8	9	10
2/6/92 (Post-Construction)	8	6	8	8

Note: Deflections are falling weight deflectometer measurements at the load center and are corrected to a 9,000 lb load at 70°F.

presence of rubber further "softens" the mix. The [METRO] RUMAC moduli values are typical of other rubber-modified mixes tested at OSU" [15].

Based on previous experience, the resilient modulus test results are highly dependent on the void contents of the sample, and higher void contents often result in weaker pavements. The higher void content of the METRO RUMAC samples may have reduced their resilient moduli. Based on the void contents of cores removed from the road near the samples tested for resilient modulus and fatigue, the METRO RUMAC, with an estimated void content of 10.2%, was much less dense than the Class "B" mix, whose estimated void content was 6.9%. Void contents are listed in Table 5.2c.

5.5.3 Fatigue

Each core that was tested for resilient modulus was also tested at OSU for diametral fatigue [15, 18]. The test results are listed in Table 5.2b.

The METRO RUMAC cores had much higher fatigue lives than the cores from the conventional "B" mix. While most of this increased fatigue life may be due to resiliency imparted to the pavement by the rubber, air voids may have some effect on fatigue life. According to Lundy and Scholz: "As was the case for the modulus testing, fatigue results are affected by the air content of the mixture [15]." Although the diametral fatigue test is occasionally used in pavement research, at present there is insufficient data to tell if this test accurately predicts fatigue in ODOT mixes.

5.5.4 Stripping

Stripping was determined by visual examination of broken cores. No stripping was seen on any cores from the four pavements.

5.5.5 Void Content

Void contents were measured on cores removed from the center of the outer lanes of the new pavement. The test results are listed in Table 5.2c. These values can be evaluated when they are compared to the first compaction void content limits for the mix design criteria shown in Table 2.6. The void content at first compaction are supposed to simulate the voids in the pavement just after construction.

Void contents of open-graded cores and mix design samples were calculated from bulk and maximum specific gravities of unsealed samples measured by following AASHTO T166 and AASHTO T209, respectively. These methods were used by the

ODOT for the design of open-graded mixes through 1991. With void contents of 8.2% and 9.3% for the ISI ARC and Class "F" pavements, respectively, the voids of both pavements were within the 1991 ODOT design criteria of 7% to 11%.

Void contents of the open-graded cores and mix design briquets were also calculated from bulk specific gravities based on caliper measurement of samples and maximum specific gravities from AASHTO T 209. This method is used by many agencies and the ODOT adopted this method in 1992 to determine the void contents of open-graded samples. Using this method, the average void contents were 12.4% and 15.7% for the ISI ARC and Class "F" mixes, respectively. These values are within the 1992 ODOT design criteria of 10% to 20%.

Void contents of the dense-graded cores were determined following AASHTO T166 and AASHTO T209. With an average void content of 10.2%, the METRO RUMAC pavement had a much higher void content than the design limits of 3% to 5%. With an average void content of 6.9%, the Class "B" mix had a slightly higher average void content than the design limits of 5.5% to 6.5%. However, it is common for Class "B" mixes to have higher in-place void contents than the design criteria, and many Class "B" pavements have void contents ranging from 7% to 9%. On this project, the Class "B" mix's average void content was slightly lower than these commonly observed values.

5.6 Summary

The old pavement was cracked, potholed, ravelled, and rutted. Most of the heavily distressed areas were inlay patched just before the overlay.

When the post-construction inspection was made, all of the new test and control pavements were uncracked, had no ruts, and had no weathering or ravelling.

Friction values of the test and control sections were similar and adequate. Ride values were within the range expected for a thin overlay over a rough road.

As expected of a relatively thin overlay over a strong road, none of the four surface treatments significantly increased the strength of the roadway. Also, none of the four surfacings was clearly superior to the others at strengthening the pavement.

Laboratory tests to predict rutting indicate that the METRO RUMAC mix and Class "B" mix had similar resistance to rutting. However, this rut prediction test is performed experimentally in Oregon and its predictions should be interpreted with caution.

6.0 PRICES AND COSTS

This chapter presents the major differences in prices and costs between the rubberized and conventional mixes. The bid prices are summarized in Table 6.1.

6.1 ISI ARC and Class "F" Prices and Costs

6.1.1 Bid Prices and Mix Costs

On this project, the asphalt-rubber binder was a significant addition to the total mix cost. This binder was more expensive than conventional asphalt and the binder content of the ISI ARC was higher than the asphalt content of a typical open-graded mix. Based on the ISI ARC's binder content of 9.25% by weight of mix and the bid price of $480 per ton, the binder cost was $45.60 per ton of mix. This was about five times higher than the asphalt cost for a ton of Class "F" mix. The binder had a relatively high unit price as ISI had to bring a full set of equipment and people to the job site for this small quantity of 167 tons of asphalt-rubber. This price may drop significantly for projects with larger binder quantities.

The Class "F" mix had a 6% asphalt content and an asphalt bid price of $150 per ton. This resulted in an asphalt cost of $9.00 per ton of mix.

The bid price for furnishing the estimated 1,666 tons of ISI ARC mix and 1,971 tons of Class "F" mix were identical at $21 per ton. This bid price did not include binder or asphalt.

For the ISI ARC, 60 yd^3 of blotter material at a bid price of $23 per yd^3 was included in the contractor's prices. Although this material was not used, it added $0.83 per ton to the overall cost of the ARC mix.

The total cost of the ISI ARC in-place, including binder, furnishing the mix, and blotter material, was $67.43 per ton of mix. Using the job mix formula specific gravity of 1.98 (based on briquet volume by caliper measurement) and a layer thickness of 2 inches, this mix would have cost $6.26 per square yard if compacted to design density.

The cost of the Class "F" mix in-place, including asphalt and furnishing the mix, was $30.00 per ton of mix. Based on a job mix formula specific gravity of 2.20 (based on briquet volume by caliper measurement) and a layer thickness of 2 inches, this mix would have cost $3.09 per square yard if compacted to design density.

6.1.2 Other Costs

To the ODOT, there would be an estimated $0.13 per ton increase in mix design and testing costs between the ISI ARC and Class "F" mixes, based on the assumptions listed below:

1) The mix design for the ISI ARC was provided at no cost to the ODOT by the asphalt-rubber supplier while the Class "F" design was made by the ODOT.

2) Acceptance and check tests were made on 10,000 tons of mix using the ODOT's 1992 testing requirements and test prices, including acceptance and check tests on the rubber and base asphalt and similar tests on the asphalt-rubber.

3) Five ten-hour days used by an Engineering Specialist I from the ODOT project manager's crew to verify that the rubber was sampled correctly and that the rubber was added to the asphalt in the correct amount.

This is a significant cost increase; for a typical 10,000 ton project, the project manager would need to budget an extra $1,300 for engineering costs.

6.2 METRO RUMAC and Class "B" Prices and Costs

6.2.1 Bid Prices and Mix Costs

For this project, there was a significant increase in mix costs due to the addition of rubber, as this material was costly and the presence of rubber in the mix required a higher asphalt content. The mix's 2% by weight rubber content required an estimated 33 tons of rubber; the bid price was $560 per ton of rubber, for a rubber cost of $11.20 per ton of mix.

The asphalt content of the METRO RUMAC was 6.6% by weight of mix; the bid price was $150 per ton for the 105 tons of asphalt used, for an asphalt cost of $9.90 per ton of mix. This was slightly higher than the cost of the asphalt for the Class "B" mix.

The bid price of furnishing the METRO RUMAC was $25 per ton of mix, which was higher than the bid price of $21/ton for the Class "B" mix. Most of this additional price was due to the labor and equipment needed to add the rubber to the mix.

The cost of the METRO RUMAC mix in-place, including rubber, asphalt, and furnishing the mix, was $46.10 per ton. Based on a job mix formula specific gravity of 2.365 (based on the briquet's immersed unit weight) and a layer thickness of 2 inches, this mix would have cost $5.10 per square yard if compacted to design density.

This is a significant cost increase; for a typical 10,000 ton project, the project manager would need to budget an extra $5,300 for engineering costs.

6.3 Summary

Based on the total cost of the mixes in-place and including materials, the ISI ARC mix cost about twice as much as the Class "F" mix. The ISI ARC's higher price was due to the use of relatively expensive asphalt-rubber, a greater binder content, and the need to provide blotter material.

An increase in engineering costs of $0.13 per ton is estimated when ISI ARC is used in place of Class "F"; based on a 10,000 ton job and 1992 mix design, testing, and labor costs.

The METRO RUMAC mix was priced over 1-1/2 times higher than the Class "B" mix, based on the total costs of the mixes in-place and including materials. The higher price of the METRO RUMAC mix was due to both the costs of the rubber and a higher asphalt content.

To store and feed the rubber into the mix in an efficient and accurate manner, the contractor estimated it would cost about $135,000 to $145,000 for the needed equipment.

An increase in engineering costs of $0.53 per ton is estimated when METRO RUMAC is used in place of Class "B" mix, based on a 10,000 ton job and 1992 mix design, labor, and testing costs.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents conclusions and recommendations about the test pavements based on their ease of construction, post-construction inspections and testing, and initial costs.

7.1 ISI ARC

7.1.1 Conclusions

Construction using this rubberized mix went smoothly, and the resulting pavement is a good representative of an open-graded ISI ARC overlay. Much of the ease in construction was due to the system's high degree of refinement, as it is a proven system that has been under continuous development by ISI and its predecessors for several decades. In addition, using this system placed little burden on the contractor, as ISI obtained the rubber and base asphalt, mixed the rubber with the asphalt to make the binder, and pumped the binder into the mix plant. No stack emission opacity problems were noted with this mix.

This rubber modified mix was costly, as its total cost per square yard of coverage was over twice as high as the conventional open-graded control mix. Although the cost of the ISI ARC may be reduced to a certain degree on larger scale projects, it is likely that the ISI ARC will still cost substantially more than conventional mixes.

Besides the higher bid prices, the ODOT's costs for future ARC paving projects may be higher than corresponding costs for conventional mixes, as the quality of the rubber and base asphalt, and the proportioning of the asphalt and rubber may need verification.

The frictional values, ride characteristics, and deflection reductions of the ISI ARC were similar to those of typical ODOT open-graded pavements.

7.1.2 Recommendations

To save testing and inspection costs, a performance based asphalt-rubber binder specification is needed. With a performance based specification, the quality of the individual ingredients in the asphalt-rubber binder and the proportions will not need verification. As a result, a check on the asphalt-rubber binder quality will be greatly simplified.

8.0 REFERENCES

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APPENDIX

ISI ARC and METRO RUMAC SPECIFICATIONS

N.E. 181st - Troutdale (Overlay) Section
I-84

MODIFIED CLASS "F" ASPHALT-RUBBER CONCRETE MIXTURE, OPEN-GRADED

Asphalt concrete for Modified Class "F" Asphalt-Rubber Concrete Mixture, Open-Graded pavement shall be constructed in conformance with Section 403 of the Supplemental Standard Specifications, dated September, 1989, supplemented and/or modified as follows:

403.10 Aggregate - On page 6, add the following:

(f) Blotter material - Blotter material, if required, shall be composed of fine aggregate or sand meeting the following gradations requirements when tested in accordance with ASTM C 136 or AASHTO T 27.

Sieve Size	Percent Passing (by Weight)
3/8"	100
No. 4	75-100
No. 16	45-80
No. 50	10-30
No. 100	0-10

403.11(a) Asphalt cement (asphalt) - On pages 6 and 7, delete this subsection and substitute the following:

(a) Asphalt-Rubber Binder:

Asphalt-Rubber Binder - The asphalt-rubber binder takes the place of the normal asphalt cement required for the modified Class "F" asphalt concrete wearing course mixture of the test section in the westbound travel lanes between Stations 724+00 and 765+00 as shown on the plans for construction.

The asphalt-rubber binder shall be a uniform reacted blend of compatible paving grade asphalt cement, ground recycled vulcanized rubber, extender oil, and if required, liquid antistripping agent when indicated by standard moisture susceptibility tests. The asphalt-rubber binder shall be Type II binder and shall meet the physical parameters listed in Table 1 for the type of binder specified when reacted at 350°F± 10°F for 60 minutes.

N.E. 181st Avenue - Troutdale (Overlay) Section
Cold Planing and Paving

TABLE 1

SPECIFICATIONS FOR ASPHALT-RUBBER BINDER

		Type I (a)	Type II (b)	Type III (c)
Apparent Viscosity, 347° F Spindle 3, 12 RPM, cps (ASTM 2669)	Min Max	1,000 4,000	1,000 4,000	1,000 4,000
Haake Viscosity, 350°F, #1 Rotor, cps*	Min Max	1,000 4,000	1,000 4,000	1,000 4,000
Penetration, 77° F, 100g, 5 sec.: 1/10 mm. (ASTM D5)	Min Max	25 75	50 100	75 150
Penetration, 39.2° F, 200g, 60 sec.: 1/10 mm. (ASTM D5)	Min	15	25	40
Softening Point: ° F (ASTM D36)	Min	130	120	110
Resilience, 77° F: % (ASTM D3407)	Min	20	10	0
Ductility, 39.2° F, 1 cpm: cm. (ASTM D113)	Min	5	10	15
RTFO Residue, (ASTM D2872 or AASHTO T 240) Penetration Retention, 39.2° F: %	Min	75	75	75
Ductility Retention, 39.2° F: %	Min	50	50	50

a. Type I Hot Climate - Average July max 110° F
Average Jan. low 30° F or above

b. Type II Moderate Climate - Average July max 100° F
Average Jan. low 15-30° F

c. Type III Cold Climate - Average July max 80° F
Average Jan. low 15° F or lower

*Haake viscosity tests can be used in place of ASTM 2669 viscosity tests for construction quality control.

Mineral Contaminants - For each rubber type and grade, the mineral contaminant amount shall not be greater than 0.25% by weight as determined after water separating a 50 gm. rubber sample in a 1 liter glass beaker filled with water.

Metal Contaminants - The rubber shall contain no visible metal particles as indicated by thorough stirring of a 50 gm. sample with a magnet.

Packaging - The ground rubber shall be supplied in moisture resistant disposable bags which weigh either 50± 2 Lbs. or 60± 2 Lbs. The bags shall be palletized into units each containing 50 bags to provide net pallet weights of either 2500± 100 lbs. or 3000± 100 lbs. Glue shall be placed between layers of bags to increase the unit stability during shipment. Palletized units shall be double wrapped with U. V. resistant stretch wrap.

Labeling - Each bag of rubber shall be labeled with the manufacturer designation for the rubber, the specific type, and grade of rubber in accordance with this specification (example - Type I, Grade A), the nominal bag weight designation (50 or 60 lb.), and manufacturer lot number designation. Palletized units shall contain a label which indicates the manufacturer designation, rubber grade and type, net pallet weight, and production lot number.

Certification - The manufacturer shall ship along with the rubber, certificates of compliance which certify that all requirements of this specification are complied with for each production lot number or shipment.

Anti-Stripping Agent - If required by the Job-Mix Formula to produce appropriate water resistance, an anti-stripping agent that is heat stable and approved for use by the specifying agency shall be incorporated into the asphalt-rubber material at the percentage required by the job mix formula. It shall be added to the asphalt cement prior to blending with the ground rubber.

ASPHALT-RUBBER BINDER DESIGN - The binder design shall be performed by the asphalt-rubber supplier. The proportion of ground rubber shall be between 15 and 20 percent by weight of the total binder.

The asphalt-rubber supplier shall supply to the Project Manager a blend formulation at least 10 days before pavement construction is scheduled to begin. The blend formulation shall consist of the following information:

Supply System - An asphalt-rubber supply system equipped with a pump and metering device capable of adding the binder by volume to the aggregate at the percentage required by the job-mix formula.

Temperature Gage - An armored thermometer of adequate range in temperature reading shall be fixed in the asphalt-rubber feed line at a suitable location near the mixing unit.

ASPHALT-RUBBER MIXING AND REACTION PROCEDURE

Asphalt Cement Temperature - The temperature of the asphalt cement shall be between 375°F and 425°F at the addition of the ground rubber.

Blending and Reacting - The asphalt and ground rubber shall be combined and mixed together in a blender unit, pumped into the agitated storage tank, and then reacted for a minimum of 45 minutes from the time the ground rubber is added to the asphalt cement. Temperature of the asphalt-rubber mixture shall be maintained between 325°F and 375°F during the reaction period.

Transfer - After the material has reacted for at least 45 minutes, the asphalt-rubber shall be metered into the mixing chamber of the asphalt concrete production plant at the percentage required by the job-mix formula.

Delays - When a delay occurs in binder use after its full reaction, the asphalt-rubber shall be allowed to cool. The asphalt-rubber shall be reheated slowly just prior to use to a temperature between 325° and 375°F, and shall also be thoroughly mixed before pumping and metering into the hot plant for combination with the aggregate. The viscosity of the asphalt-rubber shall be checked by the asphalt-rubber supplier. If the viscosity is out of the range specified in Section 3 of this specification, the asphalt-rubber shall be adjusted by the addition of the either asphalt cement or ground rubber as required to produce a material with the appropriate viscosity.

ASPHALT-RUBBER PRODUCTION RECORDS - The asphalt-rubber supplier shall maintain records indicating for each batch of asphalt-rubber binder produced the quantity of asphalt cement in gallons, the temperature of the asphalt cement, the amount of antistripping or other additives, if used, in gallons, and the quantity of ground rubber in pounds. This information shall be provided to the Project Manager on a daily basis.

These samples shall be supplied so they can be shipped to and received at the Division's Materials Laboratory in Salem at least 30 calendar days before anticipated use in the ARC pavement.

This 30-day period will begin when samples of all materials complying with specifications have been received at the Materials Laboratory.

403.13(a-1) JMF materials testing - On page 10 in paragraphs 2 and 3, change "AC" to "ARC".

403.13(a-2) JMF cost responsibility - On page 10, delete this subsection and substitute the following:

> (2) JMF cost responsibility - The Division will provide one JMF for the ARC mix specified at no cost to the Contractor. The costs of development of any additional JMF requested by the Contractor will be borne by the Contractor.

403.14 Tolerances - On pages 11 and 12, substitute Asphalt-Rubber Binder for Asphalt Cement.

403.15 Process Control - On pages 14 and 15, throughout this subsection, change Asphalt to Asphalt-Rubber.

403.16 Acceptance Sampling and Testing - Beginning on page 16 through 19, throughout this subsection change Asphalt to Asphalt-Rubber.

403.21 Asphalt Concrete Mixing Plant - On pages 20, 21, and 22, throughout this subsection change Asphalt to Asphalt-Rubber.

403.22(d) Hauling equipment - On page 22, delete this subsection and substitute the following:

(d) Coat the beds with a minimum amount of a soapy solution or silicone emulsion to keep the AC from sticking to the beds. Do not use diesel oil.

403.24 Compactors - On pages 23 and 24, delete this subsection and substitute the following:

(d) Heating temperatures - Heat the asphalt to at least 325°F, but not more than 375°F, when it enters the mixer. Unless specified otherwise by the JMF, the mixing temperature should be at least 275°F, but not more than 325°F, and the mixture spreading temperature immediately behind the paver should be at least 250°F, but not more than 300°F. Within the applicable mixture spreading temperature limits, the Project Manager may adjust the laydown temperature in 10°F increments as follows:

- Up if the aggregate coating, moisture content, workability, or compaction requirements are not attained.
- Down if the aggregate coating, moisture content, workability, and compaction requirements are attained.

403.36(d) AC mixture storage - On page 27, revise maximum storage time to 1 hour.

403.38(a) Hauling - On page 27, add the following:

Just prior to loading of the mixture, the truck bed shall be sprayed with a light application of a soapy solution or a silicone emulsion (oiling with kerosene or diesel fuel will not be permitted due to adverse effects on the binder) to reduce sticking of the mixture to the truck bed.

403.39(a-1) Temperature - On page 29, change the minimum compaction temperature to 200°F.

403.39(3) Roller damage surface repair - On page 30, delete this subsection and replace with the following:

(3) Roller damage surface repair - Correct any displacement of any course at once, with rakes and addition of fresh mixture when required, regardless of thickness. Do not displace the line and grade of edges.

(a) Prevent the ARC from sticking to the wheels and spotting or defacing the ARC by wetting them with a minimum of water or, if necessary, soapy water.

(b) Blotter material, if required, shall be placed on the warm mat prior to opening to traffic. The use, rate, and location for the blotter material shall be designated by the

CLASS "B" RUMAC ASPHALT CONCRETE MIXTURE, DENSE-GRADED

Asphalt concrete for the Class "B" Rubber Modified Asphalt Concrete Mixture, Dense-Graded pavement shall be constructed in conformance with Section 403 of the Supplemental Standard Specifications of the Oregon State Highway Division, dated September, 1989, supplemented and/or modified as follows:

403.01 Scope - On page 1, delete this subsection and substitute the following:

This work consists of construction of one or more courses of rubber modified asphalt concrete (RUMAC) pavement plant mixed into a uniformly coated mass, which is a mixture of mineral aggregate, asphalt cement and crumb rubber (def. below), hot laid on prepared foundation, compacted to specified density, and finished to a specified smoothness to the lines, grades, thickness and cross sections shown on the plans or as established by the Engineer.

403.02 Definitions and Abbreviations - On page 1, add the following to this subsection:

(a) Definitions - Add the following definition to this subsection:

Rubber Modified Asphalt Concrete - A hot mixture of asphalt cement, graded aggregate, mineral filler, crumb rubber, and if required, anti-stripping additives.

Crumb Rubber - Rubber particles processed from whole used tires. The rubber particles sized greater than 10 mesh should be processed by granulation method. The rubber particles sized less than 10 mesh can be processed by granulation method or grinding method.

Materials

403.11 Asphalt Cement, Additives, Mineral Filler and Aggregate Treatment - On page 6, delete this subsection heading and substitute the following heading:

and grade of the crumb rubber, the nominal bag weight, and manufacturer lot number designation. Palletized units shall contain the above information plus the net pallet weight.

The crumb rubber, tested in accordance with AASHTO T 27 using a 100 gram sample, shall be within the following Broadband Gradations:

Sieve Size	Percent Passing (by weight)
No. 4	100
No. 8	70-100
No. 16	40-65
No. 30	20-35
No. 50	5-15

Material produced within broadband gradations shall be produced with a maximum variation of ±5% from the average gradation for each sieve size.

The following chemical analysis shall apply to the rubber granulate:

Specific Gravity	1.15±.05
Percent of Carbon Black	35.0 MAX.
Percent of Ash	8.0 MAX.
Percent of Acetone Extract	23.0 MAX.

The rubber granulator (processor) shall furnish a written certification of compliance with the foregoing specifications.

Further, if State reimbursement funds for used tire recycling are to be applied for and used, the granulator (processor) shall furnish a written certification of used tire origin, acceptable to the DEQ's administrator of the used tire reimbursement program. This might include the sole use of Oregon tires, or an exchange by the processor of an equivalent amount of Oregon tires.

403.13(a) JMF for permanent courses - On pages 9 and 10, delete the first, second, third, and fourth paragraphs from this subsection and substitute the following:

(a) JMF for RUMAC - The Contractor shall take representative, composite samples of aggregate after 1,000 tons

(c) Field Adjustments for JMF - Do not adjust the JMF without the consent and approval of the Engineer of Materials and Research.

403.15 Process Control - On page 15, add the following to this subsection:

(d) Crumb Rubber - The crumb rubber shall be tested for sieve analysis and moisture content at the start of production and every 500 tons of production thereafter.

403.16 Acceptance Sampling and Testing - On page 15, delete the first paragraph of this subsection and substitute the following:

All acceptance sampling and testing will be performed by the Engineer as required by 106.19 of the Supplemental Specifications with this exception: The Contractor will perform the sampling and extractions for all check tests on the RUMAC mix. The Division will perform the record sampling and testing.

Equipment

403.21 Asphalt Concrete Mixing Plant - On page 22, add the following to this subsection:

(p) Rubber Modified Asphalt Concrete Mixing Plant - The type of plant used for the manufacture of bituminous mixtures may be either a batch or drum mix plant. Mixing plants shall conform to the requirement of subsection 403.21, except the following shall be added:

1. Requirements for Batch Plants - The amount of granulated rubber shall be determined by weighing on springless dial scales, or by a method which uniformly feeds the mixer within plus or minus 0.20 percent of the required amount as indicated in subsection 403.13(b). To obtain maximum accuracy, the addition of preweighted bags directly to the pugmill is recommended.

2. Requirements for Drum Mixing Plants - Granulated rubber introduced into the mixer shall be drawn from storage bins by a continuous mechanical feeder which will uniformly feed the mixer within ± 0.20 percent of the required amount as indicated in subsection 403.13(b).

- A gross static weight of at least 6 tons.
- No drive wheel static weight requirement.

(b) Vibratory Rollers - Vibratory rollers shall:

- Be equipped with amplitude and frequency controls.
- Be specifically designed to compact AC.
- Be capable of at least 2,000 vibrations per minute.
- Be equipped with fully operational water spray bars to coat the roller drum with water mixed with a wetting agent.
- Use of a wetting agent such as tri-sodium phosphate is recommended. No petroleum based wetting agents may be used.

If used for finish rolling, the roller shall:

- Have a gross static weight of at least 6 tons.
- Not be operated in the vibratory mode.

(c) Pneumatic-tired rollers - Do not use pneumatic-tired rollers.

403.34 Drying and Heating Aggregate and AC - On page 26, add the following to this subsection:

(e) Heating Temperatures for Rubber Modified Asphalt Concrete - The heating temperatures will be specified in the job mix formula (JMF) and will have a tolerance of plus or minus 25°F.

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403.91 Payment - On page 40, add the following to this subsection: (for RUMAC)

Pay Item	Unit of Measurement
Class "B" Rubber Modified Asphalt Concrete Mixture	Ton
Asphalt in RUMAC Mixture	Ton
Rubber Granulate in Mixture	Ton

The unit price bid per ton for Rubber Modified Asphalt Concrete shall include the cost of furnishing all materials including granulated rubber and all equipment and labor necessary to complete the work.