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ALASKA DEPARTMENT OF TRANSPORTATION

Use of Rubber-Modified Hot-Mix Asphalt to Reduce Studded Tire Wear And Plastic Deformation

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13. ABSTRACT

In 1986, the A-C couplet pavement in Anchorage, Alaska was paved using the PlusRide crumb rubber hot-mix asphalt (HMA) technology. This pavement is still in use and, over the years, exhibited excellent resistance to studded tire wear and superior rutting performance.

The objective of this study is to reevaluate the use of crumb rubber (from recycled tires) in HMA used in projects constructed in the 1980's. The aim is to improve on the A-C couplet mix design and reduce the risk of rutting failure of rubber-modified hot mix asphalt (RHMA) by using highly crushed aggregate, coarse ground crumb rubber, and polymer modified asphalt cement.

The laboratory phase of this study consisted of testing several candidate trial mixes to develop an optimal RHMA. This was achieved by using the Marshall method to design the mixes, the Prall abrasion tester to simulate studded tire wear, and the loaded wheel rut tester to evaluate mix resistance to plastic deformation.

Using the RHMA developed during the laboratory phase of this study, about 14,000 tons of RHMA were placed in 2007 as a surface course on the Elmore Road (Abbott Loop Extension) project in Anchorage. In subsequent years, rut depth measurements revealed that rutting at Elmore Road is less than that of conventional HMA mixes such as those placed at Tudor Road (using local and hard aggregate mixes). It is projected that the average rut depth at Elmore Road will reach 0.5-in in about 13 years, compared to about 7 and 10 years at the Tudor Road local and hard aggregate mixes, respectively.

Despite its higher initial cost, it is expected that roadways paved with RHMA will have a lower life cycle cost than those paved with conventional HMA. It is anticipated that RHMA will be used in several future urban south-central paving projects.

14. KEYWORDS : asphalt, crumb rubber, HMA, pavement, performance, plastic deformation, RHMA, rutting, studded tire wear

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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	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	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 (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

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	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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EXECUTIVE SUMMARY

The main distress modes of hot-mix asphalt (HMA) pavements in high traffic volume areas of Central and Southeastern Regions of Alaska Department of Transportation and Public Facilities (ADOT&PF) are studded tire wear in winter, and plastic deformation in summer. These distresses exhibit themselves as rutting in the form of pavement longitudinal depressions in the vehicle wheel paths.

In 1986, the A-C couplet pavement in Anchorage, Alaska was paved using the PlusRide crumb rubber HMA technology. This pavement is still in use and, over the years, exhibited excellent resistance to studded tire wear and superior rutting performance.

The objective of this study is to reevaluate the use of crumb rubber (from recycled tires) in HMA used in projects constructed in the 1980's. The aim is to improve on the A-C couplet mix design and reduce the risk of rutting failure of rubber-modified hot mix asphalt (RHMA) by using highly crushed aggregate, coarse ground crumb rubber, and polymer modified asphalt cement.

The laboratory phase of this study consisted of testing several candidate trial mixes to develop an optimal RHMA. This was achieved by using the Marshall method to design the mixes, the Prall abrasion tester to simulate studded tire wear, and the loaded wheel rut tester to evaluate mix resistance to plastic deformation.

Using the RHMA developed during the laboratory phase of this study, about 14,000 tons of RHMA were placed in 2007 as a surface course on the Elmore Road (Abbott Loop Extension) project in Anchorage. Using new RHMA construction specifications, the technology consisted of adding granulated crumb rubber into the mixing chamber of the hot asphalt plant with hot aggregate and polymer modified asphalt binder.

In subsequent years, using a road surface profiler, pavement condition surveys were carried out at the Elmore Road RHMA project. Rut depth measurements revealed that rutting at Elmore Road is less than that of conventional HMA mixes such as those placed at Tudor Road (using local and hard aggregate mixes). It is projected that the average rut depth at Elmore Road will reach 0.5-in in about 13 years, compared to about 7 and 10 years at the Tudor Road local and hard aggregate mixes, respectively.

Despite its higher initial cost, it is expected that roadways paved with RHMA will have a lower life cycle cost than those paved with conventional HMA. It is anticipated that RHMA will be used in several future urban paving projects in the Central Region of ADOT&PF.

1- PROBLEM STATEMENT

Alaska Department of Transportation and Public Facilities (ADOT&PF) pavement performance data indicated that roadway asphalt pavements carrying high traffic volumes in the Central and Southeastern Regions of ADOT&PF typically have useful lives of less than eight years. These roadways have an average annual daily traffic (AADT) of over 5,000 vehicles per lane. The main observed distress or failure mode of these pavements is rutting in the wheel paths caused by:

- Surface wear and abrasion caused by a high percentage of studded tire usage in the winter, and
- Plastic deformation in the summer.

2- OBJECTIVES

The objective of this research is to reevaluate the use of ground crumb rubber (produced from recycled tires) in hot mix asphalt (HMA) as it was designed and constructed when it was mandated in the 1980's. HMA made using the PlusRide method (dry process) has demonstrated excellent resistance to studded tires. This study aims at improving the rubber-modified hot mix asphalt (RHMA) design and reducing its failure risk by:

- Using highly crushed aggregate,
- using coarse ground crumb rubber,
- Using polymer modified asphalt cement, and
- Developing construction specifications for the RHMA.

The mix design will use the Marshall method, then the Prall test to simulate studded tire wear on asphalt mixes, and the loaded wheel rut tester to evaluate resistance to plastic deformation. This technology will add dry crumb rubber into the mixing chamber of a hot plant with hot aggregate and asphalt cement.

3- BACKGROUND

A review of the data in ADOT&PF's Pavement Management System (PMS) reveals that typical service lives of HMA pavements are as summarized in Table 1.

TABLE 1 Typical Service Lives of Some AK HMA Pavements

Location	Mix Type	Life	Prall Value	Aggregate	Nordic Value
Anchorage	PlusRide	20	14-16	Local	13
	Type II	5-7	40-50	Local	13
	SMA	6-8	30-50	Local	13
Juneau	Type II	6-8	40-60	Local	12
	Egan	10+	20	Imported	8

3.1- Studded Tire wear

Roadways having high vehicular volumes with studded tires exhibit a 0.75-in rut depth in about six to eight years. Typically ruts in the wheel paths are about 58-in apart, the same width as a compact car or truck. Note that commercial vehicles and busses do not use studded tires. This rutting condition governs pavement life as opposed to pavement roughness/smoothness. This condition requires pavement rehabilitation.

ADOT&PF's PMS data indicate that the rubber-modified HMA (PlusRide) placed in the 1980's in Anchorage continues to outperform any other HMA surface course. In Juneau, HMA placed with "hard aggregate" show improved performance over other mixes subjected to high volumes of studded tire traffic. Laboratory testing of aggregates and HMA, using the Nordic abrasion tester and the Prall tester, respectively, provided the ability to design these mixes.

The Nordic abrasion test is a wet ball mill test of the coarse aggregate used in the HMA. In this test, a low aggregate wear/loss (low Nordic abrasion value) means that an HMA using the aggregate will have greater resistance to studded tire wear. Scandinavian and Alaskan research indicate that the use of "hard" aggregates, as evaluated in a Nordic abrasion tester, in HMA pavements resists studded tire wear better than local aggregates that have higher Nordic abrasion values.

The Swedish Prall test uses ball bearings on the surface of a prepared HMA core that is vigorously vibrated up and down while 40° F water is injected over the surface, flushing away loose HMA particles. Swedish research has found this test to simulate studded tire wear well: a lower Prall value indicates less material removal from the tested specimen. Therefore a low Prall value is desired. Prall tests results show that pavement samples, from the Anchorage A-C couplet, made with crumb rubber using the PlusRide system in the 1980's, to be resistant to studded tire wear. This is supported by PMS annual rut depth measurements.

3.2- Plastic Deformation

In Central and Southeastern Regions, urban rut depth measurements, collected in the spring and fall, indicate that rutting is caused in the winter by surface wear and abrasion due to studded tire usage, and in the summer, by plastic deformation. Typically winter rutting is two to three times greater than summer rutting. Summer rutting mostly occurs in pavements built with neat asphalt cement. To mitigate summer plastic deformation, ADOT&PF is currently specifying HMA that uses performance graded polymer modified asphalt cement, and highly fractured, cubical aggregates. It was observed that minimal plastic deformation occurs in summer using these materials. These mixes are developed using both Superpave and Marshall mix design procedures.

3.3- Crumb Rubber in HMA

Ground crumb rubber from recycled tires is incorporated in HMA using one of two processes. In the wet process, fine crumb rubber (at least 15% by asphalt weight) is digested in the asphalt cement prior to mixing with aggregate. The resulting hot mix is referred to as asphalt-rubber hot mix (ARHM). This mix is being used routinely and with success in Arizona, Texas, and California. However, this process requires specialty mixing equipment. Typically, States using the wet process add crumb rubber to neat asphalt cement, and the resulting asphalt–rubber binder is not performance graded in specifications or for acceptance.

In the dry process, granulated crumb rubber (2-3% by mix weight) is added to the mix as an aggregate replacement. The resulting hot mix is called rubber-modified hot mix asphalt (RHMA). States had limited success with RHMA. Consequently the dry process was discontinued as a standard process due to royalties and increased cost of RHMA over conventional mix.

Some of the beneficial effects of adding crumb rubber to HMA and expected pavement performance enhancements are detailed in the publications cited in the References section of this report. These benefits are summarized below:

- Compatibility: Crumb rubber chemically interacts with asphalt cement and elastomeric polymers, increasing the resilience and softening point, decreasing stress elongation, and reducing the fracture temperature. The finer rubber particles are, the better the chemical interaction is.
- De-icing: The flexibility / compressibility of coarse rubber particles on the pavement surface are reported to break the ice bond to the pavement surface with traffic in some rubberized mixes; however, this is not expected of the mix developed in this research.
- Durability: HMA pavement containing rubber is more resistant to reflective cracking, stripping, oxidation and other distresses.
- Flexibility: Resilient modulus test results show approximately 7 times the fatigue life over conventional mixes.
- Flushing: Asphalt mixes with rubber can absorb higher asphalt contents without flushing; however, the ratio of asphalt cement and crumb rubber must be diligently maintained to prevent flushing as the crumb rubber affects the void structure of the HMA.
- Low Temperature Performance: The addition of rubber into the asphalt cement lowers the low performance grade temperature in the Performance Grading (PG) system, making the mix more flexible and more resistant to thermal cracking.
- Moisture Damage: Mixes with rubber are designed with lower air voids (2%–4%) and higher asphalt content making them more resistant to water intrusion and moisture damage.
- Noise Abatement: Arizona DOT demonstrated that the use of rubberized asphalt mixes contribute to traffic noise reduction.

- Reflective Cracking: Rubberized asphalt mixes resist reflective cracking much more than conventional mixes as demonstrated by tests in Sweden, Arizona, and other locations in the US.
- Skid Resistance: Due to protruding coarse rubber particles, the pavement surface texture gives improved skid resistance during wet or icy pavement conditions, with tests showing a reduction of stopping distances by up to 60%.
- Viscosity: The addition of crumb rubber to asphalt cement increases viscosity thus increasing the binder's high performance grade temperature, thus making the mix more resistant to plastic deformation.

Table 2 compares materials and mix design parameters of ADOT&PF conventional HMA, hard aggregate HMA, and rubber-modified HMA.

TABLE 2 Comparison of Mix Properties

	Normal HMA	Hard Aggregate HMA	RHMA (1980's)
Coarse **Aggregate** Source	Local	Import (50% of mix weight)	Local
Fine **Aggregate** Source	Local	Local or Imported	Local
Grading	Dense	Dense or Gap	Gap
Asphalt Binder	Unmodified	Polymer Modified	Unmodified
Rubber	None	None	2-3% by mix weight
Mix Design	50, 75 blow Marshall	Superpave, 75, 100 gyrations	50 blow Marshall
Design Voids Total Mix	4%	4%	2.5 – 3%
VMA	13 min	13 min	none

4- LABORATORY STUDY

4.1- Aggregate Gradations

This research was partly aimed at evaluating and improving the aggregates used in RHMA, by comparing changes to the aggregates used on the A-C couplet in 1986. The gradation, hardness and shape properties were considered. The premise that the aggregate gradation needs to be gap-graded to allow inclusion of rubber particles is used. To provide voids for the coarse crumb rubber particles, the PlusRide system required a 10% difference in weight of material passing the 1/4 inch sieve and retained on the #8 sieve. It should also be recognized that rubber particles expand when absorbing oils from the asphalt cement.

The intent here is twofold:

- To transmit the wheel loading through the aggregate skeletal structure of the asphalt mix by aggregate-to-aggregate contact and interlock (the aggregate skeletal structure should not collapse under repeated loading, thus a highly fractured cubical aggregate will be required), and
- To provide enough crumb rubber to resist studded tire wear.

Table 3 and Figure 1 show aggregate gradations and properties of:

#1- PlusRide mix aggregate used on A-C Couplet, 1985
#2 - Elmore Road RHMA aggregate, 2007.

TABLE 3 Comparison of Old and New RHMA Aggregate Properties

Sieve	A-C Couplet 1985	Elmore Road 2007
¾"	100	100
½"	73	72
3/8"	49	52
¼"	35	(42)
#4	34	39
#8	31	28
#16	26	21
#30	20	16
#50	15	12
#100	11	10
#200	7.5	7.4
Fracture		99% 2 face
Nordic Abrasion	12	12
LA		
Sodium Soundness		
Degradation		
Thin- Elong 3:1 5:1		7 0
Fine Aggr Angularity		44.9

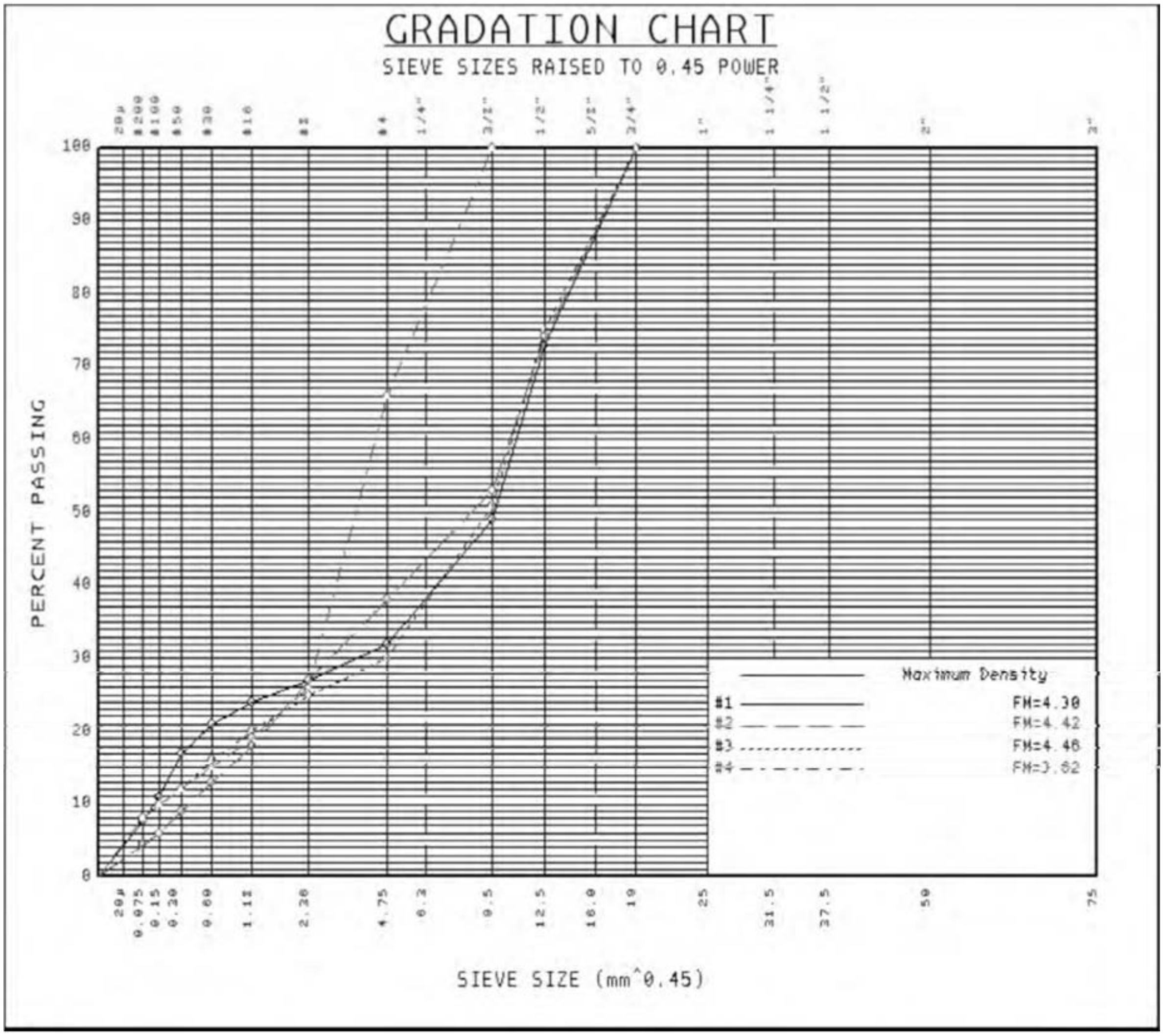


FIGURE 1 Aggregate gradation of RHMA at A-C Couplet (#1) and Elmore Road (#2).

4.2- Crumb Rubber Gradations

This research attempted to simplify the use of crumb rubber in the dry process by having a fine (F) component added at the asphalt terminal as a terminal blend, and then adding the larger, coarser (C) portion as aggregate at the asphalt plant. The crumb rubber gradation in the PlusRide mix on A-C couplet worked well in the past and the 80:20 (C:F) blend averaged 2.2% of the total mix with gradations shown in Table 4.

TABLE 4 Size Distribution of Crumb Rubber Modifiers

Sieve Size	**Coarse Rubber PlusRide**	**Research Coarse**	**Fine Rubber PlusRide**	**Research Fine**	**80C:20F Blend PlusRide**	**Terminal Blend Rubber**	**Elmore Mix Rubber 2007**
		05A-0042		05A-0041			
¼"	100				100		100
#4	70-90	100			76-92		97
#8		46					29
#10	10-20	18	100	100	28-36		
#16		2		99			1
#20	0-5		50-100		10-24		
#30				32			0
#50				7		100	

4.3- Asphalt Binders Used

In this research, all asphalt binders were polymer-modified asphalts (PMA) with about 4% SBS. Some binders were additionally modified with minus #50 crumb rubber (particles finer than 0.3 mm) to simulate terminal blending, and to take into account the presence of the fine fraction/portion (20%) of the PlusRide rubber component. It is believed that using the minus #50 crumb rubber (< 0.3 mm) may have minimal influence on the Dynamic Shear Rheometer (DSR) results as the gap between the specimen plates is maintained at 1 mm during binder Performance Grade (PG) testing. PG grading of rubberized asphalt is still a topic of national debate. The Pacific Coast Asphalt User Producers Group performed round robin testing of rubberized asphalt cement. ADOT&PF results are included in Appendix A. Table 5 shows PG binder test results.

TABLE 5 Performance Grade Test Results for All Binders

		PG 52-28	**PG64-28 PMA**	**PG58-28 PMA**	**PG58-28 PMA +7.5% CR**	**PG58-28 PMA +3.0%CR**	Spec.
		05A-0924	05A-0918	05A-1982	04A-2718	05A-0001	
	PG Grade	PG52-28	PG64-28	PG58-28	PG76-28	PG64-28	
AASHTO T53	Softening Point		176+	142	167	154	125°F
ASTM D5801	Toughness, in-lbs		95.4*	139.6	118.1*	129.5	110
ASTM D5801	Tenacity, in-lbs		85.8*	131.8	96.8*	115.1	75
ASTM D4402	Viscosity 135°C, PaS	0.1917	1.1565	0.6668	1.9021	0.9513	3 Max
AASHTO T315	G*/Sinδ, kPa	1.380	1.850	2.310	1.73	1.24	1.00 min
	Phase Angle, degree	88.3	54.3	64.8	53.2	62.3	-
RTFO Aged Binder							
AASHTO T240	Mass Loss, %	0.17	0.13	0.24	0.25	0.27	1.0 max
AASHTO T315	G*/Sinδ, kPa	2.520	2.700	4.100	2.22	3.47	2.20 min
	Phase Angle, degrees	86.9	60.0	64.5	58.3	63.4	-
PAV Aged Binder							
AASHTO T315	G*Sinδ, kPa	3118	1036	2171	4188	3789	5000 max
	Phase Angle, degree	56.3	58.6	56.1	45.9	47.9	-
AASHTO T313	BBR Creep Stiffness						
	S, MPa	215	158	186	277	352	300 max
	m-value	0.354	0.358	0.359	0.304	0.278	0.300 min.

AASHTO T314	Direct Tension	2.531	5.625			1.437	1.0 min.

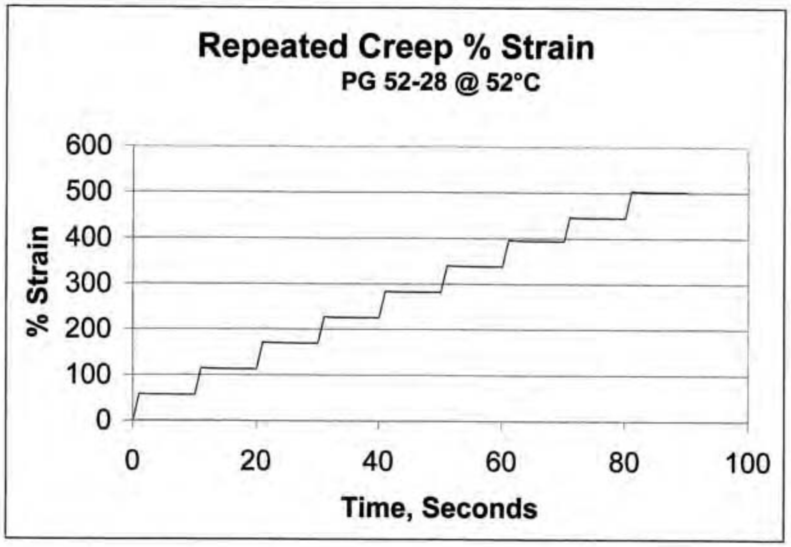
* Indicates that binder snapped from head during testing

Using the DSR device, multiple stress creep recovery (MSCR) testing (an early version of the Standard test) was performed to compare the behavior of the three types of binders:

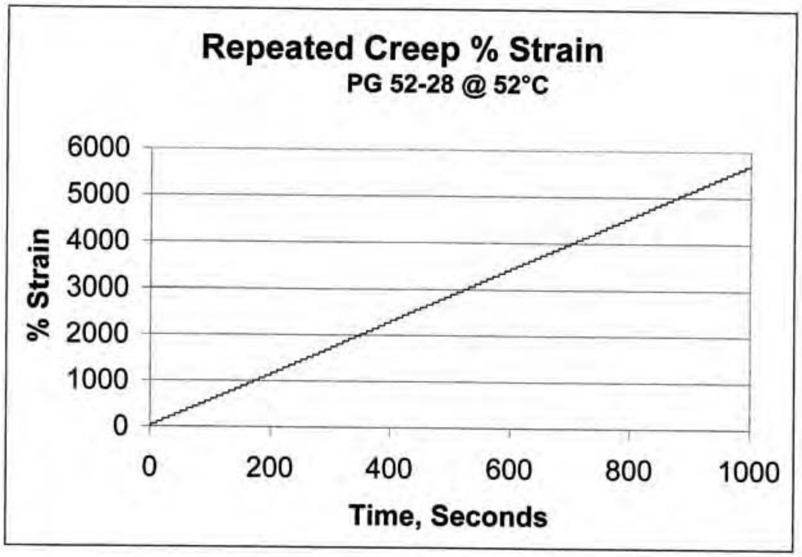
- Unmodified, neat binder,
- Polymer-modified (with SBS) binder, and
- Polymer-modified (with SBS) plus crumb rubber binder.

In the MSCR test, the DSR shears the binder by applying a torque in one direction for 1 second and then releases the torque for 9 seconds, allowing recovery/relaxation of the permanent deformation to occur. This is done for two strain levels, low (for 10 cycles) and high (100 cycles). At each cycle, permanent deformation and elastic recovery are measured. The test is performed at the high performance grade of the binder.

MSCR test results for the neat, unmodified binder PG 52-28 are shown in Figure 2.



(a)



(b)

FIGURE 2 MSCR test results for PG 52-28 for (a) low strain (10 cycles) and (b) high strain (100 cycles) levels.

Figure 3 shows MSCR test results for the PG 64-28 polymer-modified (no rubber) asphalt.

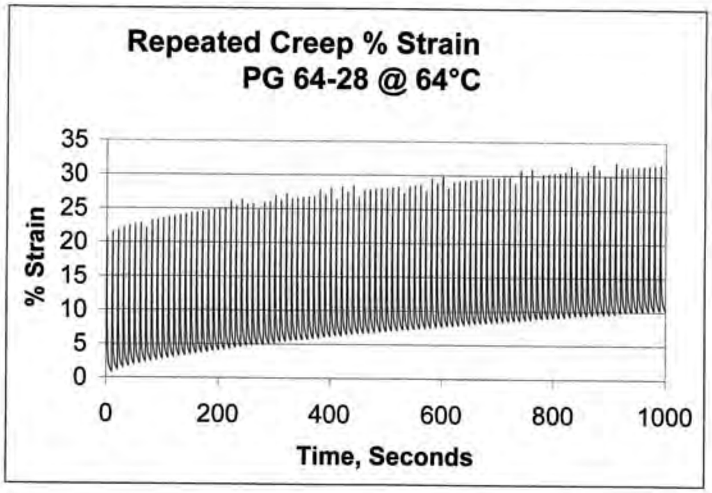


FIGURE 3 MSCR tests results for PG 64-28 PMA at high strain level (100 cycles)

Figure 4 shows MSCR test results for the PG 58-28 polymer-modified asphalt with 7.5% crumb tire rubber (TR).

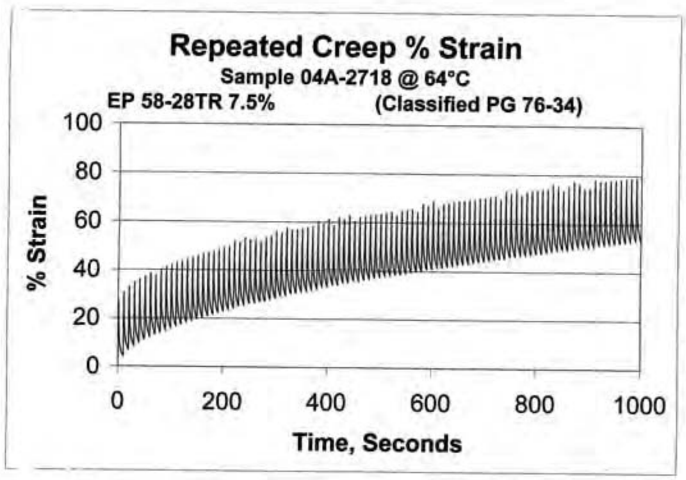
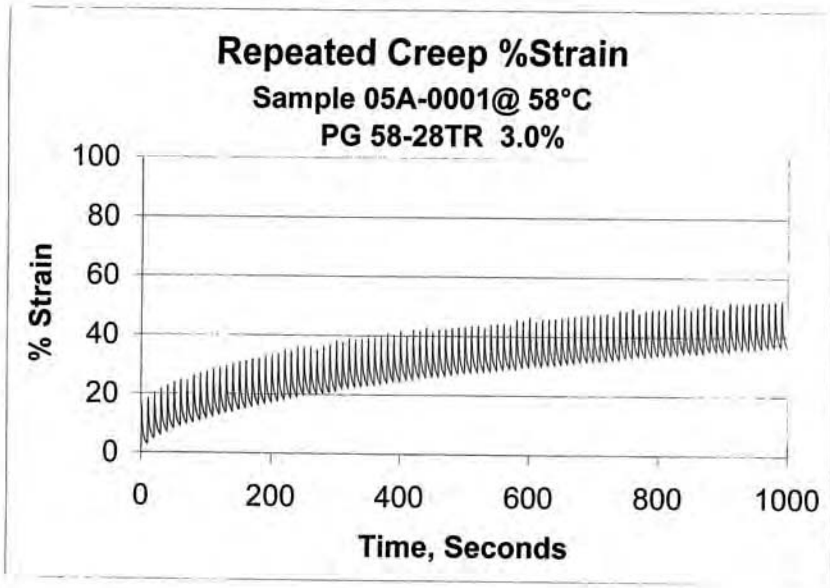
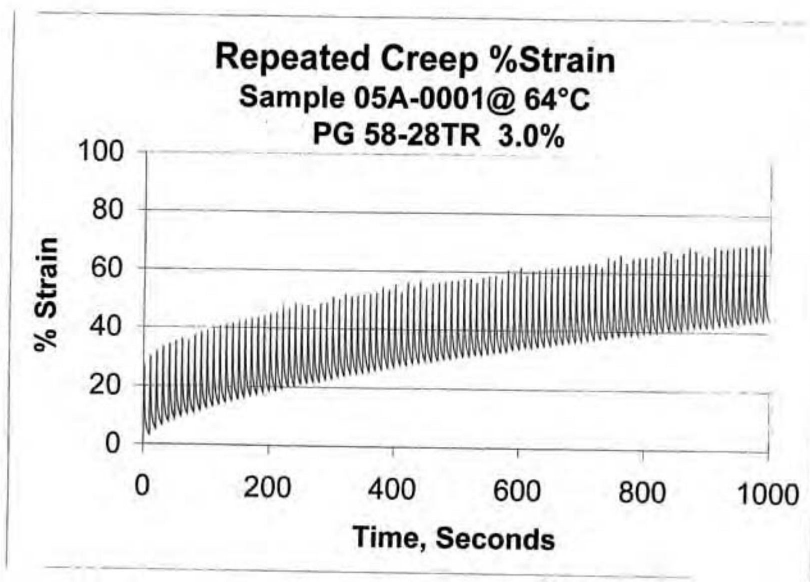


FIGURE 4 MSCR tests results for PG 58-28 PMA + 7.5% TR at high strain level (100 cycles)

Figure 5 illustrates MSCR test results for PG 58-28 polymer-modified binder with 3% crumb rubber, at 58°C and 64°C, respectively.



(a)



(b)

FIGURE 5 High strain level MSCR test results for PG 58-28 PMA + 3% TR at (a) 58 C and (b) 64 C.

From the results depicted in Figures 2 to 5, it is seen that polymer-modified binders exhibit about 20% strain recovery in each cycle and about 10% to 40% total deformation in this test series. The value of this testing is to understand that permanent deformation of the unmodified binder is 6000% whereas that of the modified binder is at about 40% when tested at the high PG temperature. This resistance to deformation translates into resistance to plastic deformation in the asphalt-aggregate hot mix.

4.4- Mix Properties and Design Procedures

The Marshall mix design method (50 blows per face of test specimen) was used as the preferred method after an initial use of the Superpave gyratory compactor on a couple of mixes in 6-in diameter molds. Unless the mix was cooled under load in the gyratory molds, the rubber would expand after compaction and distort the volumetric calculations. No attempt was made to cool the asphalt mix in the molds while maintaining the load as this is not practical during production mix designs. The 50 blow Marshall method was used and the specimens were extruded in the normal manner. The coarse rubber content ranged between 2% and 3% of the mix weight. The design criteria was to design a mix that would yield Prall Abrasion values less than 25 and Georgia Loaded Wheel rut depth values (rut index) less than 7mm. Table 6 lists the test results achieved.

TABLE 6 Mix Results using PlusRide Lab Gradations

Lab No	A-C Couplet	03A-2767	04A-0033	04A-0033
Asphalt Cement	Chevron AC-5	PG 70-34 TR	PG 52-28	PG 70-34 TR
Design % AC	7.2	7.1	7.0	7.1
% Coarse CR	2.5 total	2.3	2.0	1.0
% Fine CR			0.5	
% Cellulose			0.30	
Max SpG		2.438	2.397	2.397
%Void Filled	92	87	85	88
% Voids Total Mix	2.2	2.5	2.7	2.2
VMA		19.0	17.3	17.6
Stability	870	2334	640	1840
Flow	25		30	24
Unit Weight	145.9	145.7	145.2	148.0
Rut Index		7.2	8.4	4.0
Prall	15 (core)	13.4	25	20

Testing of the aggregates meeting the PlusRide gradation used on the A-C Couplet demonstrated that the mix needs more than 2.0 percent coarse crumb rubber included in the mix, and a target of 2.5% should be used. The A-C Couplet mix has a Prall value of 15, while the mixes having less than 2.3% crumb rubber did not perform as well in the Prall test. Note that the plastic deformation induced by the Georgia Loaded Wheel Rut tester (rut index) as more coarse rubber was included in the mix. Stability values are much higher when polymer / rubber modified asphalt cement was used. The lab mix with 2.3% coarse crumb rubber performed well as did the 2.5% on the existing A-C Couplet. Therefore this percentage would be recommended for project use.

Next, a series of tests was undertaken using binders in the following sequence:

- no addition of crumb rubber, then
- adding coarse rubber into the mix with polymer-modified asphalt binder, then
- adding terminally blended polymer-modified asphalt and minus #50 mesh crumb rubber.

Table 7 summarizes mix test results using Type V (Superpave) aggregate gradations. This series of test further identified the need to have coarse crumb rubber content of at least 2.0 % by weight of total mix, therefore 2.5% is recommended. In addition, terminally blended fine rubber in the asphalt cement does not seem to lower the Prall results without the coarse rubber particles in the mix.

TABLE 7 Mix Test Results using Type V (Superpave) Gradations

Lab No	03A-1286	04A-2705	04A-2709	04A-2743	04A-2744	05A-0118	05A-0146
Asphalt Cement	PG 58-28	PG 64-28	PG 64-28	PG 58-28 TR (3%)	PG 58-28 TR (7%)	PG 58-28 TR (3%)	PG 64-28 TR (3%)
Design % AC	5.1	6.0	5.9	6.2	5.3	6.0	5.0
% Coarse CR		1.0	0.5			1.0	1.0
% Fine CR							
% Cellulose							
Max SpG	2.531	2.523	2.529	2.512	2.540		
%Void Filled	73	84	82	83	80		
% Voids Total Mix	4	3	3	3	3		
VMA	14.8	18.4	17.2	16.8	15.1		
Stability	(Gyr)	3640	4100	2800	3260		
Flow		29	31	19	20		
Unit Weight	151.0	150.0	151.4	151.7	153.3		
Rut Index	2.6	2.9	2.5	2.1	2.0	4.1	2.3
Prall	20	19.8	22.3	22.9	19.8	21	22
Nordic	12	12	12	12	12	12	6

4.5- Prall Abrasion Tests

It was decided that the mix which would have the best performance in this study would be used in an actual paving project, the Abbott Loop Extension project. The project, later renamed Elmore Road, required a "quiet" pavement. Arizona's Open Graded Friction Course (OGFC) was duplicated and tested in the laboratory with local Alaskan materials. Arizona's mix performance was similar to that of other mixes, however when local materials were used, it performed poorly in the Prall test. Therefore a finer PlusRide mix (- 3/8-in grading) was evaluated and found to perform satisfactorily. It is labeled OGFC in the project specifications (Appendix B) and bid tab (Appendix C). Table 8 summarizes these test results.

TABLE 8 Test Results and Mix Properties for OGFC Mixes

Lab No	04A-0174	04A-0309	05A-0241	05A-0318	05A-0318
Asphalt Cement	AZ PG 58-22 TR (23.5%)	PG 64-28 TR (10%)	PG 58-28 TR (8%)	PG 70-28 TR (3%)	PG 70-28 TR (3%)
Design % AC	7.0	7.8		9.0	9.0
% Coarse CR		1		2.5	2.5
% Fine CR					
% Cellulose					
Max SpG	2.568	2.408		2.327	
%Void Filled	7.4	78		84	
% Voids Total Mix		4.5		4	
VMA		20.5		27.3	
Stability		1990		1320	
Flow		30		27	
Unit Weight	149.0	143.2		138.4	
Rut Index	2.3	5.0		2.6	2.6
Prall	20.3	6.2	32	11	10.6
Nordic	24.9	12	12	12	8
	AZ grad.	Mushy Mix, AZ grad	Poor Prall, AZ grad.	Fine + Ride, Local Aggr	Fine + Ride, Hard Aggr

The mix void structure had to be designed to about 2.5% to 3% to resist abrasion as measured by the Prall test. In mix calculations, the amount of coarse crumb rubber was considered to be part of the void structure since it was compressible (asphalt cement and aggregates are not). The addition of crumb rubber increases the asphalt content of the mix when designing for a specific air voids content (i.e. voids in total mix). The addition of coarse crumb rubber up to 1.5% by weight of total mix does not lower the Prall test results nor does it create rebound after compaction of mix samples. At 3% air voids and higher percentages of crumb rubber by weight of mix, the mix is very elastic during compaction. It tends to expand and is difficult to keep its compacted density after extrusion from the Marshall mold. Therefore a 2.5% coarse crumb rubber by weight of total mix was an adequate target in a mix design and is considered at the verge of creating an elastic mix.

The last two columns of Table 8 demonstrate that the use of hard aggregate does not improve the Prall value if adequate coarse rubber particles are in the mix. Prall abrasion testing of PlusRide gradation aggregates from a local source (Nordic Abrasion = 12) and hard source (N.A. = 8), did not show a significant difference in the abrasion value. Therefore it was decided not to include hard aggregates in the RHMA placed at Elmore Road. In Table 8, the mix described in the column before last (labeled 05A-0318) will be used to provide a "quiet" pavement similar to the noise levels that Arizona has been achieving with their –3/8-in open graded friction course (OGFC) mixes.

5- COST IMPLICATIONS

The initial cost of asphalt mixes containing either hard aggregates or crumb rubber is typically higher than that of conventional mixes. However, based on life-cycle cost analyses, the annualized cost of these special mixes are less than those of conventional mixes.

Tudor Road in Anchorage was resurfaced with hot-mix asphalt (HMA) that used "hard" and local aggregates in the eastbound and westbound lanes, respectively. Appendix C shows HMA bid prices for this project. The bid prices for HMA using local aggregates ranged from \$53 to \$66/ton. For the hard aggregate HMA, the bid prices ranged from \$79 to \$113/ton (i.e. 60% higher than that of local aggregates) on a project costing \$8.4 million. The price of the polymer modified asphalt cement, PG 64-28, is included in these bid prices. Based on this bid, the use of hard aggregates is expected to increase a project's cost by 15% (\$1.26 million) while increasing pavement life's by about 300%. This is estimated to be a saving of \$16 millions of future pavement rehabilitation costs and motorists costs incurred due to construction.

Similarly, the use of the PlusRide rubberized pavement is summarized in research reports included in the References section of this report. In the 1980's, the rubberized mix cost was 50% to 60% higher than that of conventional HMA, however its use increased pavement life by about 300%. In this system, dry rubber was added to hot dried aggregate and unmodified asphalt cement.

In the Elmore Road bid (Appendix C), Superpave designed RHMA with PG 64-28 (polymer modified asphalt cement) would have cost \$62.00/ton, using the same aggregate, 3% crumb rubber, and terminally blended asphalt cement with polymer and rubber (PG70-34 TR). All was bid at \$105.50/ ton of mix (i.e. 70% higher). In this project's case, the asphalt surface cost was 4% of the total project cost. This RHMA mix is expected to yield the same increased pavement life as the PlusRide mix placed on the A-C Couplet in 1986.

6- PAVEMENT PERFORMANCE

In the summer of 2007, a portion of Anchorage's Elmore Road (also known as Abbott Loop Extension) received a new pavement where the surface course consisted of the RHMA developed during this research study. About 14,000 tons of RHMA were placed on the 3-miles long portion. About 1.8 miles consisted of a two-lane roadway (Abbott Road to 64th Avenue), where a 3-in RHMA surface course was placed, and the rest (64th Avenue to Tudor Road) was a four-lane roadway where the surface course consisted of a 2-in RHMA over asphalt-treated base. After the construction of a RHMA field test strip, revisions were made and it was decided to use 6.9% asphalt binder and 2.0% granulated crumb rubber in the mix.

The pavement condition was annually surveyed using a Road Surface Profiler (RSP) operated by the ADOT&PF's Central Region Materials section. The RSP collects pavement roughness/smoothness data (reported as International Roughness Index, IRI) and pavement surface deformation data (reported as rut depth).

Of particular interest to the Elmore Road RHMA pavement performance are the rut depth measurements. Table 9 summarizes the RSP-measured average rut depths for the 3-mile Elmore Road RHMA pavement.

TABLE 9 Elmore Road RHMA Pavement Average Rut Depths

Survey Date	Average Rut Depth, in (mm)
July 2008	0.050 (1.3)
May 2009	0.070 (1.8)
Oct. 2009	0.076 (1.9)
May 2010	0.110 (2.7)

Figure 6 shows the rut depth accumulation with time for the Elmore Road RHMA pavement (referred to as Type R). In addition, the figure includes, for comparative purposes, Anchorage-area pavement rutting performance of:

- A-C couplet PlusRide mix,
- Tudor Road "local aggregate" conventional HMA, and
- Tudor Road "hard aggregate" HMA.

For the Elmore Road data, a regression line through the four data points yields the following equation:

$$\text{Average rut depth} = 0.0372 * \text{Age (years)} + 0.0114 \quad ; \quad (R^2 = 0.93)$$

According to this relationship, it is expected that the average rut depth of the Elmore Road RHMA pavement will reach the threshold level of 0.5-in in about 13 years after construction (i.e. in 2020). In comparison, it is projected (Figure 6) that Tudor Road conventional pavements, built with local (westbound) and hard (eastbound) aggregate HMA, will reach an average rut depth of 0.5-in in about 7 and 10 years, respectively.

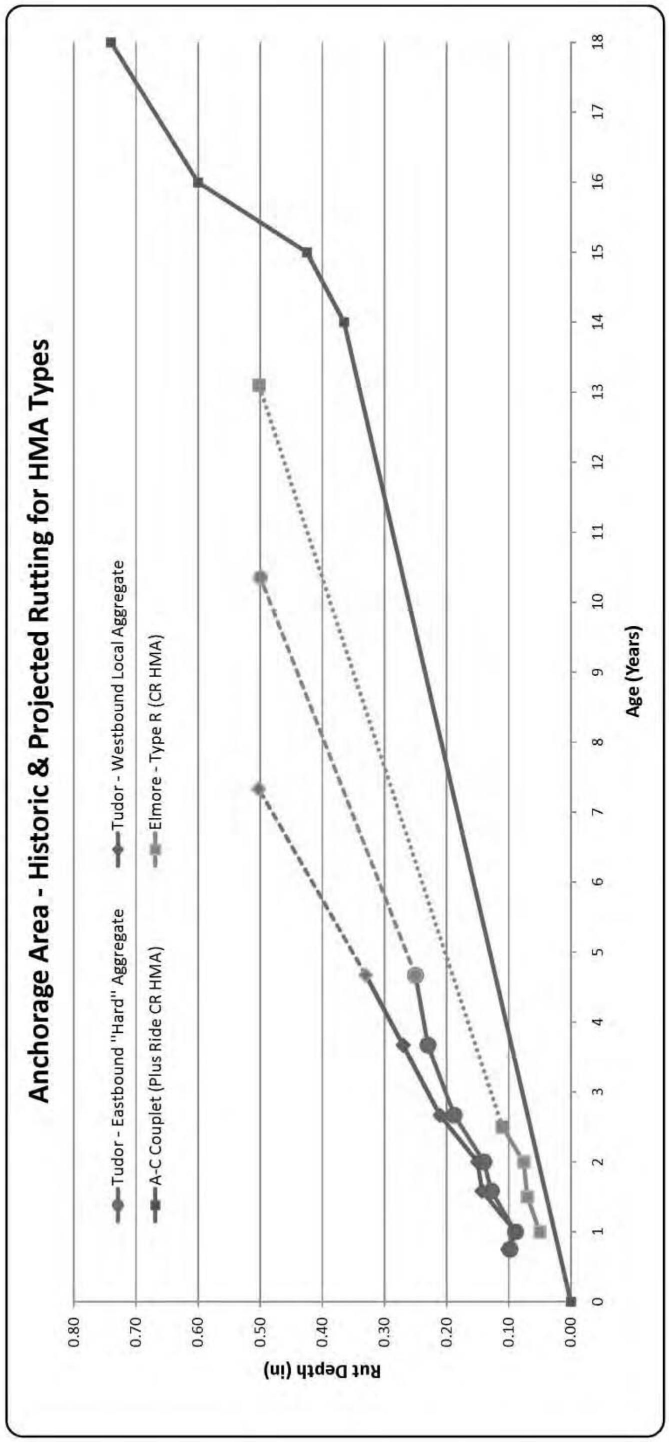


FIGURE 6 Comparison of average rut depth accumulation with time.

7- SUMMARY AND CONCLUSIONS

According to the ADOT&PF PMS data, the PlusRide rubber-modified hot-mix asphalt (RHMA) pavement placed at the A-C couplet in Anchorage in 1986 has outperformed conventional hot-mix asphalt pavements in terms of studded-tire wear and plastic deformation. The crumb rubber consisted of granulated recycled tire rubber.

This research aimed at fine tuning the A-C couplet RHMA design through laboratory testing of trial mixes comprising of different aggregate gradations, hardness, granulated crumb rubber contents and polymer-modified asphalts. The Marshall method was used to design these mixes. The Prall abrasion device and loaded wheel rut tester were used to simulate mix studded tire wear and plastic deformation, respectively. An optimal RHMA was developed during this laboratory phase of the study.

In 2007, Anchorage's Elmore Road project received a new pavement consisting of a RHMA surface course. About 14,000 tons of RHMA were placed on the 3-mile long roadway using new RHMA construction specifications (Appendix B). The RHMA produced (referred to Type V-R) consisted of adding granulated crumb rubber into the mixing chamber of the hot asphalt plant with hot aggregate and polymer modified asphalt binder. The following ingredients were used:

- Local crushed aggregate: gradation shown in Table 3; Nordic abrasion value = 12; 99% double fractured face; 7% flat-elongated particles (1:3),
- Polymer-modified binder: PG 64-34, 6.9% by mix weight, and
- Granulated crumb rubber: 2% by weight of mix, [- 1/4" x #10, i.e. 2 - 6mm].

In subsequent years, using a road surface profiler, pavement condition surveys were carried out at the Elmore Road RHMA project. Rut depth measurements revealed that rutting at Elmore Road is less than that of conventional HMA mixes, such as the ones placed at Tudor Road, using local (westbound) and hard (eastbound) aggregate mixes. It is projected that the average rut depth at Elmore Road will reach 0.5-in in about 13 years, compared to about 7 and 10 years at the Tudor Road local and hard aggregate mixes, respectively.

Despite its higher initial cost (Appendix C), it is expected that roadways paved with RHMA will have a lower life cycle cost than those paved with conventional HMA. It is anticipated that RHMA will be used in several future paving projects in the Central Region of ADOT&PF.

8- REFERENCES

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APPENDIX A: DSR Results

The following test results are included to illustrate the effect of specimen plate gap on the Dynamic Shear Rheometer (DSR) test results. This was done as part of the Pacific Coast Asphalt User Producer Group round robin testing. The DSR testing in the current study, described in this report, was performed with the 1mm gap specified for PG testing.

All tests run at 64°C.

Sample	%Strain	3 mm G*	3 mm Delta	3 mm G*/sinδ	1 mm G*	1 mm Delta	1 mm G*/sinδ
F	12.27	6.83	65.6	7.50	7.80	56.1	9.40
C	12.29	13.34	65.5	14.65	19.02	47.9	25.62
D	12.26	6.73	65.3	7.41	8.31	55.5	10.09
B	12.26	14.22	65.1	15.68	17.23	54.3	21.23
I	11.99	1.13	79.3	1.15	1.24	80.0	1.26
G	11.95	1.21	79.3	1.24	1.21	80.2	1.23
H	12.02	1.09	79.6	1.11	1.20	80.2	1.22
A	12.29	14.57	65.0	16.07	18.56	51.7	23.66
E	12.26	6.74	64.6	7.46	8.22	57.3	9.77

% Rubber by Mass retained on #50 Sieve

Sample	% Rubber
A	13.6
B	15.6
C	14.7
D	12.9
E	12.8
F	13.0
G	3.0
H	2.9
I	2.4

The sizes of the particles in the rubber asphalt from US Oil is estimated to be between the #16 and #30 on samples A thru F. Samples G,H & I is estimated to be between #30 and #50.

APPENDIX B: Specifications

SECTION 409

RUBBERIZED ASPHALT CONCRETE PAVEMENT

409-1.01 DESCRIPTION. Construct one or more layers of plant-mixed hot rubberized asphalt concrete pavement on an approved surface, to the lines, grades, and depths shown on the Plans.

MATERIALS

409-2.01 COMPOSITION OF MIXTURE - JOB MIX DESIGN. Meet the requirements of Table 409-1 for the Job Mix Design performed in accordance with ATM 417.

TABLE 409-1
ASPHALT CONCRETE MIX DESIGN REQUIREMENTS

DESIGN PARAMETERS	
Voids in Total Mix, %	2.0 – 4.0
Compaction, number of blows each side of test specimen	50
Voids in Mineral Aggregate, % min.	
Type V-R	18.0
Type R-OGFC	18.0
Stability, pounds	900 min
Rut Index	5 max
Asphalt Content, Min. percent	6.0
Stabilizing Additive, % total mix weight	0.15

The approved Job Mix Design will specify the target values for gradation, the target value for asphalt cement content, the Maximum Specific Gravity (MSG) of the mix, the additives, and the allowable mixing temperature range.

Target values for gradation in the Job Mix Design must be within the broad band limits shown in Subsection 409-2.02 for the type of asphalt concrete pavement specified but asphalt concrete mixture will have the full tolerances in Table 409-2 applied for evaluation in accordance with 409-4.03 except the tolerances for the largest sieve specified will be plus 0% and minus 1%, and the #200 sieve is limited by the broad band limits.

Do not produce asphalt concrete mixture for payment until the Engineer approves the Job Mix Design. Do not mix asphalt concrete mixtures produced from different plants.

Submit the following to the Engineer at least 15 days before the production of asphalt concrete mixture:

1. A letter stating the location, size, and type of mixing plant, the proposed gradation for the Job Mix Design, gradations for individual stockpiles with supporting process quality control information, and the blend ratio of each aggregate stockpile. The proposed gradation must meet the aggregate requirements for each type of asphalt concrete pavement specified in the Contract.

2. Representative samples of each aggregate (coarse and/or intermediate, fine, and natural blend material) in the proportions required for the proposed mix design. Furnish a total of 500 pounds of material.

3. Five separate 1-gallon samples of the asphalt cement proposed for use in the mixture. Include name of product, manufacturer, test results of the applicable quality requirements of Subsection 702-2.01, manufacturer's certificate of compliance per Subsection 106-1.05, a temperature viscosity curve for the asphalt cement or manufacturer's recommended mixing and compaction temperatures, and current Material Safety Data Sheet.

4. One sample, of at least 1/2 pint, of the anti-strip additive proposed, including name of product, manufacturer, and manufacturer's data sheet, and current Material Safety Data Sheet.

5. Samples of rubber (20 pounds) proposed for use with a manufacturer’s certification of composition.

6. Samples of stabilizing additive (5 pounds) proposed for use with a manufactures certifications of composition

The Engineer will then evaluate the material and the proposed gradation using ATM 417 and the requirements of Table 409-1 for the appropriate type of asphalt concrete pavement specified and establish the approved Job Mix Design, which will become a part of the Contract.

The Engineer will assess a fee of $2,500.00 under Item 409(6), Asphalt Price Adjustment, for each mix design subsequent to the approved Job Mix Design for each Type and Class of Asphalt Concrete Pavement specified.

No payment for asphalt concrete pavement for which a new Job Mix Design is required, will be made until the new Job Mix Design is approved. Approved changes apply only to asphalt concrete mixture produced after the submittal of the changes.

Changes. Failure to achieve results conforming to Table 409-1 or changes in the source of asphalt cement, source of aggregates, aggregate quality, aggregate gradation, or blend ratio, will require a new Job Mix Design. Submit changes and new samples in the same manner as the original submittal.

409-2.02 AGGREGATES.
Use a minimum of three stockpiles for crushed asphalt concrete aggregate (coarse, intermediate, and fine). Place blend material in a separate pile.

Coarse Aggregate (retained on the No. 4 sieve). Crushed stone or crushed gravel consisting of sound, tough, durable rock of uniform quality. Remove all natural fines passing a #4 sieve before crushing aggregates. Free from clay balls, organic matter, and other deleterious material. Not coated with dirt or other finely divided mineral matter. Meet the following requirements:

	I	Type V-R	Type OGFC
LA Wear, % max	**AASHTO T 96**	**45**	**45**
Degradation Value, min	**ATM 313**	**30**	**30**
Sodium Sulfate Loss % max (5 cycles)	**AASHTO T 104**	**9**	**9**
Fracture, min %	**WAQTC FOP for AASHTO TP61**	**98, 2-face**	**98, 2-face**
Flat-Elongated Pieces, max % **1:5** **1:3**	**ATM 306**	 **3** **8**	 **3** **8**
Nordic Abrasion, max.%	**ATM 312**	**12**	**12**
Absorption, max. %	**AASHTO T85**	**2.0**	**2.0**

BROAD BAND GRADATIONS FOR ASPHALT CONCRETE PAVEMENT AGGREGATE

Percent Passing by Weight

Sieve	Type V-R	TYPE OGFC
1 inch	100	
¾ inch	90-100	
½ inch	65-75	
3/8 inch	48-60	100
1/4 inch		54-64
No. 4	30-40	40-46
No. 8	20-30	22-28
No. 16	≤ 22	15-23
No. 30	≤ 17	12-18
No. 50	≤ 14	9-15
No. 100	≤ 12	7-13
No. 200	3-8	6- 10

Note: The JMF gradation must provide a minimum of 10 percent difference of percent passing the ¼ inch and the No. 8 sieve. No tolerance is allowed beyond the Broad Band limits of the #200 sieve.

Fine Aggregate (passing the #4 sieve). Remove all natural fines passing a #4 sieve before crushing aggregates for this asphalt concrete mixture. Consist entirely of aggregate produced from aggregate crushing process and be non-plastic as determined by WAQTC FOP for AASHTO T 90. Meet the quality requirements of AASHTO M 29, including S1.1, Sulfate Soundness and Type V-R shall meet the following:

Property	**Test Method**	**Requirement**
Fine Aggregate Angularity	AASHTO T 304	45% min.

409-2.03 ASPHALT CEMENT. Meet AASHTO M 320, PG 70-34 and the following requirements:

ASTM D5801	Toughness, min,	110 in-lbs
	Tenacity, min	75 in-lbs

Contain 3% min. granulated rubber from ambient ground tires, sized to minus 50 mesh, and meet the properties specified in 409-2.05 except gradation.

Provide test reports for each batch of asphalt cement showing conformance to the specifications in prior to delivery to the project. Document the storage tanks used for each batch on the test report, the anti-strip additives required by the mix design be added during load out for delivery to the project, and a printed weight ticket for anti-strip is included with the asphalt cement weight ticket. The location where anti-strip is added may be changed with the written approval of the Engineer.

Furnish the following documents at delivery:

1. Manufacturer's certificate of compliance (106-1.05).
2. Conformance test reports for the batch.
3. Certificate of analysis of rubber from rubber supplier noting sieve and chemical analysis. rubber source, and moisture content
4. Batch number and storage tanks used.
5. Date and time of load out for delivery.
6. Type, grade, temperature, and quantity of asphalt cement loaded.
7. Type and percent of anti-strip added.

409-2.04 ANTI-STRIP ADDITIVES. Use anti-strip agents in the proportions determined by ATM 414 and included in the approved Job Mix Design. At least 70% of the aggregate must remain coated when tested according to ATM 414. A minimum of 0.25 percent of weight of asphalt cement is required.

409-2.05 GRANULATED TIRE RUBBER. The granulated rubber shall be produced from ambient ground whole passenger or truck tires (heavy equipment tires shall not be used). The ground rubber shall be free of wire and cord, free flowing. Calcium carbonate or talc (meeting
ASTM M 17) may be added, up to a maximum of 4% by weigh, to maintain the free flowing condition of the rubber. Add rubber during the mixing process in the asphalt plant. Meet the following gradation requirements.

Sieve Size	Percent Passing
1/4 inch	100
No. 4	80-95
No. 8	25-45
No. 16	0-4

The chemical Analysis shall meet the following limits:

Natural Rubber	15-30%
Carbon Black	25-38%
Ash	8% max
Acetone Extract	10-18%

The specific gravity shall be 1.15 $\pm$ 0.05
The moisture content shall be less than 0.75%
Rubber shall contain no metal particles, less than 0.5% fiber, mineral contaminates less than 0.25%,
Estimated addition rate is 2 – 4% of total mix weight as determined by Engineer.

409-2.06 STABILIZING ADDITIVE. Use cellulose stabilizing additives at a dosage rate of 0.15 percent by weight of the total mix. The allowable tolerance per ton shall not exceed 10 percent of the required weight of the stabilizing additive.

The cellulose stabilizing additive shall conform to the properties shown in Table 407-2.

TABLE 407-2
CELLULOSE STABILIZING ADDITIVE

Property	Requirement
Sieve Analysis:	
Method A - Alpine Sieve Analysis[1]:	
Fiber Length	0.25 in.(max)
Percent passing 0.150 mm sieve	60-80
Method B - Mesh Screen Analysis[2]:	
Fiber Length	0.035-0.060 in (avg)
Percent passing No. 20 sieve	75-95
Percent passing No. 40 sieve	55-75
Percent passing No. 140 sieve	10-30
Ash Content[3]	20% non-volatiles (max)
pH[4]	7.5 +/-1.0
Oil Absorption[5]	5.0 +/-1.0 times fiber weight
Moisture Content[6]	< 5%
Bulk Density[7]	1.25-2.50 lbs/ft^3

Notes:

(1) Method A - Alpine Sieve Analysis. This test is performed using an Alpine Air Jet Sieve (Type 200 LS). A representative five gram sample of fiber is sieved for 14 minutes at a controlled vacuum of 22 inches (+/- 3 inches) of water. The portion remaining on the screen is weighed.

(2) Method B - Mesh Screen Analysis. This test is performed using No. 20, 40,60,80,100, and 140 sieves, nylon brushes and a shaker. A representative 10 gram sample of fiber is sieved, using a shaker and two nylon brushes on each screen. The amount retained on each sieve is weighed and the percentage passing calculated.

(3) Ash Content. A representative 2-3 gram sample of fiber is placed in a tared crucible and heated between 593 and 649 C for not less than two hours. The crucible and ash are cooled in a desiccator and reweighed.

(4) pH Test. Five grams of fiber is added to 100 ml of distilled water, stirred and let sit for 30 minutes. The pH is determined with a probe calibrated with pH 7.0 buffer.

(5) Oil Absorption Test. Five grams of fiber is accurately weighed and suspended in an excess of mineral spirits for not less than five minutes to ensure total saturation. It is then placed in a screen mesh strainer (approximately 0.5 square millimeter hole size) and shaken on a wrist action shaker for ten minutes (approximately 1.25 inch motion at 240 shakes/minute). The shaken mass is then transferred without touching, to a tared container and weighed. Results are reported as the amount (number of times its own weight) the fibers are able to absorb.

(6) Moisture Content. Ten grams of fiber is weighed and placed in a 121 C forced air oven for two hours. The sample is then reweighed immediately upon removal from the oven.

(7) Bulk Density. Fluff fiber with air or Hobart Mixer, weigh out 25 grams of fiber, place in 100 ml cylinder, tap cylinder and measure volume.

409-2.06 PROCESS QUALITY CONTROL. Sample and test materials for quality control of the asphalt concrete mixture according to Subsection 106-1.03. Provide copies of these test results to the Engineer within 24 hours.

Failure to perform quality control forfeits your right to a retest under Subsection 409-4.02.

Submit a paving and plant control plan at the pre-paving meeting to be held a minimum of 5 working days before initiating paving operations. Address the sequence of operations and joint construction. Outline steps to assure product consistency, to minimize segregation, and to prevent premature cooling of the asphalt concrete mixture. Include a proposed quality control testing frequency for gradation, asphalt cement content, and compaction.

CONSTRUCTION REQUIREMENTS

409-3.01 WEATHER LIMITATIONS. Do not place the asphalt concrete mixture on a wet surface, on an unstable/yielding roadbed, when the base material is frozen, or when weather conditions prevent proper handling or compaction of the mix. Do not place asphalt concrete mixture unless the roadway surface temperature is at least 50° F for Type V-R and 60 °F for Type OGFC. Stop placement of OGFC when the ambient temperature falls below 65°F. Place mix only between June 1 – July 31.

409-3.02 EQUIPMENT, GENERAL. Use equipment in good working order and free of asphalt concrete mixture buildup. Make all equipment available for inspection and demonstration of operation a minimum of 24 hours before placement of asphalt concrete mixture.

409-3.03 ASPHALT MIXING PLANT. Meet AASHTO M 156. Use an asphalt plant designed to dry aggregates, maintain accurate temperature control, and accurately proportion asphalt cement and aggregates. Calibrate the asphalt plant and furnish copies of the calibration data to the Engineer at least 4 hours before asphalt concrete mixture production.

Provide a scalping screen at the asphalt plant to prevent oversize material or debris from being incorporated into the asphalt concrete mixture.
Provide a tap on the asphalt cement supply line just before it enters the plant (after the 3-way valve) for sampling asphalt cement.

Provide systems to uniformly blend in cellulose and granulated rubber into the mix.

409-3.04 HAULING EQUIPMENT. Haul asphalt mixtures in trucks with tight, clean, smooth metal beds, thinly coated with a minimum amount of paraffin oil, lime water solution, or an approved manufactured asphalt release agent. Do not use petroleum fuel as an asphalt release agent.

Cover the asphalt concrete mixture in the hauling vehicle, when directed.

409-3.05 ASPHALT PAVERS. Use self-propelled pavers equipped with a heated vibratory screed. Control grade and cross slope with automatic grade and slope control devices. Use a 30-foot minimum ski, or other approved grade follower, to automatically actuate the paver screed control system. Use grade control on either (a) both the high and low sides or (b) grade control on the high side and slope control on the low side.

Use a screed assembly that produces a finished surface of the required smoothness, thickness and texture without tearing, shoving or displacing the asphalt concrete mixture. Heat and vibrate screed extensions. Place auger extensions within 20 inches of the screed extensions or per written manufacturer’s recommendations.

Equip the paver with a means of preventing the segregation of the coarse aggregate particles from the remainder of the bituminous plant mix when that mix is carried from the paver hopper back to the paver augers. The means and methods used shall be approved by the paver manufacturer and may consist of chain curtains, deflector plates, or other such devices and any combination of these.

The following specific requirements apply to the identified bituminous pavers:

(1) Blaw-Knox bituminous pavers shall be equipped with the Blaw-Knox Materials Management Kit (MMK).
(2) Cedarapids bituminous pavers must have been manufactured in 1989 or later.
(3) Caterpillar bituminous pavers shall be equipped with deflector plates as identified in the December 2000 Service Magazine – entitled: New Asphalt Deflector Kit {6630, 6631, 6640}.

The Contractor shall supply a Certificate of Compliance that verifies the required means and methods used to prevent bituminous paver segregation have been implemented.

The Engineer shall approve all means and methods used to prevent bituminous paver segregation before the bituminous paver is used to place bituminous plant mix on the project.

The use of a “Layton Box” or equivalent towed paver is allowed on bike paths, sidewalks, and driveways.

409-3.06 ROLLERS. Use both steel-wheel (static or vibratory) rollers, pneumatic rollers are not recommended. Operate rollers according to manufacturer's instructions. Avoid crushing or fracturing of aggregate. Use rollers designed to compact hot asphalt concrete mixtures and reverse without backlash. Release agent may be required on the drum to prevent adhesion of the mix.

409-3.07 PREPARATION OF EXISTING SURFACE. Prepare existing surfaces in conformance with the Plans and Specifications. Prior to applying tack coat to the existing surface, clean out loose material from cracks in existing pavement wider than 1 inch in width full depth then fill using asphalt concrete tamp in place. Clean, wash, and sweep existing paved surfaces of loose material.
Preparation of a milled surface,

- Prelevel remaining ruts, pavement delaminations, or depressions having a depth greater than ½-inch with Asphalt Concrete, Type IV. No density testing is required for the leveling course material. The Engineer will inspect and accept this material.

- If planning breaks through existing pavement remove 2 inches of existing base and fill with Asphalt Concrete, Type II, Class B. Notify the Engineer of pavement areas that might be considered thin or unstable during pavement removal.

Existing surface must be approved by the Engineer before applying tack coat.

Prior to placing the asphalt concrete mixture, uniformly coat contact surfaces of curbing, gutters, sawcut pavement, cold joints, manholes, and other structures with tack coat material meeting Section 402.

Allow emulsion tack coat to break before placement of asphalt concrete mixture on these surfaces.

409-3.08 PREPARATION OF ASPHALT. Provide a continuous supply of asphalt cement to the asphalt mixing plant at a uniform temperature, within the allowable mixing temperature range.

409-3.09 PREPARATION OF AGGREGATES. Dry the aggregate so the moisture content of the asphalt concrete mixture, sampled at the point of acceptance for asphalt cement content, does not exceed 0.5% (by total weight of mix), as determined by WAQTC TM 6.

Heat the aggregate for the asphalt concrete mixture to a temperature specified in the mix design.

Adjust the burner on the dryer to avoid damage to the aggregate and to prevent the presence of unburned fuel on the aggregate. Asphalt concrete mixture containing soot or fuel is considered unacceptable per Subsection 105-1.11.

409-3.10 MIXING. Combine the aggregate, asphalt cement, rubber, and additives in the mixer in the amounts required by the Job Mix Design. Mix to obtain 98% coated particles when tested according to AASHTO T 195.

For batch plants, put the dry aggregate in motion before addition of asphalt cement.

Mix discharge temperature at the plant shall be between 320° - 350° F

409-3.11 TEMPORARY STORAGE. Silo type storage bins may be used, provided that the characteristics of the asphalt concrete mixture are not altered. Signs of visible segregation, heat loss, changes from the Job Mix Design, change in the characteristics of asphalt cement, lumpiness, or stiffness of the mixture are causes for rejection.

409-3.12 PLACING AND SPREADING. Place the asphalt concrete mixture upon the approved surface, spread, strike off, and adjust surface irregularities. Use asphalt pavers to distribute asphalt concrete mixture, including leveling courses. The maximum compacted lift thickness allowed is 3 inches.

Use hand tools to spread, rake, and lute the asphalt concrete mixture in areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impracticable.

When the section of roadway being paved is open to traffic, pave adjacent traffic lanes to the same elevation within 24 hours. Place approved material against the outside pavement edge when the drop-off exceeds 2 inches.

When multiple lifts are specified in the Contract, do not place the final lift until all lower lifts throughout that section, as defined by the Paving Plan, are placed and accepted.

Do not pave against new Portland concrete curbing until it has cured for at least 72 hours.

Place asphalt concrete mixture over bridge deck membranes according to Section 508 and the manufacturer's specifications.

Mix temperature behind the screed must be not less than 300°F

409-3.13 COMPACTION. Thoroughly and uniformly compact the asphalt concrete mixture by rolling.

During placement of asphalt concrete the Engineer may evaluate the HMA immediately behind the paver for cyclic low density using an infrared camera. If there is a temperature differential that exceeds 25° F within the newly placed mat, low density is likely to occur. The real time thermal images and thermal profile data will become part of the project records shared with the Contractor. The Contractor shall immediately adjust his laydown procedures to correct the problem. If the Engineer observes areas in any pay sublot where the thermal images indicate cyclic low density is probable, he will order those areas to be cored for determination of density. These cores will be evaluated under Subsection 409-4.06.

The target value for density is 97% of the maximum specific gravity (MSG), as determined by WAQTC FOP for AASHTO T 209. For the first lot of each type of asphalt concrete pavement, the MSG will be determined by the Job Mix Design. For additional lots, the MSG will be determined by the sample from the first sublot of each lot.

Acceptance testing for density will be performed in accordance with WAQTC FOP for AASHTO T 166/T 275 using a 6-inch diameter core. (Acceptance testing for density of leveling course or temporary pavement is not required.)

Do not leave rollers or other equipment standing on pavement that has not cooled sufficiently to prevent indentation.

Continue rolling the mat until the temperature drops below 140° F.

409-3.14 JOINTS. Minimize the number of joints to ensure a continuous bond, texture, and smoothness between adjacent sections of the pavement.

Remove to full depth improperly formed joints resulting in surface irregularities. Replace with new, and thoroughly compact.

Precut all pavement removal to a neat line with a power saw or by other approved method.

Form transverse joints by saw-cutting back on the previous run to expose the full depth of the course or use a removable bulkhead. Skew transverse joints between 15-25 degrees.

Offset the longitudinal joints in one layer from the joint in the layer immediately below by at least 6 inches. Align the joints of the top layer at the centerline or lane lines. Where preformed marking tape striping is required, offset the longitudinal joint in the top layer not more than 6 inches from the edge of the stripe.

Seal the vertical edge of all longitudinal joints with Crafco 34524 Joint Adhesive or approved equal before paving against it. Apply a 1/8 inch thick band of joint adhesive over the surface according to manufacturer's recommendations.

For the top layer of asphalt concrete pavement, the minimum specification limit for longitudinal joint density is 91% of the MSG of the panel completing the joint. Cut one 6 inch diameter core centered on the longitudinal joint at each location the panel completing the joint is cored for acceptance density testing. Density will be determined in accordance with WAQTC FOP for AASHTO T 166/T 275.

Seal the pavement surface 12 inches on each side of all the longitudinal joints while the pavement is clean, free of moisture, and before traffic marking with GSB-78 (from Asphalt Systems), or approved equal.

409-3.15 SURFACE TOLERANCE. The Engineer will test the finished surface after final rolling at selected locations using a 16-foot straightedge. Correct variations from the testing edge, between any two contacts of more than 1/4 inch.

(Note to the Designer, delete this portion of the specifications on projects that are remote, low volume, gravel to pave, small urban projects, and ownership transfers, also delete Evaluation of Pavement for Smoothness in 409-4.02)

The Engineer will measure the surface smoothness of the top layer of asphalt concrete pavement in the driving lanes with an inertial profiler before final acceptance of the project. Remove and replace, or grind smooth any area of final pavement surface that.does not meet straight edge tolerances All costs associated with meeting surface tolerances are subsidiary to the Asphalt Concrete pay item.

After completion of corrective work, the Engineer will measure the pavement surface in the driving lanes a second time for a smoothness price adjustment. No measurements will be taken in turn lanes, lane transitions, or within 25 feet of the existing pavement at the project beginning and end.

Smoothness will be measured in both wheel paths of each lane and reported as profilograph results (PrI) filtered with a 0.2 inch blanking band. Report PrI as a job average for all measured lanes, calculated to the nearest 0.1 inch.

409-3.16 PATCHING DEFECTIVE AREAS. Remove any asphalt concrete mixture that becomes contaminated with foreign material, is segregated, or is in any way determined to be defective. Do not skin patch. Remove defective materials for the full thickness of the course. Cut the pavement so that all edges are vertical, the sides are parallel to the direction of traffic and the ends are skewed between 15-25 degrees. Coat edges with a tack coat meeting Section 402 and allow to cure. Place and compact fresh asphalt concrete mixture per Subsection 409-3.13 to grade and smoothness requirements.

All costs associated with patching defective areas are subsidiary to the Asphalt Concrete pay item.

409-4.01 METHOD OF MEASUREMENT. Section 109 and the following:

Asphalt Concrete. By weighing, no deduction will be made for the weight of asphalt cement or anti-stripping additive, or by the area of final pavement surface.

Asphalt Price Adjustment. Calculated by quality level analysis under Subsection 409-4.03.

Asphalt Cement. By the ton, as follows. Method 1 will be used for determining asphalt quantity unless otherwise directed in writing. The procedure initially used will be the one used for the duration of the project. No payment will be made for any asphalt cement more than 0.4% above the optimum asphalt content specified in the Job Mix Design.

1. Percent of asphalt cement for each sublot multiplied by the total weight represented by that sublot. Percent of asphalt cement will be determined by ATM 405 or WAQTC FOP for AASHTO T 308. The same tests used for the acceptance testing of the sublot will be used for computation of the asphalt cement quantity. If no acceptance testing is required, the percent of asphalt cement is the target value for asphalt cement in the Job Mix Design.

2. Supplier's invoices minus waste, diversion and remnant. This procedure may be used on projects where deliveries are made in tankers and the asphalt plant is producing asphalt concrete mixture for one project only.

   The Engineer may direct, at any time that tankers be weighed in the Engineers presence before and after unloading. If the weight determined at the project varies more than 1% from the invoice amount, payment will be based on the weight determined at the project.

   Any remnant or diversion will be calculated based on tank stickings or weighing the remaining asphalt cement. The Engineer will determine the method. The weight of asphalt cement in waste asphalt concrete mixture will be calculated using the target value for asphalt cement as specified in the Job Mix Design.

Temporary Pavement. By weighing. No deduction will be made for the weight of asphalt cement or anti-stripping additive.

Longitudinal Joint. By the lineal foot of longitudinal joint.

409-4.02 ACCEPTANCE SAMPLING AND TESTING. The quantity of each type of asphalt concrete mixture produced and placed will be divided into lots and the lots evaluated individually for acceptance.

A lot will normally be 5,000 tons. The lot will be divided into sublots of 500 tons, each randomly sampled and tested for asphalt cement content, density, and gradation according to this Subsection. If the project has more than 1 lot, and less than 8 additional sublots have been sampled at the time a lot is terminated, either due to completion of paving operations or the end of the construction season (winter shutdown), the material in the shortened lot will be included as part of the prior lot. The price adjustment computed, according to Subsection 409-4.03, for the prior lot will include the samples from the shortened lot.

If 8 or 9 samples have been obtained at the time a lot is terminated, they will be considered as a lot and the price adjustment will be based on the actual number of test results (excluding outliers) in the shortened lot.

If the contract quantity is between 1,500 tons and 4,999 tons, the contract quantity will be considered one lot. The lot will be divided into sublots of 500 tons and randomly sampled for asphalt cement content, density, and gradation according to this Subsection. Hot mix asphalt quantities of less than 300 tons remaining after dividing the lot into sublots will be included in the last sublot, hot mix asphalt quantities of 300 tons or greater will be treated as an individual sublot. The lot will be evaluated for price adjustment according to Subsection 409-4.03 except as noted.

For contract quantity of less than 1,500 tons (and for temporary pavement), hot mix asphalt will be accepted for payment based on the Engineer's approval of a Job Mix Design and the placement and compaction of the hot mix asphalt to the specified depth and finished surface requirements and tolerances. Remove and replace any hot mix asphalt that does not conform to the approved JMD.

Any area of finished surfacing that is visibly segregated, fails to meet surface tolerance requirements is considered unacceptable per Subsection 105-1.11.

1. Asphalt Cement. Samples for the determination of asphalt cement content will be taken from either the windrow in front of the paver, or at the end of the auger, or behind the screed prior to initial compaction. Two separate samples will be taken, one for acceptance testing and one held in reserve for retesting if applicable. At the discretion of the Engineer, asphalt cement content will be determined in accordance with ATM 405 or WAQTC FOP for AASHTO T 308.

2. Asphalt Cement Quality. The Contractor shall sample asphalt cement from the asphalt cement supply line when requested, witnessed by the Engineer's representative. After purging residual asphalt cement, take 3 one-quart samples into wide mouth one-quart metal containers. Asphalt cement will be sampled for acceptance testing in accordance with WAQTC FOP for AASHTO T 40 and tested for conformance to the specifications in Section 702. Three separate samples will be taken, one for acceptance testing, one for Contractor retesting, and one held in reserve for referee testing.

3. Aggregate Gradation.
   a. Drum Mix Plants. Samples taken for the determination of aggregate gradation from drum mix plants will be from the same location as samples for the determination of asphalt cement content. Two separate samples will be taken, one for acceptance testing and one held in reserve for retesting if applicable. The gradation will be determined in accordance with WAQTC FOP for AASHTO T

30 from the aggregate remaining after the ignition oven (WAQTC FOP for AASHTO T 308) has burned off the asphalt cement.

b. Batch Plants. Samples taken for the determination of aggregate gradation from batch plants will be from the same location as samples for the determination of asphalt cement content. Two separate samples will be taken, one for acceptance testing and one held in reserve for retesting if applicable. Dry batched aggregate gradations will be determined in accordance with WAQTC FOP for AASHTO T 27/T 11. For asphalt concrete mixture samples, the aggregate gradation will be determined in accordance with WAQTC FOP for AASHTO T 30 from the aggregate remaining after the ignition oven (WAQTC FOP for AASHTO T 308) has burned off the asphalt cement.

4. Density. Cut full depth core samples from the finished asphalt concrete pavement within 24 hours after final rolling. Neatly cut one 6-inch diameter core sample with a core drill from each sublot at the randomly selected location marked by the Engineer including locations having low cyclic density. An average of the low cyclic density cores shall be used for density evaluation and price adjustment if they are taken. Use a core extractor to prevent damage to the core. The Engineer will determine the density of the core samples in accordance with WAQTC FOP for AASHTO T 166/T 275. Do not core asphalt concrete pavement on bridge decks. Backfill and compact all voids left by coring with new asphalt concrete mixture within 24 hours.

   Failure to cut core samples within the specified period will result in a deduction of $100.00 per sample per day. Failure to backfill voids left by sampling within the specified period will result in a deduction of $100.00 per hole per day. The accrued amount will be subtracted under Item 401(6), Asphalt Price Adjustment.

5. Retesting. A retest of any sample outside the limits specified in Table 409-2 may be requested provided the quality control requirements of 409-2.05 are met. Deliver this request in writing to the Engineer within 7 days of receipt of the initial test result. The Engineer will mark the sample location for the density retest. The original test results for gradation, asphalt cement content, or density will be discarded and the retest result will be used in the price adjustment calculation regardless of whether the retest result gives a higher or lower pay factor. Only one retest per sample is allowed. Except for the first lot, gradation or asphalt cement content retesting of the sample from the first sublot of a lot will include retesting for the MSG.

409-4.03 EVALUATION OF MATERIALS FOR ACCEPTANCE. The following method of price adjustment will be applied to each type of Asphalt Concrete Pavement for which the contract quantity equals or exceeds 1,500 tons, except as specified in Subsection 409-4.02.

Acceptance test results for a lot will be analyzed collectively and statistically by the Quality Level Analysis method as specified in Subsection 106-1.03 to determine the total estimated percent of the lot that is within specification limits. Asphalt cement content results will be reported to the nearest 0.1 percent.

The price adjustment is based on the lower of two pay factors. The first factor is a composite pay factor for asphalt concrete mixture, which includes gradation and asphalt cement content. The second factor is for density.

A lot containing asphalt concrete pavement with less than a 1.00 pay factor will be accepted at an adjusted price, provided the pay factor is at least 0.75 and there are no isolated defects identified by the Engineer. A lot containing asphalt concrete pavement that fails to obtain at least a 0.75 pay factor will be considered unacceptable and rejected under Subsection 105-1.11.

The Engineer will reject asphalt concrete mixture that appears to be defective based on visual inspection. A minimum of two samples will be collected from the rejected mixture and tested if requested. If all test results are within specification limits, payment will be made for the mixture. If any of the test results fail to meet specifications, no payment will be made and the cost of the testing will be subtracted under Item 409(6), Asphalt Price Adjustment. All costs associated with removal and disposal of the rejected asphalt concrete mixture are subsidiary to the Asphalt Concrete pay item.

Outlier Test. Before computing the price adjustment, the validity of the test results will be determined by SP-7, the Standard Practice for Determination of Outlier Test Results. Outlier test results will not be included in the price adjustment calculations. Cyclic low density will not be considered outliers.

If any sieve size on a gradation test or the asphalt cement content is an outlier, then the gradation test results and the asphalt cement content results for that sublot will not be included in the price adjustment. The density test result for that sublot will be included in the price adjustment provided it is not an outlier.

If the density test result is an outlier, the density test result will not be included in the price adjustment, however, the gradation and asphalt cement content results for that sublot will be included provided neither is an outlier.

Quality Level Analysis. Pay factors are computed as follows:

1. Outliers (determined by SP-7), and any test results on material not incorporated into the work, are eliminated from the quality level analysis.

   The arithmetic mean ($\bar{x}$) of the remaining test results is determined: $\bar{x} = \frac{\Sigma x}{n}$

   Where: Σ = summation of
   x = individual test value to x_n
   n = total number of test values

   $\bar{x}$ is rounded to the nearest tenth for density and all sieve sizes except the No. 200 sieve. $\bar{x}$ is rounded to the nearest hundredth for asphalt cement content and the No. 200 sieve.

2. The sample standard deviation(s), after the outliers have been excluded, is computed:

$$s = \sqrt{\frac{n\Sigma(x^2) - (\Sigma x)^2}{n(n-1)}}$$

Where: $\Sigma (x^2)$ = sum of the squares of individual test values.
$(\Sigma x)^2$ = square of the sum of the individual test values.

The sample standard deviation (s) is rounded to the nearest hundredth for density and all sieve sizes except the No. 200 sieve. The sample standard deviation (s) is rounded to the nearest 0.001 for asphalt cement content and the No. 200 sieve.

If the computed sample standard deviation (s) is <0.001, then use s = 0.20 for density and all sieves except the No. 200. Use s = 0.020 for asphalt cement content and the No. 200 sieve.

3. The USL and LSL are computed. For aggregate gradation and asphalt cement content, the Specification Limits (USL and LSL) are equal to the Target Value (TV) plus and minus the allowable tolerances in Table 409-2. The TV is the specification value specified in the approved Job Mix Design. Specification tolerance limits for the largest sieve specified will be plus 0 and minus 1 for Quality Level Analysis purposes. The TV for density is 94% of the maximum specific gravity (MSG), the LSL is 92% of MSG and the USL is 98%.

TABLE 409-2
LOWER SPECIFICATION LIMIT (LSL) & UPPER SPECIFICATION LIMIT (USL)

Measured Characteristics	LSL	USL
1 inch sieve	TV-6.0	TV+6.0
3/4 inch sieve	TV-6.0	TV+6.0
1/2 inch sieve	TV-6.0	TV+6.0
3/8 inch sieve	TV-6.0	TV+6.0
No. 4 sieve	TV-6.0	TV+6.0
No. 8 sieve	TV-5.0	TV+5.0
No. 16 sieve	TV-5.0	TV+5.0
No. 30 sieve	TV-4.0	TV+4.0
No. 50 sieve	TV-4.0	TV+4.0
No. 100 sieve	TV-3.0	TV+3.0
No. 200 sieve[1]	TV-2.0	TV+2.0
Asphalt %	TV-0.4	TV+0.4
Density %	93	100

Note 1.Tolerances of any sieve may not exceed the broad band limits in 409-2.02

4. The Upper Quality Index (Q_U) is computed: $Q_U = \frac{USL - \bar{x}}{s}$

Where: USL = Upper Specification Limit
Q_U is rounded to the nearest hundredth.

5. The Lower Quality Index (Q_L) is computed: $$Q_L = \frac{\bar{x} - LSL}{s}$$

   Where: LSL = Lower Specification Limit
   Q_L is rounded to the nearest hundredth.

6. P_U (percent within the upper specification limit which corresponds to a given Q_U) is determined. See Subsection 106-1.03.

7. P_L (percent within the lower specification limit which corresponds to a given Q_L) is determined. See Subsection 106-1.03.

8. The Quality Level (the total percent within specification limits) is determined for aggregate gradation, asphalt cement content, and density.

   Quality Level = $(P_L + P_U) - 100$

9. Using the Quality Levels from Step 8, the lot Pay Factor is determined for Density (DPF) and gradation and asphalt cement content pay factors (PF) from Table 106-2. The maximum pay factor for the largest sieve size specification for gradation is 1.00.

10. The Composite Pay Factor (CPF) for the lot is determined using the following formula:

$$CPF = \frac{[f_{3/4\ inch}(PF_{3/4\ inch}) + f_{1/2\ inch}(PF_{1/2\ inch}) + \ldots . f_{ac}(PF_{ac})]}{\Sigma f}$$

The CPF is rounded to the nearest hundredth.

Table 401-3 gives the weight factor (f) for each sieve size and asphalt cement content.

TABLE 409-3
WEIGHT FACTORS

Gradation	Factor "f"
3/4 inch sieve	4
1/2 inch sieve	5
3/8 inch sieve	5
No. 4 sieve	4
No. 8 sieve	4
No. 16 sieve	4
No. 30 sieve	5
No. 50 sieve	5

No. 100 sieve	4
No. 200 sieve	20
Asphalt %	40

The price adjustment will be based on either the CPF or DPF, whichever is the lowest value. The price adjustment for each individual lot will be calculated as follows:

Price Adjustment = [(CPF or DPF)* -1.00] x (tons in lot) x (PAB)

* CPF or DPF, whichever is lower.

PAB = Price Adjustment Base = $________ per ton

(DESIGNER TO INSERT ESTIMATED UNIT PRICES OF MIX + 5.5% OF ASPHALT CEMENT)

EVALUATION OF ASPHALT CEMENT

Asphalt cement will be randomly sampled and tested every 200 tons and evaluated for price adjustment. If the last sample increment is 100 tons or less, that quantity of asphalt cement will be added to the quantity represented by the previous sample and the total quantity will be evaluated for price adjustment. If the last sample increment is greater than 100 tons, it will be sampled, tested and evaluated separately. Asphalt cement pay reduction factors for each sample will be determined from Table 409-4.

The total asphalt cement price adjustment is the sum of the individual sample price adjustments and will be subtracted under Item 409(6), Asphalt Price Adjustment.

Table 409-4
ASPHALT CEMENT PAY REDUCTION FACTORS
(Use the single, highest pay reduction factor)

	Spec	**Pay Reduction Factor (PRF)**								
		0	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.1**	**0.25**	**Reject or Engr Eval**
Tests On Original Binder										
Viscosity	<3 Pa-s	≤3		>3						
Dynamic Shear	>1.00 kPa	>1.00		0.99-0.88				0.87-0.71	0.70-0.50	<0.50
Toughness	>110 in-lbs	>93.5	90.0-93.4	85.0-89.9	80.0 - 84.9	75.0 - 79.9	70.0 - 74.9			<70.0
Tenacity	>75 in-lbs	>63.8	61.0-63.7	58.0-60.9	55.0 -	52.0 -	48.0 -			<48.0

					57.9	54.9	51.9			
Tests On RTFO										
Mass Loss	<1.00 %	<1. 00		1.001 - 1.092				1.093 - 1.184	1.185 - 1.276	>1.07 6
Dynamic Shear	>2.20 kPa	>2. 20		2.199 - 1.816				1.815 - 1.432	1.431 - 1.048	<1.04 8
Test On PAV										
Dynamic Shear	<500 0 kPa	<5 000		5001- 5289				5290- 5578	5579- 5867	>586 7
Creep Stiffness, S	<300 MPa	<3 00		301- 338				339- 388	389- 450	>450
Creep Stiffness, m-value	>0.30 0	>0. 300		0.299 - 0.287				0.286 - 0.274	0.273 - 0.261	<0.26 1
Direct Tension	>1.0 %	>1. 0		0.99- 0.86				0.85- 0.71	0.70- 0.56	<0.56

Asphalt Cement Price Adjustment for each sample = 5 x PAB x Qty X PRF
PAB = Price Adjustment Base
Qty = Quantity of asphalt cement represented by asphalt cement sample
PRF = Pay Reduction Factor from Table 409-4

Asphalt Cement Appeal Procedure. Once notified of a failing test result of an asphalt cement sample, the Contractor has 21 days to issue a written appeal. The appeal must be accompanied by all of the Contactor's quality control test results and a test result of Contactor's sample of this lot tested by an AASHTO accredited asphalt laboratory (accredited in the test procedure in question). The Engineer will review these test results and using ASTM D3244 determine a test value upon which to base a price reduction.

If the Contractor challenges this value, then the referee sample held by the Engineer will be sent to a mutually agreed upon independent AASHTO accredited laboratory for testing. This test result will be incorporated into the ASTM D3244 procedure to determine a test value upon which to base a price reduction. If this final value incurs a price adjustment, the Contractor under Item 408(3), Asphalt Price Adjustment, shall pay the cost of testing the referee sample.

The total Asphalt Price Adjustment is the sum of all the price adjustments for each lot.

EVALUATION OF PAVEMENT SMOOTHNESS.
(Note to the Designer, delete this portion of the specifications on projects that are remote, low volume, gravel to pave, and ownership transfers, also in 409-3.15)

The top layer of asphalt concrete pavement will be measured in accordance with 409-3.15 and evaluated for a smoothness price adjustment. The Engineer will calculate the smoothness price adjustment as follows:

Smoothness Price Adjustment = PAB x PQ x SF
PAB = Price Adjustment Base (409-4.03)
PQ = Final quantity of Asphalt Concrete Mixture, tons
PrI = Final measured pavement smoothness, inches/mile
SF = Smoothness Factor

If the PQ is less than 1,500 tons, the SF = 0
If the PQ is 1,500 to 5,000 tons, the SF = 0.1166 – (0.01666 x PrI)
If the PQ is greater than 5,000 tons, the SF = 0.0583 – (0.0083 x PrI)

The smoothness price adjustment will be applied under Item 409(6), Asphalt Price Adjustment.

EVALUATION OF LONGITUDINAL JOINT DENSITY. Longitudinal joint density price adjustments apply when asphalt concrete mixture quantities are equal to or greater than 1,500 tons. An price adjustment will be based on the average of all the joint densities on a project and determined as follows:

1. If project average joint density is less than 91% MSG, apply the following disincentive:

   Deduct = ($1.00 per lineal foot) x (lineal feet of paved joint for the entire project) x (91 % – Project Average Joint Density %) x 100 (Note: convert % to decimals in this equation)

2. If project average joint density is greater than 91% MSG apply the following incentive:

   Add = ($1.00 per lineal foot) x (lineal feet of paved joint for the entire project) x (Project Average Joint Density % – 91%) x 100 (Note: convert % to decimals in this equation)

The longitudinal joint price adjustment will be included in Item 409(6), Asphalt Price Adjustment.

409-5.01 BASIS OF PAYMENT.

Separate payment will not be made for asphalt cement or anti-strip additives for Item 409(3), Temporary Pavement, or asphalt concrete for leveling course.

Asphalt cement, anti-stripping additives, tack coat, and crack sealing (409-3.07) are subsidiary to the asphalt concrete pavement unless specified as pay items.

Price adjustments will not apply to:

1. Asphalt Concrete Mixture for leveling course
2. Temporary Pavement

Payment for furnishing and installing joint adhesive and sealing the pavement adjacent to the joints will be paid as 409(9) Longitudinal Joint Adhesive and Sealing.

Payment will be made under:

Pay Item	Pay Unit
409(1) Asphalt Concrete, Type V-R	Ton
409(2) Asphalt Cement, PG 70-34 TR	Ton
409(3) Asphalt Concrete, Type OGFC	Ton
409(6) Asphalt Price Adjustment	Contingent Sum
409(9) Longitudinal Joint Adhesive and Sealing	Lineal Foot

APPENDIX C: Bid Results

Bid Results

Tudor Rd Resurfacing, Anchorage 4/29/05					
No.	Item	Qty	Bid Low	Bid 2nd	
401(1A)	HMA IIB	2,906 ton	$36.00	$38.00	
401(2)	PG 52-28	175 ton	$290.00	$300.00	
408(1)	HMA V	15,500 ton	$38.00	$31.00	
408(1H)	HMA VH	19,000 ton	$85.00	$57.00	
408(2)	PG 64-28	1,897 ton	$510.00	$400.00	
Total Bid			$8,389,969	$8,518,051	
Abbott Loop Ext. Anchorage 8/2/05					
No.	Item	Qty	Bid Low	Bid 2nd	Bid 3rd
401(1)	HMA IIB	11,305 ton	$40.00	$35.00	$30.00
401(2)	PG 52-28	777 ton	$250.00	$300.00	$325.00
409(1)	HMA V-R	13,680 ton	$60.00	$70.00	$40.00
409(2)	PG70-34TR	1,075 ton	$650.00	$600.00	$325.00
409(3)	OGFC	2,300 ton	$45.00	$100.00	$50.00
Total Bid			$38,417,816	$42,251,130	$46,345,092

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