ASPHALT-RUBBER CONCRETE (ARC) EVALUATION

Eastside Bypass
Klamath Falls Section

Interim Report

OR-RD-99-14

by

Liz Hunt, P.E.
Andrew Griffith, P.E.
Research Group
Oregon Department of Transportation

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16. Abstract

This report reviews the construction of four pavement test sections using asphalt-rubber as the binder and three hot mix asphalt concrete pavement control sections. The pavements were constructed in Klamath Falls, Oregon in 1992. The control sections were constructed with hot mix asphalt concrete. The test sections consisted of one gap graded asphalt-rubber concrete (ARC) mix and two open graded ARC mixes. The fourth test section was constructed using a powdered rubber asphalt-rubber concrete (PRARC) open graded mix. The ARC binder was made by blending shredded tire material and asphalt. The PRARC binder was made by blending natural rubber and asphalt. Powdered rubber from tire sources was supposed to have been used, but unfortunately, natural rubber was used instead. The blending for both types of binders was done at the asphalt plant by International Surfacing, Inc. There were two open graded mix control sections and one dense graded mix control section.

There were no problems in constructing the open graded and gap graded ARC test sections. There were some concerns with construction of the PRARC mix. Possibly because of the natural rubber or the slightly higher binder content, the PRARC mat was sticky. Just after compaction, several applications of sand were needed as a blotter on the surface of the mat prior to opening the section to traffic.

The ARC test sections, PRARC test section and the control sections showed no signs of rutting or cracking when inspected several days after construction. Friction values of the test and control sections were similar, indicating adequate skid resistance. Deflection data indicated the pavement overlays and inlays reduced pavement deflection.

Development of performance based specifications are needed for asphalt-rubber mixes to ensure satisfactory performance after placement. Performance of the sections will be monitored and documented through the *Crumb Rubber Modifier Study* being coordinated by ODOT's Research Group.

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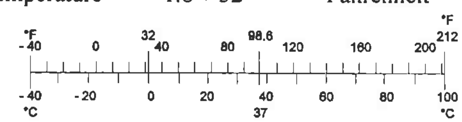
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	inches	25.4	millimeters	mm
Ft	feet	0.305	meters	m
Yd	yards	0.914	meters	m
Mi	miles	1.61	kilometers	km
		AREA		
In^2	square inches	645.2	millimeters squared	mm^2
Ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
Ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
Gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
Oz	ounces	28.35	grams	g
Lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
□F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	□C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
□C	Celsius temperature	1.8 + 32	Fahrenheit	□F



* SI is the symbol for the International System of Measurement

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ASPHALT-RUBBER CONCRETE (ARC) EVALUATION
EASTSIDE BYPASS - KLAMATH FALLS SECTION

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1.0 INTRODUCTION

1.1 BACKGROUND

The storage and disposal of worn rubber tires is a problem for local governments. One option to consider is using the waste tire rubber in asphalt concrete pavements. The first application of this process in Oregon pavement construction was with rubber modified asphalt concrete (RUMAC). RUMAC is produced by adding rubber to aggregate which is then mixed with the binder (dry process).

To test another alternative, the Eastside Bypass, Klamath Falls Section project was constructed with asphalt-rubber concrete (ARC) to allow for comparison to RUMAC. The ARC is created by blending the rubber with the binder before mixing with the aggregate (wet process). Prior to this project, the Oregon Department of Transportation (ODOT) had no experience with ARC pavement construction.

Another factor in choosing the Eastside Bypass project in Klamath Falls for ARC testing was the climate in the project area. The RUMAC projects constructed by ODOT were located in a geographic area of the state with mild climates and relatively small changes in temperature. Klamath Falls, however, undergoes significant seasonal temperature changes, which would allow analysis of the ARC under these conditions. On the Eastside Bypass project, test sections were constructed using asphalt-rubber concrete and standard ODOT hot mix asphalt concrete.

The purpose of the research was to compare the asphalt-rubber concrete test sections with the standard ODOT hot mix asphalt concrete mixes. The Eastside Bypass project test sections were constructed and original data collected in 1992. At that time, ODOT was investigating systems to meet requirements of the Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA encouraged the use of recycled rubber in asphalt pavements with the aim of achieving 20 percent usage by 1997. The ISTEA goal is no longer a federal mandated requirement. Although ODOT is currently not using ARC as a paving material, the findings in this report can be used to determine the appropriate use of asphalt-rubber or to address issues if future mandates or policy changes evolve.

1.2 ODOT TEST SECTIONS FOR RESEARCH

The Eastside Bypass, Klamath Falls Section project included four test sections and three conventional mix control sections.

Test Sections

ARC - The ARC test sections were constructed with asphalt-rubber blended by International Surfacing, Inc. (ISI) using a "wet process". In this process, crumb rubber produced from tire grindings is mixed with asphalt. The asphalt-rubber is then mixed with 19 mm - 0 mm, gap graded or open graded aggregate to produce asphalt-rubber concrete (ARC). Two mixes, ISI ARC open graded (Class "F") mix (2 test sections) and an ISI ARC gap graded (Modified Class "B") mix test section, were used in the test sections.

Powdered Rubber Asphalt Rubber Concrete (PRARC) - One test section was constructed with the PRARC open graded (Class "F") mix. PRARC uses a type of "wet process" similar to the ISI process. The difference is that the binder is blended with powdered rubber from tires to create powdered rubber asphalt concrete.

For the Eastside Bypass project, the ISI ARC gap and open graded mixes used recycled tire rubber. The rubber used in the powdered rubber PRARC section, unfortunately, was natural rubber and not rubber made from tire sources. As a result, conclusions about the use of powdered rubber from recycled tires cannot be determined from this project's test section.

Control Sections

ODOT Open Graded Class "F" Mix (25 mm - 0 mm) – Two sections were constructed with an open graded "F" mix.

ODOT Dense Graded Class "B" Mix (25 mm - 0mm) – One control section was constructed with a dense graded "B" mix.

1.3 OBJECTIVES

The particular combination of asphalt concrete mix designs was chosen to gather as much information as possible on one construction project. This would allow a thorough evaluation of the use of recycled tire rubber in hot mix asphalt concrete pavements. Although most of these processes had been tried in other areas of the state, none had been constructed on the same project.

The primary research objective was to evaluate and compare the constructability and performance of ISI ARC gap graded, ISI ARC open graded, and PRARC open graded mixes to conventional Class "B" and Class "F" mixes. A second objective was to determine appropriate revisions to the ODOT specifications for wearing surfaces that contain recycled tire rubber. A third objective was to recommend changes to the ODOT mix design procedure for including ground used tire rubber. A fourth objective was to develop ODOT construction sampling methods and test procedures to determine the appropriate asphalt binder content, aggregate gradation, and rubber content of the various mixes.

Annual monitoring of the test and control sections will continue until 1999. This report will document the construction details relating to the test sections including:

- The project's location and design;
- Materials;
- Mix designs;
- Construction process;

- Sampling and testing;
- In-place unit costs; and
- Pavement conditions.

The long-term performance will be documented in the reports for State Planning and Research (SP&R) Project #355, "Crumb Rubber Modifiers in Asphalt Concrete Pavements."

2.0 LOCATION, DESIGN, AND MATERIALS

2.1 LOCATION, LAYOUT, CROSS SECTION, AND DESIGN

The Eastside Bypass Section is located on Highway 50 (State Route 39) in Klamath Falls, Oregon as shown in the Vicinity Map, Figure 2.1(a). A close-up of the project site is contained in Figure 2.1(b).

Both ends of the test and control pavement sections were marked on the shoulder with paddles that display the mix type. Within each test and control pavement section, shorter evaluation sections were designated for performance monitoring until 1999. The evaluation sections were marked with "Coring Site" paddles installed near the roadway shoulders.

Table 2.1 below, gives the location of the test and control sections by station and mile post. Each section contained a 64 mm thick wearing course. Note that the X miles refer to negative miles. Figure 2.2 depicts the test section layout.

Table 2.1: Test Section Layout

Test Section	Milepoints Stationing	Lane Lift
ODOT Class "B"	M.P. X5.21 to X5.02 (STA 73+50 to 83+50)	Outer Eastbound Top Lift
ISI ARC Modified Class "B" (Curbed Section)	M.P. X5.02 to X4.49 (STA 83+50 to 111+50)	Outer Eastbound Top Lift
PRARC Class "F"	M.P. X4.42 to X4.07 (STA 115+50 to 133+75)	Outer Eastbound Top Lift
ODOT Class "F"	M.P. X4.03 to X3.78 (STA 136+00 to 149+00)	Outer Eastbound Top Lift
ODOT Class "F"	M.P. X3.78 to X3.97 (STA 149+00 to 139+00)	Outer Westbound Top Lift
ISI ARC Class "F"	M.P. X3.97 to X4.42 (STA 139+00 to 115+50)	Outer Westbound Top Lift
ISI ARC Modified Class "B"	M.P. X4.49 to X5.21 (STA 111+50 to 73+50)	Outer Westbound Top Lift

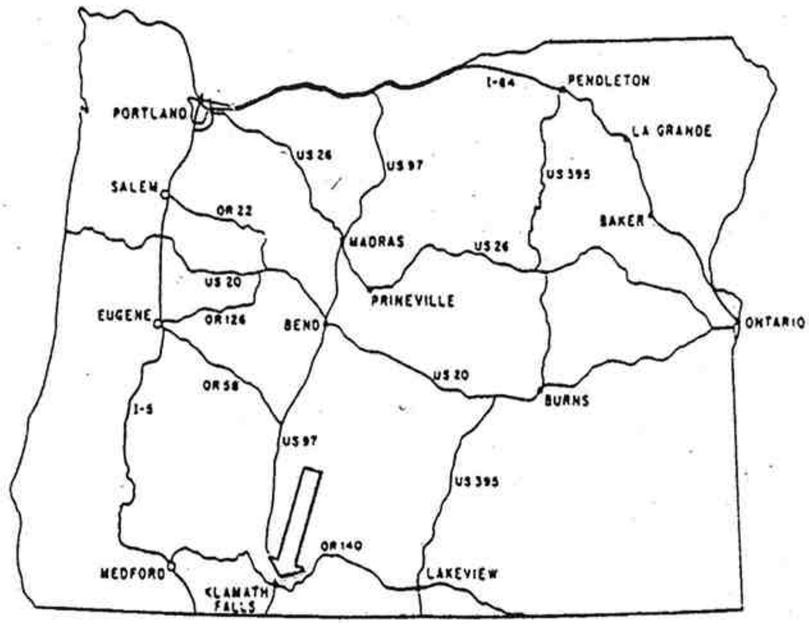

Figure 2.1(a): Project Location

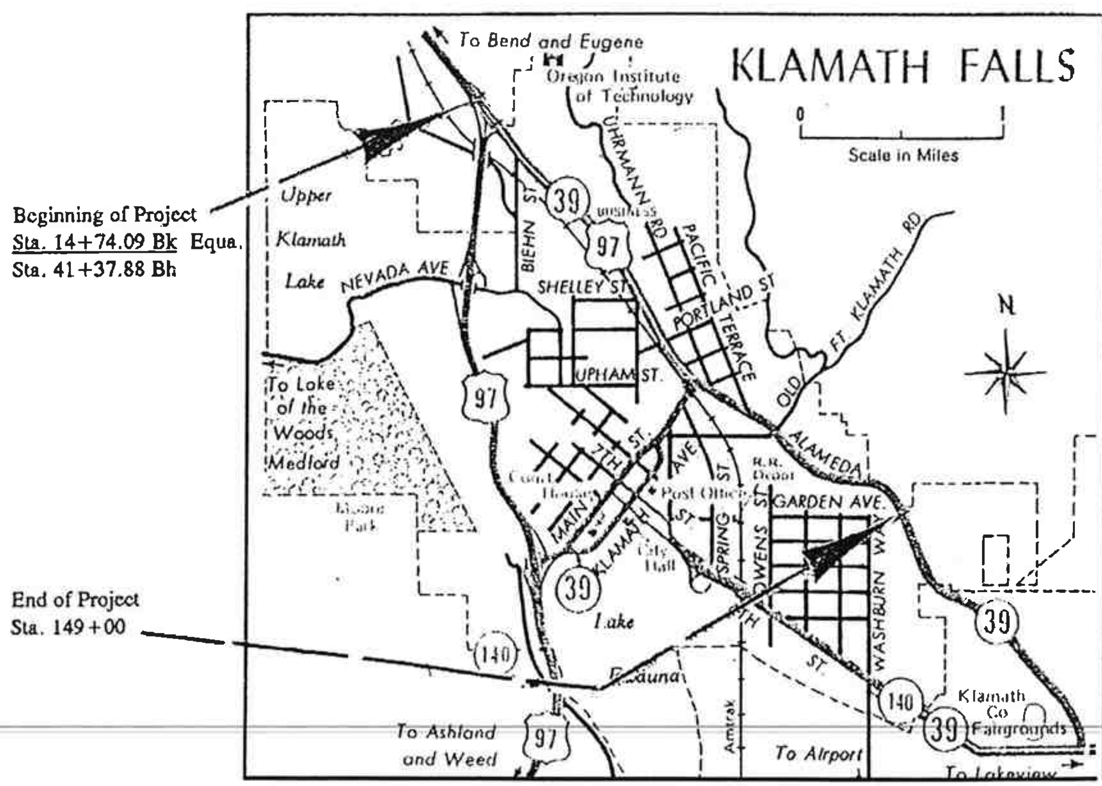

Figure 2.1(b): Close-up of Project Site

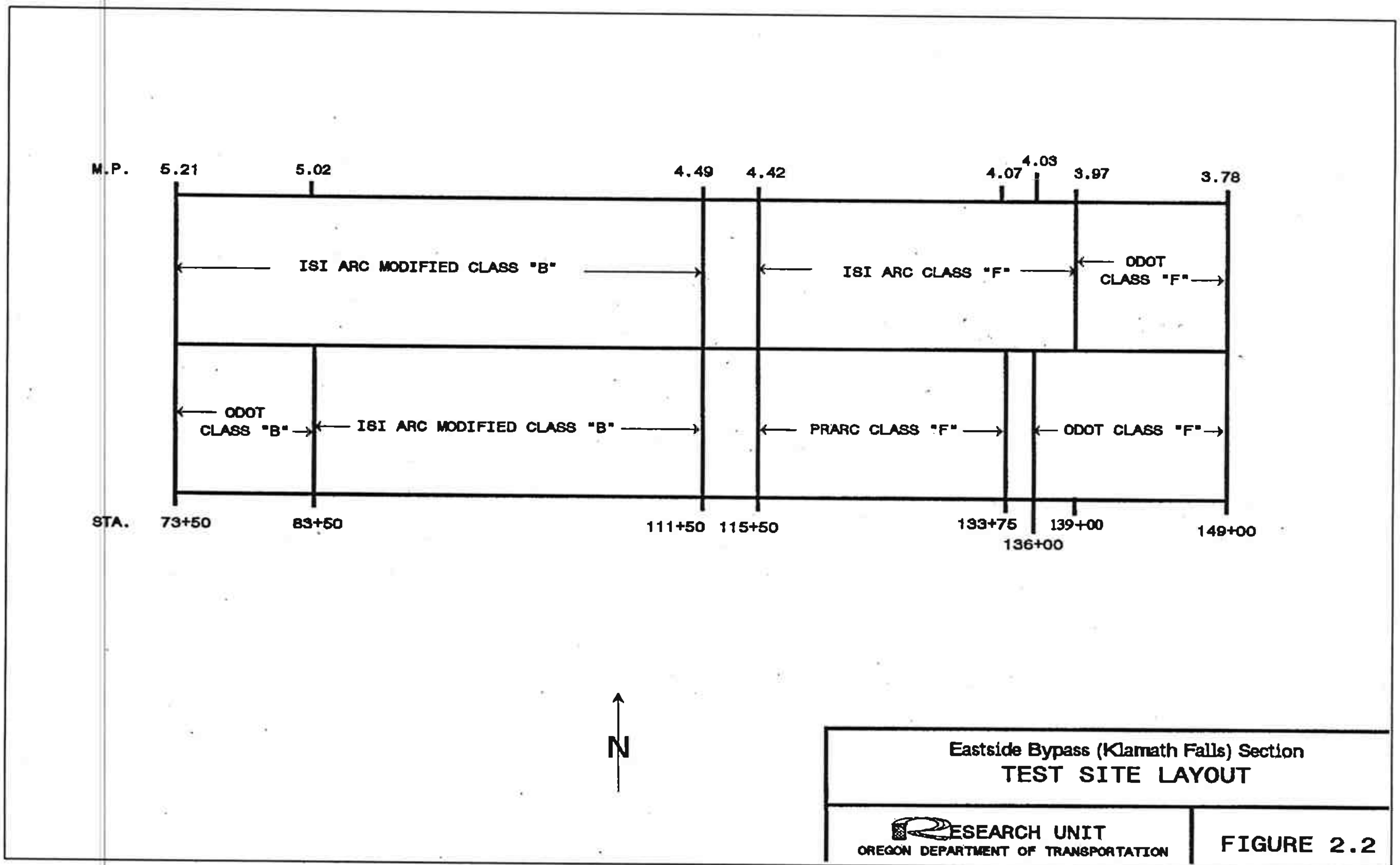

Figure 2.2: Test Site Layout

The aim of the Eastside Bypass, Klamath Falls Section project was to rehabilitate the existing pavement to provide additional structural capacity for future traffic growth. Construction of the project would also improve driving conditions and enhance safety and rideability.

As shown in the Typical Cross Section, Figure 2.3, the existing asphalt concrete pavement had four 3.7 m travel lanes with 1.2 m shoulders on each side with a fifth left turn lane at the intersections. The old pavement was a 165 to 305 mm-thick layer of asphalt concrete. The original pavement was constructed in the 1940's. The pavement had been rehabilitated during the 1960's and 1970's with 50 to 100 mm of asphalt concrete overlay. The base layer under the old pavement included crushed aggregate of varying thickness. The subgrade material was identified as clayey silt with some sand.

A pavement condition survey was performed in the summer of 1990. The survey indicated that the existing pavement condition varied along the roadway. At that time, the pavement rated fair to poor in condition.

The existing pavement was cold planed to a depth of 64 mm from STA 73+06 to STA 113+25 to eliminate the pavement distress and maintain the pavement profile at the existing curb line. The removed material was then replaced with 64 mm of new pavement. The original pavement design specified a 64 mm inlay followed by a 64 mm overlay of dense graded mix. The final pavement design included only the 64 mm inlay with the ISI ARC Modified Class "B" mix. In order to maximize the curb height and evaluate a reduced thickness ARC section, the Region suggested constructing the inlay but deleting the overlay. The reduced pavement thickness was compared to the control section, also constructed through the curb section with only a 64 mm inlay.

From STA 113+25 to STA 149+00, the existing pavement was overlaid to a minimum thickness of 64 mm.

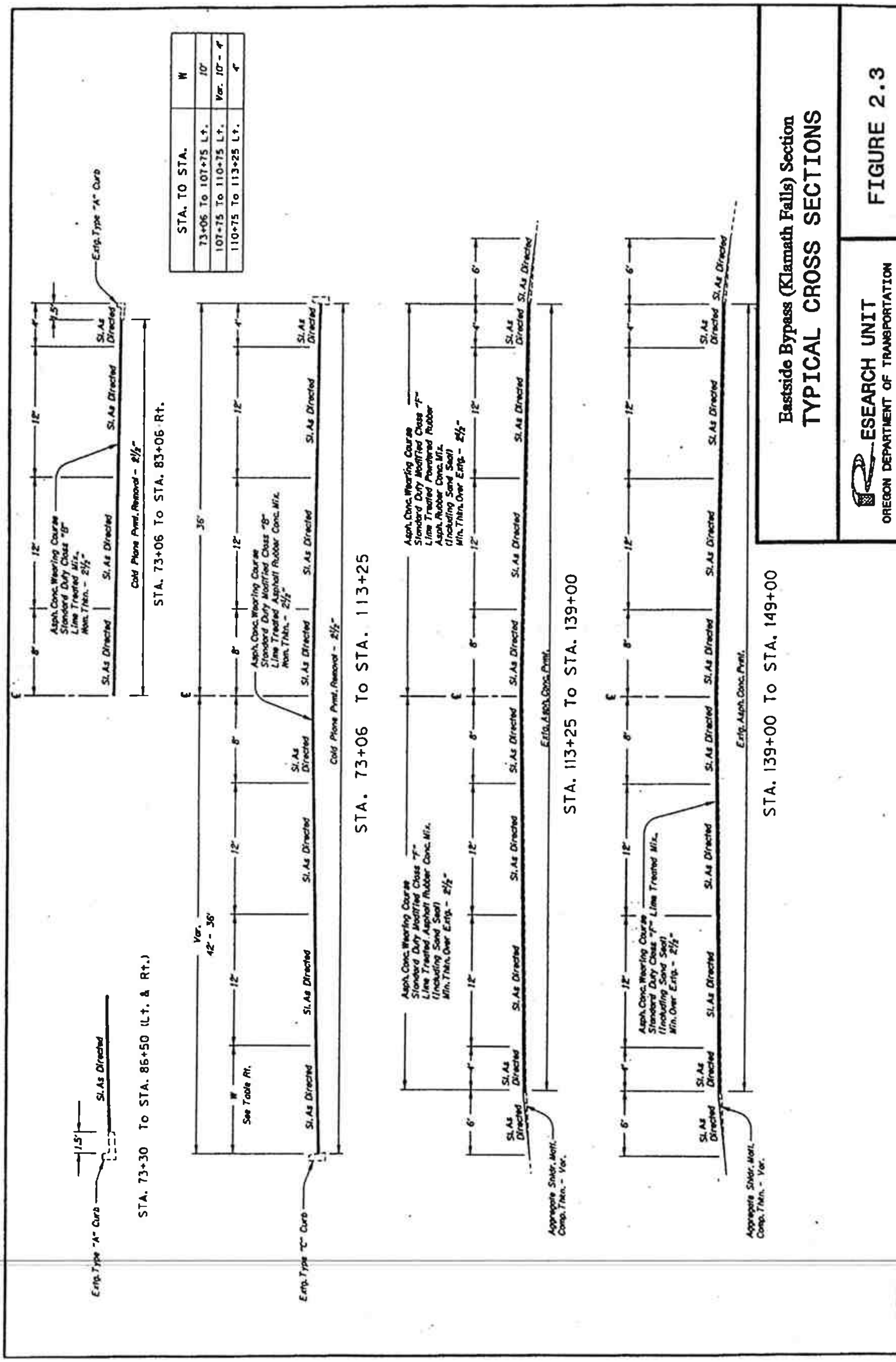

Figure 2.3: Typical Cross Section

2.2 ENVIRONMENT AND TRAFFIC

The project is located in the south central climatic region of Oregon. This region's weather is characterized by cold, dry, snowy winters, and warm, dry summers. The climate was a significant factor in selecting the Eastside Bypass for research.

The test and control pavements are located on a primary state highway which runs through the City of Klamath Falls.

The climate and traffic data for the highway is included in Table 2.2.

Table 2.2: Environment and Traffic Data Eastside Bypass

Elevation, meters	1,251
Average Daily Temperature of Coldest Month, January, °C	5
Average Daily Temperature of Warmest Month, July, °C	20
Average Annual Precipitation, mm	450
1992 Average Daily Traffic, (vehicles/day)	10,200
Heavy trucks, (% of Average daily traffic)[1]	1.1
1992 Annual 80 kn Equivalent Single Axle Loads, (ESALs)	27,483

[1]Single unit, 2-axle, 6-tire or larger vehicles are classified as "heavy trucks.

2.3 MATERIALS AND SUPPLIERS

Paving material suppliers used on the project are listed in Table 2.3. The materials used in the overlay and inlay are described below:

Asphalt Concrete - The ISI ARC Modified Class "B", ISI ARC Class "F", PRARC Class "F", and conventional asphalt concrete mixes were supplied by the contractor.

Binders and Components - ISI's Type II asphalt-rubber binder was used for both the ISI ARC open graded mix and the ISI ARC gap graded mix. This binder contained 77% (of total binder weight) Witco PBA-2, 6% Witco Cyclogen "L" extender oil, and 17% Atlos #1710 Type IIA ground automobile and truck tire rubber.

The PRARC contained 79% Witco PBA-2, 6% Witco Cyclogen "L", and 15% Rouse NR-80 powdered rubber. The binder was blended at the construction site the same way as the ISI Type II asphalt-rubber.

Albina PBA-3 and PBA-6 were used in the conventional ODOT dense graded standard duty (SD) and open graded SD control sections.

Table 2.3: Materials Suppliers

Material	Supplier
Asphalt Cement: PBA-3 and PBA-6	Albina Fuel 3246 N.E. Broadway Portland, OR 97212 Contact Person: Bob Davis
Granulated Rubber	Atlos Rubber Inc. 1522 Fishburn Avenue Los Angeles, CA 90063 Contact Person: Robert Winters
Powdered Rubber	Rouse Rubber Industries, Inc. P.O. Box 820369 1000 Rubber Way Vicksburg, MI 39182-0369 Contact Person: Mike Rouse
Extender Oil	Witco Corporation Golden Bear Products P.O. Box 456 Chandler, AZ 85244-0161
Asphalt-Rubber ISI ARC Binder	International Surfacing, Inc. 6751 W. Galveston Chandler, AZ 85226 Contact Person: Kent Hansen
Lime	Chemstar Hydrated Lime Type N
Truck Bed Release Agent	Slipeazee SB (Water Soluble) Rochester Midland Manufacturing Co. Rochester, NY

Rubber - Crumb rubber used by ISI was supplied by Atlos Rubber Inc. in Los Angeles, California. The rubber was delivered on pallets with a net weight of 1362 kg in 27 kg bags. There were two production lots of rubber used in the ISI mix with slightly different gradations. The slightly varied gradations changed the consistency of the binder a little but did not affect the ISI ARC mixes.

The powdered rubber was supplied by Rouse Rubber Industries, Inc. in Vicksburg, Mississippi. The intent of using powdered rubber was to test Rouse Rubber Industries' GR-80 or an equivalent product produced by another manufacturer. The rubber specifications for this project were based on specifications for GR-80, which is a powdered rubber made from tires. The rubber supplied by ISI for the test section was Rouse Rubber Industries' NR-80.

The NR-80 rubber was delivered in 23 kg bags. The specifications required the powdered rubber to be produced from ground tires. The rubber supplied, however, was from a non-tire source.

Extender Oil - Witco Cyclogen "L" was supplied by Golden Bear Division of Witco Chemical Company in Klamath Falls, Oregon.

Truck Bed Release Agent - Slipeazee SB (water soluble) was supplied by Rochester Midland Manufacturing Company.

Aggregates - Crushed basalt from the quarry located on Stukel Mountain, ODOT Source No. 18-036-4, was used as the aggregate for all mixes. The aggregates were produced in four separate stock piles that included 25 mm – 12.5 mm, 12.5 mm – 6.3 mm, 6.3 mm – 2.0 mm, and 2.00 mm – 0. As a precaution against potential moisture damage, the aggregates were lime treated prior to entering the paving hot mix plant at a rate by weight of 1.0% of weight of the dry aggregate.

2.4 SPECIFICATIONS AND TEST RESULTS ON BINDERS, GRANULATED RUBBER, POWDERED RUBBER, AND ASPHALT-RUBBER

This section provides the specifications and test results of products that were incorporated in the various mixtures to construct the control and test sites. Most of the tests followed AASHTO, ASTM and ODOT methods *(AASHTO 1990, ASTM 1991,ODOT 1986)*. Special sampling and test methods are discussed in Chapter 4. The sections of the specifications that apply to the ISI ARC and PRARC are included in the project's Special Provisions, attached as Appendix A. The specification limits listed in the tables relate to the specifications at the time of construction. Current specifications can be found on the ODOT web site at http://www.dot.state.or.us/techserv/roadway/supplement/0745supl.pdf.

2.4.1 Binders

Paving Grade asphalts were tested by standard laboratory procedures for PBA graded asphalt cement. The test results for PBA-3 and PBA-6 are included in Tables 2.4 and 2.5, respectively.

ISI ARC Binder - For the ISI ARC mixes, the suppliers sent representative samples of PBA-2, ground tire rubber, and extender oil to the laboratory of Western Technologies, Inc. in Phoenix, Arizona, for the mix designs. The laboratory reacted the asphalt, rubber and extender oil to make the Type II binder. The test results and specifications are listed in Table 2.6.

Powdered Rubber ARC - For the PRARC mix, the suppliers sent representative samples of PBA-2, ground tire rubber, and extender oil to the laboratory of Western Technologies, Inc. in Phoenix, Arizona, for the mix designs. The laboratory reacted the asphalt, rubber, and extender oil to make the binder. The test results and specifications are listed in Table 2.7.

2.4.2 Rubber

ISI ARC Rubber - The specifications and test results are listed in Table 2.8(a). The ISI ARC rubber met specifications.

Rouse Rubber Industries' NR-80 Powdered Rubber - The specifications and test results are listed Table 2.8(b). The powdered rubber did not meet specifications. The gradation was too coarse and was deficient passing all of the sieves. Also, the NR-80 powdered rubber exceeded the allowable ash content. This is indicative of rubber that is not from a tire source.

Table 2.4: Binder Test Results - PBA-3 (Dense-graded Binder)

Test	Method	Test Results	Specifications
Pen. @ 39.2°F (4 °C), 100g, 5s, on Residue (dmm)	AASHTO T49[b]	11[a], 13[c]	None
Pen. @ 39.2°F (4 °C), 200g, 60s, on Residue (dmm)	AASHTO T49[b]	39[a], 38[c]	30 (min.)
Pen. @ 77°F (25 °C), 100g, 5s, on Residue (dmm)	AASHTO T49[b]	73[a], 70[c]	None
Abs. Vis. @ 140°F (60 °C), on Original (P)	AASHTO T202[d]	2,140[a], 2,330[c]	1,100 (min.)
Abs. Vis. @ 140°F, 30 cm, Hg Vac, on Residue (P)	AASHTO T202[b,d]	5,150[a], 5,640[c]	3,000 (min.)
Abs. Vis. Ratio (Residue/Original)	AASHTO T202	2.4[a], 2.4[c]	4.0 (max.)
Kin. Vis. @ 275°F (135 °C), on Original (cSt)	AASHTO T201	592[a], 632[c]	2,000 (max.)
Kin. Vis. @ 275°F, on Residue (cSt)	AASHTO T201[b]	865[a], 930[c]	275 (min.)
Duct. @ 45°F (27.2 °C), 1 cm/min., on Residue (cm)	AASHTO T51[b,e]	27[a], 25+[c]	None
Duct. @ 77°F, 5 cm/min., on Residue (cm)	AASHTO T51[b,e]	81[a], 100+[c]	75 (min.)
Flash Point, COC, Original (°F)	AASHTO T48	545[a] (285 °C), 570[c] (299 °C)	450 (min.) (230 °C)
Loss on Heating, of Residue (%)	AASHTO T47[b]	.14[a], .14[c]	None

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Acceptance tests on the binder used in mix design for ODOT Class "B" mix.
[b] AASHTO T240 method used to age asphalt.
[c] Check/record test on the binder used in Class "B" mix.
[d] Viscosity determined at 1 sec^{-1} using ASTM P-159 (Vol. 4.03, 1985) with Asphalt Institute Vacuum Capillary Viscometers.
[e] AASHTO T51 as modified by the Washington DOT (using a special method of applying the release agent).

Table 2.5: Binder Test Results - PBA-6 (Open-graded Binder)

Test	Method	Test Results	Specifications
Pen. @ 39.2°F (4 °C), 100g, 5s, on Residue (dmm)	AASHTO T49[b]	12[a], 12[c]	None
Pen. @ 39.2°F (4 °C), 200g, 60s, on Residue (dmm)	AASHTO T49[b]	36[a], 37[c]	30 (min.)
Pen. @ 77°F (25 °C), 100g, 5s, on Residue (dmm)	AASHTO T49[b]	67[a], 73[c]	None
Abs. Vis. @ 140°F (60 °C), on Original (P)	AASHTO T202[d]	3,010[a], 3,440[c]	2,000 (min.)
Abs. Vis. @ 140°F, 30 cm, Hg Vac, on Residue (P)	AASHTO T202[b,d]	6,490[a], 10,000[c]	5,000 (min.)
Abs. Vis. Ratio (Residue/Original)	AASHTO T202	2.2[a], 2.9[c]	4.0 (max.)
Kin. Vis. @ 275°F (135 °C), on Original (cSt)	AASHTO T201	682[a], 785[c]	2,000 (max.)
Kin. Vis. @ 275°F, on Residue (cSt)	AASHTO T201[b]	1,000[a], 1,210[c]	275 (min.)
Duct. @ 45°F (27.2 °C), 1 cm/min., on Residue (cm)	AASHTO T51[b,e]	25+[a], 25+[c]	None
Duct. @ 77°F, 5 cm/min., on Residue (cm)	AASHTO T51[b,e]	98+[a], 92[c]	60 (min.)
Flash Point, COC, Original (°F)	AASHTO T48	580[a] (304 °C) 585[c] (307 °C)	450 (min.) (230 °C)
Loss on Heating, of Residue (%)	AASHTO T47[b]	.25[a], .37[c]	None

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Acceptance tests on the binder used in mix design for ODOT Class "F" mix.
[b] AASHTO T240 method used to age asphalt.
[c] Check/record test on the binder used in Class "F" mix.
[d] Viscosity determined at 1 sec^{-1} using ASTM P-159 (Vol. 4.03, 1985) with Asphalt Institute Vacuum Capillary Viscometers.
[e] AASHTO T51 as modified by the Washington DOT (using a special method of applying the release agent).

Table 2.6: Binder Test Results - ISI Type II Asphalt Rubber (ISI ARC Mixes)

Test	Method	Test Results	Specifications[i]
Pen. @ 39.2°F (4 °C), 200g, 60s, on Original (dmm)	ASTM D5	33[a], 29[c], 38[d]	25 (min.)
Pen. @ 39.2°F (4 °C), 200g, 60s, on Residue (dmm)	ASTM D5	27[a], 33[c], 20[d]	None
Pen. Retention @ 39.2°F, (Residue/Original x 100) (%)	ASTM D2872	82[a], 114[c], 76[d]	75 (min.)
Pen. @ 77°F (25 °C), 100g, 5s, on Original (dmm)	ASTM D5	55[a], 56[c], 52[d]	50 (min.) 100 (max.)
Cone Pen. @ 77°F, 150 g, on Original	ASTM D217	51[c]	None
Apparent vis. @ 347°F (175 °C), Spindle 3, 10 to 20 RPM,: on Original (cP)[b]	ASTM 2669	None	1,000 (min.) 4,000 (max.)
Haake Vis. @ 350°F (177 °C), #1 Rotor, on Original (cP)[b]	(Reference 6)	2,250[c] 1,300[e] 3,500[f] 7,000[g]	1,000 (min.) 4,000 (max.)
Softening Point, on Original (°F)	ASTM D36	149[a] (65 °C), 131[c] (55 °C), 136[d] (58 °C)	120 (min.) (50 °C)
Duct. @ 39.2°F, 1 cpm, on Original (cm)	ASTM D113	17[a], 12.5[c], 31[d]	10 (min.)
Duct. @ 39.2°F, 1 cpm, on Residue (cm)	ASTM D113	14+[a], 16[c], 25[d]	None
Duct. Retention @ 39.2°F, (Residue/Original x 100) (%)	ASTM D2872	128[c], 81[d]	50 (min.)
Resilience @ 77°F, Rebound, on Original (%)	ASTM D3407	21[c]	10 (min.)

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Acceptance tests on binder including 6% cyclogen "L", 17% Atlos 1710 ground rubber, and 77% Witco PBA-2 used in mix design for ISI "F" mix and ISI modified Class "B" mix.

[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 at 344°F (173 °C).

[d] ODOT check/record tests on binder used in ISI ARC mix.

[e] Viscosity from ISI's on-site test at 30 minutes reaction time at 341°F (172 °C).

[f] Viscosity from ISI's on-site test at 135 minutes reaction time at 352°F (178 °C).

[g] Viscosity from ISI's on-site test at 360 minutes reaction time at 362°F (183 °C).

[h] AASHTO T179 used to age binder for ISI's mix design, and AASHTO T240 was used to age ODOT's sample.

[i] Parameters apply to asphalt-rubber reacted at 350°F (175 °C)± 10°F (5 °C)± for 30 minutes.

Table 2.7: Binder Test Results - Powdered Rubber ARC

Test	Method	Test Results[a]	Specifications
Pen. @ 39.2°F (4 °C), 200g, 60s, on Original (dmm)	ASTM D5	19[c], 45[d]	25 (min.)
Pen. @ 39.2°F, 200g, 60s, on Residue (dmm)[f]	ASTM D5	25[d]	None
Pen. Retention @ 39.2°F (4 °C), (Residue/Original x 100) (%)	ASTM D2872	56[d]	75 (min.)
Pen. @ 77°F (25 °C), 100g, 5s, on Original (dmm)	ASTM D5	71[c], 85[d]	50 (min.) 100 (max.)
Cone Pen. @ 77°F, 150 g, on Original	ASTM D217	66[c]	None
Apparent vis. @ 347°F (175 °C), Spindle 3, 12 rpm, on Original (cP)[b]	ASTM 2669	None	1,000 (min.) 4,000 (max.)
Haake Vis. @ 350°F, #1 Rotor, on Original (cP)[b]	(Reference 6)	3,500[c] 2,250[e]	1,000 (min.) 4,000 (max.)
Softening Point, on Original (°F)	ASTM D36	130[c] (54 °C), 129[d] (54 °C)	120 (min.) (50 °C)
Duct. @ 39.2°F, 1 cpm, on Original (cm)	ASTM D113	21[c], 25+[d]	10 (min.)
Duct. @ 39.2°F, 1 cpm, on Residue (cm)[f]	ASTM D113	25[d]	None
Duct. Retention @ 39.2°F, Residue/Original x 100) (%)	ASTM D2872	81[d]	50 (min.)
Resilience @ 77°F, Rebound, on Original (%)	ASTM D3407	16[c]	10 (min.)

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Tested binder was 6% cyclogen "L", 15% Rouse NR-80 powdered rubber, and 79% Witco PBA-2.
[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 at 310°F (154 °C).
[d] ODOT check/record tests on binder used in PRARC mix.
[e] Viscosity from ISI's on-site test at 30 minutes reaction time at 315°F (157 °C).
[f] AASHTO T240 was used to age the ODOT's binder sample.

Table 2.8(a): Granulated Rubber - Atlos 1710 Rubber Type II Used in ISI ARC

Gradation (% Passing)	Test Results	Specification
Sieve Size #10 (2.03 mm) #16 (1.18 mm) #30 (600 µm) #50 (300 µm) #200 (75µm)	 100 100 54.1 18.9 0.0	 100 70 – 100 25 – 60 0 – 20 0 – 5
Max Length	Okay	3/16"
Fiber Content	0.0	< 0.5%
Moisture Content	0.43%	< 0.75%
Mineral Contaminants	< 0.25%	< 0.25%
Metal Contaminants	None visible	No visible

Table 2.8(b): Powdered Rubber - Rouse NR80 Ultrafine Powder Used in PRARC

Sieve Size: #60 #80 (175 µm) #100 (150 µm) #200 (75 µm)	NR-80 89.6, 97.1[b] 61.7, 76.2[b] 44.5, 59.0[b] 0.0, 10.1[b]	 99 – 100 89 – 100 74 – 90 24-90
Moisture Content	0.37, 1.1[b]	< 1%
Specific Gravity (ASTM D297-16)[a]	1.17	1.15± 0.02
Acetone Extract (ASTM D297-19)[a]	18.7%	23% max.
Carbon Black Content (ASTM D297-39)[a]	29.1%	34% max.
Ash Content (ASTM D297-39)[a]	10.8%	7% max.
Rubber Hydrocarbon (ASTM D297)[a] Content (by difference)	41.4%	42% max.

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Modified test method. Methods on file in the ODOT's Research Unit.
[b] Tests performed on backup sample.

2.5 MIX DESIGNS

This section presents the mix designs and job mix formulae for the test and control pavements.

2.5.1 ODOT's Class "B", Dense Graded, Mix Design

The mix design used ODOT's modified Hveem method *(George, Boyle & Blachly 1989)*. Broadband limits, mix design criteria, and design mix properties are listed in Table 2.9.

Table 2.9: Broadband Limits, Mix Design Criteria, and Design Mix Characteristics at Design Binder Contents – Class "B", Dense-Graded, Mix

Characteristics	Class "B" Mix Design Criteria	Class "B" Design Mix
Gradation (% Passing Screen)		
1-inch (25.4 mm)	99 - 100[a]	100[b]
3/4-inch (19.1 mm)	90 - 98	95
1/2-inch (12.7 mm)	75 - 91	80
3/8-inch (9.5 mm)	-	72
1/4-inch (6.3 mm)	50 - 70	56
#10 (2.03 mm)	21 - 41	29
#40 (425 μm)	8 - 24	13
#200 (75 μm)	2 - 7	5.6
Binder Content (%)	4 - 8[a]	6.1
Binder Film Thickness	Sufficient	Sufficient
Sp. Gr. @ 1st Comp.	None	2.297[c]
Voids @ 1st Comp. (%)	5.5 - 6.5	5.4
Stab. @ 1st Comp. (Hveem)	≥37	39
Sp. Gr. @ 2nd Comp.	None	2.358[c]
Voids @ 2nd Comp. (%)	≥2.5	2.9
Stab. @ 2nd Comp. (Hveem)	≥37	46
Rice Max. Sp. Gr.	None	2.427
Voids in Mineral Aggregate (%)	≥14	14.9
Index of Ret. Strength (%)[d]	≥75	80
Index of Ret. Resilient Modulus (%)	≥70	117

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Broadband limits for gradation and binder content. Gradations are percentage of dry ingredient weight, including 1% lime. Binder contents are percentage of total mix weight.
[b] Mix design sample at design binder content test results in this column.
[c] Based on immersed unit weight of unsealed core (AASHTO T166).
[d] Based on effect of water on cohesion of compacted bituminous mixtures (AASHTO T165).

2.5.2 ISI ARC Modified Class "B", Gap Graded, Mix Design

The design criteria and procedures were based on ODOT's modified Hveem method *(George, Boyle & Blachly 1989)*. The mix design was supplied by Western Technologies, Inc. The mix design data is shown in Table 2.10.

International Surfacing, Inc. (ISI) proposed to waive the Index of Retained Resilient Modulus (IRM_r) testing as a requirement for approval of the proposed mix design. The suitability of the test was questioned for a gap graded mix since the procedure was developed for dense graded mixes. ODOT waived the requirement with the understanding that the test would still be

Table 2.10: Broadband Limits, Mix Design Criteria, and Design Mix Characteristics at Design Binder Contents – ISI ARC Modified Class "B"

Characteristics	ODOT Modified Class "B" ARC Mix Design Criteria	ISI ARC Modified Class "B" Design Mix
Gradation (% Passing Screen)		
1-inch (25.4 mm)	99 - 100[a]	100[b]
3/4-inch (19.1 mm)	90 - 98	92
1/2-inch (12.7 mm)	65 - 85	71
3/8-inch (9.5 mm)	-	56
1/4-inch (6.3 mm)	25 - 40	33
#10 (2.03 mm)	10 - 25	17
#40 (425 μm)	4 - 12	9
#200 (75 μm)	2 - 6	4.9
Rubber Content (%)	15 - 20[c]	17
Binder Content (%)	7.5 - 9.5[a]	8.0
Sp. Gr. @ 1st Comp.	None	2.253[d]
Voids @ 1st Comp. (%)	3 - 5	3.1
Stab. @ 1st Comp. (Hveem)	≥35	28
Sp. Gr. @ 2nd Comp.	None	2.295[d]
Voids @ 2nd Comp. (%)	None	1.4
Rice Max. Sp. Gr.	None	2.327
Stab. @ 2nd Comp. (Hveem)	≥35	28
Voids in Mineral Aggregate (%)	≥17	18.2
Tensile Strength Ratio (%)	None	93.6

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Broadband limits for gradation and binder content. Gradations are percentage of dry ingredient weight, including 1% lime. Asphalt-rubber binder contents are percentage of total mix weight.
[b] Mix Design values interpolated from briquette with 6.5% and 7% binder content.
[c] Rubber content is percentage of total asphalt-rubber blend.
[d] Based on immersed unit weight of unsealed core (AASHTO T166).

performed for informational purposes. During the "information testing", the specimen at a binder content of 7.5% did not survive the conditioning. The specimen at a binder content of 8% had an IRM_r of 92% and the specimen at a binder content of 8.5% had an IRM_r of 173%. The results indicate adequate resistance to moisture damage according to ODOT criteria.

Index of Retained Strength (IRS) (AASHTO T165) samples did not survive conditioning, so stripping was evaluated based on the Tensile Strength Ratio (TSR). The TSR for the ISI ARC Modified Class "B" design mix was 93.6%, indicating acceptable resistance to stripping. ODOT uses the TSR test to estimate shipping susceptibility. The minimum accepted TSR is 80%.

2.5.3 ODOT's Class "F", Open Graded, Mix Design

This design used an ODOT modified Hveem procedure to determine asphalt content based on void contents, stabilities, and binder film thickness *(George, Boyle & Blachly 1989)*. 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 2.11.

Table 2.11: Broadband Limits, Mix Design Criteria, and Design Mix Characteristics at Design Binder Contents – Class "F", Open-Graded, Mix

Characteristics	Class "F" Mix Design Criteria	Class "F" Design Mix
Gradation (% Passing Screen)		
1-inch (25.4 mm)	99 – 100[a]	100[b]
3/4-inch (19.1 mm)	85 - 96	91
1/2-inch (12.7 mm)	60 - 71	66
3/8-inch (9.5 mm)	-	47
1/4-inch (6.3 mm)	17 - 31	27
#10 (2.03 mm)	7 – 19	14
#40 (425 μm)	-	8
#200 (75 μm)	1 – 6	4.3
Binder Content (%)	4 – 8[a]	6.0
Binder Film Thickness	Sufficient[c]	Thick[c]
Rice Max. Sp. Gr.	None	2.375
Voids in Mineral Aggregate (%)	None	-
Index of Retained Strength (%)[d]	≥75	75
Draindown (%)	≥75	75

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Broadband limits for gradation and binder content. Gradations are percentage of dry ingredient weight, including 1% lime. Binder contents are percentage of total mix weight.
[b] Mix Design sample at design binder content test results in this column.
[c] Visual examination based on ODOT mix design procedure and guidelines (*Chehovits 1989*).
[d] Based on effect of water on cohesion of compacted bituminous mixtures (AASHTO T165).

2.5.4 ISI ARC Class "F", Open Graded, Mix Design

The original design was provided by Western Technologies, Inc. of Phoenix, Arizona for ISI. At ODOT's request, the design objective was to produce a free-draining and durable pavement. The design was based on methods included in "Design of Open-Graded Asphalt Friction Courses," Report No. FHWA-RD-74-2, modified to account for the properties of asphalt-rubber binder *(Chehovits 1989)*. The target asphalt content was 7.5%.

After the design was submitted to the State, ODOT's Bituminous Laboratory converted the design to their standard format and presented it to the contractor. Broadband limits and data from the mix design are listed in Table 2.12.

Table 2.12: Broadband Limits, Mix Design Criteria, and Design Mix Characteristics at Design Binder Contents - ISI ARC "F", Open-Graded, Mix

Characteristics	ISI ARC Mix Design Criteria	ISI ARC Design Mix
Gradation (% Passing Screen)		
1-inch (25.4 mm)	99 – 100[a]	100
3/4-inch (19.1 mm)	85 - 96	91
1/2-inch (12.7 mm)	60 - 71	66
3/8-inch (9.5 mm)	-	50
1/4-inch (6.3 mm)	12 - 38	20
#10 (2.03 mm)	4 – 14	10
#40 (425 µm)	0 - 8	6
#200 (75 µm)	0 – 5	3.6
Mineral Filler	.5 – 1.5	Not used
Binder Content (%)	8 – 11[a]	7.5
% Rubber in Binder	15 – 20[a]	17
Sp. Gr. @ 1st Comp.	None	1.88[c]
Voids @ 1st Comp. (%)	None	7.2[d], 20.2[c]
"Rice" Max. Sp. Gr.	None	2.356
Index of Retained Strength (%)[e]	≥75	Waived
Binder Runoff @ 300°F (150 °C)	≥1/4"[b] (6 mm)	0" - 1/4"

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Broadband limits for gradation, binder and rubber content. Gradations are percentage of dry ingredient weight, including 1% lime. Binder content is percentage of total mix weight.
[b] Diameter of spots based on FHWA-RD-74-2.
[c] Based on dimensional analysis.
[d] Calculated from specific gravity determined by immersed unit weight of unsealed core.
[e] Based on effect of water on cohesion of compacted bituminous mixtures (AASHTO T165).

ISI proposed to waive the IRM_r testing (ODOT Test Method 315) as a requirement for approval of the proposed mix design. ISI stated that it was their opinion that the test method was not appropriate for open graded ARC mixtures and therefore, should not be required. ODOT waived the requirement. IRM_r testing was done, however, for informational purposes.

The results of the IRM_r testing on three specimens at varying binder contents, indicated a decrease in IRM_r with increasing binder content. A binder content of 7.4% would meet the minimum IRM_r requirement of 70%. Typically, an increase in the index of retained resilient modulus would be expected with an increase in binder content. ISI provided the following possible reasons for a decrease in IRM_r with increasing binder content *(Beaty & Stonex 1992)*:

> "Open graded mixes take on water easily during vacuum saturation because of their high volume of voids, but also drain freely for the same reason. The target design air void content for the "F" mix was 20%. Experience has shown when a specimen is removed from the saturating vessel, some of the water in the voids may run out, thus lowering the degree of saturation. As binder content increased, the void volume of the "F" mix test specimens decreased. This makes the specimens increasingly less free draining, resulting in a greater degree of saturation than the lower binder content specimens. With a higher degree of saturation, the samples are more likely to incur greater damage during the freeze-thaw cycle, resulting in a lower index of retained resilient modulus."

ISI also suggested that the variance in IRM_r could be due to specimen conditioning procedure. The procedure specifies a vacuum pressure of 30.5 mm of HG and a saturation time of 30 minutes. The procedure does not control the degree of saturation so that all the specimens may not be equally saturated. A degree of saturation based on volume of air voids may be more effective for the open graded mixes *(Beaty & Stonex 1992)*.

The index of retained strength samples did not survive conditioning in the 60°C waterbath (AASHTO T165). The IRS criteria was waived. Root-Tunnicliff tests run by ISI, using a freeze/thaw conditioning, however, had acceptable results.

ODOT currently requires that a TSR test be performed on a dense graded surrogate sample for all open graded mixes.

2.5.5 PRARC Class "F", Open Graded, Mix Design

The mix design used for the PRARC was the same design developed for the ISI ARC Class "F" mix. The intent was to construct the mixes the same to evaluate the constructability and performance. The PRARC mix design data is shown in Table 2.13.

ODOT waived the requirement for IRM_r testing. In addition, index of retained strength samples did not survive conditioning in the 60°C waterbath (AASHTO T165) and the IRS criterion was waived. The current ODOT requirement uses the TSR test on a surrogate dense graded sample to determine stripping susceptibility.

Table 2.13: Broadband Limits, Mix Design Criteria, and Design Mix Characteristics at Design Binder Contents – PRARC "F", Open-Graded, Mix

Characteristics	ISI ARC Mix Design Criteria	PRARC "F" Design Mix
Gradation (% Passing Screen)		
1-inch (25.4 mm)	99 – 100[a]	100[b]
3/4-inch (19.1 mm)	85 - 96	91
1/2-inch (12.7 mm)	60 - 71	66
3/8-inch (9.5 mm)	-	50
1/4-inch (6.3 mm)	12 - 38	20
#10 (2.03 mm)	4 – 14	10
#40 (425 μm)	0 - 8	6
#200 (75 μm)	0 – 5	3.6
Mineral Filler	.5 – 1.5	1.0
Binder Content (%)	8 – 11[a]	7.5 8.0[d]
% Rubber in Binder	15 – 20[a]	15
Sp. Gr. @ 1st Comp.	None	1.88[e] 1.92[d,e]
Voids @ 1st Comp. (%)	None	7.5[f], 20.2[e] 6.5[d,f],18.0[d,e]
"Rice" Max. Sp. Gr.	None	2.356 2.340[d]
Index of Retained Strength (%)[g]	≥75	Waived
Binder Runoff @ 300°F (150 °C)	≥1/4"[c] (6 mm)	Satisfactory

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] Broadband limits for gradation, binder, and rubber content. Gradations are percentage of dry ingredient weight, including 1% lime. Binder content is percentage of total mix weight.
[b] Mix design sample at design binder content.
[c] Diameter of spots based on FHWA-RD-74-2.
[d] Results of tests at field adjusted binder content of 8%.
[e] Based on dimensional analysis.
[f] Calculated from specific gravity determined by immersed unit weight of unsealed core.
[g] Based on effect of water on cohesion of compacted bituminous mixtures (AASHTO T165).

2.5.6 Open Graded Mix Design Comparison

The open graded ISI ARC, PRARC, and Class "F" mixes had different binder contents and gradation.

Binder Content - For the ISI ARC and PRARC mixtures, the binder content broadband limits of 8% to 11% were higher than the limits of 4% to 8% for the Class "F" mix. According to ISI, the relatively low viscosity of conventional asphalt at high temperatures limits the amount of asphalt that can be added to an open-graded mix, and any asphalt in excess of this limited amount drains to the bottom of the mix. However, they claim the blending of rubber with the asphalt increases the viscosity of the binder at mixing and placement temperatures. As a consequence of this higher viscosity, additional binder can be used in the mix to give the aggregate a thicker coating without causing excessive draindown.

Gradation - In comparison to the Class "F" mix, the ISI ARC and PRARC broadband limits allowed approximately 4% less aggregate passing the 2.03 mm screen and about 1% less fines passing the 75 μm screen. According to ISI, the amount of fine aggregate was reduced to make room for the asphalt-rubber binder and retain a porous open graded pavement.

2.6 SUMMARY

The ODOT Class "B" mix control section consisted of a 64 mm pavement inlay. The ISI ARC Modified Class "B" mix (gap-graded) was also a 64 mm pavement inlay. The original design called for an additional 64 mm dense graded mix overlay, however, a reduced section was finally specified through the curbed section. The Class "F" mix control section, ISI ARC Class "F" and PRARC Class "F mix test sections" were each 64 mm overlays placed on existing distressed asphalt concrete pavement.

The Class "B" mix design used for the control section was the standard method used by ODOT. The method is based on Hveem compacted void content, stability, asphalt binder film thickness, IRS and IRM_r. This design called for 6.1% PBA-3. Lime treated aggregates were required.

The design criteria and procedures for the ISI ARC Modified Class "B" mix were based on ODOT's modified Hveem method. The mix design was supplied by Western Technologies, Inc. The design called for 8.0% binder that included 17% tire grindings, 6% extender oil, and 77% PBA-2. Lime treated aggregates were required.

The Class "F" mix design used for the control section was based on asphalt binder film thickness, IRS, and asphalt draindown. This design called for 6.0% PBA-6. Lime treated aggregates were required.

The ISI ARC open-graded mix design was performed by Western Technologies Lab based on a modified version of a FHWA technique on binder draindown. This design called for 7.5% binder that included 17% tire grindings, 6% extender oil and 77% PBA-2. Lime treated aggregates were required.

The PRARC Class "F" mix design used the same mix design procedure as the ISI ARC Class "F" Mix. The recommended binder content for PRARC was 7.5%. The binder content was later field adjusted to 8%. The binder included 15% powdered rubber, 6% extender oil, and 79% PBA-2.

Extender oil was added to soften the asphalt-rubber binders to meet the specifications for penetration tests. The cold penetration retention test (4 °C) results for the ISI asphalt-rubber were 76%, and 56% for the powdered rubber asphalt-rubber (PRAR). The lower value, especially for the PRAR, may be an indication that the binder is susceptible to thermal cracking.

Standard tests to evaluate moisture susceptibility of the mixes included IRM_r and IRS. The IRM_r tests were waived for evaluation of the asphalt-rubber modified mixes since it was felt the test was inappropriate for gap graded or open graded mixes. In addition, the samples did not survive the conditioning for the IRS testing so that test was also waived. Although the mixes did not survive the conditioning, it is presumed that this is not an indication of the moisture susceptibility of the mix, but is attributed to the gradation of the aggregate.

ODOT currently uses the TSR test on surrogate dense graded samples to evaluate moisture susceptibility.

3.0 CONSTRUCTION

This chapter describes the test and control section wearing courses constructed in September 1992. The test results, test methods, and random measurements of air temperature, road weather data are listed in Tables 3.1(a) through 3.1(e). AASHTO and ODOT sampling and testing methods were used in most cases *(AASHTO 1990, ODOT 1986, ODOT 1992)*. The Special Provisions of the contract specifications that apply to the ISI ARC and the PRARC construction are included in Appendix A.

Table 3.1(a): Job Mix Specifications and Properties - Class "B"

Test	Method	Test Results	Job Mix Specifications
Gradation (% Passing Screen):	AASHTO T11 and T27 AASHTO T2		
1-inch (25.4 mm)		100[a,b]	99-100[b,d]
¾-inch (19.1 mm)		96	90-98
½-inch (12.7 mm)		82	75-91
¼-inch (6.3 mm)		55	50-62
#10 (2.0 mm)		28	24-34
#40 (425 µm)		12	8-18
#200 (75 µm)		5.2	3.6-7.0
Binder Content (%)	ODOT TM321 ODOT TM322	6.2[c]	5.6-6.6[c]
Moisture Content (%)	ODOT TM311M	.33[c]	.8 (max)[c,f]

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[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.

Table 3.1(b): Job Mix Specifications and Properties - ISI ARC Modified Class "B"

Test	Method	Test Results	Job Mix Specifications
Gradation (% Passing Screen):	AASHTO T11 and T27 AASHTO T2		
1-inch (25.4 mm)		100[a,b]	99-100[b,e]
¾-inch (19.1 mm)		94	90-98
½-inch (12.7 mm)		69	65-85
¼-inch (6.3 mm)		34	27-39
#10 (2.0 mm)		19	12-22
#40 (425 µm)		9	4-12
#200 (75 µm)		3.8	2.9-6.9
Binder Content (%)	ODOT TM321 ODOT TM322	7.9[c]	7.5-8.5[c]
Moisture Content (%)	ODOT TM311M	.25[c]	.8 (max)[c,g]
Mix Temp. at Discharge, °F, (°C)		300[h] (149)	290-310[i] (143-154)
Mix Temp. behind Paver, °F, (°C)		280-290[f,h] (138-143)	275-310[i] (135-154)
Placement Air Temp., °F, (°C)		75-82[e,h] (24-28)	60 min[h] (16)
Placement Surface Temp °F, (°C)		104-140[e,h] (40-60)	None
Wind Speed, mph, (m/s)		0-5[e,h] (0,2.2)	None
Weather		Cloudy	None

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[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] Estimated.
[g] Specifications in Special Provisions.
[h] Random measurements.
[i] Limits in job mix formula.

Table 3.1(c): Job Mix Specifications and Properties - ODOT Class "F

Test	Method	Test Results	Job Mix Specifications
Gradation (% Passing Screen):	AASHTO T11 and T27 AASHTO T2		
1-inch (25.4 mm)		100[a,b]	99-100[b,d]
3/4-inch (19.1 mm)		94	85-96
1/2-inch (12.7 mm)		68	60-71
1/4-inch (6.3 mm)		28	21-33
#10 (2.0 mm)		14	9-19
#40 (425 μm)		7	3-13
#200 (75 μm)		3.1	2.3-6.0
Binder Content (%)	ODOT TM321 ODOT TM322	6.1[c]	5.5-6.5[c]
Moisture Content (%)	ODOT TM311M	.29[c]	.8 (max)[c,f]
Mix Temp. at Discharge °F, °C		250[h] (121)	247-257[e] (119-125)

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[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.
[h] Estimated.

Table 3.1(d): Job Mix Specifications and Properties - ISI ARC Class "F"

Test	Method	Test Results	Job Mix Specifications
Gradation (% Passing Screen):	AASHTO T11 and T27 AASHTO T2		
1-inch (25.4 mm)		100[a,b]	99-100[b,d]
3/4-inch (19.1 mm)		94	85-96
1/2-inch (12.7 mm)		71	60-71
1/4-inch (6.3 mm)		20	14-26
#10 (2.0 mm)		10	5-14
#40 (425 µm)		6	1-8
#200 (75 µm)		2.5	1.6-5.0
Binder Content (%)	ODOT TM321 ODOT TM322	7.5[c]	7.3-7.7[c]
Moisture Content (%)	ODOT TM311M	.18[c]	.8 (max)[c,e]
Mix Temp. at Discharge °F, (°C)		300[g] (149)	275-310[f] (135-154)

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[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] Specifications in Special Provisions.
[f] Limits in job mix formula.
[g] Thermometer inserted into mix.

Table 3.1(e): Job Mix Specifications and Properties - PRARC Class "F

Test	Method	Test Results	Job Mix Specifications
Gradation (% Passing Screen):	AASHTO T11 and T27 AASHTO T2		
1-inch (25.4 mm)		100[a,b]	99-100[b,d]
3/4-inch (19.1 mm)		93	85-96
1/2-inch (12.7 mm)		68	60-71
1/4-inch (6.3 mm)		20	14-26
#10 (2.0 mm)		11	5-14
#40 (425 µm)		6	1-8
#200 (75 µm)		2.7	1.6-5.0
Binder Content (%)	ODOT TM321 ODOT TM322	7.5[c,i]	7.3-7.7[c]
Moisture Content (%)	ODOT TM311M	.28[c]	.8 (max)[c,f]
Mix Temp. at Discharge, °F, (°C)		280-285[e,j] (138-141)	290-310[g] (143-154)
Mix Temp. behind Paver, °F, (°C)		280-285[e,h,j]	275-310[g] (135-154)
Placement Air Temp., °F, (°C)		56-80[e,h] (13-27)	60 min[f] (16)
Placement Surface Temp, °F, (°C)		60-116[e,h] (16-47)	None
Weather		Clear	None
Wind Speed, mph, (m/s)		0-10 (4.5)	None

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[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.
[h] Random measurements.
[i] Binder content was increased to 8% by field adjustment.
[j] Thermometer inserted into mix.

3.1 BINDER MANUFACTURE AND HANDLING

ISI ARC Binder - The delivery of the base asphalt and 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. Considerable open space was needed for ISI's blending operation.

The rubber (Atlos #1710 Type IIA), was delivered on pallets in 27 kg bags. The pallets had a 1,360 kg net load. The base asphalt was blended with extender oil at the refinery. The base asphalt temperature at delivery was 180 °C.

A pump mounted on the tanker trailer pulled asphalt from the tanker and pumped it into a "helper" tank. Normally the "helper" tank truck would have a pump to pull off the tanker trucks, however, the pump was broken on the "helper" unit and the tanker had to pump. Asphalt was heated to 200 °C in the helper tank before it was pumped into the storage tank on the blending unit. The "helper" tank was insulated with a capacity of 7,250 kg to 7,700 kg. The temperature of the base asphalt was maintained at 202 °C.

The temperature of the asphalt was raised to 215 °C in the blending unit prior to the addition of rubber. A large storage tank was used as an intermediate step in the heating of the asphalt. After a reaction time of one hour, the asphalt-rubber was pumped into shuttle trucks. Three shuttle trucks and one nurse truck were used at the mix plant.

Powdered Rubber ARC Binder - The powdered rubber was supplied and blended by ISI. Originally, Rouse Rubber, Inc. was going to do the blending. However, the contractor would have had to store the PRAR in his tanks and pump the PRAR with his pumps. Also, the contractor was concerned that the Rouse blender could not keep up with the mix plant production. Because of these considerations, the contractor used ISI to do the PRAR blending.

The Rouse NR-80 rubber was delivered on pallets in 27 kg bags. The base asphalt was blended with the 6% extender oil at the refinery. The base asphalt temperature at delivery was estimated at 177 °C. The reaction temperature for the PRARC was 154 °C with a reaction time of 60 minutes. ODOT instructed ISI to use its customary asphalt-rubber batch blending method for the PRARC.

Class "F" and Class "B" Binders - Conventional equipment and procedures were used to add these asphalts to the mix plant.

3.2 MIXING PLANT

All mixes were produced in a Stansteel 7,200 kg batch plant with a rated capacity of over 540 Mg per hour. The plant, however, usually operates with 5,400 kg batches at a maximum capacity of around 440 Mg per hour. The aggregate was fed to the plant from three separated stockpiles. Lime was added to the aggregate on the belt from an auger feed.

The aggregates were proportioned on to the cold feed belt, heated through the drier, elevated to the gradation screening unit and re-proportioned into four separated sizes in the 19 mm - 12.5 mm, 12.5 mm - 6.3 mm, 6.3 mm - 2 mm, and 2 mm - 0 mm hot aggregate bins. The separated sizes were then proportioned into batch weights, mixed with the binder, dumped into the hauling trucks and hauled to the area to be paved.

ODOT Class "B" Mix - No special equipment or procedures were needed for this conventional mix.

ISI ARC Modified Class "B" Mix (Gap Graded) - Mixing was the same as ISI ARC Class "F" mix except for the aggregate gradation. The gradation differed from the conventional "B" mix constructed in one of the control sections as noted in the following table, Table 3.2:

Table 3.2: Class "B" Mix Gradation Comparison to ISI ARC Modified Class "B" Mix

Sieve Size	ODOT Class "B" Design	ISI ARC Modified Class "B" Mix	% Less than ODOT Class "B" Mix
1" (25.4 mm)	100	100	---
3/4" (19.1 mm)	95	92	3
1/2" (12.7 mm)	80	71	9
1/4" (6.3 mm)	56	33	23
#10 (2.0 mm)	29	17	12
#40 (425 μm)	13	9	4
#200 (75 μm)	5.6	4.9	0.7

ODOT Class "F" Mix - Normal construction procedures were followed for open graded hot mix.

ISI ARC Class "F" Mix - Mixing the ISI ARC Class "F" Mix was routine, with the exception of some gradation changes. First, the ISI ARC "F" mix design required 7% less passing the 6.3 mm sieve, 4% less passing the 2.0 mm sieve and 7% less passing the 75 μm sieve than the conventional "F" mix. Also, the ISI ARC "F" mix was discharged from the plant at 150 °C rather than at 120 °C for the ODOT Class "F" mix.

PRARC Class "F" Mix - The same procedures and exceptions listed with the ISI ARC "F" mix were also true for this mix.

The inner lane of this section was paved with a binder content of 7.5%. After a field adjustment to add more binder, the outer lane of the pavement was constructed using a binder content of 8%. The only exception occurred from Station 116+50 to 117+50, where a 7.5% binder content was placed in the outer lane.

3.3 HAULING

The mixtures were hauled to the paving site in end dump trucks and end dump trailers with hauling time of about 30 minutes. A water soluble truck bed release agent, "Slipeaze SB", was used. Drivers said the release agent worked inconsistently. Some loads would be released cleanly and others would stick to the dump bed.

3.4 PLACEMENT AND COMPACTION

The paving operation was slow since some of the dump trucks were used to haul pavement grindings from the cold milling operation and were not available to haul hot mix. The specifications stated that all cold planed lanes must be repaved the same day the pavement was removed.

The mixes were placed using conventional equipment. A Caterpillar AP1050 paver laid the mix. Three rollers were used that included:

- Caterpillar CB-514 double-drum vibratory roller;
- Caterpillar CB-414, 7 Mg double-drum vibratory roller; and
- Hamm D85 double-drum vibratory roller.

In addition, some high traffic volume intersections were sanded after rolling and rolled again with a small Dynapac CC10, 2.3 Mg roller.

ISI ARC Modified Class "B" Mix - No major problems were noted with placement of this mix. Breakdown rolling was done with five vibratory coverages using the CB514. Slight checking was noted in the mat after the vibratory breakdown passes. The mat sizzled behind the first pass of the breakdown roller since the mat temperature was over 135 °C. Initially, no intermediate rolling was done. Finish rolling was done with a minimum of two passes. The pavement was rolled four additional times to remove any roller marks. All the finished rolling was done in the static mode. The mat internal temperature was 102 °C after breakdown rolling.

The paver operator commented that the mix did not appear to smoke more than a normal mix. He said the only difference was the smell attributed to the added rubber.

ISI ARC Class "F" Mix - No problems were noted with the laydown of this mix. The mix was produced at 150 °C. No binder runoff was noted at the plant. Since this was an open graded mix, there were no compaction requirements other than a rolling pattern. Therefore, no density readings were taken.

Powdered Rubber ARC - The mix temperature behind the paver was 138 °C to 141 °C. No density readings were taken. Problems with mix stickiness were noted with this material. The contractor had trouble providing a mat that would handle traffic without sticking. The mat was tested with a pick-up truck to check for tackiness. To reduce the stickiness, a light application of sand was applied to the mat and the mat retested for tackiness. Several applications of sand were required before traffic was allowed on the pavement.

3.5 SEAL COAT AND SAND BLOTTER

Shortly after paving, a fog seal was shot on the inside lanes and median of the ODOT Class "F" mixes, ISI ARC, and the PRARC Class "F" mixes. The outside lanes and shoulders were not treated. Normally on open graded pavements, all lanes including the shoulder would have been sealed. However, in this case they were not sealed to further evaluate the effectiveness of sealing open graded pavements. The application rate included 0.4 l/m^2 of CSS-1 emulsion with 6.3 mm - 2.0 mm cover aggregate at 0.002 m^3/m^2. The seal coat did not appear to plug the openness of the surface. The sealed section appeared to reduce the water spray as much as the unsealed sections.

All intersections, except Washburn Way, were sanded before traffic was allowed. The sanding prevented the vehicles' tires from sticking to the thick film of binder on the surface aggregate. The intersection on the test section at Washburn Way was watered to cool the mat since there was not enough time to sand.

As noted earlier, the only full test section that required a sand blotter was the PRARC Class "F" mix section. The outside lane required two passes of the sanding truck; the inside lane required only one pass.

3.6 SUMMARY

The blending of the asphalt-rubber for the Modified Class "B" mix, ISI ARC Class "F" mix, and PRARC Class "F" mix required specialized blending and pumping equipment supplied by ISI. A slightly different aggregate gradation and higher mixing and placing temperatures were needed. This caused no problems for the contractor. In addition, no extra equipment was needed to mix, haul, place, or compact this material. There were no problems noted with the finished pavement, with the exception of vehicle tires adhering to the freshly paved surface.
This problem was especially noticeable on the PRARC Class "F" mix section. No problems were noted when the Class "F" or Class "B" control mixes were paved.

During construction, a portion of the PRARC test section was paved with a field adjusted binder content of 8.0% (versus the mix design 7.5%). The ISI and PRARC mixtures did not exhibit a runoff problem even with the high binder content of 7.5% and 8.0% versus 6.0% for the conventional "F" mix.

4.0 SAMPLING AND TESTING

This chapter describes the special sampling and testing methods needed for the Modified Class "B" mix, ISI ARC Class "F", and the PRARC Class "F" mix. The sections of the contract's Special Provisions that applied to the ISI ARC mixes and PRARC Class "F" mix are contained in Appendix A.

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 a 60 minute reaction time. The sampling at the end of its reaction period was important. As seen in the Haake Viscosity test results in Table 2.6, the viscosity of the asphalt-rubber increased as the reaction time between the asphalt and the rubber lengthened. Within 30 minutes and 60 minutes of reaction time, the viscosities were 1,300 centipoise (cP) and 2,250 cP, respectively. These results were within the specification limits of 1,000 cP to 4,000 cP.

Powdered rubber asphalt-rubber sampling indicated the same trend as the ISI binder. As seen in Table 2.7, test sampling at 30-minute and 60-minute reaction times, resulted in viscosities of 2,250 cP and 3,500 cP, respectively.

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. This included a Haake or Brookfield viscometer with a heating unit to bring the asphalt-rubber to testing temperature for viscosity testing, and a ball penetration tool for resilience testing.

ISI conducted viscosity tests and others to assure that the base asphalt properties, rubber characteristics, and rubber content of the asphalt-rubber were within the specification limits.

The use of ISI ARC and PRARC required more testing than when using conventional asphalt. There were additional acceptance and check tests on the rubber gradation and rubber properties. Verifying the binder's rubber content required an inspector to witness the entire asphalt-rubber blending operation. The tests and inspections listed above added considerably to ODOT's project management costs.

4.2 RUBBER SAMPLING AND TESTING

4.2.1 Rubber Sampling

The rubber needed to be sampled for acceptance tests. One quart friction lid cans were used as sample containers to ensure the rubber sample would not be contaminated and moisture would not be lost from the sample during the interval between sampling and testing.

4.2.2 Rubber Testing

The specifications for the rubber supplied by ISI included limits for gradation, particle length, fiber content, moisture content, mineral contaminants, and metal contaminants. The specifications for the powdered rubber included gradation, particle length, moisture content, specific gravity, percent of acetone extract, percent of carbon black, percent of ash, and percent of rubber hydrocarbon content. These tests indicate whether or not the crumb or powdered rubber is made from recycled tires, and also measure properties such as gradation and contamination. See Tables 2.8(a) and 2.8(b) for test results for the crumb and powdered rubber used on this project.

4.2.3 Rubber Content Determination

This project used a "wet process" to add the tire rubber to the mixture. The base asphalt had been pre-mixed with an extender oil, ground rubber or powdered rubber in an "in-line" blending pump at a rate of 17 percent or 15 percent, respectively. The percentage of rubber was determined by empty sack count per tank of asphalt-rubber.

4.2.4 Binder Content Determination

The nuclear asphalt content gauge was used on this project and worked satisfactorily to identify total binder in the mixture.

4.3 SUMMARY

The ISI ARC Modified Class "B" mix, ISI ARC "F" mix, and PRARC Class "F" mix binder required special sampling and testing methods. Samples of the asphalt-rubber binders similar to binders used in the construction mix were taken at the end of the reaction period. As mentioned previously, apparent viscosity measurements required specialized equipment that the laboratory did not have at the ODOT Materials Laboratory. The tests needed to assure that the ISI ARC and PRARC mixes' base asphalt properties, rubber properties, and rubber content were within specifications were done by ISI at the site. Due to the equipment limitations, tests were not done at the ODOT Materials Laboratory.

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.

Current performance is also documented. Additional detail regarding performance is available through the "Crumb Rubber Study" reports published by the ODOT Research Group.

5.1 PAVEMENT EVALUATION - VISUAL INSPECTIONS

5.1.1 Pre-Construction Visual Inspection

The roadway was visually inspected, rated, and wheel ruts measured several months before construction.

As an overview, the original pavement included some areas of medium to high levels of alligator cracking, and medium to high rutting in most areas. Medium to high levels of raveling were measured over more than 25% of the travel lanes. Maintenance patching appeared on more than 25% of the lanes and the pavement was exhibiting distress. Bleeding areas were mostly small and in isolated areas. Figure 5.1(a-c) shows the typical condition of the original pavement.

Figure 5.1(a): State Route 39, Southbound at M.P. X4.77 (Prior to construction)

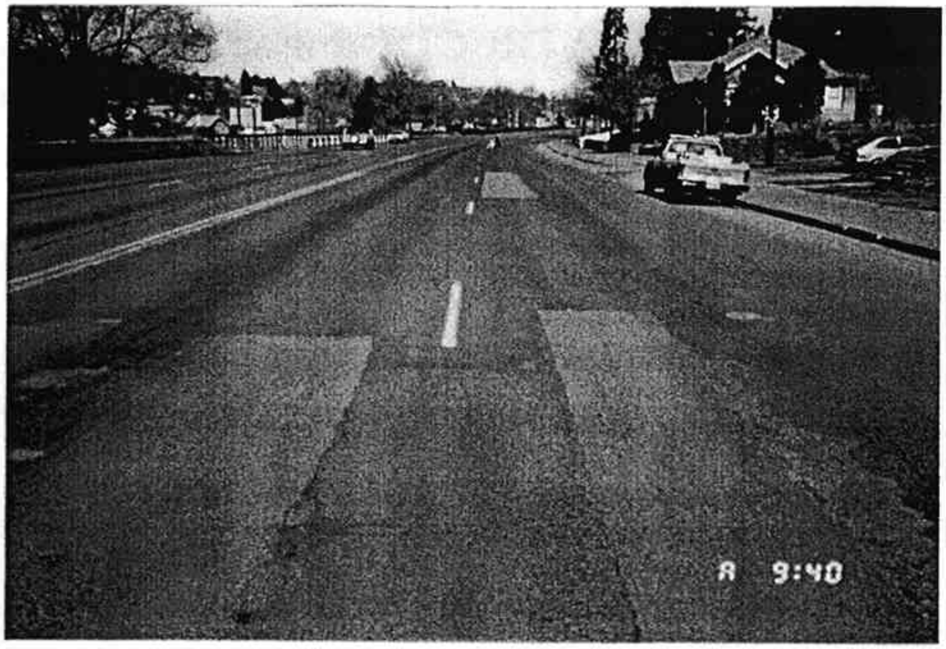

Figure 5.1(b): State Route 39, Northbound at M.P. X5.00 (Prior to construction)

Figure 5.1(c): State Route 39, Southbound at M.P. X4.62 (Prior to construction)

5.1.2 Post-Construction Visual Inspection

The roadway was visually inspected a few days after construction. There was no cracking or visible rutting in any of the test sections. The ISI ARC Modified Class "B" mix, ISI ARC Class "F" mix, PRARC Class "F" mix, and Class "F" mix all had the same basic surface texture. All Class "F" mix sections had been fog sealed in the inside lane and median, however, the outer lane and shoulder of these open-graded sections were not sealed in order to compare long term performance with the sealed areas.

Based on a visual inspection in 1998, the ODOT Class “B” mix is performing better than the ISI ARC Modified Class “B” mix. This section (both control and test) includes less AC than suggested in the original mix design (See Section 2.1). The ISI ARC Modified Class “B” mix appears to be raveling more than the control section. The test section is also more rutted; 12 mm ruts were measured compared to 6 mm for the control. The stability of the ISI ARC Modified Class “B” mix was less than the specification limit, which indicates a potential for rutting.

The ODOT Class “F” mix is also performing better than the ISI ARC Modified Class “F” mix and the PRARC Class “F” mix. Both of the rubber mixes appear to be raveling more than the control. Rutting is also more significant in the rubber mixes with rut depths near 20 mm versus less than 12 mm for the control sections.

5.2 DEFLECTIONS

Deflections were measured several months before construction in August 1991 and a month after construction in October 1992. The test results are listed in Table 5.1. The deflection testing was performed with a Falling Weight Deflectometer (FWD). The measurements are at the load center and corrected to 4,080 kg load at 21 ^{o}C. Before construction, average deflections ranged from 0.1 mm - 0.7 mm. Consequently, the variability and deterioration in the pavement resulted in the decision to remove the top 64 mm in some areas prior to inlaying with new mix or to put an overlay over existing pavement in other areas.

With the exception of the ISI ARC class "F" mix, the new wearing surfaces decreased the deflections of the pavements. Since the deflections for the ISI ARC class "F" mix varied by only 0.05 mm, the difference is considered insignificant.

Table 5.1: Pavement Deflections

	Average Deflections in Thousandths of an Inch (mm)				
Date	**ODOT Class "B"**	**ISI ARC Modified Class "B"**	**ODOT Class "F"**	**ISI ARC Class "F"**	**PRARC Class "F"**
August 1991 (Pre Const.)	25 (0.64)	15 (0.38)	21 (0.53)	17 (0.43)	13 (0.33)
October 1992 (Post Const.)	21 (0.53)	11 (0.28)	16 (0.41)	19 (0.48)	7 (0.18)

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

5.3 FRICTION

The pavement friction was measured after construction in October 1992. All testing was done at speeds near 64 km/hr (40 mph) in the left wheelpath of the outer lane. The test data was adjusted to standard 40 mph friction numbers (FN_{40}) using correlation equations. The friction number is a unitless quantity that measures the friction between the tire and the pavement. The higher the FN_{40}, the greater the friction. The test methods, calibration techniques, and equipment conformed to AASHTO T 242-90 (*2*).

All sections had average friction numbers typical of newly constructed asphalt concrete in Oregon. The average skid numbers for the ISI ARC class "F" mix, and PRARC Class "F" mix were 8% and 5% less, respectively, than the ODOT Class "F" mixes. The ISI ARC Modified Class "B" mix skid number was about the same as the control section for the westbound lane. The skid number for the eastbound lane, however, was about 7% less than the control.

The lower skid numbers for the ISI ARC and PRARC mixes may be a function of the binder adhesion being greater than the standard mixes. The binder on the ISI ARC and PRARC binders may wear off more slowly under traffic than the conventional binders because of the increased adhesion. Another explanation may be that the reduced skid numbers are due to the higher binder content in the ISI ARC and PRARC mixes as compared to the control mixes.

In 1998, the skid numbers for all of the mixes were well above acceptable levels in the 49 to 56 range. The highest skid numbers were for the ISI ARC Modified Class "B" mix at 56; then the ODOT Class "B" mix and ODOT Class "F" at 54; followed by the PRARC Class "F" mix at 53 and ISI ARC Class "F" mix at 49.

5.4 STRIPPING

Stripping was evaluated by visual examination of broken cores. No stripping was seen on any cores sampled from the five test pavements.

5.5 VOID CONTENT AND STABILITIES

Void contents were measured on cores removed from the center of the outer lanes of the new pavement. Two cores were taken from each test section and the average of the two test results are listed in Table 5.2. These values can be evaluated when compared to the first compaction void content limits for the mix design criteria shown in Tables 2.8 to 2.12, inclusive. The void content at first compaction (as received) simulates the voids in the pavement just after construction.

Void contents of the dense graded cores were determined following AASHTO T166 and AASHTO T209. The average void contents for the ODOT Class "B" mix and the ISI ARC Modified Class "B" mix were 3.4. The void content is within the specification for the ISI ARC Modified Class "B" mix but low for the ODOT Class "B" mix. The low void content for the "B" mix could lead to rutting, flushing or bleeding of the pavement.

Void contents of open graded cores and mix design samples were calculated from bulk specific gravities based on AASHTO T166 and maximum specific gravities from AASHTO T209. The average air void contents were 9.2%, 5.9%, and 6.2% for the ODOT Class "F" mix, ISI ARC Class "F" mix, and the PRARC Class "F" mix, respectively.

The "as constructed" void test data in Table 5.2 indicates that the as constructed void contents compare with the design mix void contents for the ISI ARC Class "F" mix and PRARC Class "F" mix shown in Tables 2.11 and 2.12. Note that the comparison is made on void ratios calculated by the same test method--AASHTO T166. A more appropriate testing method for open graded cores later adopted by ODOT, is dimensional analysis. With dimensional analysis of open graded mixes, caliper measurements of the cores are taken to calculate bulk specific gravities of the samples.

The stabilities of the ODOT Class "B" mix cores met specifications, being greater than 37. The stabilities of the ISI ARC Modified Class "B" mix cores were below the specified value of greater than 35. The two stabilities for the ISI ARC Modified "B" mix were 33 and 24. A void content of 1.6% corresponded to the low stability value of 24, which would indicate excess binder in the mix.

Table 5.2: Core Void Content and Stabilities (As-constructed)

Test Product	**ODOT Class "B" Mix**		**ISI ARC Modified Class "B"**		**ODOT Class "F" Mix**		**ISI ARC Class "F" Mix**		**PRARC Class "F" Mix**	
	Spec.[a]	Actual	Spec.[a]	Actual	Spec.[a]	Actual	Spec.[a]	Actual	Spec.[a]	Actual
As received Bulk Specific Gravity	None	2.34	None	2.29	None	2.23	None	2.22	None	2.23
% Voids	5.5 - 6.5	3.4	3-5	3.4	None	9.2	None	5.9	None	6.2
Hveem Stability	≥ 37	39	≥ 35	33	None	30	None	33	None	35
Recompacted Bulk Specific Gravity	None	2.39	None	2.33	None	2.28	None	2.28	None	2.30
% Voids	≥ 2.5	1.2	None	1.6	None	6.9	None	3.5	None	3.3
Hveem Recompacted Stability	≥ 37	45	≥ 35	24	None	45	None	48	None	46
Maximum Specific Gravity (AASHTO T209)	None	2.42	None	2.37	None	2.45	None	2.36	None	2.38

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

[a] The specification values are taken from the appropriate Mix Design Criteria contained in Tables 2.8 – 2.12.

The stability tests were performed by the Hveem method on 100 mm diameter cores. The cores were tested "as received" after removing the existing pavement portion and after heating and recompacting to simulate years of traffic consolidation.

The Hveem stabilities for the open graded mixes meet the criteria, as shown in Table 5.2.

5.6 SUMMARY

The old pavement was cracked, potholed, raveled, and rutted. Most of the heavily distressed areas were milled out and inlayed, while the other areas received a 64 mm overlay.

When the first post construction inspection was made, all of the new test and control pavements were not cracked, without ruts, and had exhibited no signs of weathering or raveling. 1998 inspections indicate that the control sections are performing better than the test sections.

Deflection data indicated that the inlays and overlays reduced the deflection of the pavement for all pavements except the ISI ARC Class "F" mix which did not change.

Immediately after construction friction values of the test and control sections were similar and indicate adequate skid resistance. The ISI ARC and PRARC Class "F" mixes have lower skid numbers than the "F" mix control section. The lower skid numbers may be attributed to greater binder cohesion. In 1998, all sections have acceptable skid numbers between 49 and 56.

No stripping was seen on any of the cores removed from the test or control sections after construction.

The as-constructed void contents were within the specifications for the ISI ARC Modified Class "B" mix but low for the ODOT Class "B" mix. However, as noted in annual surveys of the pavement conditions, the ODOT Class "B" mix has performed satisfactorily. The void contents of the open graded mixes compared well with the mix design.

The as constructed stabilities for the "B" mix cores were within the specification. The stabilities for the open graded mixes met the specification. The stability of the ISI ARC Modified Class "B" mix was below the specified minimum. However, as noted in annual surveys of the pavement conditions since construction, the ISI ARC Modified Class "B" mix test sections have performed satisfactorily.

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.

Table 6.1: Bid Prices and Unit Costs

Item	Bid Item Quantity, Tons (Mg)	Bid Price Per Unit
Class "B" A.C.		
Asphalt	419 (380)	\$187.00 per ton (\$206.17/Mg)
Furnishing Class "B"	6,875 (6,236)	\$ 22.00 per ton (\$24.26/Mg)
Total Cost of Class "B" in-place	6,875	\$34.39 per ton/\$3.70 per yd^2 (2" thick) (\$37.92/Mg/\$4.44/m^2) (51 mm thick)
Class "B" Modified Gap Graded ARC		
Asphalt-Rubber	516 (468)	\$440.00 per ton (\$485.12/Mg)
Furnishing ISI ARC Class "B" Mod.	3,956 (3,588)	\$ 22.00 per ton (\$24.26/Mg)
Total Cost of ISI ARC Class "B" Mod. In-Place	3,956	\$58.59 per ton/\$6.18 per yd^2 (2" thick) (\$64.60 Mg/\$7.39/m^2)
Class "F" A.C.		
Asphalt	543 (492)	\$197.00 per ton (\$217.20/Mg)
Furnishing Class "F"	8,930 (8,100)	\$ 22.00 per ton (\$24.26/Mg)
Total Cost of Class "F" In-Place	8,930	\$34.85 per ton/\$3.50 per yd^2 (2" thick) (\$38.42/Mg/\$4.19/m^2)
Class "F" ISI ARC		
Asphalt-Rubber	97 (88)	\$440.00 per ton (\$485.12/Mg)
Furnishing Class "F" ISI ARC	1,291 (1,171)	\$ 24.00 per ton (\$26.46/Mg)
Total Cost of Class "F" ISI ARC In-Place	1,291	\$58.45 per ton/\$5.42 per yd^2 (2" thick) (\$64.44/Mg/\$6.48/m^2)
Class "F" PRARC		
Asphalt Rubber	80 (73)	\$440.00 per ton
Furnishing Class "F" PRARC	1,020 (925)	\$ 24.00 per ton
Total Cost of Class "F" PRARC In-Place	1,020	\$63.12 per ton/\$5.85 per yd^2 (2" thick) (\$69.59/Mg/\$6.70/m^2)

Note – Test data are entered in the format (dual units) used at the time the testing was conducted in 1992.

6.1 BID PRICES AND MIX COSTS

For this project, the use of asphalt-rubber resulted in significantly higher costs. The binder was more expensive than conventional asphalt and the binder percentages of the ISI ARC Modified Class “B” mix, ISI ARC Class "F" mix and the PRARC Class "F" mix were higher than corresponding conventional mixes. The binder content was 1.9% higher for the ISI ARC Modified Class "B" mix, and 1.5% higher for both the ISI ARC and PRARC Class "F" mixes.

The mobilization costs for the ISI and the powdered rubber processes increased the unit cost of the binder significantly because of the small quantity used. See Table 6.1 for the unit cost summary. The mobilization cost was not a separate bid item and was covered under total cost. Although unit costs associated with ISI ARC and PRARC mixes were higher, it seems reasonable to expect the unit price to drop for projects with larger asphalt-rubber binder quantities.

The unit costs were determined using the job mix formula density, assuming a 51 mm lift thickness. An example of the cost differential between conventional Class "F" mix and ISI ARC Class "F" mix would be:

- Binder for ODOT "F" mix - $217/Mg;
- Binder for ISI ARC Class "F" mix and PRARC Class "F" mix- $485/Mg

The binder for ISI ARC Class "F" mix and PRARC Class "F" mix is about 2.2 times greater than the binder for the conventional ODOT "F" mix.

In looking at the total cost in-place, the ISI ARC Class "F" and PRARC Class "F" mixes were also much greater.

- ODOT "F" mix - $38.42/Mg
- ISI ARC "F" mix - $64.44/Mg
- PRARC "F" mix - $69.59/Mg

The ISI ARC "F" mix was 1.7 times greater than the in place cost for conventional ODOT "F" mix. The PRARC "F" mix cost was 1.8 times greater than the ODOT "F" mix.

The ISI ARC Modified Class "B" mix cost was $64.60/Mg as compared to $37.91/Mg for the conventional ODOT Class "B" mix. (1.7 times as much as the conventional mix).

Even with lower anticipated unit costs on larger paving projects, these added costs are considerable and must be taken into account when planning paving projects using asphalt-rubber mixes.

6.2 SUMMARY

Based on the total cost of the mixes in-place and including materials, the ISI ARC Modified Class "B" mix cost 1.7 times as much as the conventional mix. The ISI ARC Class "F" and PRARC Class "F" mixes cost nearly 1.8 times as much as the ODOT Class "F" mix. The ISI ARC Class "F" and PRARC Class "F" mix higher prices were due to the use of relatively expensive asphalt-rubber, greater binder content, as well as special equipment mobilization costs.

7.0 CONCLUSIONS AND RECOMMENDATIONS

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

7.1 CONCLUSIONS

7.1.1 ISI ARC Modified Class "B" (Gap Graded)

The asphalt-rubber binder was the same product that was used in the ISI ARC Class "F" mixture. The lab tested field mix samples did not satisfy the design criteria for Hveem stability. The cost per Mg for the ISI ARC Modified Class "B" mix was greater than the Class "B" mix. A reduced pavement thickness of 64 mm was compared to the control section, constructed through the curb section with only a 64 mm inlay. After six years, performance of the mix was not superior to the control Class "B" mix. Continued use of this product does not appear cost effective.

7.1.2 ISI ARC Class "F" Mix

Construction using this rubberized mix went smoothly, and the resulting pavement is a good representative of an open graded ISI ARC overlay. In addition, by using this system, the contractor was helped by ISI in several key areas in preparing the asphalt-rubber mix. 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.

This rubber modified mix was costly, as its total cost per square meter of coverage was nearly 1.5 times the cost of 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. Performance after six years, however, has not been superior to the control "F" mix. Continued use of this does not appear cost effective.

7.1.3 Powdered Rubber ARC Class "F" Mix

Construction using this product was not much different than ISI ARC Class "F" mix except that a field adjustment was made to increase the binder content. The higher binder content and use of rubber (NR-80) from a non-tire source made it necessary to use a sand blotter over the entire test section to keep the mix from being picked up on vehicle tires after compaction.

The cost of the PRARC Class "F" mix was more than the ISI ARC Class "F" mix. The additional cost could be due to the increased cost of producing finer (powered) rubber. After six years, the control Class "F" mix performance is superior to the PRARC Class "F". The PRARC Class "F" mix as tested would not be cost effective.

7.2 RECOMMENDATIONS

Asphalt concrete mixes using the ISI process and powdered rubber ARC are constructable. Because of ODOT's specification change, asphalt rubber is now specified through a performance based specification. With a performance based specification, the quality of the individual ingredients will not need verification. As a result, the quantity of rubber could be determined by certification and check testing on the asphalt-rubber binder quality would be simplified. ODOT's current PBA–6GR specification (rubber modified binder) is included in Appendix B.

No changes to the 1999 ODOT specifications are recommended for wearing surfaces that contain asphalt-rubber cement. If a gap graded mix is selected for future use, investigation will be necessary to determine a suitable stripping test. A surrogate dense graded TSR test could be used, similar to tests required on open graded mixes.

ODOT should continue to monitor the test and control sections through the "Crumb Rubber Modifiers in Asphalt Concrete Pavements" project. The project is evaluating all ODOT asphalt concrete pavements that include rubber to determine long term performance and ultimately cost effectiveness.

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APPENDIX A

SPECIAL PROVISIONS AND SUPPLEMENTAL STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION

OREGON STATE HIGHWAY DIVISION
SALEM, OREGON

REVISIONS

Changes in this document have been made by letter dated as follows	If the letter or letters fail to reach you, it shall be your responsibility to request such letter or letters from the Oregon State Highway Division at Salem, Oregon before bidding.
JUN 16 1992	

KIND OF WORK PAVING

SECTION EASTSIDE BYPASS (KLAMATH FALLS) PHASE 1

HIGHWAY KLAMATH FALLS-MALIN

COUNTY KLAMATH

PROPOSALS TO BE RECEIVED JUNE 25, 1992

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

Description

These asphalt-rubber concrete mixtures shall be constructed in accordance with Section 00745 of the 1991 Standard Specifications for Highway Construction supplemented and/or modified as follows:

00745.00 Scope - Delete this subsection and add the following:

Standard Duty Modified Class "B" Lime Treated Asphalt-Rubber Concrete Mixture shall be used on the wearing course of a test section from Station 83+06 Rt. to Station 113+25 Rt. and Station 73+06 Lt. to Station 113+25 Lt.

Standard Duty Modified Class "F" Lime Treated Asphalt-Rubber Concrete Mixture shall be used on the wearing course of a test section from Station 113+25 Lt. to Station 139+00 Lt.

00745.01 Abbreviations - Add the following:

- AC or ARC - Asphalt-Rubber Concrete
- GGARC - Modified Class "B" Asphalt-Rubber Concrete, Gap-Graded
- OGARC - Modified Class "F" Asphalt-Rubber Concrete, Open-Graded

00745.02 Definitions - Delete the fourth definition and substitute the following:

Asphalt or Asphalt-Rubber - Asphalt-rubber binder consisting of base asphalt, rubber, and additives as required.

Base Asphalt - The asphalt cement used in the asphalt-rubber binder.

Mixture - Asphalt-rubber concrete hot mixture of asphalt-rubber, graded aggregate, and additives as required.

Rubber - Ground recycled vulcanized tire rubber.

00745.03 Reclaimed Asphalt Pavement (RAP) Material - Delete this subsection and substitute the following:

RAP shall not be used.

Materials

00745.10 Aggregate - Add the following:

(c) Blotter material - Blotter material shall be composed of fine aggregate or sand meeting the following gradation when tested in accordance with AASHTO T27.

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

00745.11(b-1) Asphalt Cement - Delete this subsection and substitute the following:

(1) Asphalt-Rubber - The asphalt-rubber takes the place of the normal asphalt cement in the AC.

The asphalt-rubber shall be a uniform reacted blend of base asphalt, rubber, and if required, extender oil and/or antistripping agent. The asphalt-rubber shall meet the physical parameters listed in Table 1 for the asphalt-rubber when reacted at 350°F± 10°F for 30 minutes.

TABLE 1

SPECIFICATIONS FOR ASPHALT-RUBBER

Apparent Viscosity, 347°F, Spindle 3, 10 to 20 RPM: cps (ASTM 2669)[1]	Min Max	1,000 4,000
Haake Viscosity, 350°F, #1 Rotor: cps[2]	Min Max	1,000 4,000
Penetration, 77°F, 100g, 5 sec.: 1/10 mm. (ASTM D5)	Min Max	50 100
Penetration, 39.2°F, 200g, 60 sec.: 1/10 mm. (ASTM D5)	Min	25
Softening Point: °F (ASTM D36)	Min	120
Resilience, 77°F: % (ASTM D3407)	Min	10
Ductility, 39.2°F, 1 cm/min: cm. (ASTM D113)	Min	10
RTFO Residue, (AASHTO T 240) Penetration Retention, 39.2°F: %	Min	75
Ductility Retention, 39.2°F: %	Min	50

[1]The spindle speed used for the Apparent Viscosity test shall be noted in the Asphalt-Rubber Design.

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

a. Asphalt-Rubber Materials

1. Base Asphalt - The base asphalt shall comply with requirements of AASHTO M-226 or the OSHD 1992 Specifications for Asphalt Materials. The grade selected shall be determined by laboratory testing performed by the asphalt-rubber supplier to insure appropriate compatibility and reacting characteristics.

2. Rubber

General - The rubber shall be produced from processing recycled automobile and/or truck tires by ambient grinding methods. The rubber shall be vulcanized and substantially free from contaminants including fabric, metal, mineral, and other non-rubber substances. The rubber shall be sufficiently dry to be free flowing and not produce a foaming problem when added to the base asphalt. Up to 4% by weight of talc or other appropriate blocking agent can be added to reduce agglomeration of the rubber particles.

Gradation and Particle Length - When tested in accordance with AASHTO T27 using a 100 gram sample, the rubber shall meet the following gradation limits for the type of rubber specified.

	Percent Passing		
Sieve Size	Type I (For OGARC)	Type II (For OGARC or GGARC)	Type III (For GGARC)
No. 8	100	---	---
No. 10	95-100	100	100
No. 16	40-60	70-100	98-100
No. 30	0-20	25-60	70-100
No. 50	0-10	0-20	10-40
No. 200	---	0-5	0-5
Max. Particle Length	3/16"	3/16"	---

Fiber Content - The fiber content shall be less than 0.5% by weight. The fiber content shall be determined by weighing fiber agglomerations and free fabric which are formed during the gradation test procedure. Rubber particles shall be removed from the fiber agglomerations and free fabric before weighing.

Moisture Content - The moisture content shall be less than 0.75% by weight. The moisture content will be determined by weighing a 100 gram crumb rubber sample both before and after it is placed in an oven and subjected to a temperature of 225°F for one hour.

Mineral Contaminants - The amount of mineral contaminant 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 thoroughly stirring a 50 gm. sample with a magnet.

Packaging - The rubber shall be supplied in either moisture resistant disposable bags which weigh either 50±2 Lbs. or 60±2 Lbs. or reusable bulk containers holding 2,000 pounds or more of rubber. 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. The weight of the rubber in the bulk containers shall be within 1.0 percent of the certified weight. The containers shall not be stacked on top of each other during storage or shipment.

Labeling - Each bag of rubber shall be labeled with the manufacturer's designation for the rubber and the specific type of rubber in accordance with this specification (example - Type I), the nominal bag weight designation (50 or 60 lb.), and the manufacturer's lot number designation. Palletized units shall contain a label which indicates the manufacturer's designation, rubber type, net pallet weight, and production lot number. Bulk containers (2,000+ Lbs.) shall have the manufacturer's designation, rubber type, certified weight of rubber, and production lot number clearly marked on a side.

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.

3. Extender Oil - An extender oil may be added, if necessary, to the base asphalt in order to produce an asphalt-rubber meeting the requirements of Table 1. Extender oil shall be a resinous, high flash point, aromatic hydrocarbon meeting the following test requirements:

Viscosity at 100°F: SSU (AASHTO T72)	2500 min.
Flash Point, COC: °F (ASTM D92)	390 min.
Molecular Analysis (ASTM D2007):	
Asphaltenes, Wt. %	0.1 max.
Aromatics, Wt. %	55.0 min.

4. Antistripping Additive - Add liquid antistripping additives meeting the requirements of Section 02710 to the asphalt-rubber to satisfy the

Index of Retained Strength (IRS) and the Index of Retained Resilient Modulus (IRM_R), as specified in 00745.13(b-1-a). Add the antistripping additive to the base asphalt prior to blending with the rubber.

b. Asphalt-Rubber Design - The asphalt-rubber design shall be performed by the asphalt-rubber supplier. The proportion of rubber shall be between 15 and 20 percent of the total asphalt-rubber weight.

The asphalt-rubber supplier shall supply to the Project Manager an asphalt-rubber design at least 21 days before pavement construction is scheduled to begin. The asphalt-rubber design shall consist of the following information:

Source of Base Asphalt
Grade of Base Asphalt

Source and Grade of Extender Oil
Percentages of Base Asphalt and Extender Oil by Total Weight of the Asphalt-Rubber

Source of Rubber
Type of Rubber
Percentage of Rubber by Total Weight of the Asphalt-Rubber

If rubber from more than one source is utilized the above information will be required for rubber from each source.

Source of Antistripping Additive
Percentage of Antistripping by Additive Weight of the Base Asphalt
Physical properties of the asphalt-rubber in accordance with Table 1.

c. Asphalt-Rubber Mixing and Production Equipment - All equipment utilized in production and proportioning of the asphalt-rubber shall be described as follows:

Base Asphalt Heating Tank - An asphalt heating tank with a hot oil heat transfer system or retort heating system capable of heating the base asphalt to the necessary temperature for blending with the rubber. This unit shall be capable of heating a minimum of 2,500 gallons of asphalt.

Blender - A mechanical blender designed for asphalt-rubber with a two stage continuous mixing process capable of producing a homogeneous mixture of base asphalt and rubber, at the ratios specified in the asphalt-rubber design, as directed by the engineer. This unit shall be equipped with a rubber feed system capable of supplying the base asphalt feed system in a continuous blending process. A separate base asphalt feed pump and finished product pump are required. This unit shall have both a base asphalt totalizing meter indicating cumulative flow in gallons and a flow rate meter indicating flow rates in gallons per minute.

Storage Tank - An asphalt-rubber storage tank equipped with a heating system to maintain the proper temperature for pumping and adding of the asphalt-rubber to the aggregate and an internal mixing unit within the storage vessel capable of maintaining a proper mixture of asphalt-rubber.

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

Temperature Gauge - 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.

d. Asphalt-Rubber Mixing and Reaction Procedure

Base Asphalt Temperature - The temperature of the base asphalt shall be between 375°F and 450°F at the addition of the rubber.

Blending and Reacting - The base asphalt and rubber shall be combined and mixed together in a blender unit, pumped into the agitated storage tank, and then reacted for a minimum of 30 minutes from the time the rubber is added to the base asphalt. The temperature of the asphalt-rubber shall be between 325°F and 375°F during the reaction period.

Transfer - After the material has reacted for at least 30 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 asphalt-rubber 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°F 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 00745.11(b-1), the asphalt-rubber shall be adjusted by the addition of the either base asphalt or rubber as required to produce a material with the appropriate viscosity.

00745.11(b-2) Asphalt Cement Additives - Delete this subsection.

00745.11(b-3) Mineral Filler - Delete the first sentence and substitute the following:

Mineral filler shall not be used.

00745.11(b-4) Aggregate Treatment - Delete the first sentence and substitute the following:

Treat crushed aggregates with dry hydrated lime meeting the requirements of 02090.20.

00745.11(b-4-c) Treatment During AC Mixture Production - Revise the minimum moisture contents of the aggregate to:

4.00% for the GGARC mix.
3.00% for the OGARC mix.

00745.12(b) Broadband Limits - Replace the second paragraph and the table and footnote in this subsection with the following:

Do not exceed these limits without a contract change order. Specified aggregate proportions are given by weight of the total aggregates including lime.

	BROADBAND LIMITS	
Sieve Size (% Passing)	Modified Class "B" Gap-Graded ARC	Modified Class "F" Open-Graded ARC
1"	99 - 100	99 - 100
3/4"	90 - 98	85 - 96
1/2"	65 - 85	60 - 71
1/4"	25 - 40	12 - 38
No. 10	10 - 25	4 - 14
No. 40	4 - 12	0 - 8
No. 200	2 - 6	0 - 5
Asphalt-Rubber*	7.5 - 9.5	8 - 11

*Percent of total mix (by weight)

00745.13 Job Mix Formula (JMF) and Adjustments - Delete the first paragraph of this subsection and substitute the following:

Do not begin production of ARC for use on the project until the JMF is approved by the Engineer of Materials & Research. The JMF shall be provided by the asphalt-rubber supplier, and it shall be submitted to the Engineer of Materials & Research at least 21 calendar days before anticipated use in the ARC pavement.

00745.13(b-1) JMF for Permanent Courses - Delete the second and third paragraphs from this subsection and substitute the following:

To test the materials used in the ARC for specification compliance and calibrate the nuclear asphalt content gauge, furnish representative samples of materials to be used in each JMF project to the Project Manager as follows:

Material	Amount
Aggregate	100 pounds of each separated size (2 bags)
Lime	20 pounds
Asphalt-Rubber (including anti-strip, if specified in JMF)	2 gallons in 1 quart containers
Base Asphalt	1/2 gallon in 1 quart containers
Rubber	5 pounds
Extender Oil (if used)	1/2 gallons in 1 quart containers.

Provide these representative samples so they can be shipped to and received at the Division's Materials Laboratory in Salem at least 21 calendar days before anticipated use in the AC pavement. This 21-day period begins when samples of all materials complying with specifications have been received at the Division's Materials Laboratory.

00745.13(b-1-a) JMF Materials Testing - Delete the third paragraph of this subsection and substitute the following:

Obtain, when directed, a 25-pound sample of ARC mixture from the plant discharge of the first 500 tons of ARC mixture produced, immediately after the asphalt-rubber blending and plant operation is consistent. The sample will be tested to determine if the mixture achieves the JMF criteria including IRS, and if applicable, IRM_R. If the produced mixture does not achieve the JMF criteria, adjustments to the JMF in use may be made by the Engineer of Materials & Research.

00745.13(b) JMF Cost Responsibility - Delete this subsection and substitute the following:

The cost(s) of the JMF(s) shall be borne by the contractor.

00745.14 Tolerances and Limits - Revise the "Asphalt Cement" constituent of Mixture and Tolerances as follows:

	Standard Duty ARC
Asphalt-Rubber Cement - OSHD TM 319 (Nuclear)	±0.5%
Asphalt-Rubber Cement - OSHD TM 321 (Cold Feed/Meter)	±0.2%

Also, revise the temperature of mixture at placement limits as follows:

Standard Duty ARC

See 00745.43d

In addition, add "OSHD TM 311M - 91" at the end of the Moisture content at time of discharge and revise the Moisture limits as follows:

Standard Duty ARC

0.80% Max.

00745.15(c-2) Mixture Control - Add the following to this subsection:

d. Asphalt-Rubber - The asphalt-rubber supplier shall maintain records indicating for each batch of asphalt-rubber produced; the quantity of base asphalt to the nearest 0.01 ton; the temperature of the base asphalt; the amount of other additives, if used, to the nearest 0.001 ton; and the quantity of rubber, to the nearest 0.001 ton. This information shall be provided to the Project Manager on a daily basis.

00745.15(c-2-a) Asphalt Content - Delete.

00745.15(c-2-b) Aggregate Gradation - Delete.

00745.16(b-2) AC Mixture - Delete this subsection and substitute the following:

(2) ARC Mixture - Take samples when directed by the Engineer as follows:

a. Random Sampling - The Engineer will determine when and where to sample on a random basis. A sample will not be required from the first 25 tons of mixture produced each day.

b. Aggregate Gradation - Take one sample from each sublot using an approved mechanical sampling device as required by 00745.21(o) when directed as follows:

- Drum Plants - After lime treatment from the cold feed prior to entering the dryer.
- Batch Plants - If no aggregate is rejected from the storage bins, cold feed, or hot feed prior to screening. Otherwise sample from the hot bins.

c. Asphalt-Rubber Content and Moisture Content of Mix - Take one sample from each sublot, when directed, from the discharge of the paving plant mixer prior to incorporation into the storage hopper or silo. Use an approved mechanical sampling device as required by 00745.21(o). For batch plants that discharge directly into trucks, the sample may be taken directly from the truck.

d. Compaction - Sample for compaction according to 00745.49.

e. Lot Size - A lot is the total quantity of material or work produced per JMF with the same specification limits of all constituents. Increase sampling frequency of lots with two or less sublots according to 00165.30.

f. Sublot Size - A sublot is 500 tons of ARC, except when sampled at an increased frequency according to 00745.16(b-2-e) of these special provisions or when a terminated sublot.

g. Acceptance Testing:

1. General - The Engineer will furnish copies of the following test results by noon of the next workday after sampling:

   - Acceptance testing performed in the field.
   - The CPF of the completed sublots after three sublots have been produced.

   The results of the Division testing in the Materials Laboratory will be reported, when available.

2. Aggregate Gradation - Except as noted below, aggregate samples will be tested using AASHTO T 27 and AASHTO T 11.

- For batch plants, if hot bins samples are used, separated size test results will be mathematically combined in the proportions as batched.

- Cold feed by sieve analysis.

3. Asphalt-Rubber Content - Asphalt-rubber content will be tested using:

   - Dense Graded Mix - OSHD TM 319 (Asphalt Content of Bituminous Mixtures by Nuclear Method).

   - Open Graded Mix - OSHD TM 319, or if elected, OSHD TM 321 (Asphalt Content by Cold Feed/Meter Procedure) from the continuous or drum mix plant's asphalt metering/weighing system and confirm by invoices and tank stickings.

   If OSHD TM 321 is used, perform an initial plant calibration according to OSHD TM 322 (Asphalt Concrete Plant Calibration) before the start of paving and then once a week thereafter, or any time there is a breakdown or change in plant equipment.

4. Moisture Content of Mix - Samples will be tested using OSHD TM 311M-91.

5. Asphalt Aging - ARC shall be excluded from asphalt aging testing.

6. Backup Testing - If the test result of any ARC constituent (except asphalt-rubber content determined by the nuclear gage method TM 319) varies from the JMF by 1-1/2 times or more the tolerance limits specified in 00745.14, a backup sample from the random sample will be tested. The test result which yields the highest CPF through that sublot will be used. If the original and backup test results yield the same CPF, the original test results will be used.

   If the asphalt-rubber content test result as determined by TM 319 varies from the JMF by more than the tolerance limit, the nuclear gage operation will be verified by checking against a calibration sample with a known asphalt-rubber content. The original asphalt-rubber content sample will then be retested and the result from the retest will be used to determine the CPF.

7. Compaction - Acceptance testing for compaction will be according to 00745.49. New nuclear gage tests will be obtained for any failing sublot of pavement, at the same randomly selected sites used for the original nuclear gage tests, if a new test is requested in writing on the same day nuclear gage tests are provided. The average of these five new density tests will constitute the "in place" density of the sublot of pavement and will prevail over the original nuclear results.

   The Engineer may test any area that appears defective in compaction and require further compaction of any area that does not meet specifications.

Add this subsection:

00745.16(b-3) Asphalt-Rubber, Base Asphalt, Rubber, and Extender Oil - Take samples when directed by the Engineer as follows:

a. Asphalt-Rubber Binder - Take two one-quart friction top cans of the asphalt rubber to be used in each sublot after the asphalt-rubber has completed its reaction period and immediately before it is pumped into the mix plant. Provide these samples to the Project Manager.

b. Base Asphalt - Take two one-quart containers, when directed, of the base asphalt to be used in the first, fifth, and every fifth sublot thereafter. Provide these samples to the Project Manager.

c. Rubber - Take three one-quart friction top cans of rubber when directed, from the rubber used in the asphalt-rubber for the first, fifth, and every fifth sublot thereafter. To assure that the samples have a moisture content representative of the rubber added to the base asphalt, sample from freshly opened bags or containers and seal the cans of rubber immediately after sampling. Provide these samples to the Project Manager.

d. Extender Oil - Take two one-quart cans, when directed, of the extender oil to be used in the first, fifth, and every fifth sublot thereafter. Provide these samples to the Project Manager.

e. Acceptance Testing:

1. Asphalt-Rubber - Check tests will be made on samples from the first, fifth, and every fifth sublot thereafter. Complete tests will be made on samples from the first, twentieth, and every twentieth sublot thereafter. Samples from intervening sublots will be tested if a sublot's samples do not meet specifications. Test methods and specifications in 00745.11(b-1) will be used.

2. Base Asphalt - Complete tests will be made on samples from the first, twentieth, and every twentieth sublot thereafter based on 00745.11(b-1-a-1) of these special provisions. Samples from intervening sublots will be tested if a sublot's samples do not meet specifications.

3. Rubber - Complete tests will be made on samples from the first, twentieth, and every twentieth sublot thereafter based on 00745.11(b-1-a-2). Samples from intervening sublots will be tested if a sublot's samples do not meet specifications.

4. Extender Oil - Complete tests will be made on samples from the first, twentieth, and every twentieth sublot thereafter based on 00745.11(b-1-a-3). Samples from intervening sublots will be tested if sublot's samples do not meet specifications.

Equipment

00745.21(o) Sampling Devices - Add the following:

Provide a mechanical sampling device for each hot bin used in batch plants.

00745.22 Hauling Equipment - Delete the first and second sentences of the second paragraph of this subsection and substitute the following:

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

00745.24 Compactors - Delete this subsection and substitute the following:

Provide specified self-propelled rollers capable of reversing without backlash, as follows:

(a) Steel-Wheeled Rollers - Steel wheeled rollers shall have:

- For OGARC, a gross static weight of at least 8 tons and no more than 10 tons.

- For GGARC, a gross static weight of at least 8 tons and no more than 12 tons.

- Pads and a watering system to prevent sticking of the paving mixture to the steel-tired wheels (drums). Water or a nonpetroleum based wetting agent shall be used. Do not use diesel oil.

(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.

(c) Pneumatic-Tired Rollers - Pneumatic-tired rollers shall not be used.

Add this subsection:

00745.25 Blotter Spreading Equipment - Blotter shall be spread using hopper or whirl type tailgate spreaders.

Construction

00745.43(d) Heating Temperatures - Delete this subsection and substitute the following:

Heat the asphalt-rubber to at least 325°F, but not more than 375°F, when it enters the mixer. Unless specified otherwise by the JMF, the temperature of the ARC at discharge from the mixer and immediately behind the paver shall be as follows:

	ARC TEMPERATURE (°F)	
Grading	At Mixer	Behind Paver
OGARC	275 to 325	250 to 300
GGARC	290 to 325	275 to 300

If the mixture placement temperature behind the paver is specified by the JMF, the Project Manager may adjust this temperature within the limits shown above 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.

00745.49(b-2-a) General - Delete the second paragraph and substitute the following:

For the GGARC, vibratory rollers should be used for at least the first breakdown coverage. Breakdown compaction shall consist of at least 3 complete coverages.

00745.49(d) Open-Graded AC - Delete the second paragraph of this subsection and substitute the following:

For the OGARC, do not use rollers in the vibratory mode. Use at least two complete breakdown coverages and at least two complete intermediate coverages. Perform additional coverages, as directed and as necessary, to obtain thorough compaction and finish rolling.

Maintenance

Add the following subsection:

00745.63 Blotter Material - 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 Engineer. Unless otherwise designated by the Engineer, the blotter material shall be applied at a rate of approximately 1 to 2 pounds per square yard. Blotter material shall be spread in a uniform coverage across the ARC mat. Any piles, ridges or uneven distribution of blotter material shall be eliminated by spreading and/or removing with hand tools or mechanical means as the Contractor elects prior to the final roll or coverage.

Measurement

00745.80 General - The quantity of ARC mixture was computed on the basis of aggregates having a specific gravity of 2.75.

00745.81(b) Asphalt - In the second sentence of the second paragraph, substitute the word "acceptance" for the word "extraction" and substitute "0.01" for "0.1."

00745.81 Blotter Material - There will be no measurement of blotter material.

Payment

00745.90 General - Delete the second paragraph and substitute the following:

Payment for all acceptable ARC incorporated into the project will be made under applicable pay items and pay units, as follows:

Pay Item	Unit of Measurement
(a) Std. Duty Mod. Class "B" Lime Treated ARC Mix.	Ton
(b) Std. Duty Mod. Class "F" Lime Treated ARC Mix.	Ton
(c) Asphalt-Rubber in ARC Mixture	Ton

The unit bid price per ton for Asphalt-Rubber shall include the cost of furnishing all materials, which includes the asphalt-rubber, base asphalt, rubber, and if used, extender oil and/or antistripping additives.

No separate or additional payment will be made for furnishing and applying blotter material.

00745.95 AC Price Adjustments - In both price adjustment formulas, after "JMF %", substitute "÷" for "-".

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

Description

This asphalt-rubber concrete mixture shall be constructed in accordance with Section 00745 of the 1991 Standard Specifications for Highway Construction supplemented and/or modified as follows:

00745.00 Scope - Delete this subsection and add the following:

Standard Duty Modified Class "F" Lime Treated Powdered Rubber Asphalt-Rubber Concrete Mixture shall be used on the wearing course of a test section from Station 113+25 Rt. to Station 139+00 Rt.

Eastside Bypass (Klamath Falls), Phase 1 Section
Paving

00745.01 Abbreviations - Add the following:

AC or PRARC - Powdered Rubber Asphalt-Rubber Concrete
PRAR - Powdered Rubber Asphalt-Rubber

00745.02 Definitions - Delete the fourth definition and substitute the following:

Asphalt or PRAR - Powdered rubber asphalt-rubber binder consisting of base asphalt, powdered rubber, and additives as required.

Base Asphalt - The asphalt cement used in the PRAR.

Mixture - PRARC hot mixture of PRAR, graded aggregate, and additives as required.

00745.03 Reclaimed Asphalt Pavement (RAP) Material - Delete this subsection and substitute the following:

RAP shall not be used.

Materials

00745.11(b-1) Asphalt Cement - Delete this subsection and substitute the following:

(1) PRAR - The PRAR takes the place of the normal asphalt cement in the AC. The PRAR shall be a uniform reacted blend of base asphalt, powdered rubber, and if required, antistripping agent. The base asphalt and rubber compatibility shall be checked and verified by the powdered rubber supplier.

a. PRAR Materials

1. Base Asphalt - Use the type and grade of base asphalt supplied for the ARC sections unless directed otherwise. The base asphalt shall comply with requirements of AASHTO M-226 or the OSHD 1992 Specifications for Asphalt Materials.

2. Powdered Rubber

Gradation and Particle Length - When tested using a 100 gram sample, the rubber shall meet the following gradation limits.*

POWDERED RUBBER

Sieve Size	(Passing U.S. Standard Screens)
No. 60	99 - 100
No. 80	89 - 100
No. 100	74 - 90
No. 200	24 - 90

*Test Method on file in the ODOT's Research Unit.

Moisture Content - The moisture content shall be less than 1.0% by weight. Test method on file in the ODOT's Research Unit.

The following shall apply to the powdered rubber:

Test	Method	Specification
Specific Gravity	ASTM D 297-16 (1991) Modified*	1.15 ± .02
Acetone Extract Percentage	ASTM D 297-19 (1991) Modified*	23% Max.
Carbon Black Content	ASTM D 297-39 (1991) Modified*	34% Max.
Ash Content	ASTM D 297-39 (1991) Modified*	7% Max.
Rubber Hydrocarbon Content (by difference)	ASTM D 297 (1991) Modified*	42% Max.

* Test methods on file in the ODOT's Research Unit.

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

4. Antistripping Additive - If required by the JMF, add liquid antistripping additives meeting the requirements of Section 02710 to the PRAR. Add the antistripping additive to the base asphalt prior to blending with the powdered rubber.

b. PRAR - The proportion of rubber shall be 15 percent of the total PRAR weight.

c. PRAR Mixing and Production Equipment - The equipment utilized in production and proportioning of the PRAR shall meet the following requirements:

Blender - A mechanical blender designed for PRAR with a continuous mixing process capable of producing a homogeneous mixture of base asphalt and powdered rubber. A separate base asphalt feed pump is required.

d. PRAR Mixing and Reaction Procedure

Base Asphalt Temperature - The temperature of the base asphalt available to the blending unit shall be between 325°F and 350°F.

Blending and Reacting - The base asphalt and powdered rubber shall be combined and mixed together in a blender unit and then reacted until it maintains a constant viscosity. The minimum reaction time for the reaction temperature used will be determined by the powdered rubber supplier's testing on the rubber and base asphalt used for the PRARC.

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

Delays - If the PRAR is not used within 4 hours after the end of its reaction time, its temperature will be lowered to 300°F to 310°F. Agitation is necessary during this storage period. Viscosity shall be measured daily.

00745.11(b-2) Asphalt Cement Additives - Delete this subsection.

00745.11(b-3) Mineral Filler - Delete the first sentence and substitute the following:

Mineral filler shall not be used.

00745.11(b-4) Aggregate Treatment - Delete the first sentence and substitute the following:

Treat crushed aggregates with dry hydrated lime meeting the requirements of 02090.20.

00745.11(b-4-c) Treatment During AC Mixture Production - Revise the minimum moisture contents of the aggregate to:

3.00% for the PRARC mix.

00745.12(b) Broadband Limits - Replace the second paragraph and the table and footnote in this subsection with the following:

Do not exceed these limits without a contract change order. Specified aggregate proportions are given by weight of the total aggregates including lime.

Sieve Size (% Passing)	BROADBAND LIMITS Modified Class "F" PRARC
1"	99 - 100
3/4"	85 - 96
1/2"	60 - 71
1/4"	12 - 38
No. 10	4 - 14
No. 40	0 - 8
No. 200	0 - 5
PRAR*	8 - 11

*Percent of total mix (by weight)

00745.13(b-1) JMF for Permanent Courses - Delete the second and third paragraphs from this subsection and substitute the following:

To test the materials used in the PRARC for specification compliance and to calibrate the nuclear asphalt content gauge, furnish representative samples of materials to be used in each JMF project to the Project Manager as follows:

Material	Amount
Aggregate	100 pounds of each separated size (2 bags)
Lime	20 pounds
Base Asphalt	2 gallons in 1 quart containers
Rubber	10 pounds
Antistripping Additive (if used)	1 pint in a metal container

Provide these representative samples so they can be shipped to and received at the Division's Materials Laboratory in Salem at least 21 calendar days before anticipated use in the PRARC pavement. This 21-day period begins when samples of all materials complying with specifications have been received at the Division's Materials Laboratory.

To test the compatibility of the base asphalt and powdered rubber, and to determine the minimum reaction time for the PRAR; furnish two gallons of the base asphalt in one-quart containers to the powdered rubber supplier at least 21 calendar days before anticipated use in the PRARC pavement. This 21-day period begins when the base asphalt samples have been received at the powdered rubber supplier.

00745.13(b-1-a) JMF Materials Testing - Delete the third paragraph of this subsection and substitute the following:

Obtain, when directed, a 25-pound sample of PRARC mixture from the plant discharge of the first 500 tons of PRARC mixture produced, immediately after the PRAR blending and plant operation is consistent. The sample will be tested to determine if the mixture achieves the JMF criteria. If the produced mixture does not achieve the JMF criteria, adjustments to the JMF in use may be made by the Engineer of Materials & Research.

00745.14 Tolerances and Limits - Revise the "Asphalt Cement" constituent of Mixture and Tolerances as follows:

	Standard Duty PRARC
PRAR Cement - OSHD TM 319 (Nuclear)	±0.5%
PRAR Cement - OSHD TM 321 (Cold Feed/Meter)	±0.2%

In addition, add "OSHD TM 311M - 91" at the end of the Moisture content at time of discharge and revise the Moisture limits as follows:

Standard Duty PRARC
0.80% Max.

00745.15(c-2) Mixture Control - Add the following to this subsection:

d. PRAR - The contractor shall maintain records for the PRAR used in each sublot; the quantity of base asphalt to the nearest 0.01 ton; the temperature of the base asphalt; the amount of other additives, if used, to the nearest 0.001 ton; and the quantity of powdered rubber, to the nearest 0.001 ton. This information shall be provided to the Project Manager on a daily basis.

00745.15(c-2-a) Asphalt Content - Delete.

00745.15(c-2-b) Aggregate Gradation - Delete.

00745.16(b-2) AC Mixture - Delete this subsection and substitute the following:

(2) PRARC Mixture - Take samples when directed by the Engineer as follows:

a. Random Sampling - The Engineer will determine when and where to sample on a random basis. A sample will not be required from the first 25 tons of mixture produced each day.

b. Aggregate Gradation - Take one sample from each sublot using an approved mechanical sampling device as required by 00745.21(o) when directed as follows:

- Drum Plants - After lime treatment from the cold feed prior to entering the dryer.

- Batch Plants - If no aggregate is rejected from the storage bins, cold feed, or hot feed prior to screening. Otherwise sample from the hot bins.

c. PRAR Content and Moisture Content of Mix - Take one sample from each sublot, when directed, from the discharge of the paving plant mixer prior to incorporation into the storage hopper or silo. Use an approved mechanical sampling device as required by 00745.21(o). For batch plants that discharge directly into trucks, the sample may be taken directly from the truck.

d. Compaction - Sample for compaction according to 00745.49.

e. Lot Size - A lot is the total quantity of material or work produced per JMF with the same specification limits of all constituents. Increase sampling frequency of lots with two or less sublots according to 00165.30.

f. Sublot Size - A sublot is 500 tons of PRARC, except when sampled at an increased frequency according to 00745.16(b-2-e) of these special provisions or when a terminated sublot.

g. Acceptance Testing:

1. General - The Engineer will furnish the following test results by noon of the next workday after sampling:

- Acceptance testing performed in the field.

- The CPF of the completed sublots after three sublots have been produced.

The results of Division testing in the Materials Laboratory will be reported when available.

2. Aggregate Gradation - Except as noted below, aggregate samples will be tested using AASHTO T 27 and AASHTO T 11.

    - For batch plants, if hot bins samples are used, separated size test results will be mathematically combined in the proportions as batched.

    - Cold feed by sieve analysis.

3. PRAR Content - PRAR content will be tested using:

    - Open Graded Mix - OSHD TM 319, or if elected, OSHD TM 321 (Asphalt Content by Cold Feed/Meter Procedure) from the continuous or drum mix plant's asphalt metering/weighing system and confirm by invoices and tank stickings.

      If OSHD TM 321 is used, perform an initial plant calibration according to OSHD TM 322 (Asphalt Concrete Plant Calibration) before the start of paving and then once a week thereafter, or any time there is a breakdown or change in plant equipment.

4. Moisture Content of Mix - Samples will be tested using OSHD TM 311M-91.

5. Asphalt Aging - PRARC shall be excluded from asphalt aging testing.

6. Backup Testing - If the test result of any PRARC constituent (except PRAR content determined by the nuclear gage method TM 319) varies from the JMF by 1-1/2 times or more the tolerance limits specified in 00745.14, a backup sample from the random sample will be tested. The test result which yields the highest CPF through that sublot will be used. If the original and backup test results yield the same CPF, the original test results will be used.

If the PRAR content test result as determined by TM 319 varies from the JMF by more than the tolerance limit, the nuclear gage operation will be verified by checking against a calibration sample with a known PRAR content. The original PRAR content sample will then be retested and the result from the retest will be used to determine the CPF.

7. Compaction - Acceptance testing for compaction will be according to 00745.49(d).

   The Engineer may test any area that appears defective in compaction and require further compaction of any area that does not meet specifications.

Add this subsection.

00745.16(b-3) Base Asphalt and Powdered Rubber - Take samples when directed by the Engineer as follows:

a. Base Asphalt - Take two one-quart containers, when directed, of the base asphalt to be used in the first, fifth, and every fifth sublot thereafter. Provide these samples to the Project Manager.

b. Powdered Rubber - Take three one-quart friction top cans of powdered rubber when directed, from the powdered rubber for the first, fifth, and every fifth sublot thereafter. To assure that the samples have a moisture content representative of the powdered rubber added to the base asphalt, sample from freshly opened bags or containers and seal the cans or rubber immediately after sampling. Provide these samples to the Project Manager.

c. Acceptance Testing:

   1. Base Asphalt - Complete tests will be made on samples from the first, twentieth, and every twentieth sublot thereafter based on 00745.11(b-1-a-1) herein. Samples from intervening sublots will be tested if a sublot's samples do not meet specifications.

   2. Powdered Rubber - Complete tests will be made on samples from the first, twentieth, and every twentieth sublot thereafter based on 00745.11(b-1-a-2) herein. Samples from intervening sublots will be tested if a sublot's samples do not meet specifications.

Equipment

00745.21(o) Sampling Devices - Add the following:

Provide a mechanical sampling device for each hot bin used in batch plants.

Measurement

00745.80 General - The quantity of PRARC mixture was computed on the basis of aggregates having a specific gravity of 2.75.

00745.81(b) Asphalt - In the second sentence of the second paragraph, substitute the word "acceptance" for the word "extraction" and substitute "0.01" for "0.1."

Payment

00745.90 General - Delete the second paragraph and substitute the following:

Payment for all acceptable PRARC incorporated into the project will be made under applicable pay items and pay units, as follows:

Pay Item	Unit of Measurement
(a) Std. Duty Mod. Class "F" Lime Treated Pwrd. Rubber ARC Mixture	Ton
(b) Asphalt-Rubber in Powdered Rubber ARC Mixture	Ton

The unit bid price per ton for Asphalt-Rubber in Powdered Rubber ARC Mixture shall include the cost of furnishing all materials, which includes the powdered rubber asphalt-rubber concrete, base asphalt, powered rubber, and if used, antistripping additives.

00745.95 AC Price Adjustments - In both price adjustment formulas, after "JMF %", substitute "÷" for "-".

SECTION 00749 - MISCELLANEOUS ASPHALT CONCRETE STRUCTURES

Construct miscellaneous asphalt concrete structures according to Section 00749 of the Standard Specifications.

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BID SCHEDULE

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EASTSIDE BYPASS (KLAMATH FALLS), PHASE 1
Paving

Item No.	Item Description	Unit of Measure	Quantity	Unit Price (In Figures)	Total (In Figures)
	BRIDGES				
16.	Thrie Beam Steel Railing	Lin. Ft.	618	$______!____	$______!__
	BASES				
17.	Cold Plane Pavement Removal, 2-1/2" Deep	Sq. Yd.	78,350	$______!____	$______!__
18.	Aggregate Shoulders	Ton	1,050	$______!____	$______!__
	WEARING SURFACES				
19.	Aggregate in Emulsified Asphalt Sand Seal	Ton	150	$______!____	$______!__
20.	Emulsified Asphalt in Sand Seal	Ton	80	$______!____	$______!__
21.	Asphalt in Tack Coat	Ton	45	$______!____	$______!__
22.	Standard Duty Class "B" Lime Treated AC Mixture	Ton	8,430	$______!____	$______!__
23.	Standard Duty Class "C" Lime Treated AC Mixture	Ton	665	$______!____	$______!__
24.	Standard Duty Class "C" Lime Treated AC in Leveling	Ton	800	$______!____	$______!__
25.	PBA-3 or PBA-6 Asphalt in Mixture	Ton	544	$______!____	$______!__
26.	Standard Duty Class "F" Lime Treated AC Mixture	Ton	7,910	$______!____	$______!__
27.	PBA-6 Asphalt in Mixture	Ton	435	$______!____	$______!__
28.	Std. Duty Mod. Class "B" Lime Treated ARC Mix.	Ton	4,250	$______!____	$______!__
29.	Std. Duty Mod. Class "F" Lime Treated ARC Mix.	Ton	1,300	$______!____	$______!__
30.	Asphalt-Rubber in ARC Mixture	Ton	485	$______!____	$______!__

Item No.	Item Description	Unit of Measure	Quantity	Unit Price (In Figures)	Total (In Figures)
31.	Std. Duty Mod. Class "F" Lime Treated Pwrd. Rubber ARC Mix.	Ton	1,300	$____.__	$____.__
32.	Asphalt-Rubber in Powdered Rubber ARC Mixture	Ton	124	$____.__	$____.__
33.	Extra for Asphalt Approaches	Each	18	$____.__	$____.__
	PERMANENT TRAFFIC CONTROL AND GUIDANCE DEVICES				
34.	Guard Rail, Type 2A	Lin. Ft.	4,700	$____.__	$____.__
35.	Guard Rail, Type 3	Lin. Ft.	38	$____.__	$____.__
36.	Guard Rail Anchors, Type 1	Each	9	$____.__	$____.__
37.	Guard Rail End Pieces, Type C	Each	9	$____.__	$____.__
38.	Guard Rail Transition	Each	3	$____.__	$____.__
39.	Extra for 8' Posts	Each	150	$____.__	$____.__
40.	Delineators, Type 1	Each	80	$____.__	$____.__
	PERMANENT TRAFFIC CONTROL AND ILLUMINATION SYSTEMS				
41.	Remove Existing Signs	Lump Sum	All	Lump Sum	$____.__
42.	Remove and Reinstall Existing Signs	Lump Sum	All	Lump Sum	$____.__
43.	Wood Sign Posts	Lump Sum	All	Lump Sum	$____.__
44.	Signal Pole Mounts	Lump Sum	All	Lump Sum	$____.__
45.	Type "B" Signs in Place	Sq. Ft.	17	$____.__	$____.__
46.	Type "G" Signs in Place	Sq. Ft.	176	$____.__	$____.__
47.	Type "R" Signs in Place	Sq. Ft.	108	$____.__	$____.__
48.	Type "RR" Signs in Place	Sq. Ft.	9	$____.__	$____.__
49.	Type "W1" Signs in Place	Sq. Ft.	123	$____.__	$____.__
50.	Type "WA" Signs in Place	Sq. Ft.	5	$____.__	$____.__

APPENDIX B

GROUND RUBBER MODIFIED ASPHALT CEMENT (PBA-6GR GRADE)

General Requirements: The asphalt cement furnished under this specification shall be petroleum asphalt prepared by the refining of crude petroleum, by the addition of ground tire rubber as the primary modifier and when required by the addition of other modifiers designed to provide the characteristics specified. It shall be homogeneous and free from water, and it shall not have been distilled at a temperature high enough to injure by burning or high enough to produce flecks of carbonaceous matter. It shall meet the following requirements at the time of use when tested according to the following methods. For asphalt containing an anti-stripping additive, requirements will be extended five percent for all characteristics except Solubility in Trichloroethylene.

Performance specifications for PBA-6GR Ground Rubber Modified Asphalt Cement are the same as PBA-6 as listed above with the following modifications:

(a) The Kinematic Viscosity on Original Binder (AASHTO T-201) specification may be deleted if the Contractor makes a written request accepting full responsibility for the pumpability of the asphalt cement within the Contractor's plant. Agreement to delete this specification will be documented by contract change order.

(b) The Ductility on the RTFO Aged Residue specification (AASHTO T-51) is deleted.

(c) The Certificate of Compliance accompanying the Refinery Test Report shall certify ground recycled tire rubber was used as the predominant modifier.

(d) The Refinery Test Report shall include the amount of ground recycled tire rubber and the total amount of modifier(s) used in the asphalt, expressed as a percentage by weight of total PBA-6GR.

(e) The ground recycled tire rubber shall conform to the gradation listed below. An alternate gradation may be proposed in writing to the Engineer. If approved, the Engineer will issue a contract change order. Test in accordance with ASTM C 136 amended as follows:

To a 100.0 gram sample of ground recycled tire rubber, add 5.0 grams of talc. Mix the ground rubber and talc for a minimum of one minute by shaking by hand in a sealed one liter jar. Continue shaking or open the jar and stir until particle agglomerates and clumps are broken and the talc is uniformly mixed. Then sieve the combined material for 10 minutes, sum the total weight of the contents of each sieve, and the pan, and subtract 100. The remainder is to be subtracted from the bottom pan contents. This is the adjusted bottom pan contents, accounting for talc used.

Sieve Size	Percent Passing
425 µm	100
180 µm	90 – 100
150 µm	70 – 90
75 µm	25 – 50