Ontario Tire Stewardship

Summary of Rubber Modified Asphalt Product Specifications around the World

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Abstract:

This report presents the results of an international survey on the use of rubber modified asphalt product specifications. Agencies surveyed included those in North America, China, and Scandinavia.

Based on the survey responses, there is wide interest in using ground tire rubber in asphalt pavements. The objective of this report is to synthesize the specifications from different regions and to help identify the elements that may help the practices and specifications of Ontario, Canada. The specifications are summarized in the following order:

- Asphalt rubber binder
- Terminal blend rubber binder
- Rubberized hot mix asphalt including gap-graded and open-graded
- Terminal blend hot mix
- Asphalt rubber chip seals
- Asphalt rubber interlayer

The report also includes recommendations to improve the specification for practices in Ontario, Canada.

Keywords: Ground Tire Rubber, Asphalt Rubber, Rubberized Asphalt Concrete, Chip Seals and Interlayers

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Disclaimer

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The content does not necessarily reflect the official views or policies of the Ontario Tire Stewardship (OTS) or the Ministry of Transportation of Ontario (MTO).

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1.0 Introduction

Asphalt rubber was invented by Charles H. MacDonald in 1964 in Phoenix, Arizona. Since then it has been used all over the world. Asphalt rubber has the advantages of an engineering product as well as a sustainable practice because Crumb Rubber Modifiers used in asphalt rubber are made of waste tires.

Agencies that apply rubber modified asphalt pavement follow specifications based on their experiences. The format and extent of the specifications from different agencies may be different from each other, but generally they have the following common sections:

1. *Description:* Define the type of process to be used.

2. *Materials:* List all materials, specifications, test methods, and mix composition to be used (method specification). For end result, performance, and/or warranty specifications, identify who is responsible for these materials usage decisions.

3. *Construction Requirements:* Identify key requirements for weather, surface preparation, equipment, material properties (e.g., moisture content of RAP, mix temperatures) for method specifications. For end result, performance, and warranty specifications, identify who is responsible for these decisions. Information on minimum expectations for materials, workmanship, and performance criteria is also included in this section.

4. *Method of Measurement:* Define the units in which each product or material is to be measured (e.g., liquid RA in gallons, cement slurry in tons, square yards of surface) and how performance criteria are to be measured.

5. *Basis of Payment:* Define payment for accepted quantities and include description of what is included in the units.

Specifications of various rubber modified pavement products have been collected from agencies in different countries. This study will try to compare and summarize the similarity and differences to ensure a successful rubber modified pavement project.

2.0 Objectives

The objectives of the report are to:

- Compare the specifications and practices of using rubber modified asphalt products from several different countries.
- Find suitable products and/or specifications for cold regions such as those encountered in Ontario, Canada.
- Recommend changes to the current specifications used by the MTO.

3.0 Asphalt Rubber Binder Specifications

By definition of ASTM D8, asphaltrubber is a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles [ASTM D8-97]. The ASTM D6114 further defines the detailed requirement on base asphalt cement, ground recycled tire rubber, and three types of asphalt rubber binders. Type I is recommended for use in hot climates; Type II is recommended for use in warm climates; and Type III is recommended for cold regions [ASTM D6114-97(2002)]. The following section summarizes the specifications on the asphalt rubber binder from the agencies surveyed.

3.1 Crumb Rubber

Crumb Rubber Modifier (CRM) is an important component of the asphalt rubber and rubber modified asphalt. The typical specifications for CRM from various agencies are summarized in Table 1. The CRM generally used in terminal blend is much finer than the one used in field blend. For field blended asphalt rubber, Ontario's CRM gradation is finer than in California and Arizona. However, California also uses a high nature rubber and extender oil which Ontario does not use. The asphalt modifier specified by California is a resinous, high flash point, aromatic hydrocarbon compound. Ontario's CRM is also finer than Type A of Arizona, Grade A of Texas, New Jersey, and China. It is similar to Type B of Arizona and Grade B of Texas. but it is coarser than Grade C of Texas and Types A, B, and C of Florida. Finer CRM makes it easier to blend and interact with base asphalt binder. Ontario's CRM is on the medium to fine side. However, it doesn't have a maximum moisture content requirement. Additives such as calcium carbonate are not used in Ontario's specifications.

Table 1. Comparison of CR Specifications from Various Agencies

Agencies	Source	Gradation	Additives	Other Notes
MTO / Ontario Canada (Field Blend)	Passenger vehicle tires only; not devulcanized; ambient or cryogenic ground rubber, or both; shall be dry and free-flowing	#8:2.36 mm (100) #10:2.00 mm (100) #16:1.18 mm (80-100) #30:600 um (40-60) #50:300 um (5-15) #100:150 um (0-10)	No	CRM specific gravity 1.1 to 1.2

Agencies	Source	Gradation	Additives	Other Notes
MTO / Ontario Canada (Terminal Blend)	Passenger vehicle tires only; no uncured; not devulcanized; ambient or cryogenic ground rubber, or both; shall be dry and free-flowing	1.0 mm (100) No particle shall exceed 0.5 mm in any axis. Gradation should be suitable to Type III of ASTM.	No	CRM specific gravity 1.1 to 1.2
California/ Caltrans	Combination of scrap tire and high natural CRM; Ground or granulated rubber at ambient temperatures	The length of the particles should not exceed 4.75 mm; Dry; Scrap Tire Gradation: #8:2.36 mm (100) #10:2.00 mm (98-100) #16:1.18 mm (45-75) #30:600 um (2-20) #50:300 um (0-6) #100:150 um (0-2) #200:75 um (0) High Natural CR Gradation: #8:2.36 mm (100) #10:2.00 mm (100) #16:1.18 mm (95-100) #30:600 um (35-85) #50:300 um (10-30) #100:150 um (0-4) #200:75 um (0-1)	Could add 3% calcium carbonate or talc;	CRM specific gravity 1.1 to 1.2

Agencies	Source	Gradation	Additives	Other Notes
Arizona DOT	Scrap tires or shredded tires from autos, trucks, or other equipment owned in USA	Two gradations. For RHMA-G and RHMA-O, use Type B gradation; #10:2.00 mm (100) #16:1.18 mm (65-100) #30:600 um (20-100) #50:300 um (0-45) #200:75 um (0-5) Not more than 0.5 % fabric. Chip Seals, use Type A gradation: #8:2.36 mm (100) #10:2.00 mm (95-100) #16:1.18 mm (0-10) Not more than 0.1 percent fabric. Minimum 20% by weight of asphalt cement.	Could add calcium carbonate up to 4% by weight of granulated rubber.	CRM specific gravity 1.05± 0.05

Agencies	Source	Gradation	Additives	Other Notes
Texas DOT	Auto or truck tires processed by ambient temperature grinding; free from contaminants; free flowing; and non-foaming when added to hot asphalt binder	Three gradations for asphalt rubber. Grade A: #8: 2.36 mm (100) #10:2.00 mm (95-100) #50:300 um (0-10) Grade B: #10:2.00 mm (100) #16:1.18 mm (70-100) #30:600 um (25-60) #200:75 um (0-5) Grade C: #16:1.18 mm(100) #30: 600 um (90-100) #40: 425 um (45-100) Min 15% by wt of asphalt cement. For HMA use ASTM Types I or II with Grade C. For surface seals, use ASTM Types II or III with Grade B. For SMA, meets Types I or II with Grade B or Grade C.		
Florida DOT	The ground tire rubber is ambient ground at or above ordinary room temperature. The rubber must be sufficiently dry and free from contaminants.	There are three gradations for ground tire rubber: Type A: #50:300 um (100) #100:150 um (50-80) Type B: #30:600 um (100) #50:300 um (40-60) Type C: #16:1.18 mm(100) #30: 600 um (70-100) #50: 300 um (20-40)	Up to 4% by weight of rubber of talc or other inert dusting agent to prevent sticking and caking of rubber particles. Moisture content maximum 0.75%	Acetone Extract: maximum 25% Rubber Hydrocarbon: 40-55% Ash Content: Maximum 8% Carbon Black Content: 20-40% Natural Rubber: 16-45%

Agencies	Source	Gradation	Additives	Other Notes
New Jersey DOT	CRM shall be ambient ground, free of wire or other contaminating materials. Scrap tire or shredded tire from autos, trucks, or other equipment in USA	Crumb Rubber Gradation: #8:2.36 mm (100) #16:1.18 mm (65-100) #30:600 um (20-100) #50:300 um (0-45) #200:75 um (0-5)	Add up to 4% calcium carbonate to prevent the particles from sticking together. Moisture content: maximum 0.75%	
Massachusetts DOT	Granulated rubber from a vulcanized rubber product from ambient temperature processing.	Gradation: #8:2.36 mm (100) #10: 2.00 mm (95-100) #16: - #30:600 um (0-10) #50:300 um (0-5)	Density: 1.15 ± 0.05 g/cm^3 4% calcium carbonate	
Jiangsu Province, China	Free of wire or other contaminating materials. Fiber should be less than 0.5%.	Crumb Rubber Gradation: #10:2.00 mm (100) #16:1.18 mm (65-100) #30:600 um (20-100) #50:300 um (0-45) #200:75 um (0-5)	Density: 1.15 ± 0.05 g/cm^3 4% calcium carbonate	

3.2 Rubberized Asphalt Cement

In Ontario, asphalt rubber is called rubberized asphalt cement. It should be produced as a Type III asphalt rubber binder, according to ASTM 6114, which is suitable for cold regions. Table 2 summarizes the binder and CRM blending temperature and other requirements during the asphalt rubber binder production.

The CRM content of the rubberized asphalt cement used by different agencies is different, but typically follows ASTM asphalt rubber standard of more than 15% by weight of the binder. California, Arizona, and Massachusetts use more than 20%, while Texas and New Jersey use less than 20%. Ontario, Canada uses 18-20% of CRM in its rubberized asphalt cement.

The blending temperatures used by different agencies vary, ranging from 165 – 226 ^{o}C (330 – 440 ^{o}F). Ontario's specifications only mentioned the blending temperature. California, Arizona,

New Jersey, and Massachusetts DOTs specified higher temperatures when adding CRM into the base asphalt cement. California is at the higher end with a specification of 190 -226°C (375-440°F) when CRM is added and 190-218°C (375-425°F) when blending. Ontario's blending temperature 180 °C (356°F) is similar to that of Arizona and is in the middle of all agencies in the Table 2.

Blending time is also a big factor affecting final uniform formation of rubberized asphalt cement. The field blend viscosity, normally measured by a Haake viscometer, increases at the beginning of the blending process, reaches a peak value, and then starts to drop or remain constant with longer blending times. This procedure is called asphalt rubber design profile and is required by California. Ontario doesn't require an asphalt rubber design profile. It requires a minimum of 45 minutes of blending time and requires field blend viscosity of 1500 – 4000 cP.

The common tests specified for rubberized asphalt cement are field blend rotational viscosity, cone penetration, resilience, and softening point.

Table 2. Comparison of Rubberized Asphalt Cement from Various Agencies

Agency	CRM percentage	Blending temperature	Blending time	Field blend viscosity, cP, and other tests	Others
Ontario, Canada	18-20%	180 °C (356°F)	45 minutes	1500-4000 using California LP-11; Penetration 25-70 Resilience 18% min; Softening point, 52-74 °C (125-165°F)	CRM gradation, mixing method, dosage, reaction time, storage condition, etc. shall be determined by contractor. Make sure anti-stripping agent is compatible with the RMA mix and RAC.
California	20 ± 2%; for CR, 75% scrap tire CR and 25% high natural CR.	190 -226°C (375-440°F) when CRM is added. 190-218°C (375-425°F) when blending.	45 minutes min.	1500-4000 using California LP-11; Penetration 25-70 Resilience 18% min; Softening point, 52-74 °C (125 - 165°F)	Asphalt modifier should be added to the binder at 2.5 to 6% of paving asphalt. The asphalt modifier shall be a resinous, high flash point, aromatic hydrocarbon compound. Maximum of 2 reheat cycles.

Agency	CRM percentage	Blending temperature	Blending time	Field blend viscosity, cP, and other tests	Others
Arizona	Min 20%	180-205^{o}C (350-400^{o}F) when CRM is added. 165-190^{o}C (325-375^{o}F) when blending.	60 minutes minimum.	1500-4000 cP; Penetration minimum 10-25; softening point, minimum 52-57^{o}C (125-135 ^{o}F)	Submit an asphalt rubber design by an approved lab.
Texas	Minimum 15%	Didn't mention	Didn't mention	1500-5000 cP; Penetration 25-75 for hot mix, 50-100 for surface treatment. Resilience, 20% minimum for hot mix, 10% minimum for surface treatment. Flash point, 232^{o}C(450^{o}F)	Application temperature range: 165-220^{o}C (325-425^{o}F); Maximum 220^{o}C(425^{o}F); Storage maximum 220^{o}C(425^{o}F).
Florida	Minimum 20%	168-190^{o}C (335-375^{o}F)	30 minutes minimum	1500 cP. Rubber gradation is Type C	Excess asphalt rubber can be used for non rubber mix as long as AR binder is less than 2% of regular binder.
New Jersey	Minimum 17%	180-205^{o}C-(350-400^{o}F) when CRM is added. 165-190^{o}C (325-375^{o}F) when blending.	60 minutes minimum	ASTM Type II; 2000-4000 cP; Resilience, 25% minimum	

Agency	CRM percentage	Blending temperature	Blending time	Field blend viscosity, cP, and other tests	Others
Massachusetts	23±2%	175-220°C (347-430°F) when CRM is added. Above 160°C (320°F) when blending.	Didn't mention	2000-5000 cP	Add diluent, Grade #1 Fuel Oil and less than 7.5% by volume for spray application.
Jiangsu Province, China	Didn't mention	165-180°C (325-350°F)	Didn't mention	1500-4000 cP; cone penetration 25 minimum; Elastic Recovery 25°C, 60%min	Additive, cement or hydrated lime.

4.0 Terminal Blend Binder Specifications

Terminal blend asphalt is a type of rubberized asphalt cement where crumb rubber is blended with base PG graded asphalt cement at an asphalt refinery or terminal. Unlike the asphalt rubber field blend rubberized asphalt cement, terminal blend is stable without the need of agitation during storage or transportation. It can be used just like conventional liquid asphalt cement, but it contains rubber between 5-20% by weight of asphalt cement depending on agency specification. Terminal blends have been used in the United States since 1990s. California started to use terminal blends in 1996. Recently, terminal blends have been combined with warm mix additives in California. In this section, the Ontario terminal blend specification is compared with the NSSP used by California.

4.1 Crumb Rubber

For Ontario, the CRM shall be 100% passing 1 mm sieve. The amount of CRM by weight of terminal blend RAC shall be between 10 and 15%. The terminal blend should be compatible with anti-stripping additives to ensure a good dissolution and reaction time.

In California, there is no specification on the gradation of CRM, but the top size is about 30-40 mesh. The supplier is required to certify 10% minimum tire rubber modifier in binder. There is a solubility requirement based on AASHTO T44 and the solubility should be a minimum of 97.5%.

4.2 Material Property Testing of Terminal Blends

For Ontario, the specification requires terminal blend asphalt cement to meet the Type III asphalt rubber binder according to ASTM D6114 as well as PGAC grade specified.

In California, terminal blend asphalt cement shown in Table 3 is comparable with polymer modified asphalts. It basically requires the Superpave performance grade specified with some modifications highlighted in Table 3. Compared with conventional asphalt cements, the solubility requirement is reduced from 99% to 97.5% for terminal blends with an increase in the requirement on phase angle at the high temperature and percent recovery from elastic recovery testing results.

Since terminal blends are similar to polymer modified asphalt, they can be used in any hot mix or surface treatment application where polymer modified asphalts are used.

5.0 Asphalt Rubber Field Blend Mix Specifications

Asphalt rubber field blends have high viscosity and are more effective when used with gap-graded or open- graded mixes. In 2011, Ontario built several pilot projects using the asphalt rubber with gap- graded hot mix asphalt (Tabib et. al. 2012). The following sections present a comparison of specifications for using asphalt rubber field blend with gap - or open – graded mixes from various agencies.

5.1 Rubberized Hot Mix Asphalt Gap-Graded

Rubber Modified Asphalt gap-graded mixes consist of mixing gap-graded aggregate and field blended rubberized asphalt cement and then spreading and compacting the mix to satisfy an agency's specification. Most agencies have a similar requirement in their specifications. The following shows some differences among agencies.

5.1.1 Mix Design Aspect

Not all agencies surveyed used gap-graded asphalt rubber mix. As shown in Table 4, the binder content of Ontario mix design is on the lower side of that used by other agencies. For California, the asphalt cement content should not be less than 7% or higher than 9%. In California, the Contractor provides the Engineer a Material Safety Data Sheet (MSDS) for each of the constituent components of the asphalt-rubber binder, for the completed mixture of asphalt-rubber binder and for the Type G rubberized asphalt concrete. This should be done in Ontario as well to make sure there are no deleterious particles in the asphalt cement. The warm mix technologies may be able to help Ontario with cold temperature paving.

Table 3. California NSSP on Terminal Blend Asphalt Cement (See Appendix F for Details)

Property	AASHTO Test Method	Grade	
		PG 64–28 PM	PG 76–22 PM
Original Binder			
Flash point, min °C	T 48	230	230
Solubility, min % [b]	T 44[c]	97.5	97.5
Viscosity at 135°C[d], max, Pa·s	T 316	3.0	3.0
Dynamic shear, Test temperature at 10 rad/s, °C min G*/sin(delta), kPa	T 315	64 1.00	76 1.00
RTFO test[g], Mass loss, max, %	T 240	1.00	1.00
RTFO Test Aged Binder			
Dynamic shear, Test temperature at 10 rad/s, °C min G*/sin(delta), kPa	T 315	64 2.20	76 2.20
Dynamic shear, Test temperature at 10 rad/s, °C max (delta), %	T 315	80[e]	80[e]
Elastic recovery[f], Test temperature °C min recovery, %	T 301	25 75	25 65
PAV[h], temperature, °C	R 28	100	110
RTFO Test and PAV Aged Binder			
Dynamic shear, Test temperature at 10 rad/s, °C max G*sin(delta), kPa	T 315	22 5000	31 5000
Creep stiffness, Test temperature, °C max S-value, MPa min M-value	T 313	-18 300 0.300	-12 300 0.300

[a]Do not modify PG Polymer Modified using polyphosphoric acid modification.
[b]The Engineer waives this specification if the supplier is an Approved Supplier as defined by the Department's *Certification Program for Suppliers of Asphalt.*
[c]The Department allows ASTM D 5546 instead of AASHTO T 44
[d]The Engineer waives this specification if the supplier provides written certification the asphalt can be adequately pumped and mixed at temperatures meeting applicable safety standards.
[e]Test temperature is the temperature at which G*/sin(delta) is 2.2 kPa. A graph of log G*/sin(delta) plotted against temperature may be used to determine the test temperature when G*/sin(delta) is 2.2 kPa. A graph of (delta) versus temperature may be used to determine delta at the temperature when G*/sin(delta) is 2.2 kPa. The graph must have at least two points that envelope G*/sin(delta) of 2.2 kPa and the test temperature must not be more than 6 degree C apart. The Engineer also accepts direct measurement of (delta) at the temperature when G*/sin(delta) is 2.2 kPa.
[f]Tests without a force ductility clamp may be performed.
[g]"RTFO Test" means the asphaltic residue obtained using the Rolling Thin Film Oven Test, AASHTO Test Method T 240 or ASTM D 2872. The residue from mass change determination may be used for other tests.

Table 4. Mix Design Parameter Comparison from Various Agencies

Agency	Mix Design Method	Binder Content and binder type	Gradation, air voids, and others	Notes
Ontario, Canada	Superpave	6.5% for 12.5 mm; 7.0% for 9.5 mm by weight of total mix; PG58-28	Gap-graded 12.5 mm, 9.5 mm, 4% design air void; VMA min is 18%	
California	Hveem mix design	7.0 to 9.0% by weight of dry aggregate; PG64-16	Gap-graded 12.5 mm, 19 mm; VMA min is 18%; Stabilometer stability value min 23.	Caltrans will convert to Superpave by 2014; Caltrans allows using approved warm mix technologies to deal with cold and night paving issues.
Arizona	Marshall mix design	5.5± 1.0% air void;	Gap-graded; VMA min 19.0%; Absorbed asphalt rubber, 0-1%.	
Jiangsu, China	Marshall mix design		Gap-graded 13.2 mm; VMA 18-23%.	Marshall stability ≥ 8000 N; Flow number 20-50.

5.1.2 Construction Considerations

Construction practices and environments are very different between the various agencies. California, Arizona, and China are very successful with their gap-graded asphalt rubber pavement. Table 5 shows the requirements used to make a successful asphalt rubber gap-graded pavement at their environment. There are missing temperature requirements in the Ontario gap-graded asphalt rubber specification. The information from other agencies may be a good starting point for Ontario.

Table 5. Construction Related Parameters for Gap-Graded Rubber Modified Asphalt

Agency	Compaction and Air Void	Ambient/Pavement Temperature	Mix Production Temperatures	Compaction Temperatures	Others
Ontario, Canada	2.5-5.5 % air voids; Compaction shall be 90.5-98.0 %.	Minimum 12 ^{o}C (54°F) for surface course and 2^{o}C (36°F) for binder course			
California	Compaction 92-98%	Above 13-18 ^{o}C (55-65 ^{o}F)	Mixing temperatures: 149-163^{o}C (300-325^{o}F);	Spread Temperature 143-149^{o}C (290-300 ^{o}F); Breakdown starts ≥138 ^{o}C (280 ^{o}F) and ends ≥ 127 ^{o}C (260 ^{o}F)	Pneumatic tired rollers not allowed; Sand shall be applied.
Arizona		Pavement temp ≥ 18°C (65^{o}F); Shall stop when ambient temp is ≤ 21°C (70 ^{o}F) and falling.		Breakdown starts ≥ 135°C (275 ^{o}F)	Roller steel wheels shall be wetted with water, or soapy water, or an approved product.
Jiangsu, China	4.5-6.5 % air void		Mixing temps: 170-180 ^{o}C (338-356°F)	Spread temp ≥ 160 ^{o}C (320°F); Breakdown starts ≥ 155^{o}C (311°F); Finish roller ends ≥ 100 ^{o}C (212°F)	Trucks should be tarped. No pneumatic roller. Permeability of finished mat ≤ 50 ml/min

5.2 Rubberized Hot Mix Asphalt Open-Graded

Open-graded rubber modified asphalt has the advantage of providing good drainage, quiet pavement, and good skid resistance even on rainy days. Due to the high viscosity of rubberized asphalt cement field blend, there is no need to add fiber for open-graded rubber modified asphalt. Open-graded rubberized asphalt has been tried in Ontario once in 2009 to produce a quiet pavement. According to Ontario MTO engineer Seyed Tabib, the noise level of RAC-O is about 3 dBA quieter than the control section, a 12.5 mm dense graded mix. However, it may ravel

under snow plow activity and freeze thaw climate scenarios. It is quiet, but may be more susceptible to damage in colder climates. The information in this section could help Ontario if open-graded rubber modified asphalt is to be considered in Ontario.

5.2.1 Mix Design Aspects

Table 6 shows the mix design method used by various agencies. Open-graded mixes could hold more asphalt cement than gap- or dense- graded mixes, particularly if they are like the high binder types used in Arizona and California for durability, and not for drainage.

Table 6. Mix Design from Various Agencies for Open-Graded Rubber Modified Asphalt

Agency	Mix Design Method	Binder Content and binder type	Gradation, air voids, and others	Notes
California	Hveem mix design	Optimal Binder Content (OBC) = OBC_1 x 1.20	Open-graded 12.5 mm.	
Arizona	Marshall mix design		Open-graded; Absorbed asphalt rubber, 0-1%. Use type B smaller CR gradation.	Mineral admixture, Portland cement or hydrated lime, 1% is required.
Texas	Superpave	Binder content based on Tex-236-F		Drain-down max 0.20%

5.2.2 Construction Considerations

The open-graded RMA requires higher ambient or underlying pavement temperature. There are temperature requirements for mix production, spreading, and compaction. Different agencies have different ways to prevent material pick up by traffic. Table 7 shows these requirements.

Table 7. Construction Requirement for Open-Graded Rubber Modified Asphalt

Agency	Compaction and Air Void	Ambient/Pavement Temperature	Mix Production Temperatures	Compaction Temperatures	Other
California	Method spec, three rollers.	Above 13-18 ^{o}C (55-65 ^{o}F)	Mixing temperatures: 149-163^{o}C (300-325^{o}C)	Spread Temperature 143-163^{o}C (290-325 ^{o}F); Breakdown starts ≥138 ^{o}C (280 ^{o}F) and ends ≥ 127 ^{o}C (260 ^{o}F)	Pneumatic tired rollers not allowed; Sand shall be applied.
Arizona		Pavement temp ≥ 30^{o}C (85 ^{o}F)	Discharge temperature from mixer ≤ 180^{o}C (350^{o}F)	Breakdown starts ≥ 135°C (275 ^{o}F)	Roller steel wheels shall be wetted with water, or soapy water, or an approved product.
Texas		Pavement temp ≥ 21^{o}C (70 ^{o}F)	Discharge temperature from mixer ≤ 180^{o}C (350^{o}F)	Spread temperature ≥138 ^{o}C (280^{o}F)	
New Jersey		Pavement temp ≥ 10^{o}C (50 ^{o}F)		Laydown temperature 135-165 ^{o}C (275-330 ^{o}F)	Static roller; keep the wheels moistened with water mixed with detergent. Using lime water to prevent material pickup by traffic.
MTO, Ontario, Canada		Air temperature >= 12 °C (54°F). If ambient temperature is below 18°C (65°F), the hauling truck shall use a tarpaulin.			Only steel-wheeled rollers

6.0 Terminal Blend Mix Specifications

Except for the usage of rubber modified asphalt produced at a terminal, the mix design and construction of terminal blend mix is very similar to the ones with conventional or polymer modified hot asphalt mix. Therefore, the Rubberized Asphalt Cement section described previously should include the major points that should be paid attention to.

7.0 Asphalt Rubber Chip Seals Specifications

Asphalt rubber chip seals normally result in better performance in terms of resisting reflective cracking and producing a longer life if placed correctly. This is due in large part to the higher binder content used during the application. The following sections describe the design and construction aspects of asphalt rubber chip seals.

7.1 Design of Asphalt Rubber Chip Seal

Asphalt rubber chip seals have been used in Arizona, California and Texas for many years. Table 8 shows the general binder design, chip aggregate, and other key design related information. In California, the chip seals also have been placed with warm mix additives. This results in a lower application temperature and less emissions.

Table 8. Design Parameters for Asphalt Rubber Chip Seal Applications.

Agency	Binder	Chips	Notes
California/Caltrans	Asphalt rubber field blend the same as hot mix. Binder application rate 2.5 - 3.0 L/m^2 (0.55 – 0.66 gal/yd^2)	Chip seals 12.5 mm; 9.5 mm gradation; Chip seal application rates are 15-22 kg/m^2 and aggregate is precoated.	Flush coat shall consist of an application of a fog seal coat followed by a sand cover to the surface of asphalt-rubber seal coat.
Arizona DOT	CRM gradation shall be Type A coarser one. Binder application rate: 0.55 ± 0.05 gal/yd2.	Uniform sized aggregate 9.5 mm. Aggregate application rates shall be 0.014 cubic yards/yd^2.	Rock shall be pre-coated with 0.40 to 0.60 % asphalt cement by weight of the aggregate.
Texas DOT	ASTM Type II or Type III AR binder. Contractors provide AR design profile.		Use grade B CR for binder. When directed by the Engineer, apply a tack coat before applying the hot asphalt-rubber treatment.

7.2 Construction of Asphalt Rubber Chip Seals

There are weather and other requirements for asphalt rubber chip seal applications that must be followed to ensure a successful product. Table 9 shows that the application normally requires a high binder application temperature and hot coated aggregate. California has found that precoating the aggregate will increase the bonding and rock retention.

Table 9. Requirement during Asphalt Rubber Chip Seal Construction by Agencies

Agency	Ambient/pavement temperature	Binder Temperature	Chip Rock Temperature	Compaction
California/Caltrans	Pavement ≥ 13°C (55°F); The ambient air temperature should be 16-43°C (60-110°F).	The binder application temperature is 196-213°C (385-415°F).	Chip application temperatures107-163°C (225-325°F).	Minimum of one complete coverage with one or more pneumatic-tired rollers shall begin within 90 seconds following the placement of the screenings. Distance between the rollers and the screenings spreader shall not exceed 60 m. A minimum of 3 complete coverages. Sweeping shall be a multi-step operation.
Arizona DOT	Ambient and pavement surface temperatures ≥ 24°C (75 °F).		Chip rock application temperature ≥ 121°C (250 °F).	Rolling is important. Shall use three pneumatic rollers.

Agency	Ambient/pavement temperature	Binder Temperature	Chip Rock Temperature	Compaction
Texas DOT	Generally air temperature is ≥ 27°C (80°F) , or above 21°C (70°F) and rising.	Binder application temperature < 218°C (425°F).	Preheat aggregate to between 121-177°C (250-350°F).	Immediately after the distributor has started spraying the hot asphaltrubber, uniformly apply the aggregate at the rate specified by the Engineer. After rolling, sweep away excess as soon as aggregate has sufficiently bonded.

8.0 Asphalt Rubber Interlayers Specifications

Asphalt Rubber Interlayers are a Stress Absorbing Membrane Interlayer (SAMI), which is a membrane seal that is used to retard the rate of reflection cracking from an underlying layer into new overlays. It consists of an application of an Asphalt Rubber Chip Seal. An HMA overlay is then placed over the SAMI. If necessary, traffic may be allowed to operate on the SAMI prior to construction of the overlay.

8.1 Design of Asphalt Rubber Chip Seal Interlayer

Asphalt rubber chip seal interlayers have been commonly used in many agencies. Table 10 shows the general design related information.

Table 10. Design Parameters for Asphalt Rubber Chip Seal Interlayers (SAMI)

Agency	Binder	Chips	Notes
California/Caltrans	Asphalt rubber field blend the same as hot mix. Binder application rate 2.5 - 3.0 L/m^2 (0.55 – 0.66 gal/yd^2)	Chip seals 12.5 mm; 9.5 mm gradation; Chip seal application rates are 15-22 kg/m^2.	Rock shall be pre-coated. No flush coat. No sanding on SAMI.
Arizona DOT	CRM gradation shall be Type A coarser one. Binder application rate: 0.55 ± 0.05 gal/yd2.	Uniform size aggregate 9.5 mm. Aggregate application rates shall be 0.014 cubic yards/yd^2.	Rock shall be pre-coated with 0.40 to 0.60 % asphalt cement by weight of the aggregate. If the asphaltrubber membrane has been subjected to traffic, a tack coat, as herein before specified, shall be applied at the rate of approximately 0.06 gal/yd^2 prior to placement of the asphaltic concrete.
Florida DOT	Use ARB20 with 20% CR. Binder application rate is 0.6-0.8 gal/yd^2.	Use No 6 stone, slag, or gravel. Spread the chip aggregate at a rate between 0.26 and 0.33 ft^3/yd^2	Ensure a well-bonded interlayer by adjusting the thickness and temperature of the initial layer of asphalt concrete.
Massachusetts DOT	AC-10 or AC-20 as base asphalt. The percent of rubber shall be 23 ± 2%.	Shall be crushed stone. Crushed gravel stone is not allowed. Should be pre-coated rock. Application rate, 15-20 kg/m^2.	Pot holes, depressions, cracks larger than 20 millimeters and other irregularities will be patched with hot bituminous mix and compacted. For spraying and/or better "wetting" of the cover material, a diluents, Grade #1 Fuel Oil, <7.5%, can be added to the rubberized asphalt cement.

8.2 Construction of Asphalt Rubber Chip Seal Interlayer

Table 11 shows the construction related project information for the Asphalt Rubber Chip Seal Interlayers used by different agencies.

Table 11. Requirement during Asphalt Rubber Chip Seal Interlayer Construction

Agency	Ambient/pavement temperature	Binder Temperature	Chip Rock Temperature	Compaction
California/Caltrans	Pavement ≥ 13°C (55°F); The ambient air temperature should be 16-43°C (61-109°F).	The binder application temperature is 196-213°C (385-415°F).	Chip application temperatures107-163°C (225-325°F).	Minimum of one complete coverage with one or more pneumatic-tired rollers and shall begin within 90 seconds following the placement of the screenings. Distance between the rollers and the screenings spreader shall not exceed 60 m. A minimum of 3 complete coverages. Sweeping shall be a multi-step operation.

Agency	Ambient/pavement temperature	Binder Temperature	Chip Rock Temperature	Compaction
Arizona DOT	Ambient and pavement surface temperatures ≥24°C (75 °F).		Chip rock application temperature ≥ 121°C (250 °F).	Three pneumatic rollers. Asphalt Rubber Interlayer shall be placed dates that specified. Higher elevation need to be placed during summer.
Florida DOT	Air temperature is above 10°C (50 °F) and rising. Wind is not very strong to cool pavement quickly.			Do not separate the application of the asphalt rubber binder and the application of the cover material by more than 91m (300 ft), unless approved by the Engineer.
Massachusetts DOT	Ambient temperature ≥ 10 °C (50°F).	Application temperature: 140-170 °C (284-338°F). Binder Application rate: 2.75 ± 0.25 liter/m^2.	Aggregate should be pre-heated 120-150 °C (248-302°F) and coated with 0.5-1.0% asphalt AC-20.	At least two multiple wheel self-propelled pneumatic-tired rollers. SAMI should be overlaid immediately following completion of sweeping.

9.0 Summary and Recommendations for the MTO, Ontario, Canada

After comparing the different specifications from various agencies on rubber modified asphalt, the following summary and recommendations can be drawn:

1. The Crumb Rubber Modifier (CRM) is an important component of the asphalt rubber and rubber modified asphalt. The typical specifications for CRM from various agencies are summarized in Table 1. The CRM generally used in terminal blend is much finer than the one used in field blend. For field blended asphalt rubber, Ontario's CRM gradation is finer than that of California and Arizona. However, California also uses a high nature rubber and extender oil which Ontario doesn't use. The asphalt modifier specified by California shall be a resinous, high flash point, aromatic hydrocarbon compound. Ontario's CRM is also finer than the Type A of Arizona, Grade A of Texas, New Jersey, and China. It is similar as Type B of Arizona and Grade B of Texas, but it is coarser than Grade C of Texas and Types A, B, and C of Florida. Finer CRM makes it easier to blend and interact with a base asphalt binder. Ontario's CRM is on the medium to fine side. However, it doesn't have a maximum moisture content requirement. Additives such as calcium carbonate, which can absorb moisture and keep CRM dry during mixing, are not used in Ontario specifications.

2. In Ontario, asphalt rubber is called rubberized asphalt cement. It generally consists of a Type III asphalt rubber binder according to ASTM 6114, which is suitable for cold regions. The blending temperatures of Ontario rubberized asphalt cement are slightly lower than that of California, similar to Arizona andNew Jersey, and higher than those of Florida. New Jersey and Arizona require a longer blending time of 60 minutes minimum. California uses an asphalt modifier (extender oil) to promote interaction of CRM and base asphalt cement.

3. The terminal blend asphalt is a type of rubberized asphalt cement where crumb rubber is blended with base PG graded asphalt cement at an asphalt refinery or terminal. Unlike the asphalt rubber field blend rubberized asphalt cement, the terminal blend is stable without the need of agitation during store or transportation. It can be used just like conventional liquid asphalt cement, but it contains rubber between 5-20% by weight of asphalt cement depending on agency specification. California required the solubility test of terminal blend to be minimum 97.5%.

4. According to the Ontario specification, terminal blend asphalt cement is required to meet the Type III asphalt rubber binder according to ASTM D6114 as well as PGAC grade specified. However, it may be difficult to meet the PGAC solubility requirement and ASTM 6114 asphalt rubber requirement.

5. For rubber modified asphalt gap-graded mix, the asphalt cement content of Ontario mix is at the lower side compared with other agencies, such as California and Arizona, probably

due to using the Superpave mix design method. California also provides the option to use warm mix technologies. The warm mix technologies may be able to help Ontario with cold temperature paving.

6. Construction practices and environments vary greatly between agencies. California, Arizona, and China have had very successful programs with their gap-graded asphalt rubber pavement. Table 5 shows the requirements to make a successful asphalt rubber gap-graded pavement in different environments. Ontario follows an End Result Specification (ERS); therefore, they do not specify temperature requirements in their HMA specification. The information from other agencies may be a good reference for contractors to build a quality RMA pavement.

7. The open-graded rubber modified asphalt has the advantage of producing good drainage, quiet pavements, and good skid resistance even during rainy days. Because of the high viscosity of rubberized asphalt cement field blend, there is no need to add fiber for open-graded rubber modified asphalt. Open-graded rubberized asphalt may not be suitable for use in cold regions, such as Ontario. The information in this report could helpif open-graded rubber modified asphalt is used in Ontario.

8. Asphalt rubber chip seals normally have better performance in terms of resisting reflective cracking and result in longer lives if placed right. The materials, design, and construction of different specifications were compared and summarized. This information could help Ontario if any asphalt rubber chip seal projects were to be implemented.

9. Asphalt Rubber Interlayers are a Stress Absorbing Membrane Interlayer (SAMI) used to retard the rate of reflection cracking from an underlying layer into new overlays. Asphalt rubber chip seal interlayers have been commonly used by many agencies. The key information about materials and construction has been summarized into Tables 10 and 11. This information could be useful for Ontario in the future.

10.0 References

1. ASTM D8, Standard Terminology Relating to Materials for Roads and Pavements. ASTM international, 2011.
2. ASTM D6114, Standard Specification for Asphalt-Rubber Binder. ASTM International, 2009.
3. Caltrans, Maintenance Technical Advisory Guide (MTAG) Volume I - Flexible Pavement Preservation Second Edition. Chapter 7, 2008.
4. Tabib, Seyed and Mohamed Hegazi, Summary of 2011 Rubberized Asphalt Pilot Projects Constructed in Ontario Canada, draft report, March 2012.

Appendix A: Ontario Specifications Using Wet Process Field Blend

SUPERPAVE 12.5FC 1 R-GAP GRADED - Item No.

Special Provision

Rubber Modified Hot Mix Asphalt

313.01 SCOPE

Subsection 313.01 of OPSS 313 is amended by the addition of the following:

This Special Provision covers the additional requirements for the construction of a trial section that includes the use of rubber material processed in Ontario from Ontario tire waste. The trial section shall incorporate rubber in the HMA using the wet process-field blend.

313.05 MATERIALS

313.05.01 Hot Mix Asphalt

Subsection 313.05.01 of OPSS 313 is deleted and replaced with the following:

The Materials used in the production of HMA shall be according to OPSS 1151, with the following amendments:

The HMA types, lift and location of the trial section are provided in Table R1.

1151.02 REFERENCES

Section 1151.02 of OPSS 1151 is amended by addition of the following:

American Society for testing and Materials (ASTM) Standards

ASTM D5644	Test Methods for Rubber Compounding Materials - Determination of Particle Size Distribution of Recycled Vulcanized Particle Rubber
ASTM D6114	Standard Specification for Asphalt-Rubber Binder
ASTM D217	Standard Test Methods for Cone Penetration of Lubricating Grease
ASTM D5329	Standard Test Methods for Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements
ASTM D36	Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)
ASTM D297	Standard Test Methods for Rubber Products-Chemical Analysis

State of California Laboratory Procedure

LP-11	Rotational Viscosity Measurement of Asphalt Rubber Binder

1151.03 DEFINITIONS

Section 1151.03 of OPSS 1151 is amended by addition of the following:

Ambient Ground: means scrap tire rubber processed or ground at or above 20°C to provide irregularly shaped, torn particles with relatively large surface areas.

Crumb Rubber (CR): means scrap tire rubber that is reduced in size for use in asphalt paving materials such as hot mix asphalt or asphalt cement or both.

Cryogenic Ground: means scrap tire rubber processed or ground at temperatures low enough that the rubber shatters.

Rubberized Asphalt Cement (RAC): means asphalt-rubber binder; which is PGAC modified with crumb rubber through the wet process.

Rubber Modified Asphalt (RMA): hot mix asphalt that contains crumb rubber added as an aggregate, as RAC or as both. May also refer to CR added with the asphalt cement to the aggregates during mix production of the HMA.

Superpave 12.5FC 1 R-Gap graded: means RMA with gap-graded aggregates having 12.5 mm nominal maximum size and contains RAC produced using the wet process-field blend. Requirements for Superpave 12.5FC 1 R-Gap Graded are specified in this special provision.

Transition Area: means the length of the section within which the change from one section to the next shall be fully accomplished.

1151.04 DESIGN AND SUBMISSION REQUIREMENTS

1151.04.01 Design Requirements

Subsection 1151.04.01 of OPSS 1151 is amended by the addition of the following:

1151.04.01.07 Rubber Modified Asphalt

The RMA mix designs shall be according to the respective Superpave mix type specified in addition to including CR using the process specified in Table R1 and according to the following:

a) Wet Process-Terminal Blend (not applicable to this Contract)

The mix shall be designed to incorporate RAC in place of PGAC. Wet process-terminal blend RAC shall be produced by the PGAC supplier at their asphalt terminal.

b) Wet Process-Field Blend

The mix shall be designed to incorporate RAC in place of PGAC. Wet process-field blend RAC shall be produced at the hot mix asphalt plant using a field blending plant.

The Superpave 12.5FC 1 R-Gap Graded mix design and JMF shall be according to the requirements specified in Table R2, Table 3 of OPSS 1151, and LS-309. For mix design purposes, the RAC shall be produced in the laboratory according to the following procedure:

- Heat up the base PGAC to 180^{o}C. Add 18-20% CR by weight of the PGAC while continuously blending the

compound.
- Continue blending the RAC for 45 minutes at 180°C.

1151.04.02 Submission Requirements

Subsection 1151.04.02 of OPSS 1151 is amended by the addition of the following:

The Contractor shall submit a plan and schedule to the Contract Administrator within two weeks of contract award describing how the Contractor will meet all the requirements of this non-standard special provision for review and approval including the following information in writing:

a) Special actions to be taken to assure that the CR will be available meeting the requirements of the Contract Documents, including that the CR processor selected by the Contractor or asphalt cement supplier or both can provide the material required for the Contract, and how the Contractor will assure that the CR processor selected has sufficient time to produce the quantity of CR required.

b) Information such as CR supplier's name, address, CR gradation, materials safety data sheet (MSDS), method and equipment used to mix CR into mix, CR dosage, RAC reaction time, mixing temperature, RAC storage conditions and any need for agitation, RAC blending location (hot mix asphalt plant vs. asphalt supplier's terminal) shall be provided.

c) Special actions to be taken to prevent swelling of the briquettes during the mix design.

d) Special actions to be taken to assure that the CR will be homogeneously distributed in the RMA.

e) Special actions to be taken to prevent pick-up during compaction of the RMA.

f) Product information on CR including information on how it was ground, whether cryogenic or ambient or both, shall be submitted with the mix design.

g) A letter from the CR supplier indicating that the CR they are supplying is produced in Ontario from tires scrapped in Ontario.

No RMA shall be placed on any trial section until the Contract Administrator acknowledges receipt of the plan and schedule in writing. Separate mix designs shall be submitted for each RMA type and for the control (regular HMA) mix.

1151.05 MATERIALS

Section 1151.05 of OPSS 1151 is amended by addition of the following:

1151.05.06 Rubber Modified Asphalt and Rubberized Asphalt Cement

1151.05.06.01 General

Materials for the RMA shall conform to OPSS 313 except as amended by this special provision. It is the Contractor's responsibility to identify a facility to produce the mixes in accordance with the supplier's instructions for the use of their materials. The Contractor is responsible for obtaining from the suppliers any and all information required for the proper preparation, handling, storage and use of their materials.

The Contractor shall be solely responsible for obtaining materials, producing mixes, transportation, storage and use of all materials. The Contractor shall assure that the RMA is produced to prevent any deleterious effects to

the finished product. The Contractor shall be responsible for ensuring cross contamination does not occur between the sections.

The Contractor shall contact Ontario Tire Stewardship (OTS), at either of the contact information below, who will facilitate the sourcing of the field blending plant, needed for producing Superpave 12.5FC 1 R-Gap Graded. The field blending plant shall only be sourced through OTS. The Contractor shall be responsible for the cost of supplying and operating the field blending plant. The Contractor shall allocate sufficient space at the hot mix asphalt plant to house the field blending plant. An area of about 30 m x 20 m would be sufficient for the field blending plant. The Contractor shall provide points of contact for supply lines from and to the field blending plant. The Contractor shall cooperate with the operator of the field blending plant and harmonize the operation of the field blending plant with the hot mix asphalt plant in order to produce the RMA mix meeting the requirements of the Contract Documents. The Contractor shall be responsible to supply and feed the CR into the field blending plant.

Andrew Horsman, Executive Director
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405 the West Mall, Suite 500
Toronto, ON M9C 5K7
Tel: 416-626-9185
ahorsman@ontariots.ca

Jennifer Barbazza, Manager, Operations & Special Projects
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1151.05.06.02 Crumb Rubber

The CR shall be processed from whole passenger vehicle tires. Heavy equipment tires shall not be used. Use of uncured or devulcanized rubber will not be permitted. CR shall be in the form of ambient or cryogenic ground rubber, or both. The CR shall be produced in Ontario from tires scrapped in Ontario. CR shall not contain more than 0.01% of wire and 0.05% fabric by weight. CR shall be free of other contaminants. The CR shall be dry and free-flowing and not produce foaming when blended with the PGAC. The CR shall have a specific gravity in the range of 1.1 to 1.2, as determined according to ASTM D 297.

The CR shall meet the gradation requirements specified in Table R3 determined according to ASTM D5644. No particles shall exceed a length of 5 mm as measured on any axis.

The Contractor shall contact Ontario Tire Stewardship (OTS), at the above contact information, who will facilitate the sourcing of the CR.

1151.05.06.03 Aggregates

Aggregate gradation for Superpave 12.5FC 1 R-Gap Graded shall be according to Table R2. Physical properties of aggregate for Superpave 12.5FC 1 R-Gap Graded shall meet the requirements of Superpave 12.5FC 1 specified elsewhere in the Contract Documents.

1151.05.06.04 Rubberized Asphalt Cement

CR added to the RAC shall meet the gradation requirements specified in Table R3 determined according to ASTM D5644. Wet-terminal blend RAC shall be produced as a Type III Asphalt Rubber Binder according to ASTM D6114. CR dosage by mass of wet-terminal blend RAC shall be 10% to 15%. Wet-field blend RAC (after reaction) shall meet the requirements found in Table R4. CR dosage by mass of wet-field blend RAC shall be 18% to 20%. For the production of the RAC, parameters such as CR gradation, mixing method and equipment, dosage, reaction time, mixing temperature, storage conditions and need for agitation, blending location (project site vs. asphalt supplier's terminal) shall be determined by the Contractor.

When the RAC supplier specifies a CR gradation with additional restrictions, the CR shall also meet the RAC supplier's gradation requirements. The CR material, PGAC and any antistripping additives required shall be compatible to ensure a good dissolution and reaction time. RAC produced shall be a homogenous mixture of CR and asphalt cement.

In case of terminal blend, the following asphalt cement suppliers have indicated their ability to supply the RAC:

a) Bitumar; b) Coco; c) McAsphalt; d) Shell

1151.07 PRODUCTION

1151.07.01 Anti-Stripping Additives

Subsection 1151.07.01 of OPSS 1151 is amended by addition of the following:

When an anti-stripping agent is to be incorporated into the mix, the Contractor shall contact and consult with each supplier to determine whether or not the proposed anti-stripping agent is compatible with the RMA or RAC or both. In those cases where a supplier deems that the anti-stripping agent is incompatible, that anti-stripping agent shall not be used and the Contractor shall select and employ another anti-stripping agent that the suppliers indicate is compatible with the mix and RAC.

1151.07.03 Field Blending Plant

The Contractor shall contact OTS a minimum of 6 weeks prior to paving Superpave 12.5FC 1 R-Gap Graded to coordinate delivery and operation of the field blending plant. OTS contact information is provided earlier in this special provision.

313.07 CONSTRUCTION

313.07.06.01 Operational Constraints

Clause 313.07.06.01 of OPSS 313 is amended by addition of the following:

The Contractor shall provide a minimum of 7 Days notice in writing to the Contract Administrator and to the Ministry's Regional Head of Quality Assurance Section before paving any trial section.

313.07.06.02 Paving

Clause 313.07.06.02 of OPSS 313 is amended by addition of the following:

The Contractor shall construct the trial section as indicated in Table R1, full width including shoulders. Transition areas shall be less than 50 m in length at the start and end of the trial section. The Contractor shall

adjust the paving and compaction operations to eliminate roller pick-up and provide a smooth surface without tearing, cracking, or shoving.

313.07.15 Sampling

Subsection 313.07.15 of OPSS 313 is amended by the addition of the following clause:

313.07.15.06 Rubber Modified Asphalt

Samples shall not be taken from the transition areas. In addition to other samples specified in the Contract Documents, the Contractor shall procure RMA samples of a minimum quantity specified in Table R5 for each of the control and trial sections.

Sample labeling shall include: highway number, highway direction, lane number, contract number, section (trial or control), mix type, corresponding Lot/Sublot numbers, station, date sampled. The Contractor shall deliver the samples specified in Table R5 to the address below:

c/o Seyed Tabib
Bituminous Section, MERO
Shipping and Receiving
Room 15, Building C
1201 Wilson Ave,
Toronto, ON M3M 1J8

Section 313.07 of OPSS 313 is amended by the addition of the following subsection:

313.07.19 Identification of RMA Paving Limits

The Contractor shall provide to the Contract Administrator, no later than 7 Days after completion of RMA paving, an as built sketch identifying the stations as well as the GPS data for the RMA paving limits. The GPS data shall be geo-referenced and NAD83 geographic coordinates (latitude, longitude) shall be used. Geographic coordinates (latitude, longitude) shall be provided within metre-level accuracy.

313.08 QUALITY ASSURANCE

313.08.01.02.01 Lot Size

Clause 313.08.01.02.01 of OPSS 313 is amended by the addition of the following:

Each mix type for the trial section shall be considered as a single lot with a minimum of three sublots.

313.08.01.02.03 Basis of Acceptance

Clause 313.08.01.02.03 of OPSS 313 is amended by the addition of the following:

a) Acceptance of Crumb Rubber
   i. All CR shall meet the gradation requirements specified in Table R3 determined according to ASTM D5644.

b) Acceptance of Rubber Modified Asphalt (RMA)

i. Acceptance and pay adjustment of the RMA containing RAC-terminal blend shall be determined accordance to the respective mix type HMA requirements specified elsewhere in the Contract Documents.
ii. Acceptance and pay adjustment of the Superpave 12.5FC 1 R-Gap Graded shall be according to requirements for Superpave 12.5FC 1 specified elsewhere in the Contract Documents with the exception of air voids and compaction. VMA will not be considered an acceptance criterion for Superpave 12.5FC 1 R-Gap Graded. Aggregate physical properties for Superpave 12.5FC 1 R-Gap Graded shall be according to requirements for Superpave 12.5FC 1 specified elsewhere in the Contract Documents.
iii. RMA containing RAC wet-terminal blend will be rejectable if there are clumps of CR in the RMA visible to the naked eye.

c) Acceptance of Rubberized Asphalt Cement (RAC)
i. Acceptance of the RAC wet-terminal blend shall be determined according to the respective requirements for the PGAC grade specified according to OPSS 1101. Additionally, to be acceptable the RAC wet-terminal blend shall meet the Type III Asphalt Rubber Binder requirements of ASTM D6114.
ii. Acceptance of the RAC wet-field blend shall be according to Table R4.

313.08.01.02.04.01 General

Clause 313.08.01.02.04.01 of OPSS 313 is amended by the addition of the following:

The Owner will use LS-292 for determination of the asphalt cement content for the RMA, therefore, the referee laboratory shall also follow LS-292 (ignition oven).

313.09 MEASUREMENT FOR PAYMENT

313.09.01.01

Clause 313.09.01.01 of OPSS 313 is amended by the addition of the following item:

Superpave 12.5FC 1 R-Gap Graded

313.10 BASIS OF PAYMENT

313.10.01.01

Clause 313.10.01.01 of OPSS 313 is amended by the addition of the following item:

Superpave 12.5FC 1 R-Gap Graded - Item

313.10.01.02.02.04 Payment Factor for Voids

Clause 313.10.01.02.02.04 of OPSS 313 is deleted in its entirety and replaced with the following:

For Superpave 12.5FC 1 R-Gap Graded, as long as the lot mean air voids is between 2.5 and 5.5 percent, the payment factor for voids, PF_{VOIDS}, shall be equal to either:

a) PF_{GAC}, if the PF_{GAC} is less than 1.0; or,
b) 1.0, if the PF_{GAC} is equal to or greater than 1.0.

Otherwise, if the lot mean air voids is outside the 2.5-5.5 percent range, the PF_{VOIDS} shall be considered to be 0.5.

313.10.01.02.02.06 Payment Factor for Combined Mix Properties and Compaction

Clause 313.10.01.02.02.06 of OPSS 313 is amended by the addition of the following:

For Superpave 12.5FC 1 R-Gap Graded, as long as the lot mean compaction is between 90.5 and 98.0 percent, the payment factor for compaction, PF_C, shall be equal to either:

a) PF_M, if the PF_M is less than 1.0; or,
b) 1.0, if the PF_M is equal to or greater than 1.0.

Otherwise, if the lot mean compaction is outside the 90.5-98.0 percent range, the PF_C shall be considered to be 0.65.

Table R1
Trial Section

Trial Section	Pavement Course	Location (Stations)	Mix Type
Wet Process-Field Blend	Surface	15+000 to 19+000	Superpave 12.5FC 1 R-Gap Graded

Table R2
Superpave 12.5FC 1 R-Gap Graded Properties

Hot Mix Asphalt Type	Percentage Passing by Dry Mass of Aggregates						Traffic Category	Base PGAC Grade	% Air Voids	% VMA min.	RAC_{BID} (%)
	Sieve Size, mm										
	12.5	9.5	4.75	2.36	1.18	0.075					
Superpave 12.5FC 1 R-Gap Graded	90-100	78-92	28-42	15-25	5-15	2-7	C	58-28	4	18	6.5

Table R3
Gradation Requirements for Crumb Rubber

Process	Sieve	Percent Passing Sieve by Mass
Wet-Field Blend	2.36 mm	100
	2.00 mm	100
	1.18 mm	80 – 100
	600 µm	40 – 60
	300 µm	5 – 15
	150 µm	0 – 10

Table R4
Requirements for Field Blend RAC (after reaction)

Test Parameter	Test Method	Specification Limit
Field Viscosity @ 191°C (375°F),	California Laboratory Procedure	1500 – 4000

centipoises (see Note 1)	LP-11	
Cone Penetration @ 25°C, 0.1 mm	ASTM D 217	25 – 70
Resilient @ 25°C, % Rebound	ASTM D 5329	18 minimum
Field Softening Point, °C	ASTM D 36	52 – 74
Notes: 1. The operator of the field blending plant usually has a field viscometer. This test shall be carried out at least once per production day and the results observed and recorded by the Contract Administrator.		

Table R5
Additional Sample Requirements

Trial Section	RAC or PGAC (litres)	Crumb Rubber (kg)	RMA or HMA (kg)
Wet Process-Field Blend	4	5	50
Control (regular HMA)	4	N/A	50

SUPERPAVE 9.5 R-GAP GRADED - Item No.

Special Provision

Rubber Modified Hot Mix Asphalt

313.01 SCOPE

Subsection 313.01 of OPSS 313 is amended by the addition of the following:

This Special Provision covers the additional requirements for the construction of trial sections that include the use of rubber material processed in Ontario from Ontario tire waste. The trial sections shall incorporate rubber in the HMA using the wet process.

313.05 MATERIALS

313.05.01 Hot Mix Asphalt

Subsection 313.05.01 of OPSS 313 is deleted and replaced with the following:

The Materials used in the production of HMA shall be according to OPSS 1151, with the following amendments:

The HMA types, lift and location of the control and trial sections are provided in Table R1.

1151.02 REFERENCES

Section 1151.02 of OPSS 1151 is amended by addition of the following:

American Society for testing and Materials (ASTM) Standards

ASTM D5644	Test Methods for Rubber Compounding Materials - Determination of Particle Size Distribution of Recycled Vulcanizate Particle Rubber
ASTM D6114	Standard Specification for Asphalt-Rubber Binder
ASTM D217	Standard Test Methods for Cone Penetration of Lubricating Grease
ASTM D5329	Standard Test Methods for Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements
ASTM D36	Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)
ASTM D297	Standard Test Methods for Rubber Products-Chemical Analysis

State of California Laboratory Procedure

LP-11	Rotational Viscosity Measurement of Asphalt Rubber Binder

1151.03 DEFINITIONS

Section 1151.03 of OPSS 1151 is amended by addition of the following:

Ambient Ground: means scrap tire rubber processed or ground at or above 20°C to provide irregularly shaped, torn particles with relatively large surface areas.

Crumb Rubber (CR): means scrap tire rubber that is reduced in size for use in asphalt paving materials such as hot mix asphalt or asphalt cement or both.

Cryogenic Ground: means scrap tire rubber processed or ground at temperatures low enough that the rubber shatters.

Rubberized Asphalt Cement (RAC): means asphalt-rubber binder; which is PGAC modified with crumb rubber through the wet process.

Rubber Modified Asphalt (RMA): hot mix asphalt that contains crumb rubber added as an aggregate, as RAC or as both. May also refer to CR added with the asphalt cement to the aggregates during mix production of the HMA.

Superpave 12.5FC 2 R: means RMA that meets the requirements of Superpave 12.5FC 2 and contains RAC that is produced using wet process-terminal blend.

Superpave 9.5 R-Gap Graded: means RMA with gap-graded aggregates having 9.5 mm nominal maximum size and contains RAC produced using the wet process-field blend. Requirements for Superpave 9.5 R-Gap Graded are specified in this special provision.

Transition Area: means the length of the section within which the change from one section to the next shall be fully accomplished.

1151.04 DESIGN AND SUBMISSION REQUIREMENTS

1151.04.01 Design Requirements

Subsection 1151.04.01 of OPSS 1151 is amended by the addition of the following:

1151.04.01.07 Rubber Modified Asphalt

The RMA mix designs shall be according to the respective Superpave mix type specified in addition to including CR using the process specified in Table R1 and according to the following:

a) Wet Process-Terminal Blend

   The mix shall be designed to incorporate RAC in place of PGAC. Wet process-terminal blend RAC shall be produced by the PGAC supplier at their asphalt terminal.

b) Wet Process-Field Blend

   The mix shall be designed to incorporate RAC in place of PGAC. Wet process-field blend RAC shall be produced at the hot mix asphalt plant using a field blending plant.

The Superpave 9.5 R-Gap Graded mix design and JMF shall be according to the requirements specified in Table R2, Table 3 of OPSS 1151, and LS-309. For mix design purposes, the RAC shall be produced in the laboratory according to the following procedure:

- Heat up the base PGAC to 180°C. Add 18-20% CR by weight of the PGAC while continuously blending the compound.
- Continue blending the RAC for 45 minutes at 180°C.

1151.04.02 Submission Requirements

Subsection 1151.04.02 of OPSS 1151 is amended by the addition of the following:

The Contractor shall submit a plan and schedule to the Contract Administrator within two weeks of contract award describing how the Contractor will meet all the requirements of this non-standard special provision for review and approval including the following information in writing:

a) Special actions to be taken to assure that the CR will be available meeting the requirements of the Contract Documents, including that the CR processor selected by the Contractor or asphalt cement supplier or both can provide the material required for the Contract, and how the Contractor will assure that the CR processor selected has sufficient time to produce the quantity of CR required.

b) Information such as CR supplier's name, address, CR gradation, materials safety data sheet (MSDS), method and equipment used to mix CR into mix, CR dosage, RAC reaction time, mixing temperature, RAC storage conditions and any need for agitation, RAC blending location (hot mix asphalt plant vs. asphalt supplier's terminal) shall be provided.

c) Special actions to be taken to prevent swelling of the briquettes during the mix design.

d) Special actions to be taken to assure that the CR will be homogeneously distributed in the RMA.

e) Special actions to be taken to prevent pick-up during compaction of the RMA.

f) Product information on CR including information on how it was ground, whether cryogenic or ambient or both, shall be submitted with the mix design.

g) A letter from the CR supplier indicating that the CR they are supplying is produced in Ontario from tires scrapped in Ontario.

No RMA shall be placed on any trial section until the Contract Administrator acknowledges receipt of the plan and schedule in writing. Separate mix designs shall be submitted for each RMA type and for the control mix.

1151.05 MATERIALS

Section 1151.05 of OPSS 1151 is amended by addition of the following:

1151.05.06 Rubber Modified Asphalt and Rubberized Asphalt Cement

1151.05.06.01 General

Materials for the RMA shall conform to OPSS 313 except as amended by this special provision. It is the Contractor's responsibility to identify a facility to produce the mixes in accordance with the supplier's instructions for the use of their materials. The Contractor is responsible for obtaining from the suppliers any and all information required for the proper preparation, handling, storage and use of their materials.

The Contractor shall be solely responsible for obtaining materials, producing mixes, transportation, storage and use of all materials. The Contractor shall assure that the RMA is produced to prevent any deleterious effects to the finished product. The Contractor shall be responsible for ensuring cross contamination does not occur between the sections.

The Contractor shall contact Ontario Tire Stewardship (OTS), at either of the contact information below, who will facilitate the sourcing of the field blending plant, needed for producing Superpave 9.5 R-Gap Graded. The field blending plant shall only be sourced through OTS. The Contractor shall be responsible for the cost of supplying and operating the field blending plant. The Contractor shall allocate sufficient space at the hot mix asphalt plant to house the field blending plant. An area of about 30 m x 20 m would be sufficient for the field blending plant. The Contractor shall provide points of contact for supply lines from and to the field blending plant. The Contractor shall cooperate with the operator of the field blending plant and harmonize the operation of the field blending plant with the hot mix asphalt plant in order to produce the RMA mix meeting the requirements of the Contract Documents. The Contractor shall be responsible to supply and feed the CR into the field blending plant.

Andrew Horsman, Executive Director
Ontario Tire Stewardship
405 the West Mall, Suite 500
Toronto, ON M9C 5K7
Tel: 416-626-9185
ahorsman@ontariots.ca

Jennifer Barbazza, Manager, Operations & Special Projects
Ontario Tire Stewardship
405 the West Mall, Suite 500
Toronto, ON M9C 5K7
Tel: 416-916-4818
jbarbazza@ontariots.ca

1151.05.06.02 Crumb Rubber

The CR shall be processed from whole passenger vehicle tires. Heavy equipment tires shall not be used. Use of uncured or devulcanized rubber will not be permitted. CR shall be in the form of ambient or cryogenic ground rubber, or both. The CR shall be produced in Ontario from tires scrapped in Ontario. CR shall not contain more than 0.01% of wire and 0.05% fabric by weight. CR shall be free of other contaminants. The CR shall be dry and free-flowing and not produce foaming when blended with the PGAC. The CR shall have a specific gravity in the range of 1.1 to 1.2, as determined according to ASTM D 297.

The CR shall meet the gradation requirements specified in Table R3 determined according to ASTM D5644. No particles shall exceed a length of 5 mm as measured on any axis.

The Contractor shall contact Ontario Tire Stewardship (OTS), at the above contact information, who will facilitate the sourcing of the CR.

1151.05.06.03 Aggregates

Aggregate properties for RMA shall meet the requirements of Superpave 12.5FC 2 specified elsewhere in the Contract Documents. Coarse and fine aggregate properties for Superpave 9.5 R-Gap Graded shall meet the requirements of Superpave 12.5FC 2 specified elsewhere in the Contract Documents.

1151.05.06.04 Rubberized Asphalt Cement

CR added to the RAC shall meet the gradation requirements specified in Table R3 determined according to ASTM D5644. Wet-terminal blend RAC shall be produced as a Type III Asphalt Rubber Binder according to ASTM D6114. CR dosage by mass of wet-terminal blend RAC shall be 10% to 15%. Wet-field blend RAC (after reaction) shall meet the requirements found in Table R4. CR dosage by mass of wet-field blend RAC shall be 18% to 20%. For the production of the RAC, parameters such as CR gradation, mixing method and equipment, dosage, reaction time, mixing temperature, storage conditions and need for agitation, blending location (project site vs. asphalt supplier's terminal) shall be determined by the Contractor.

When the RAC supplier specifies a CR gradation with additional restrictions, the CR shall also meet the RAC supplier's gradation requirements. The CR material, PGAC and any antistripping additives required shall be compatible to ensure a good dissolution and reaction time. RAC produced shall be a homogenous mixture of CR and asphalt cement.

In case of terminal blend, the following asphalt cement suppliers have indicated their ability to supply the RAC:

a) Bitumar; b) Coco; c) McAsphalt; d) Shell

1151.07 PRODUCTION

1151.07.01 Anti-Stripping Additives

Subsection 1151.07.01 of OPSS 1151 is amended by addition of the following:

When an anti-stripping agent is to be incorporated into the mix, the Contractor shall contact and consult with each supplier to determine whether or not the proposed anti-stripping agent is compatible with the RMA or RAC or both. In those cases where a supplier deems that the anti-stripping agent is incompatible, that anti-stripping agent shall not be used and the Contractor shall select and employ another anti-stripping agent that the suppliers indicate is compatible with the mix and RAC.

1151.07.03 Field Blending Plant

The Contractor shall contact OTS a minimum of 6 weeks prior to paving Superpave 9.5 R-Gap Graded to coordinate delivery and operation of the field blending plant. OTS contact information is provided earlier in this special provision.

313.07 CONSTRUCTION

313.07.06.01 Operational Constraints

Clause 313.07.06.01 of OPSS 313 is amended by addition of the following:

The Contractor shall provide a minimum of 7 Days notice in writing to the Contract Administrator and to the Ministry's Regional Head of Quality Assurance Section before paving any trial section.

313.07.06.02 Paving

Clause 313.07.06.02 of OPSS 313 is amended by addition of the following:

The Contractor shall construct the control section and trial sections as indicated in Table R1, full width including shoulders. Transition areas shall be less than 50 m in length at the start of the trial and control sections. The Contractor shall adjust the paving and compaction operations to eliminate roller pick-up and provide a smooth surface without tearing, cracking, or shoving.

313.07.15 Sampling

Subsection 313.07.15 of OPSS 313 is amended by the addition of the following clause:

313.07.15.06 Rubber Modified Asphalt

Samples shall not be taken from the transition areas. In addition to other samples specified in the Contract Documents, the Contractor shall procure RMA samples of a minimum quantity specified in Table R5 for each of the control and trial sections.

Sample labeling shall include: highway number, highway direction, lane number, contract number, section (trial or control), mix type, corresponding Lot/Sublot numbers, station, date sampled. The Contractor shall deliver the samples specified in Table R5 to the address below:

c/o Seyed Tabib
Bituminous Section, MERO
Shipping and Receiving
Room 15, Building C
1201 Wilson Ave,
Toronto, ON M3M 1J8

Section 313.07 of OPSS 313 is amended by the addition of the following subsection:

313.07.19 Identification of RMA Paving Limits

The Contractor shall provide to the Contract Administrator, no later than 7 Days after completion of RMA paving, an as built sketch identifying the stations as well as the GPS data for the RMA paving limits. The GPS data shall be geo-referenced and NAD83 geographic coordinates (latitude, longitude) shall be used. Geographic coordinates (latitude, longitude) shall be provided within metre-level accuracy.

313.08 QUALITY ASSURANCE

313.08.01.02.01 Lot Size

Clause 313.08.01.02.01 of OPSS 313 is amended by the addition of the following:

Each mix type for the trial section shall be considered as a single lot with a minimum of three sublots.

313.08.01.02.03 Basis of Acceptance

Clause 313.0.8.01.02.03 of OPSS 313 is amended by the addition of the following:

a) Acceptance of Crumb Rubber

i. All CR shall meet the gradation requirements specified in Table R3 determined according to ASTM D5644.

b) Acceptance of Rubber Modified Asphalt (RMA)
   i. Acceptance and pay adjustment of the RMA containing RAC-terminal blend shall be determined accordance to the respective mix type HMA requirements specified elsewhere in the Contract Documents.

   ii. Acceptance and pay adjustment of the Superpave 9.5 R-Gap Graded shall be according to requirements for Superpave 9.5 specified elsewhere in the Contract Documents with the exception of VMA and coarse and fine aggregate physical properties. VMA will not be considered an acceptance criterion for Superpave 9.5 R-Gap Graded. Coarse and fine aggregate physical properties for Superpave 9.5 R-Gap Graded shall be according to requirements for Superpave 12.5FC 2 specified elsewhere in the Contract Documents. Aggregate gradation for Superpave 9.5 R-Gap Graded shall be according to Table R2.

   iii. RMA containing RAC wet-terminal blend will be rejectable if there are clumps of CR in the RMA visible to the naked eye.

c) Acceptance of Rubberized Asphalt Cement (RAC)
   i. Acceptance of the RAC wet-terminal blend shall be determined according to the respective requirements for the PGAC grade specified according to OPSS 1101. Additionally, to be acceptable the RAC wet-terminal blend shall meet the Type III Asphalt Rubber Binder requirements of ASTM D6114.
   ii. Acceptance of the RAC wet-field blend shall be according to Table R4.

313.08.01.02.04.01 General

Clause 313.08.01.02.04.01 of OPSS 313 is amended by the addition of the following:

The Owner will use LS-292 for determination of the asphalt cement content for the RMA, therefore, the referee laboratory shall also follow LS-292 (ignition oven).

313.09 MEASUREMENT FOR PAYMENT

313.09.01.01

Clause 313.09.01.01 of OPSS 313 is amended by the addition of the following item:

Superpave 9.5 R-Gap Graded

313.10 BASIS OF PAYMENT

313.10.01.01

Clause 313.10.01.01 of OPSS 313 is amended by the addition of the following item:

Superpave 9.5 R-Gap Graded - Item

313.10.01.02.02.04 Payment Factor for Voids

Clause 313.10.01.02.02.04 of OPSS 313 is deleted in its entirety and replaced with the following:

For RMA mixes, as long as the lot mean air voids is between 2.5 and 5.5 percent, the payment factor for voids, PF_{VOIDS}, shall be equal to either:

a) PF_{GAC}, if the PF_{GAC} is less than 1.0; or,
b) 1.0, if the PF_{GAC} is equal to or greater than 1.0.

Otherwise, if the lot mean air voids is outside the 2.5-5.5 percent range, the PF_{VOIDS} shall be considered to be 0.5.

313.10.01.02.02.06 Payment Factor for Combined Mix Properties and Compaction

Clause 313.10.01.02.02.06 of OPSS 313 is amended by the addition of the following:

For RMA mixes, as long as the lot mean compaction is between 90.5 and 98.0 percent, the payment factor for compaction, PF_C, shall be equal to either:

a) PF_M, if the PF_M is less than 1.0; or,
b) 1.0, if the PF_M is equal to or greater than 1.0.

Otherwise, if the lot mean compaction is outside the 90.5-98.0 percent range, the PF_C shall be considered to be 0.65.

Table R1
Trial Sections

Trial Section	Pavement Course	Location (Stations)	Mix Type
Wet Process-Field Blend	Surface	14+500 to 17+500	Superpave 9.5 R-Gap Graded
Wet Process-Terminal Blend	Surface	11+500 to 14+500	Superpave 12.5FC 2 R
Control Section	Surface	Remainder of the contract to the west of Wet Process-Terminal Blend Section	Superpave 12.5FC 2

Table R2
Superpave 9.5 R-Gap Graded Properties

Hot Mix Asphalt Type	Percentage Passing by Dry Mass of Aggregates						Traffic Category	Base PGAC Grade	% Air Voids	% VMA min.	AC_{BID} (%)
	Sieve Size, mm										
	12.5	9.5	4.75	2.36	1.18	0.075					
Superpave 9.5 R-Gap Graded	100	90-100	28-42	15-25	5-15	2-7	C	58-28	4	18	7.0

Table R3
Gradation Requirements for Crumb Rubber

Process	Sieve	Percent Passing Sieve by Mass
Wet-Terminal Blend (see Note 1)	2.36 mm	100
Wet-Field Blend	2.36 mm	100
	2.00 mm	100
	1.18 mm	80 – 100
	600 µm	40 – 60
	300 µm	5 – 15
	150 µm	0 – 10

Notes:
1. The RAC supplier shall select a gradation suitable for producing a Type III Asphalt Rubber Binder according to ASTM D6114 and this non-standard special provision in addition to meeting the minimum requirements of OPSS 1101 for the PGAC grade specified elsewhere in the Contract Documents.

Table R4
Requirements for Field Blend RAC (after reaction)

Test Parameter	Test Method	Specification Limit
Field Viscosity @ 191°C (375°F), centipoises (see Note 1)	California Laboratory Procedure LP-11	1500 – 4000
Cone Penetration @ 25°C, 0.1 mm	ASTM D 217	25 – 70
Resilient @ 25°C, % Rebound	ASTM D 5329	18 minimum
Field Softening Point, °C	ASTM D 36	52 – 74

Notes:
1. The operator of the field blending plant usually has a field viscometer. This test shall be carried out at least once per production day and the results observed and recorded by the Contract Administrator.

Table R5
Additional Sample Requirements

Trial Section	RAC or PGAC (litres)	Crumb Rubber (kg)	RMA or HMA (kg)
Wet Process-Field Blend	4	5	50
Wet Process-Terminal Blend	4	5	50
Control	4	N/A	50

Appendix B: Ontario Specifications Using Wet Process Terminal Blend

SUPERPAVE 12.5FC 1 R - Item No.

Special Provision

Rubber Modified Hot Mix Asphalt

313.01 SCOPE

Subsection 313.01 of OPSS 313 is amended by the addition of the following:

This Special Provision covers the additional requirements for the construction of a trial section that includes the use of rubber material processed in Ontario from Ontario tire waste. The trial section shall incorporate rubber in the HMA using the Wet Process-Terminal Blend.

313.05 MATERIALS
Hot Mix
313.05.01 Asphalt

Subsection 313.05.01 of OPSS 313 is deleted and replaced with the following:

The Materials used in the production of HMA shall be according to OPSS 1151, with the following amendments:

The HMA types, lift and location of the control and trial section are provided in Table R1.

1151.02 REFERENCES

Section 1151.02 of OPSS 1151 is amended by addition of the following:

American Society for testing and Materials (ASTM) Standards

ASTM D5644	Test Methods for Rubber Compounding Materials - Determination of Particle Size Distribution of Recycled Vulcanizate Particle Rubber
ASTM D6114	Standard Specification for Asphalt-Rubber Binder
ASTM D297	Standard Test Methods for Rubber Products-Chemical Analysis

1151.03 DEFINITIONS

Section 1151.03 of OPSS 1151 is amended by addition of the following:

Ambient Ground: means scrap tire rubber processed or ground at or above 20°C to provide irregularly shaped, torn particles with relatively large surface areas.

Crumb Rubber (CR): means scrap tire rubber that is reduced in size for use in asphalt paving materials such as hot mix asphalt or asphalt cement or both.

Cryogenic Ground: means scrap tire rubber processed or ground at temperatures low enough that the rubber shatters.
Rubberized Asphalt Cement (RAC): means asphalt-rubber binder; which is PGAC modified with crumb rubber through the wet process.

Rubber Modified Asphalt (RMA): hot mix asphalt that contains crumb rubber added as an aggregate, as RAC or as both. May also refer to CR added with the asphalt cement to the aggregates during mix production of the HMA.

Superpave 12.5FC 1 R: means RMA that meets the requirements of Superpave 12.5FC 1 and contains RAC that is produced using wet process-terminal blend.

Transition Area: means the length of the section within which the change from one section to the next shall be fully accomplished.

1151.04 DESIGN AND SUBMISSION REQUIREMENTS

1151.04.01 Design Requirements

Subsection 1151.04.01 of OPSS 1151 is amended by the addition of the following:

1151.04.01.07 Rubber Modified Asphalt

The RMA mix design shall be according to requirements for Superpave 12.5FC 1 and according to the following:

a) Wet Process-Terminal Blend

The mix shall be designed to incorporate RAC in place of PGAC. Wet process-terminal blend RAC shall be produced by the PGAC supplier at their asphalt terminal.

1151.04.02 Submission Requirements

Subsection 1151.04.02 of OPSS 1151 is amended by the addition of the following:

The Contractor shall submit a plan and schedule to the Contract Administrator within two weeks of contract award describing how the Contractor will meet all the requirements of this non-standard special provision for review and approval including the following information in writing:

A. Information such as CR supplier's name, address, CR gradation, materials safety data sheet (MSDS), RAC reaction time, mixing temperature, RAC storage conditions and any need for agitation shall be provided. Product information on CR including information on how it was ground, whether cryogenic or ambient or both, shall be submitted with the mix design.

B. Special actions to be taken to prevent swelling of the briquettes during the mix design.

C. Special actions to be taken to prevent pick-up during compaction of the RMA.

D. A letter from the CR supplier indicating that the CR they are supplying is produced in Ontario from tires scrapped in Ontario.

No RMA shall be placed on any trial section until the Contract Administrator acknowledges receipt of the plan and schedule in writing. Separate mix designs shall be submitted for each RMA type and for the control mix.

1151.05 MATERIALS

Section 1151.05 of OPSS 1151 is amended by addition of the following:

1151.05.06 Rubber Modified Asphalt and Rubberized Asphalt Cement

1151.05.06.01 General

Materials for the RMA shall conform to OPSS 313 except as amended by this special provision. It is the Contractor's responsibility to identify a facility to produce the mixes in accordance with the supplier's instructions for the use of their materials. The Contractor is responsible for obtaining from the suppliers any and all information required for the proper preparation, handling, storage and use of their materials.

The Contractor shall be solely responsible for obtaining materials, producing mixes, transportation, storage and use of all materials. The Contractor shall assure that the RMA is produced to prevent any deleterious effects to the finished product. The Contractor shall be responsible for ensuring cross contamination does not occur between the sections.

1151.05.06.02 Crumb Rubber

The CR shall be processed from whole passenger vehicle tires. Heavy equipment tires shall not be used. Use of uncured or devulcanized rubber will not be permitted. CR shall be in the form of ambient or cryogenic ground rubber, or both. The CR shall be produced in Ontario from tires scrapped in Ontario. CR shall not contain more than 0.01% of wire and 0.05% fabric by weight. CR shall be free of other contaminants. The CR shall be dry and free-flowing and not produce foaming when blended with the PGAC. The CR shall have a specific gravity in the range of 1.1 to 1.2, as determined according to ASTM D 297.

The CR shall meet the gradation requirements specified in Table R2 determined according to ASTM D5644. No particles shall exceed a length of 5 mm as measured on any axis.

1151.05.06.03 Aggregates

Aggregate properties for RMA shall meet the requirements of Superpave 12.5FC 1 specified elsewhere in the Contract Documents.

1151.05.06.04 Rubberized Asphalt Cement

CR added to the RAC shall meet the gradation requirements specified in Table R2 determined

according to ASTM D5644. Wet-terminal blend RAC shall be produced as a Type III Asphalt Rubber Binder according to ASTM D6114. CR dosage by mass of wet-terminal blend RAC shall be 10% to 15%. For the production of the RAC, parameters such as CR gradation, mixing method and equipment, dosage, reaction time, mixing temperature, storage conditions and need for agitation shall be determined by the Contractor.

When the RAC supplier specifies a CR gradation with additional restrictions, the CR shall also meet the RAC supplier's gradation requirements. The CR material, PGAC and any antistripping additives required shall be compatible to ensure a good dissolution and reaction time. RAC produced shall be a homogenous mixture of CR and asphalt cement.

In case of terminal blend, the following asphalt cement suppliers have indicated their ability to supply the RAC:

a) Bitumar; b) Coco; c) McAsphalt; d) Shell

1151.07 PRODUCTION
Anti-Stripping
1151.07.01 Additives

Subsection 1151.07.01 of OPSS 1151 is amended by addition of the following:

When an anti-stripping agent is to be incorporated into the mix, the Contractor shall contact and consult with each supplier to determine whether or not the proposed anti-stripping agent is compatible with the RMA or RAC or both. In those cases where a supplier deems that the anti-stripping agent is incompatible, that anti-stripping agent shall not be used and the Contractor shall select and employ another anti-stripping agent that the suppliers indicate is compatible with the mix and RAC.

313.07 CONSTRUCTION
Operational
313.07.06.01 Constraints

Clause 313.07.06.01 of OPSS 313 is amended by addition of the following:

The Contractor shall provide a minimum of 7 Days notice in writing to the Contract Administrator and to the Ministry's Regional Head of Quality Assurance Section before paving any trial section.

313.07.06.02 Paving

Clause 313.07.06.02 of OPSS 313 is amended by addition of the following:

The Contractor shall construct the control section and trial section as indicated in Table R1, full width including shoulders. Transition areas shall be less than 50 m in length at the start of the trial and control sections. The Contractor shall adjust the paving and compaction operations to eliminate roller pick-up and provide a smooth surface without tearing, cracking, or shoving.

313.07.15 Sampling

Subsection 313.07.15 of OPSS 313 is amended by the addition of the following clause:

313.07.15.06 Rubber Modified Asphalt

Samples shall not be taken from the transition areas. In addition to other samples specified in the Contract Documents, the Contractor shall procure RMA samples of a minimum quantity specified in Table R3 for each of the control and trial sections.

Sample labeling shall include: highway number, highway direction, lane number, contract number, section (trial or control), mix type, corresponding Lot/Sublot numbers, station, date sampled. The Contractor shall deliver the samples specified in Table R3 to the address below:

c/o Seyed Tabib Bituminous
Section, MERO Shipping
and Receiving Room 15,
Building C
1201 Wilson Ave,
Toronto, ON M3M 1J8

Section 313.07 of OPSS 313 is amended by the addition of the following subsection:

313.07.19 Identification of RMA Paving Limits

The Contractor shall provide to the Contract Administrator, no later than 7 Days after completion of RMA paving, an as built sketch identifying the stations as well as the GPS data for the RMA paving limits. The GPS data shall be geo-referenced and NAD83 geographic coordinates (latitude, longitude) shall be used.
Geographic coordinates (latitude, longitude) shall be provided within metre-level accuracy.

313.08 QUALITY ASSURANCE

313.08.01.02.01 Lot Size

Clause 313.08.01.02.01 of OPSS 313 is amended by the addition of the following:

Each mix type for the trial section shall be considered as a single lot with a minimum of three sublots.

313.08.01.02.03 Basis of Acceptance

Clause 313.0.8.01.02.03 of OPSS 313 is amended by the addition of the following:

F. Acceptance of Crumb Rubber: All CR shall meet the gradation requirements specified in Table R2 determined according to ASTM D5644.

G. Acceptance of Rubber Modified Asphalt (RMA): Acceptance and pay adjustment of the RMA containing RAC-terminal blend shall be determined accordance to the requirements for Superpave 12.5FC 1 specified elsewhere in the Contract Documents.

H. Acceptance of Rubberized Asphalt Cement (RAC): Acceptance of the RAC wet-terminal blend shall be determined according to the respective requirements for the PGAC grade specified according to OPSS 1101. Additionally, to be acceptable the RAC wet-terminal blend shall meet the Type III Asphalt Rubber Binder requirements of ASTM D6114.

313.08.01.02.04.01 General

Clause 313.08.01.02.04.01 of OPSS 313 is amended by the addition of the following:

The Owner will use LS-292 for determination of the asphalt cement content for the RMA, therefore, the referee laboratory shall also follow LS-292 (ignition oven).

313.09 MEASUREMENT FOR PAYMENT

313.09.01.01

Clause 313.09.01.01 of OPSS 313 is amended by the addition of the following item:

Superpave 12.FC 1 R

313.10 BASIS OF PAYMENT

313.10.01.01

Clause 313.10.01.01 of OPSS 313 is amended by the addition of the following item:

Superpave 12.5FC 1 R - Item

313.10.01.02.02.04 Payment Factor for Voids

Clause 313.10.01.02.02.04 of OPSS 313 is deleted in its entirety and replaced with the following:

For RMA mixes, as long as the lot mean air voids is between 2.5 and 5.5 percent, the payment factor for voids, PF_{VOIDS}, shall be equal to either:

G. PF_{GAC}, if the PF_{GAC} is less than 1.0; or,
H.1.0, if the PF_{GAC} is equal to or greater than 1.0.

Otherwise, if the lot mean air voids is outside the 2.5-5.5 percent range, the PF_{VOIDS} shall be considered to be 0.5.

313.10.01.02.02.06 Payment Factor for Combined Mix Properties and Compaction

Clause 313.10.01.02.02.06 of OPSS 313 is amended by the addition of the following:

For RMA mixes, as long as the lot mean compaction is between 90.5 and 98.0 percent, the payment factor for compaction, PF_C, shall be equal to either:

1. PF_M, if the PF_M is less than 1.0; or,
2. 1.0, if the PF_M is equal to or greater than 1.0.

Otherwise, if the lot mean compaction is outside the 90.5-98.0 percent range, the PF_C shall be

considered to be 0.65.

Table R1
Trial Sections

Trial Section	Pavement Course	Location (Stations)	Mix Type
Wet Process-Terminal Blend	Surface	11+300 to 13+300	Superpave 12.5FC 1 R
Control Section	Surface	13+300 to 17+650	Superpave 12.5FC 1

Table R2
Gradation Requirements for Crumb Rubber

Process	Sieve	Percent Passing Sieve by Mass
Wet-Terminal Blend (see Note 1)	1.00 mm	100

Notes:
The RAC supplier shall select a gradation suitable for producing a Type III Asphalt Rubber
1. Binder according to ASTM D6114 and this non-standard special provision in addition to meeting the minimum requirements of OPSS 1101 for the PGAC grade specified elsewhere in the Contract Documents.

Table R3
Additional Sample Requirements

Trial Section	RAC or PGAC (litres)	Crumb Rubber (kg)	RMA or HMA (kg)
Wet Process-Terminal Blend	4	2	50
Control	4	N/A	50

Appendix C: Specification for Ontario Quiet Pavement Test Section RAC-O

Test Sections of quiet pavement

Scope

This special provision covers the requirements for the construction of five (5) test sections on portions of Hamilton bound lanes of Highway 405 as follows:

- One section using open friction course (OGFC) asphalt containing polymer/fibre modified PGAC as surface course and HL4 Open Binder Course (OBC) as binder course over Superpave 19.0 binder course.
- One section using open friction course (OGFC) asphalt containing polymer/fibre modified PGAC as surface course and Superpave 19.0 as binder course.
- One section using open friction course asphalt containing crumb rubber modified PGAC obtained through wet process (RAC-O) as surface course and Superpave 19.0 as binder course.
- One section using SMA 9.5 as surface course and Superpave 19.0 as binder course.
- One section using Superpave 12.5 FC2 as surface course and Superpave 19.0 as binder course.

The purpose of the test sections is to examine the effect of various asphalt mixes on the tire-pavement noise. This is a materials-related study requiring additional care, materials sampling, and documentation as set out in this special provision. Materials and construction variability are to be carefully controlled to minimize their influence on the performance of the test sections.

Definitions

Crumb Rubber Modifier (CRM): general term for scrap tire rubber that is reduced in size for use as modifier in asphalt paving material.

Rubberized Asphalt (RA): means asphalt binder modified with CRM through wet process.

Open Graded Rubberized Asphalt Concrete (RAC-O): means hot mix asphalt obtained from mixing rubberized asphalt (RA) with open graded aggregate.

Submission and Design Requirements

The Contractor shall submit a plan and schedule to the Contract Administrator within two weeks of contract award describing how the Contractor will meet all the requirements of this special provision including asphalt modification methods and RAC-O process. The mix design information for all mixes shall be provided to the Ministry. No asphalt concrete shall be placed on any test section until the Contract Administrator issues written approval of the plan and schedule in writing.

Materials

Materials for the SMA, OGFC, RAC-O, OBC, and Superpave shall conform to OPSS 313, 1003, 1101, or as specified elsewhere in the contract, except as amended hereafter by this special provision. If the

supplier provides ingredients and instructions then it is the Contractor's responsibility to identify a facility to produce the mixes. The Contractor is responsible for obtaining from the suppliers any and all information required for the proper preparation, handling, storage and use of their materials.

The grade of PGAC to be used in the test sections shall a 70-28.

SMA

- The coarse and fine aggregates used for SMA shall be crushed from the same dolomitic sandstone source.
- The SMA shall comply with the gradation requirements - design criteria for SMA 9.5 specified elsewhere in the contract.
- The Designated Large Sieve (DLS) for SMA shall the 4.75 mm sieve as specified elsewhere in the contract.

OGFC

- The gradation of OGFC shall follow Table A below.
- Mix design shall be as per ASTM D7064-04 or later revision.
- Aggregate properties shall meet the requirement for Superpave 12.5 FC2 except that the coarse aggregate shall consist of 100% particles with minimum two crushed faces.
- Minimum allowable ambient temperature for paving OGFC shall be 12°C. If the ambient temperature is below 18°C, the hauling truck shall be covered with a sound water-repellent tarpaulin.
- Only steel-wheeled rollers shall be used for compaction.

RAC-O

- The gradation of RAC-O shall follow Table A.
- Mix design shall be as per ASTM D7064-04 or later revision.
- Aggregate properties shall meet the requirement for Superpave 12.5 FC2 except that the coarse aggregate shall consist of over 90% particles with minimum two crushed faces.
- Minimum allowable ambient temperature for paving RAC-O shall be 12°C. If the ambient temperature is below 18°C, the hauling truck shall be covered with a sound water-repellent tarpaulin.
- Only steel-wheeled rollers shall be used for compaction. Rollers must be equipped with pads and watering system to prevent excessive pick-up.

RAC-O shall be produced using either wet or semi-wet process. Dry process is not permitted in this project.

Wet process shall consist of rubberized asphalt binder conforming to ASTM D6114. Preferred minimum CRM dosage by weight of asphalt binder should be 15%. For the production of the rubberized asphalt binder, parameters such as rubber gradation, mixing method and equipment, dosage, reaction time, mixing temperature, storage conditions and need for agitation, blending

location (project site vs. asphalt supplier's terminal) shall be determined by the contractor and submitted to the Contract Administrator for review and approval within two weeks of contract award. Rubberized asphalt binder produced through the selected method shall be a homogenous mixture of CRM and asphalt binder.

Semi-wet process shall consist of HMA modified to include ultrafine CRM. The rubber shall be ground to pass the 600 μm sieve. The mix shall contain 1% CRM by mass of the RAC-O. The ultrafine ground CRM shall be proportioned into the mixer just prior to the addition of the asphalt cement during the mixing process. The CRM shall be added in a manner to ensure it is homogeneously distributed and mixed in the RAC-O without any clumping of the CRM. The Contractor shall take care during mixing to make appropriate adjustments for the low specific gravity of the CRM to ensure volumetrics are met.

HL4 OBC

- The gradation of HL4 OBC shall follow Table A.
- Mix design shall be as per ASTM D7064-04 or later revision.
- Aggregate properties shall meet the requirement for Superpave 19 except that the coarse aggregate shall consist of 100% particles with minimum one crushed face.
- Surface course over the HL4 OBC shall be placed within a minimum of 3 days of paving of the HL4 OBC.
- Minimum allowable ambient temperature for paving OBC shall be 10°C. If the ambient temperature is below 18°C, the hauling truck shall be covered with a sound water-repellent tarpaulin.
- Only steel-wheeled rollers shall be used for compaction.

Table A – Gradation Requirement for Trial Asphalt Mixes

Hot Mix Asphalt Type	Percentage Passing by Dry Weight of Aggregate							
	Sieve Size (mm)							
	19.0	16.0	12.5	9.5	4.75	2.36	1.18	0.075
OGFC	100	-	100	95-100	25-40	8-20	-	2-4
RAC-O	100	-	100	90-100	29-36	7-18	0-10	0-3
HL4 OBC	100	100	70-86	30-52	5-15	0-10	-	0-4

In addition to the requirements specified elsewhere in the contract, the tack coat applied immediately prior to placement of OGFC, HL-4 OBC, and RAC-O shall be polymer modified with the exception that no tack coat shall be applied to the surface of the HL-4 OBC.

Construction

The work required for construction shall conform to OPSS 313, except as amended by the following.

The Contractor shall provide a minimum of five (5) business days notice in writing to the Contract Administrator and also to the Ministry's Contract Control Officer before paving the test sections.

The Contractor shall be solely responsible for obtaining materials, producing mixes, transportation, storage and use of all materials. The Contractor shall assure that the modified mixes are produced to the supplier's recommendations to prevent any deleterious effects to the finished product.

The Contractor shall be responsible for the preparation of job mix formula for all hot asphalt mixes defined in this special provision, which shall meet the requirements detailed in this special provision as well as elsewhere in the contract. Surface and binder courses in each of the test sections shall be constructed using the approved job-mix formula (JMF).

The Contractor is responsible for all quality control measures to be taken to assure that the products meet the requirements of this special provision and the general requirements of this contract. The contractor shall submit separate quality control plans for each of the mixes specified in this special provision a minimum of two months prior to the start of paving. The Contractor shall submit a plan to the Contract Administrator not later than two months prior to the construction of the test sections describing what special actions will be taken to assure rubber will be homogeneously distributed in the RAC-O.

If for any reason a supplier is no longer able to provide the mix or materials then the Contractor shall make all reasonable effort to substitute the materials or mix with a similar product from a different supplier. Any change will need to be approved in writing by the Contract Administrator before paving of the test section starts.

When an anti-stripping agent is to be incorporated into the mix, the Contractor shall contact and consult with each supplier to determine whether or not the proposed anti-stripping agent is compatible with the RAC-O. In those cases where the RAC-O supplier deems the anti-stripping agent incompatible, it shall not be used in that test section, and the Contractor shall select and employ another anti-stripping agent that the supplier indicates is compatible with their mix. The Contractor shall provide a copy of the correspondence from mix producer detailing the compatibility or incompatibility with the proposed anti-stripping agent to the Contract Administrator prior to paving of that test section.

The Contractor shall be responsible for ensuring cross contamination does not occur between the test sections.

Each regular and modified hot mix asphalt used for the test sections shall not contain any reclaimed asphalt pavement (RAP). The regular and modified hot mixes shall meet all the mix property requirements specified elsewhere in the Contract.

Additional Sampling of Materials

The Contractor shall deliver to the address listed below:

1. Four (4)-litre sample of the rubberized asphalt obtained from the sampling spigot at the hot mix plant during the production of the RAC-O (applicable when the wet process is used);

2. Twenty (20) kg of CRM used in RAC-O (applicable when the semi-wet process is used);

3. In addition to those samples taken for ERS compliance, five samples of 20 kg each of the OGFC, RAC-O, and OBC mixes. Labelling shall include which test section the mix is from.

Chris Raymond
Bituminous Section, MERO
Room 15, Building C
1201 Wilson Ave,
Toronto, ON M3M 1J8

Test Sections Layout

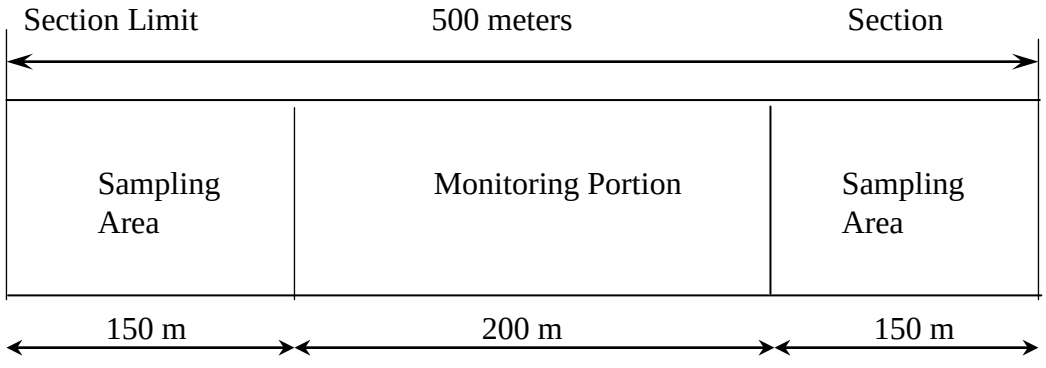
The Contractor shall construct the test sections each two lanes wide and 500 meters long including partially or fully paved shoulders, as specified. The test sections shall be constructed in conformance with OPSS 313, as amended by the special provisions in this Contract and to the lines, grades, thicknesses and cross-sections shown elsewhere in the Contract Documents.

The test sections shall be constructed in accordance with Table B indicating test section locations, thickness, and type of hot mix asphalt within each test section.

Table B: Test Section Locations

Test Section	Location	Mix Thickness and Type
A	Sta. 12+000 to Sta. 12+500	30 mm OGFC over 50 mm HL4 OBC over 50 mm Superpave 19.0
B	Sta. 12+500 to Sta. 13+000	30 mm OGFC over 50 mm Superpave 19.0
C	Sta. 13+000 to Sta. 13+500	30 mm RAC-O over 50 mm Superpave 19.0
D	Sta. 13+500 to Sta. 14+000	30 mm SMA 9.5 over 50 mm Superpave 19.0
E	Sta. 14+000 to Sta. 14+500	40 mm SP 12.5 FC2 over 50 mm Superpave 19.0

Each test section shall be constructed as shown in the schematic Test Section Layout below.
Test Section Layout



Section Limit defines the chainage where the hot mix asphalt type changes.

Sampling Area defines the section length specifically set aside for sampling both during and after construction.

Monitoring Portion defines the section length to be used for noise measurement and assessing the performance of the section through visual and other non-destructive methods.

All sections shall be constructed with the same grade asphalt cement used in the remainder of the Contract, outside of the test sections. The sequence of placement of the test sections may be changed, with the approval of the Contract Administrator, to suit field conditions.

The Contractor shall install 300 mm x 300 mm aluminium plate information signs indicating limits between sections and also limits between monitoring and sampling areas. The Ministry (Provincial Sign Shop) will supply the signs and the contractor shall pick them up from the address provided below and haul them to the construction site. The Contractor shall supply 25 mm x 25 mm x 1800 mm steel posts, and the required bolts. The Contractor shall attach the signs to the steel posts and erect the posts within the right of way at each limit to be confirmed by the Contract Administrator. The Contractor is to advise the Ministry at least five (5) business days in advance of when the signs are required for pick up. The information signs are available at the following address:

MTO Provincial Sign Shop
Location: 1927 Kipling Avenue, Rexdale, Ontario
Time: 6:30 a.m. – 2:00 p.m. Monday to Friday (except Holidays)
Contact and Phone number: Tracey Johnston 416-314-1898 ext. 303

Quality Assurance

Lot Size and Sampling

Each of the binder course and the surface course of each test section shall be considered as a single lot with three sublots (i.e., sampling areas plus monitoring section). Three random sets of samples of the mix and three sets of compaction cores shall be taken within each sublot. No compaction cores shall be taken from the Monitoring Portions. Each set of samples shall be comprised of three samples, one for QC, one for QA and one for referee testing, as specified elsewhere in the Contract. No compaction cores shall be taken for OGFC, RAC-O, and HL4 OBC.

The contractor should expect that extra samples from the test sections will be required for research purposes at no extra cost to the Owner.

Acceptance of OGFC

OGFC shall meet the requirements for surface tolerance and visual acceptance as specified elsewhere in the Contract. Acceptance of the material shall be based on the average for the lot meeting the requirements given in Table C and for air voids, no less than 2 % below the mix design requirements. No payment adjustment will apply to the mix that meets the criteria. Any sublot that does not meet the

criteria outlined in Table C will be considered rejectable and shall be removed and replaced with an acceptable OGFC mix.

Acceptance of RAC-O

RAC-O shall meet the requirements for surface tolerance and visual acceptance as specified elsewhere in the Contract. Acceptance of the material shall be based on the average for the lot meeting the requirements given in Table C and for air voids, no less than 2 % below the mix design requirements. No payment adjustment will apply to the mix that meets the criteria. No payment adjustment will apply to the mix that meets the criteria. Any sublot that does not meet the criteria outlined in Table C will be considered rejectable and shall be removed and replaced with an acceptable RAC-O mix. No particles or clumps of CRM shall be visible to the naked eye.

Acceptance of HL4 OBC

OBC shall meet the requirements for surface tolerance and visual acceptance as specified elsewhere in the Contract. Acceptance of the material shall be based on the average for the lot meeting the requirements given in Table C and for air voids, no less than 2 % below the mix design requirements. No payment adjustment will apply to the mix that meets the criteria. No payment adjustment will apply to the mix that meets the criteria. Any sublot that does not meet the criteria outlined in Table C will be considered rejectable and shall be removed and replaced with an acceptable HL4 OBC mix.

Table C - Specification Limits from Job Mix Formula (JMF)

TEST	LL (%)	UL (%)
Asphalt Cement Content	JMF - 0.5	JMF + 0.50
Designated Large Sieve*	JMF - 5.0	JMF + 5.0
4.75 mm Sieve	JMF - 5.0	JMF + 5.0
75 µm Sieve	JMF - 1.0	JMF + 1.0

* Designated Large Sieve is 4.75 mm for OGFC and RAC-O and is 9.5 mm for OBC.

Referee Testing

Testing by an independent third party referee laboratory of only the entire lot may be requested by the Contractor or the Owner for any completed lot.

Referee testing for a given lot can only be invoked by the Contractor within five business days of the Contractor receiving the Contract Administrator's calculated QC and QA payment factors for that lot. The Owner may invoke referee testing for a given lot not more than 15 business days after all the QA samples for the lot are received at the QA laboratory, or not more than 6 business days after all the QC results are received by the Contract Administrator, or not more than 15 days after a lot is terminated due to a delay of more than 20 business days in placing the complete lot, whichever is the latest date.

The referee laboratory will be designated by the Owner from a Roster Rotation List maintained by the Owner for this purpose. The Contract Administrator shall arrange for the delivery of samples to the referee laboratory. The results generated by the referee laboratory shall be used to determine the payment factors for the acceptance of the disputed properties for the disputed lots of hot mix. The results shall be binding on the Contractor and the Owner.

When QC and QA results do not agree, for any referee testing which is carried out without an outlier in the referee results, the cost of referee testing, including sample delivery, shall be borne by the party whose payment factor is further removed from that generated by the referee laboratory. However, if the payment factor determined by the referee results is exactly in between that determined by the QC and QA laboratories, the cost of the referee services shall be split between the Owner and the Contractor.

If the QC and QA results agree, the cost of referee testing, including sample delivery, shall be borne by the party requesting the referee testing.

Referee testing shall be charged at the rates outlined elsewhere in the contract.

The QC and QA results shall be deemed to agree if the difference in the compaction payment factor and the mix properties payment factor calculated using the QA and QC test results are both less than 0.025. When the QC and QA results agree, the payment factor obtained using the QC results shall apply unless either party requests referee testing. If this comparison criteria is not met, the QC and QA results shall be deemed to disagree and Referee testing may be requested by either party as described in this special provision.

Measurement for Payment

Measurement for payment for above tender items shall be by mass in tonnes according to the requirements of the Contract Documents. Measurement for payment for above tender items used for temporary ramping specified in the Contract Documents shall be measured in tonnes. Removal of temporary ramping specified in the Contract Documents shall not be measured for payment.

Basis of Payment

Payment at the Contract price for the above tender item(s) shall include full compensation for all labour, equipment, and materials required to do the work.

Appendix D: California Specifications – Gap Graded

10-1.____RUBBERIZED ASPHALT CONCRETE (TYPE G)

Rubberized asphalt concrete (Type G) shall consist of furnishing and mixing gap graded aggregate and asphalt-rubber binder and spreading and compacting the mixture. Type G rubberized asphalt concrete shall conform, except as otherwise provided, to the provisions for Type A asphalt concrete in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.

GENERAL

The Contractor shall furnish samples of aggregate to the Engineer in conformance with the provisions in Section 39-3.03, "Proportioning," of the Standard Specifications.

Aggregate for Type G rubberized asphalt concrete shall be of such quality that the optimum amount of asphalt-rubber binder to be mixed with the aggregate, as determined by the Engineer in conformance with the requirements in California Test 367 (as amended below), shall be a minimum of 7.0 percent by mass of dry aggregate and a maximum of 9.0 percent by mass of dry aggregate. Aggregates which result in an optimum asphalt-rubber binder content of less than 7.0 percent or more than 9.0 percent by mass of dry aggregate shall not be used. The Engineer will determine the exact amount of asphalt-rubber binder to be mixed with the aggregate in conformance with the requirements in California Test 367, except as follows:

A. The specific gravity used in California Test 367, Section "B. Voids Content of Specimen," will be determined using California Test 308, Method A.

B. California Test 367, Section "C. Optimum Bitumen Content," is revised as follows:

1. Plot asphalt-rubber binder content versus void content for each specimen on Form TL-306 (Figure 3), and connect adjacent points with straight lines.
2. From Figure 3 select the theoretical asphalt-rubber binder content that has __ percent voids.
3. Record the asphalt-rubber binder content in Step 2 as the Optimum Bitumen Content (OBC).
4. To establish a recommended range, use the Optimum Bitumen Content (OBC) as the high value and 0.3 percent less as the low value. Notwithstanding, the recommended range shall not extend below 7.0 percent nor shall the high value to establish the recommended range be above 9.0 percent. If the OBC is 7.0 percent, then there shall be no recommended range, and 7.0 percent shall be the recommended value.

C. Laboratory mixing and compaction shall be in conformance with the requirements of California Test 304, except that the mixing temperature of the aggregate shall be between 149°C and 163°C. The compaction temperature of the combined mixture shall be between 143°C and 149°C.

The rubberized asphalt concrete mixture, composed of the aggregate proposed for use and the optimum amount of asphalt-rubber binder as determined in conformance with the requirements in California Test 367 modified above, shall conform to the following quality requirements:

RUBBERIZED ASPHALT CONCRETE MIXTURE

Test Parameter	California Test	Requirement
Stabilometer Value, Minimum	304 and 366	23
Voids in Mineral Aggregate, Percent, Minimum	See Note	18

Note: Voids in mineral aggregate test shall be determined as described in Asphalt Institute Mix Design Methods for Asphalt Concrete (MS-2).

The asphalt-rubber binder content of the rubberized asphalt concrete (Type G) will be determined by extraction tests in conformance with the requirements in California Test 362, or will be determined in conformance with the requirements in California Test 379.

The Contractor shall furnish a Certificate of Compliance to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications for each material used in asphalt-rubber binder and the asphalt-rubber binder mixture. The Certificate of Compliance shall certify that the material conforms to the provisions in these special provisions. When requested by the Engineer, the Contractor shall submit samples with the Certificate of Compliance. The Contractor shall provide the Engineer a Material Safety Data Sheet (MSDS) for each of the constituent components of the asphalt-rubber binder, for the completed mixture of asphalt-rubber binder and for the Type G rubberized asphalt concrete.

The Contractor shall provide a Certificate of Compliance for each truck load of crumb rubber modifier (CRM), paving asphalt, and asphalt modifier delivered to the project. The Quality Control Program used by the manufacturer of each ingredient shall include a sampling and testing frequency as shown below:

A. CRM shall be tested, except for the grading requirement, at least once for every 225 tonnes of production, with a minimum of once for each project. CRM shall be tested for grading for every truck load delivered to the project.
B. Paving asphalt shall be tested at least once for every 180 tonnes of production with a minimum of once for each project.
C. Asphalt modifier shall be tested at least once for every 23 tonnes of production with a minimum of once for each project.
D. A copy of the laboratory test results for the test parameters specified in these special provisions for CRM, paving asphalt, and asphalt modifier shall be submitted to the Engineer with the Certificate of Compliance for each truck load of individual material delivered to the project.

Certified volume or weight slips shall be delivered to the Engineer for the materials supplied.

PAVING ASPHALT

The grade of paving asphalt to be used in the asphalt-rubber binder shall be Grade___ conforming to the provisions in Section 92, "Asphalts," of the Standard Specifications and these special provisions.

The paving asphalt for use in asphalt-rubber binder shall be modified with an asphalt modifier.

ASPHALT MODIFIER

The asphalt modifier shall be a resinous, high flash point, aromatic hydrocarbon compound and shall conform to the following requirements:

ASPHALT MODIFIER

Test Parameter	ASTM Designation	Requirement
Viscosity, m^2/s ($x10^{-6}$) at 100°C	D 445	X ± 3*
Flash Point, CL.O.C., °C	D 92	207 min.
Molecular Analysis:		
Asphaltenes, percent by mass	D 2007	0.1 max.
Aromatics, percent by mass	D 2007	55 min.

* The symbol "X" is the viscosity of the asphalt modifier the Contractor proposes to furnish. The value "X" which the Contractor proposes shall be between the limits 19 and 36 and shall be submitted in writing to the Engineer. A proposed change, requested by the Contractor, in the value "X" shall require a new asphalt-rubber binder design.

The asphalt modifier shall be proportionately added to the paving asphalt at the production site where the asphalt-rubber binder is blended and reacted. Asphalt modifier shall be added in an amount of 2.5 percent to 6.0 percent by mass of the paving asphalt based on the recommendation of the asphalt-rubber binder supplier. The paving asphalt shall be at a temperature of not less than 190°C or more than 226°C when the asphalt modifier is added. If the asphalt modifier is combined with the paving asphalt, before being blended with the CRM, the combined paving asphalt and asphalt modifier shall be mixed by circulation for a period of not less than 20 minutes. Premixing of asphalt modifier and paving asphalt will not be required when the ingredients of the asphalt-rubber binder are proportioned and mixed simultaneously. Asphalt modifier and paving asphalt shall be measured for proportioning with meters conforming to the provisions in Section 9-1.01, "Measurement of Quantities," of the Standard Specifications.

CRUMB RUBBER MODIFIER (CRM)

Crumb rubber modifier (CRM) shall consist of a combination of scrap tire CRM and high natural CRM. The scrap tire CRM shall consist of ground or granulated rubber derived from a combination of automobile tires, truck tires or tire buffings. The high natural CRM shall consist of ground or granulated rubber derived from materials that utilize high natural rubber sources.

Steel and fiber separation may be accomplished by any method. Cryogenic separation, if utilized, shall be performed separately from and prior to grinding or granulating.

CRM shall be ground or granulated at ambient temperature. Cryogenically produced CRM particles which can pass through the grinder or granulator without being ground or granulated respectively shall not be used.

CRM shall not contain more than 0.01-percent wire (by mass of CRM) and shall be free of other contaminants, except fabric. Fabric shall not exceed 0.05-percent by mass of CRM. The test and method for determining the percent by mass of wire and fabric is available at the Transportation Laboratory, Pavement Branch, Telephone 916-227-7300, and will be furnished to interested persons upon request. A Certificate of Compliance certifying these percentages shall be furnished to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

The length of an individual CRM particle shall not exceed 4.75 mm.

The CRM shall be sufficiently dry so that the CRM will be free flowing and not produce foaming when combined with the blended paving asphalt and asphalt modifier mixture. Calcium carbonate or talc may be added at a maximum amount of 3 percent by mass of CRM to prevent CRM particles from sticking together. The CRM shall have a specific gravity between 1.1 and 1.2 as determined by California Test 208. Scrap tire CRM and high natural CRM shall be delivered to the production site in separate bags and shall be sampled and tested separately. CRM material shall conform to the following requirements of ASTM Designation: D 297:

SCRAP TIRE CRUMB RUBBER MODIFIER

Test Parameter	Percent	
	Min.	Max.
Acetone Extract	6.0	16.0
Ash Content	—	8.0
Carbon Black Content	28.0	38.0
Rubber Hydrocarbon	42.0	65.0
Natural Rubber Content	22.0	39.0

HIGH NATURAL CRUMB RUBBER MODIFIER

Test Parameter	Percent	
	Min.	Max.
Acetone Extract	4.0	16.0
Rubber Hydrocarbon	50.0	—
Natural Rubber Content	40.0	48.0

The CRM for asphalt-rubber binder shall conform to the gradations specified below when tested in conformance with the requirements in ASTM Designation: C 136, except as follows:

A. Split or quarter 100 g ± 5 g from the CRM sample and dry to a constant mass at a temperature of not less than 57°C or more than 63°C and record the dry sample mass. Place the CRM sample and 5.0 g of talc in a 0.5-L jar. Seal the jar, then shake it by hand for a minimum of one minute to mix the CRM and the talc. Continue shaking or open the jar and stir until particle agglomerates and clumps are broken and the talc is uniformly mixed.

B. Place one rubber ball on each sieve. Each ball shall have a mass of 8.5 g ± 0.5 g, have a diameter of 24.5 mm ± 0.5 mm, and shall have a Shore Durometer "A" hardness of 50 ± 5 in conformance with the requirements in ASTM Designation: D 2240. After sieving the combined material for 10 minutes ± 1 minute, disassemble the sieves. Material adhering to the bottom of a sieve shall be brushed into the next finer sieve. Weigh and record the mass of the material retained on the 2.36-mm sieve and leave this material (do not discard) on the scale or balance. Observed fabric balls shall remain on the scale or balance and shall be placed together on the side of the scale or balance to prevent the fabric balls from being covered or disturbed when placing the material from finer sieves onto the scale or balance. The material retained on the next finer sieve (2.00-mm sieve) shall be added to the scale or balance. Weigh and record that mass as the accumulative mass retained on that sieve (2.00-mm sieve). Continue weighing and recording the accumulated masses retained on the remaining sieves until the accumulated mass retained in the pan has been determined. Prior to discarding the CRM sample, separately weigh and record the total mass of fabric balls in the sample.

C. Determine the mass of material passing the 75-µm sieve (or mass retained in the pan) by subtracting the accumulated mass retained on the 75-µm sieve from the accumulated mass

retained in the pan. If the material passing the 75-µm sieve (or mass retained in the pan) has a mass of 5 g or less, cross out the recorded number for the accumulated mass retained in the pan and copy the number recorded for the accumulated mass retained on the 75-µm sieve and record that number (next to the crossed out number) as the accumulated mass retained in the pan. If the material passing the 75-µm sieve (or mass retained in the pan) has a mass greater than 5 g, cross out the recorded number for the accumulated mass retained in the pan, subtract 5 g from that number and record the difference next to the crossed out number. The adjustment to the accumulated mass retained in the pan is made to account for the 5 g of talc added to the sample. For calculation purposes, the adjusted total sample mass is the same as the adjusted accumulated mass retained in the pan. Determine the percent passing based on the adjusted total sample mass and record to the nearest 0.1 percent.

CRM GRADATIONS

Sieve Size	Scrap Tire CRM Percent Passing	High Natural CRM Percent Passing
2.36-mm	100	100
2.00-mm	98-100	100
1.18-mm	45-75	95-100
600-µm	2-20	35-85
300-µm	0-6	10-30
150-µm	0-2	0-4
75-µm	0	0-1

ASPHALT-RUBBER BINDER

Asphalt-rubber binder shall consist of a mixture of paving asphalt, asphalt modifier, and crumb rubber modifier.

At least 2 weeks before the binder's intended use, the Contractor shall furnish the Engineer 4 one-liter cans filled with the asphalt-rubber binder proposed for use on the project. The Contractor shall supply the Engineer, for approval, a binder formulation and samples of the materials to be used in the asphalt-rubber binder at least 2 weeks before construction is scheduled to begin. The binder formulations shall consist of the following information:

A. Paving Asphalt and Modifiers:
   1. Source and grade of paving asphalt.
   2. Source and identification (or type) of modifiers used.
   3. Percentage of asphalt modifier by mass of paving asphalt.
   4. Percentage of the combined blend of paving asphalt and asphalt modifier by total mass of asphalt-rubber binder to be used.
   5. Laboratory test results for test parameters shown in these special provisions.

B Crumb Rubber Modifier (CRM):
   1. Source and identification (or type) of scrap tire and high natural CRM.
   2. Percentage of scrap tire and high natural CRM by total mass of the asphalt-rubber blend.
   3. If CRM from more than one source is used, the above information will be required for each CRM source used.
   4. Laboratory test results for test parameters shown in these special provisions.

C. Asphalt-Rubber Binder:
   1. Laboratory test results of the proposed blend for test parameters shown in these

special provisions.

2. The minimum reaction time and temperature.

The method and equipment for combining paving asphalt, asphalt modifier, and CRM shall be so designed and accessible that the Engineer can readily determine the percentages by mass for each material being incorporated into the mixture.

The proportions of the materials, by total mass of asphalt-rubber binder, shall be 80 percent ± 2 percent combined paving asphalt and asphalt modifier, and 20 percent ± 2 percent CRM. However, the minimum amount of CRM shall not be less than 18.0 percent. Lower values which are rounded up shall not be allowed. The CRM shall be combined at the production site and shall contain 75 percent ± 2 percent scrap tire CRM and 25 percent ± 2 percent high natural CRM, by mass.

The paving asphalt and asphalt modifier shall be combined into a blended mixture that is chemically compatible with the crumb rubber modifier to be used. The blended mixture is considered to be chemically compatible when it meets the provisions for asphalt-rubber binder (after reacting) found in these special provisions.

The blended paving asphalt and asphalt modifier mixture, and the CRM shall be combined and mixed together at the production site in a blender unit to produce a homogeneous mixture.

The temperature of the blended paving asphalt and asphalt modifier mixture shall be not less than 190°C nor more than 226°C when the CRM is added. The combined materials shall be reacted for a minimum of 45 minutes after incorporation of the CRM at a temperature of not less than 190°C nor more than 218°C. The temperature shall not be higher than 6°C below the actual flash point of the asphalt-rubber binder.

After reacting, the asphalt-rubber binder shall conform to the following requirements:

ASPHALT-RUBBER BINDER

Test Parameter	ASTM Test Method	Requirement	
		Min.	Max.
Cone Penetration @ 25°C, 1/10 mm	D 217	25	70
Resilience @ 25°C, Percent rebound	D 3407	18	—
Field Softening Point, °C	D 36	52	74
Viscosity @ 190°C, Pa • s ($x10^{-3}$)	See Note	1500	4000

NOTE: The viscosity test shall be conducted using a hand held Haake Viscometer Model VT-02 with Rotor 1, 24 mm in depth x 53 mm in height, or equivalent, as determined by the Engineer. The accuracy of the viscometer shall be verified by comparing the viscosity results obtained with the hand held viscometer to 3 separate calibration fluids of known viscosities ranging from 1000 to 5000 Pa • s ($x10^{-3}$). The viscometer will be considered accurate if the values obtained are within 300 Pa • s ($x10^{-3}$) of the known viscosity. The known viscosity value shall be based on the fluid manufacturers standard test temperature or the test temperature versus viscosity correlation table provided by the fluid manufacturer. Viscometers used on the project shall be verified to be accurate. The test method for determining the viscosity of asphalt-rubber binder using a hand held viscometer is available at the Transportation Laboratory, Pavement Branch, Telephone (916) 227-7300. The accuracy verification results shall be provided to the Engineer and shall be certified by a Certificate of Compliance. The Certificate of Compliance shall be furnished to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

The Contractor shall provide a Haake Viscometer, or equivalent, at the production site during combining of asphalt-rubber binder materials. The Contractor shall take viscosity readings of asphalt-rubber binder from samples taken from the feed line connecting the storage and reaction tank to the asphalt concrete plant. Readings shall be taken at least every hour with not less than one reading for each batch of asphalt-rubber binder. The Contractor shall log these results, including time and asphalt-rubber binder temperature, and a copy of the log shall be submitted to the Engineer

on a daily basis. As determined by the Engineer, the Contractor shall either notify the Engineer at least 15 minutes prior to each test or provide the Engineer a schedule of testing times.

The reacted asphalt-rubber binder shall be maintained at a temperature of not less than 190°C nor more than 218°C.

If any of the material in a batch of asphalt-rubber binder is not used within 4 hours after the 45-minute reaction period, heating of the material shall be discontinued. Any time the asphalt-rubber binder cools below 190°C and is reheated shall be considered a reheat cycle. The total number of reheat cycles shall not exceed 2. The material shall be uniformly reheated to a temperature of not less than 190°C nor more than 218°C prior to use. Additional scrap tire CRM may be added to the reheated binder and reacted for a minimum of 45 minutes. The cumulative amount of additional scrap tire CRM shall not exceed 10 percent of the total binder mass. Reheated asphalt-rubber binder shall conform to the provisions for asphalt-rubber binder.

EQUIPMENT FOR PRODUCTION OF ASPHALT-RUBBER BINDER

The Contractor shall utilize the following equipment for production of asphalt-rubber binder:

A. An asphalt heating tank equipped to heat and maintain the blended paving asphalt and asphalt modifier mixture at the necessary temperature before blending with the CRM. This unit shall be equipped with a thermostatic heat control device and a temperature reading device and shall be accurate to within ± 3°C and shall be of the recording type.

B. A mechanical mixer for the complete, homogeneous blending of paving asphalt, asphalt modifier, and CRM. Paving asphalt and asphalt modifier shall be introduced into the mixer through meters conforming to the provisions in Section 9-1.01, "Measurement of Quantities," of the Standard Specifications. The blending system shall be capable of varying the rate of delivery of paving asphalt and asphalt modifier proportionate with the delivery of CRM. During the proportioning and blending of the liquid ingredients, the temperature of paving asphalt and the asphalt modifier shall not vary more than ± 14°C. The paving asphalt feed, the asphalt modifier feed, and CRM feed shall be equipped with devices by which the rate of feed can be determined during the proportioning operation. Meters used for proportioning individual ingredients shall be equipped with rate-of-flow indicators to show the rates of delivery and resettable totalizers so that the total amounts of liquid ingredients introduced into the mixture can be determined. The liquid and dry ingredients shall be fed directly into the mixer at a uniform and controlled rate. The rate of feed to the mixer shall not exceed that which will permit complete mixing of the materials. Dead areas in the mixer, in which the material does not move or is not sufficiently agitated, shall be corrected by a reduction in the volume of material or by other adjustments. Mixing shall continue until a homogeneous mixture of uniformly distributed and properly blended asphalt-rubber binder of unchanging appearance and consistency is produced. The Contractor shall provide a safe sampling device capable of delivering a representative sample of the completed asphalt-rubber binder of sufficient size to permit the required tests.

C. An asphalt-rubber binder storage tank equipped with a heating system furnished with a temperature reading device to maintain the proper temperature of the asphalt-rubber binder and an internal mixing unit capable of maintaining a homogeneous mixture of paving asphalt, asphalt modifier, and CRM.

The equipment shall be approved by the Engineer prior to use.

AGGREGATE

The aggregate for Type G rubberized asphalt concrete shall conform to the following grading and shall meet the quality provisions specified for Type A asphalt concrete in Section 39-2.02, "Aggregate," of the Standard Specifications, except as follows:

A. California Test 211, Los Angeles Rattler loss at 500 revolutions shall be 40 percent maximum.

B. California Test 205, Section D, definition of a crushed particle is revised as follows: "A particle having 2 or more fresh mechanically fractured faces shall be considered a crushed particle."

C. The swell and moisture vapor susceptibility requirements shall not apply.

The symbol "X" in the following table is the gradation which the Contractor proposes to furnish for the specific sieve.

Aggregate Grading Requirements
Percentage Passing
12.5-mm maximum

Sieve Size	Limits of Proposed Gradation	Operating Range	Contract Compliance
19-mm	—	100	100
12.5-mm	—	90-100	90-100
9.5-mm	83-87	X±5	X±7
4.75-mm	33-37	X±5	X±7
2.36-mm	18-22	X±4	X±5
600-µm	8-12	X±4	X±5
75-µm	—	2-7	0-8

The symbol "X" in the following table is the gradation which the Contractor proposes to furnish for the specific sieve.

Aggregate Grading Requirements
Percentage Passing
19-mm maximum

Sieve Size	Limits of Proposed Gradation	Operating Range	Contract Compliance
25-mm	—	100	100
19-mm	—	95-100	90-100
12.5-mm	83-87	X±5	X±7
9.5-mm	65-70	X±5	X±7
4.75-mm	33-37	X±5	X±7
2.36-mm	18-22	X±4	X±5
600-µm	8-12	X±4	X±5
75-µm	—	2-7	0-8

PROPORTIONING, SPREADING AND COMPACTING

When batch type asphalt concrete plants are used to produce Type G rubberized asphalt concrete, the asphalt-rubber binder and mineral aggregate shall be proportioned by mass.

When continuous mixing type asphalt concrete plants are used to produce Type G rubberized asphalt concrete, the asphalt-rubber binder shall be proportioned by an asphalt meter of the mass flow, Coriolis effect type. The meter shall have been Type-approved by the Division of

Measurement Standards prior to the start of production. The meter shall be calibrated in conformance with the requirements in California Test 109. The meter shall be interfaced with the existing continuous mixing plant controller in use on the asphalt concrete plant.

Type G rubberized asphalt concrete shall be placed only when the atmospheric and pavement surface temperatures are 13°C or above.

When the atmospheric and pavement surface temperature is 18°C or higher, the following shall apply:

A. The temperature of the aggregate shall not be greater than 163°C at the time the asphalt-rubber binder is added to the aggregate.
B. Type G rubberized asphalt concrete shall be spread at a temperature of not less than 138°C or more than 163°C, measured in the mat directly behind the paving machine.
C. The first coverage of initial or breakdown compaction shall be performed when the temperature of the Type G rubberized asphalt concrete is not less than 135°C. Breakdown compaction shall be completed before the temperature of the Type G rubberized asphalt concrete drops below 121°C.

When the atmospheric or pavement surface temperature is below 18°C, the following shall apply:

A. The temperature of the aggregate shall not be less than 149°C nor more than 163°C at the time the asphalt-rubber binder is added to the aggregate.
B. The Contractor shall cover the loads of Type G rubberized asphalt concrete with tarpaulins. The tarpaulins shall completely cover the exposed Type G rubberized asphalt concrete until the Type G rubberized asphalt concrete has been completely transferred into the asphalt concrete paver hopper or deposited on the roadbed.
C. Type G rubberized asphalt concrete shall be spread at a temperature of not less than 143°C nor more than 163°C, measured in the mat directly behind the paving machine.
D. The first coverage of initial or breakdown compaction shall be performed when the temperature of the Type G rubberized asphalt concrete is not less than 138°C. Breakdown compaction shall be completed before the temperature of the Type G rubberized asphalt concrete drops below 127°C.

Pneumatic tired rollers shall not be used to compact Type G rubberized asphalt concrete.

Alternative compacting equipment conforming to the provisions in Section 39-6.03, "Compacting," of the Standard Specifications shall be used to compact the Type G rubberized asphalt concrete.

Traffic shall not be allowed on the Type G rubberized asphalt concrete until final rolling operations have been completed and sand has been applied to the surface.

Sand shall be spread on the surface of Type G rubberized asphalt concrete at a rate of 0.5 kg/m^2 to 1.0 kg/m^2. The exact rate will be determined by the Engineer. When ordered by the Engineer excess sand shall be removed from the pavement surface by sweeping. Sand shall be free from clay or organic material. Sand shall conform to the fine aggregate grading provisions in Section 90-3.03, "Fine Aggregate Grading," of the Standard Specifications.

MEASUREMENT AND PAYMENT

Rubberized asphalt concrete (Type G) will be measured and paid for by the tonne in the same

manner specified for asphalt concrete in Section 39-8, "Measurement and Payment," of the Standard Specifications.

Full compensation for furnishing and spreading sand on the rubberized asphalt concrete surface and for sweeping and removing excess sand from the pavement surface shall be considered as included in the contract price paid per tonne for rubberized asphalt concrete (Type G) and no separate payment will be made therefore.

Appendix E: California Specification – Open Graded

10-1.___RUBBERIZED ASPHALT CONCRETE (TYPE O)

Rubberized asphalt concrete (Type O) shall consist of furnishing and mixing Open Graded aggregate and asphalt-rubber binder and spreading and compacting the mixture. Type O rubberized asphalt concrete shall conform, except as otherwise provided, to the provisions for Open Graded asphalt concrete in Section 39, "Asphalt Concrete," of the Standard Specifications and to these special provisions.

GENERAL

The Contractor shall furnish samples of aggregate to the Engineer in conformance with the provisions in Section 39-3.03, "Proportioning," of the Standard Specifications.

The amount of asphalt-rubber binder to be mixed with the aggregate for Type O rubberized asphalt concrete will be determined by the Engineer using the samples of aggregates furnished by the Contractor in conformance with the provisions in Section 39-3.03, "Proportioning," of the Standard Specifications. The Engineer will determine the exact amount of asphalt-rubber binder to be mixed with the aggregate in conformance with the provisions in California Test 368 with the following exceptions. The aggregate shall be mixed with Grade _____paving asphalt and the optimum bitumen content shall be determined in conformance with the test procedure. The optimum binder content for rubberized asphalt concrete Type O shall then be determined using the following formula:

A. $OBC_2 = (OBC_1) \times 1.20$
B. OBC_1 = Optimum bitumen content using Grade ___paving asphalt
C. OBC_2 = Optimum bitumen content using asphalt-rubber binder

The asphalt-rubber binder content of the Type O rubberized asphalt concrete will be determined by extraction tests in conformance with the provisions in California Test 362, or will be determined in conformance with the provisions in California Test 379.

The Contractor shall furnish to the Engineer a Certificate of Compliance in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications for each material used in asphalt-rubber binder and the asphalt-rubber binder mixture. The Certificate of Compliance shall certify that the material conforms to the provisions in these special provisions. When requested by the Engineer, the Contractor shall also submit samples with the Certificate of Compliance. The Contractor shall provide the Engineer a Material Safety Data Sheet (MSDS) for each of the constituent components of the asphalt-rubber binder, for the completed mixture of asphalt-rubber binder and for the Type O rubberized asphalt concrete.

The Contractor shall provide a Certificate of Compliance for each truck load of crumb rubber modifier (CRM), paving asphalt, and asphalt modifier delivered to the project. The Quality Control Program used by the manufacturer of each ingredient shall include a sampling and testing frequency as follows:

A. CRM shall be tested, except for the grading requirement, at least once for every 225 tonnes of production, with a minimum of once for each project. CRM shall be tested for grading for every truck load delivered to the project.
B. Paving asphalt shall be tested at least once for every 180 tonnes of production with a minimum of once for each project.

C. Asphalt modifier shall be tested at least once for every 23 tonnes of production with a minimum of once for each project.

D. A copy of the laboratory test results for the test parameters specified in these special provisions for CRM, paving asphalt, and asphalt modifier shall be submitted to the Engineer with the Certificate of Compliance for each truck load of individual material delivered to the project.

PAVING ASPHALT

The grade of paving asphalt to be used in the asphalt-rubber binder shall be Grade ___and shall conform to the provisions in Section 92, "Asphalts," of the Standard Specifications and these special provisions.

The paving asphalt for use in asphalt-rubber binder shall be modified with an asphalt modifier.

ASPHALT MODIFIER

The asphalt modifier will be a resinous, high flash point, aromatic hydrocarbon compound and shall conform to the following requirements:

ASPHALT MODIFIER

Test Parameter	ASTM Designation	Requirement
Viscosity, m^2/s ($x10^{-6}$) at 100°C	D 445	X ± 3*
Flash Point, CL.O.C., °C	D 92	207 min.
Molecular Analysis:		
Asphaltenes, percent by mass	D 2007	0.1 max.
Aromatics, percent by mass	D 2007	55 min.

* The symbol "X" is the viscosity of the asphalt modifier the Contractor proposes to furnish. The value "X" which the Contractor proposes shall be between the limits 19 and 36 and shall be submitted in writing to the Engineer. A proposed change, requested by the Contractor, in the value "X" shall require a new asphalt-rubber binder design.

The asphalt modifier shall be proportionately added at the production site where the asphalt-rubber binder is blended and reacted. Asphalt modifier shall be added to the paving asphalt at an amount of 2.5 percent to 6.0 percent by mass of the paving asphalt based on the recommendation of the asphalt-rubber binder supplier. The exact amount will be determined by the Engineer. The paving asphalt shall be at a temperature of not less than 190°C or more than 226°C when the asphalt modifier is added. If the asphalt modifier is combined with the paving asphalt, before being blended with the CRM, the combined paving asphalt and asphalt modifier shall be mixed by circulation for a period of not less than 20 minutes. This premixing of asphalt modifier and the paving asphalt will not be required when the ingredients of the asphalt-rubber binder are proportioned and mixed simultaneously. Asphalt modifier and paving asphalt shall be measured for proportioning with meters conforming to the provisions in Section 9-1.01, "Measurement of Quantities," of the Standard Specifications.

CRUMB RUBBER MODIFIER (CRM)

Crumb rubber modifier (CRM) shall consist of a combination of scrap tire CRM and high natural CRM. The scrap tire CRM shall consist of ground or granulated rubber derived from a

combination of automobile tires, truck tires or tire buffings. The high natural CRM shall consist of ground or granulated rubber derived from materials that utilize high natural rubber sources.

Steel and fiber separation may be accomplished by any method. Cryogenic separation, if utilized, shall be performed separately from and prior to grinding or granulating.

CRM shall be ground or granulated at ambient temperature. Cryogenically produced CRM particles that can pass through the grinder or granulator without being ground or granulated respectively shall not be used.

CRM shall not contain more than 0.01-percent wire (by mass of CRM) and shall be free of other contaminants, except fabric. Fabric shall not exceed 0.05-percent by mass of CRM. The test and method for determining the percent by mass of wire and fabric is available at the Transportation Laboratory, Pavement Branch, Telephone 916-227-7300, and will be furnished to interested persons upon request. A Certificate of Compliance certifying these percentages shall be furnished to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

The length of an individual CRM particle shall not exceed 4.75 mm.

The CRM shall be sufficiently dry so as to be free flowing and not produce foaming when combined with the blended paving asphalt and asphalt modifier mixture. Calcium carbonate or talc may be added at a maximum amount of 3 percent by weight of CRM to prevent CRM particles from sticking together. The CRM shall have a specific gravity between 1.1 and 1.2 as determined in conformance with the requirements in California Test 208. Scrap tire CRM and high natural CRM shall be delivered to the production site in separate bags and shall be sampled and tested separately. CRM material shall conform to the following requirements in conformance with the requirements in ASTM Designation: D 297:

SCRAP TIRE CRUMB RUBBER MODIFIER

Test Parameter	Percent	
	Min.	Max.
Acetone Extract	6.0	16.0
Ash Content	—	8.0
Carbon Black Content	28.0	38.0
Rubber Hydrocarbon	42.0	65.0
Natural Rubber Content	22.0	39.0

HIGH NATURAL CRUMB RUBBER MODIFIER

Test Parameter	Percent	
	Min.	Max.
Acetone Extract	4.0	16.0
Rubber Hydrocarbon	50.0	—
Natural Rubber Content	40.0	48.0

The CRM for asphalt-rubber binder shall conform to the gradations specified below when tested in conformance with the requirements in ASTM Designation: C 136, except as follows:

A. Split or quarter 100 g ± 5 g from the CRM sample and dry to a constant mass at a temperature of not less than 57°C or more than 63°C and record the dry sample mass. Place the CRM sample and 5.0 g of talc in a 0.5-L jar. Seal the jar, then shake it by hand for a minimum of one minute to mix the CRM and the talc. Continue shaking or open the jar and stir until particle agglomerates and clumps are broken and the talc is uniformly mixed.

B. Place one rubber ball on each sieve. Each ball shall have a mass of 8.5 g ± 0.5 g, have a diameter of 24.5 mm ± 0.5 mm, and shall have a Shore Durometer "A" hardness of 50 ± 5 in conformance with the requirements in ASTM Designation: D 2240. After sieving the combined material for 10 minutes ± 1 minute, disassemble the sieves. Material adhering to the bottom of a sieve shall be brushed into the next finer sieve. Weigh and record the mass of the material retained on the 2.36-mm sieve and leave this material (do not discard) on the scale or balance. Observed fabric balls shall remain on the scale or balance and shall be placed together on the side of the scale or balance to prevent the fabric balls from being covered or disturbed when placing the material from finer sieves onto the scale or balance. The material retained on the next finer sieve (2.00-mm sieve) shall be added to the scale or balance. Weigh and record that mass as the accumulative mass retained on that sieve (2.00-mm sieve). Continue weighing and recording the accumulated masses retained on the remaining sieves until the accumulated mass retained in the pan has been determined. Prior to discarding the CRM sample, separately weigh and record the total mass of fabric balls in the sample.

C. Determine the mass of material passing the 75-µm sieve (or mass retained in the pan) by subtracting the accumulated mass retained on the 75-µm sieve from the accumulated mass retained in the pan. If the material passing the 75-µm sieve (or mass retained in the pan) has a mass of 5 g or less, cross out the recorded number for the accumulated mass retained in the pan and copy the number recorded for the accumulated mass retained on the 75-µm sieve and record that number (next to the crossed out number) as the accumulated mass retained in the pan. If the material passing the 75-µm sieve (or mass retained in the pan) has a mass greater than 5 g, cross out the recorded number for the accumulated mass retained in the pan, subtract 5 g from that number and record the difference next to the crossed out number. The adjustment to the accumulated mass retained in the pan is made to account for the 5 g of talc added to the sample. For calculation purposes, the adjusted total sample mass is the same as the adjusted accumulated mass retained in the pan. Determine the percent passing based on the adjusted total sample mass and record to the nearest 0.1 percent.

CRM GRADATIONS

Sieve Size	Scrap Tire CRM Percent Passing	High Natural CRM Percent Passing
2.36-mm	100	100
2.00-mm	98-100	100
1.18-mm	45-75	95-100
600-µm	2-20	35-85
300-µm	0-6	10-30
150-µm	0-2	0-4
75-µm	0	0-1

ASPHALT-RUBBER BINDER

Asphalt-rubber binder shall consist of a mixture of paving asphalt, asphalt modifier, and crumb rubber modifier.

At least 2 weeks before the binder's intended use, the Contractor shall furnish the Engineer 4 one liter cans filled with the asphalt-rubber binder proposed for use on the project. The Contractor shall supply the Engineer, for approval, a binder formulation and samples of the materials to be used in the asphalt-rubber binder at least 2 weeks before construction is scheduled to begin. The binder formulations shall consist of the following information:

A. Paving Asphalt and Modifiers:

1. Source and grade of paving asphalt.
2. Source and identification (or type) of modifiers used.
3. Percentage of asphalt modifier by mass of paving asphalt.
4. Percentage of the combined blend of paving asphalt and asphalt modifier by total mass of asphalt-rubber binder to be used.
5. Laboratory test results for test parameters shown in these special provisions. B.

B. Crumb Rubber Modifier (CRM):

1. Source and identification (or type) of scrap tire and high natural CRM.
2. Percentage of scrap tire and high natural CRM by total mass of the asphalt-rubber blend.
3. If CRM from more than one source is used, the above information will be required for each CRM source used.
4. Laboratory test results for test parameters shown in these special provisions. C.

C. Asphalt-Rubber Binder:

1. Laboratory test results of the proposed blend for test parameters shown in these special provisions.
2. The minimum reaction time and temperature.

The method and equipment for combining paving asphalt, asphalt modifier, and CRM shall be so designed and accessible that the Engineer can readily determine the percentages by mass for each material being incorporated into the mixture.

The proportions of the materials, by total mass of asphalt-rubber binder, shall be 80 percent ± 2 percent combined paving asphalt and asphalt modifier, and 20 percent ± 2 percent CRM. However, the minimum amount of CRM shall not be less than 18.0 percent. Lower values which are rounded up shall not be allowed. The CRM shall be combined at the production site and shall contain 75 percent ± 2 percent scrap tire CRM and 25 percent ± 2 percent high natural CRM, by mass.

The paving asphalt and asphalt modifier shall be combined into a blended mixture that is chemically compatible with the crumb rubber modifier to be used. The blended mixture is considered to be chemically compatible when the mixture meets the provisions for asphalt-rubber binder (after reacting) of these special provisions.

The blended paving asphalt and asphalt modifier mixture and the CRM shall be combined and mixed together at the production site in a blender unit to produce a homogeneous mixture.

The temperature of the blended paving asphalt and asphalt modifier mixture shall be not less than 190°C or more than 226°C when the CRM is added. The combined materials shall be reacted for a minimum of 45 minutes after incorporation of the CRM at a temperature of not less than 190°C or more than 218°C. The temperature shall not be higher than 6°C below the actual flash point of the asphalt-rubber binder.

After reacting, the blended asphalt-rubber binder shall conform to the following requirements:

ASPHALT-RUBBER BINDER

Test Parameter	ASTM Test Method	Requirement	
		Min.	Max.
Cone Penetration @ 25°C, 1/10 mm	D 217	25	70
Resilience @ 25°C, Percent rebound	D 3407	18	—
Field Softening Point, °C	D 36	52	74
Viscosity @ 190°C, Pa • s ($x10^{-3}$)	See Note	1500	4000

Note: The viscosity test shall be conducted using a hand held Haake Viscometer Model VT-02 with Rotor 1, 24 mm in depth x 53 mm in height, or equivalent, as determined by the Engineer. The accuracy of the viscometer shall be verified by comparing the viscosity results obtained with the hand held viscometer to 3 separate calibration fluids of known viscosities ranging from 1000 to 5000 Pa • s ($x10^{-3}$). The viscometer will be considered accurate if the values obtained are within 300 Pa • s ($x10^{-3}$) of the known viscosity. The known viscosity value shall be based on the fluid manufacturers standard test temperature or the test temperature versus viscosity correlation table provided by the fluid manufacturer. Viscometers used on the project shall be verified to be accurate. The test method for determining the viscosity of asphalt-rubber binder using a hand held viscometer is available at the Transportation Laboratory, Pavement Branch, Telephone 916-227-7300. The accuracy verification results shall be provided to the Engineer and shall be certified by a Certificate of Compliance. The Certificate of Compliance shall be furnished to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

The Contractor shall provide a Haake Viscometer, or equivalent, at the production site during the combining of asphalt-rubber binder materials. The Contractor shall take viscosity readings of asphalt-rubber binder from samples taken from the feed line connecting the storage and reaction tank and the asphalt concrete plant. Readings shall be taken at least every hour with no less than one reading for each batch of asphalt-rubber binder. The Contractor shall log these results including time and asphalt-rubber binder temperature, and a copy of the log shall be submitted to the Engineer on a daily basis. As determined by the Engineer, the Contractor shall either notify the Engineer at least 15 minutes prior to each test or provide the Engineer a schedule of testing times.

The reacted asphalt-rubber binder shall be maintained at a temperature of not less than 190°C and nor more than 218°C.

If material in a batch of asphalt-rubber binder is not used within 4 hours after the 45-minute reaction period, heating of the material shall be discontinued. Any time the asphalt-rubber binder cools below 190°C and is reheated shall be considered a reheat cycle. The total number of reheat cycles shall not exceed 2. The material shall be uniformly reheated to a temperature of not less than 190°C nor more than 218°C prior to use. Additional scrap tire CRM may be added to the reheated binder and reacted for a minimum of 45 minutes. The cumulative amount of additional scrap tire CRM shall not exceed 10 percent of the total binder mass. Reheated asphalt-rubber binder shall conform to the provisions for blended asphalt-rubber binder.

EQUIPMENT FOR PRODUCTION OF ASPHALT-RUBBER BINDER

The Contractor shall utilize the following equipment for production of asphalt-rubber binder:

A. An asphalt heating tank equipped to heat and maintain the blended paving asphalt and asphalt modifier mixture at the necessary temperature before blending with the CRM. This unit shall be equipped with a thermostatic heat control device and a temperature reading device and shall be accurate to within ±3°C and shall be of the recording type.

B. A mechanical mixer for the complete, homogeneous blending of paving asphalt, asphalt modifier and CRM. Paving asphalt and asphalt modifier shall be introduced into the mixer through meters conforming to the provisions in Section 9-1.01, "Measurement of Quantities," of the Standard Specifications. The blending system shall be capable of varying the rate of delivery of paving asphalt and asphalt modifier proportionate with the delivery of CRM. During the proportioning and blending of the liquid ingredients, the temperature of paving asphalt and the asphalt modifier shall not vary more than ±14°C. The paving asphalt feed, the asphalt modifier feed, and CRM feed shall be equipped with devices by which the rate of feed can be determined during the proportioning operation. Meters used for proportioning individual ingredients shall be equipped with rate-of-flow indicators to show the rates of delivery and resettable totalizers so that the total amounts of liquid ingredients introduced into the mixture can be determined. The liquid and dry ingredients shall be fed directly into the mixer at a uniform and controlled rate. The rate of feed to the mixer shall not exceed that which will permit complete mixing of the materials. Dead areas in the mixer, in which the material does not move or is not sufficiently agitated, shall be corrected by a reduction in the volume of material or by other adjustments. Mixing shall continue until a homogeneous mixture of uniformly distributed and properly blended asphalt-rubber binder of unchanging appearance and consistency is produced. The Contractor shall provide a safe sampling device capable of delivering a representative sample of the completed asphalt-rubber binder of sufficient size to permit the required tests.

C. An asphalt-rubber binder storage tank equipped with a heating system furnished with a temperature reading device to maintain the proper temperature of the asphalt-rubber binder and an internal mixing unit capable of maintaining a homogeneous mixture of blended paving asphalt, asphalt modifier and CRM.

The equipment shall be approved by the Engineer prior to use.

AGGREGATE

The aggregate for Type O rubberized asphalt concrete shall conform to the 12.5-mm maximum grading conforming to the provisions in Section 39-2.02, "Aggregate," of the Standard Specifications. California Test 205, Section D, definition of a crushed particle is revised as follows: "A particle having 2 or more fresh mechanically fractured faces shall be considered a crushed particle".

PROPORTIONING, SPREADING AND COMPACTING.

When batch type asphalt concrete plants are used to produce Type O rubberized asphalt concrete, the asphalt-rubber binder and mineral aggregate shall be proportioned by mass.

When continuous mixing type asphalt concrete plants are used to produce Type O rubberized asphalt concrete, the asphalt-rubber binder shall be proportioned by an asphalt meter of the mass flow, Coriolis effect type. The meter shall have been Type-approved by the Division of Measurement Standards prior to the start of production. The meter shall be calibrated in conformance with the provisions in California Test 109. The meter shall be interfaced with the existing continuous mixing plant controller in use on the asphalt concrete plant.

Type O rubberized asphalt concrete shall be placed only when the atmospheric and pavement surface temperatures are 13°C and above.

When the atmospheric and pavement surface temperature is 18°C or higher, the following shall apply:

A. The temperature of the aggregate shall not be greater than 163°C at the time the asphalt-rubber binder is added to the aggregate.
B. Type O rubberized asphalt concrete shall be spread at a temperature of not less than 138°C nor more than 163°C, measured in the mat directly behind the paving machine.
C. The first coverage of initial or breakdown compaction shall be performed when the temperature of the Type O rubberized asphalt concrete is not less than 135°C. Breakdown compaction shall be completed before the temperature of the Type O rubberized asphalt concrete drops below 121°C.

When the atmospheric or pavement surface temperature is below 18°C, the following shall apply:

A. The temperature of the aggregate shall be not less than 149°C nor more than 163°C at the time the asphalt-rubber binder is added to the aggregate.
B. The Contractor shall cover loads of Type O rubberized asphalt concrete with tarpaulins. The tarpaulins shall completely cover exposed Type O rubberized asphalt concrete until the Type O rubberized asphalt concrete has been completely transferred into the asphalt concrete paver hopper or deposited on the roadbed.
C. Type O rubberized asphalt concrete shall be spread at a temperature of not less than 143°C nor more than 163°C, measured in the mat directly behind the paving machine.
D. The first coverage of initial or breakdown compaction shall be performed when the temperature of the Type O rubberized asphalt concrete is not less than 138°C. Breakdown compaction shall be completed before the temperature of the Type O rubberized asphalt concrete drops below 127°C.

Pneumatic tired rollers shall not be used to compact Type O rubberized asphalt concrete. Traffic shall not be allowed on Type O rubberized asphalt concrete until final rolling operations have been completed and sand has been applied to the surface.

Sand shall be spread on the surface of Type O rubberized asphalt concrete at a rate of 0.5 kg/m^2 to 1.0 kg/m^2. The exact rate will be determined by the Engineer. When ordered by the Engineer excess sand shall be removed from the pavement surface by sweeping. Sand shall be free from clay or organic material. Sand shall conform to the fine aggregate grading requirements in conformance with the provisions in Section 90-3.03, "Fine Aggregate Grading," of the Standard Specifications.

MEASUREMENT AND PAYMENT

Rubberized asphalt concrete (Type O) will be measured and paid for by the tonne in the same manner specified for asphalt concrete in Section 39-8, "Measurement and Payment," of the Standard Specifications.

Full compensation for furnishing and spreading sand on the rubberized asphalt concrete surfacing and for sweeping and removing excess sand from the pavement surface shall be considered as included in the contract price paid per tonne for rubberized asphalt concrete (Type O) and no separate payment will be made therefor.

Appendix F: California Asphalt Rubber Chip Seal

10-1.___ASPHALT-RUBBER SEAL COAT

Asphalt-rubber seal coat shall consist of an application of asphalt-rubber binder and screenings precoated with paving asphalt. Asphalt-rubber seal coat shall conform to the provisions specified for seal coats in Section 37-1, "Seal Coats," of the Standard Specifications and to these special provisions.

GENERAL

Attention is directed to "Order of Work" and "Damage Claims" of these special provisions regarding placement of asphalt-rubber seal coat.

The Contractor shall furnish a Certificate of Compliance to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications for each material used in the asphalt-rubber binder and the asphalt-rubber binder mixture. When requested by the Engineer, the Contractor shall also submit samples with the Certificates of Compliance. The Contractor shall provide the Engineer a Material Safety Data Sheet (MSDS) for each of the constituent components of the asphalt-rubber binder and for the completed mixture of the asphalt-rubber binder.

The Contractor shall provide a Certificate of Compliance for each truck load of crumb rubber modifier (CRM), paving asphalt, and asphalt modifier delivered to the project.

The Quality Control Program used by the manufacturer of each ingredient shall include a sampling and testing frequency as shown below:

A. CRM shall be tested except for the grading requirement, at least once for every 225 tonnes with a minimum of once per project. CRM shall be tested for grading for every truck load delivered to the project.
B. Paving asphalt shall be tested at least once for every 180 tonnes of production with a minimum of once per project.
C. Asphalt modifier shall be tested at least once for every 23 tonnes of production with a minimum of once per project.
D. A copy of the laboratory test results for the test parameters specified in these special provisions for CRM, paving asphalt, and asphalt modifier shall be submitted to the Engineer with the Certificate of Compliance for each truck load of individual material delivered to the project.

Certified volume or mass slips shall be delivered to the Engineer for materials supplied.

On multilane roads, the maximum length of asphalt-rubber seal coat operations at any one location, including pilot-car-assisted traffic control shall be limited to kilometers. The minimum space between successive seal coat operations on adjacent lanes in the same direction of travel shall be ____kilometers.

PAVING ASPHALT

Paving asphalt to be used in the asphalt-rubber binder shall be Grade ___and shall conform to the provisions in Section 92, "Asphalts," of the Standard Specifications and these special provisions.

The paving asphalt for use in asphalt-rubber binder shall be modified with an asphalt

modifier.

ASPHALT MODIFIER

The asphalt modifier shall be a resinous, high flash point, aromatic hydrocarbon compound and shall conform to the following requirements:

ASPHALT MODIFIER

Test Parameter	ASTM Designation	Requirement
Viscosity, m^2/s (10^{-6}) at 100°C	D 445	X ± 3*
Flash Point, CL.O.C. °C	D 92	207 min.
Molecular Analysis		
Asphaltenes, percent by mass	D 2007	0.1 max.
Aromatics, percent by mass	D 2007	55 min.

* The symbol "X" is the viscosity of the asphalt modifier the Contractor proposes to furnish. The value "X" which the Contractor proposes shall be between the limits 19 and 36 and shall be submitted in writing to the Engineer. Any proposed change, requested by the Contractor, in the value "X" shall require a new asphalt-rubber binder design.

The asphalt modifier shall be proportionately added to the paving asphalt at the production site where the asphalt-rubber binder is blended and reacted. Asphalt modifier shall be added at an amount of 2.5 percent to 6.0 percent by mass of the paving asphalt based on the recommendation of the asphalt-rubber binder supplier. The paving asphalt shall be at a temperature of not less than 190°C nor more than 226°C when the asphalt modifier is added. If the asphalt modifier is combined with the paving asphalt, before being blended with the CRM, the combined paving asphalt and asphalt modifier shall be mixed by circulation for a period of not less than 20 minutes. This premixing of asphalt modifier and paving asphalt will not be required when all ingredients of the asphalt-rubber binder are proportioned and mixed simultaneously. Asphalt modifier and paving asphalt shall be measured for proportioning with meters conforming to the provisions in Section 9-1.01, "Measurement of Quantities," of the Standard Specifications.

CRUMB RUBBER MODIFIER (CRM)

Crumb rubber modifier (CRM) shall consist of a combination of scrap tire CRM and high natural CRM. The scrap tire CRM shall consist of ground or granulated rubber derived from any combination of automobile tires, truck tires or tire buffings. The high natural CRM shall consist of ground or granulated rubber derived from materials that utilize high natural rubber sources.

Steel and fiber separation shall be accomplished by any method. Cryogenic separation, if utilized, shall be performed separately from and prior to grinding or granulating.

CRM shall be ground or granulated at ambient temperature. Cryogenically produced CRM particles that pass through the grinder or granulator without being ground or granulated, respectively, shall not be used.

CRM shall not contain more than 0.01-percent wire (by mass of CRM) and shall be free of other contaminants, except fabric. Fabric shall not exceed 0.05-percent by mass of CRM. The test and method for determining the percent by mass of wire and fabric is available at the Transportation Laboratory, Office of Pavement Consulting Services, Sacramento, California, Telephone (916) 227-7300, and will be furnished to interested persons upon request.

A certificate of compliance certifying these percentages shall be furnished to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard

Specifications.

The length of an individual CRM particle shall not exceed 4.75 mm. The CRM shall be sufficiently dry so that the CRM will be free flowing and will not produce foaming when combined with the blended paving asphalt and asphalt modifier mixture. Calcium carbonate or talc may be added at a maximum amount of 3 percent by mass of CRM to prevent CRM particles from sticking together. The CRM shall have a specific gravity of between 1.1 and 1.2 as determined by California Test 208. Scrap tire CRM and high natural CRM shall be delivered to the production site in separate bags and shall be sampled and tested separately. CRM material shall conform to the following requirements as determined by ASTM Designation: D 297:

Test Parameter	SCRAP TIRE CRM Percent		HIGH NATURAL CRM Percent	
	Minimum	Maximum	Minimum	Maximum
Acetone Extract	6.0	16.0	4.0	16.0
Rubber Hydrocarbon	42.0	65.0	50.0	—
Natural Rubber content	22.0	39.0	40.0	48.0
Carbon Black Content	28.0	38.0	—	—
Ash Content	—	8.0	—	—

The CRM for asphalt-rubber binder shall conform to the gradations specified below when tested in conformance with the requirements in ASTM Designation: C 136, except as follows:

A. Split or quarter 100 g ± 5 g from the CRM sample and dry to a constant mass at a temperature of not less than 57°C nor more than 63°C and record the dry sample mass. Place the CRM sample and 5.0 g of talc in a 0.5-L jar. Seal the jar, then shake the jar by hand for a minimum of one minute to mix the CRM and the talc. Continue shaking or open the jar and stir until particle agglomerates and clumps are broken and the talc is uniformly mixed.

B. Place one rubber ball on each sieve. Each ball shall have a mass of 8.5 g ± 0.5 g, have a diameter of 24.5 mm ± 0.5 mm, and shall have a Shore Durometer "A" hardness of 50 ± 5 in conformance with the requirements in ASTM Designation: D 2240. After sieving the combined material for 10 minutes ±1 minute, disassemble the sieves. Material adhering to the bottom of a sieve shall be brushed into the next finer sieve. Weigh and record the mass of the material retained on the 2.36-mm sieve and leave this material (do not discard) on the scale or balance. Observed fabric balls shall remain on the scale or balance and shall be placed together on the side of the scale or balance to prevent the fabric balls from being covered or disturbed when placing the material from finer sieves onto the scale or balance. The material retained on the next finer sieve (2.00-mm sieve) shall be added to the scale or balance. Weigh and record that mass as the accumulative mass retained on that sieve (2.00-mm sieve). Continue weighing and recording the accumulated masses retained on the remaining sieves until the accumulated mass retained in the pan has been determined. Prior to discarding the CRM sample, separately weigh and record the total mass of fabric balls in the sample.

C. Determine the mass of material passing the 75-µm sieve (or mass retained in the pan) by subtracting the accumulated mass retained on the 75-µm sieve from the accumulated mass retained in the pan. If the material passing the 75-µm sieve (or mass retained in the pan) has a mass of 5 g or less, cross out the recorded number for the accumulated mass retained in the pan and copy the number recorded for the accumulated mass retained on the 75-µm

sieve and record that number (next to the crossed out number) as the accumulated mass retained in the pan. If the material passing the 75-µm sieve (or mass retained in the pan) has a mass greater than 5 g, cross out the recorded number for the accumulated mass retained in the pan, subtract 5 g from that number and record the difference next to the crossed out number. The adjustment to the accumulated mass retained in the pan is made to account for the 5 g of talc added to the sample. For calculation purposes, the adjusted total sample mass is the same as the adjusted accumulated mass retained in the pan. Determine the percent passing based on the adjusted total sample mass and record to the nearest 0.1 percent:

CRM GRADATIONS

	SCRAP TIRE CRM	HIGH NATURAL CRM
Sieve Sizes	Percent Passing	Percent Passing
2.36-mm	100	100
2.00-mm	98-100	100
1.18-mm	45-75	95-100
600-µm	2-20	35-85
300-µm	0-6	10-30
150-µm	0-2	0-4
75-µm	0	0-1

ASPHALT-RUBBER BINDER

Asphalt-rubber binder shall consist of a mixture of paving asphalt, asphalt modifier, and crumb rubber modifier.

At least 2 weeks before its intended use, the Contractor shall furnish the Engineer 4 one liter cans filled with the asphalt-rubber binder proposed for use on the project. The Contractor shall supply the Engineer, for approval, a binder formulation and samples of all materials to be used in the asphalt-rubber binder, at least 2 weeks before construction is scheduled to begin. The binder formulations shall consist of the following information:

A. Paving Asphalt and Modifiers

1. Source and grade of paving asphalt.
2. Source and identification (or type) of modifiers used.
3. Percentage of asphalt modifier by mass of paving asphalt.
4. Percentage of the combined blend of paving asphalt and asphalt modifier by total mass of asphalt-rubber binder to be used.
5. Laboratory test results for test parameters shown in these special provisions.

B. Crumb Rubber Modifier (CRM)

1. Source and identification (or type) of scrap tire and high natural CRM.
2. Percentage of scrap tire and high natural CRM by total mass of the asphalt-rubber blend.
3. If CRM from more than one source is used, the above information will be required for each CRM source used.
4. Laboratory test results for test parameters shown in these special provisions.

C. Asphalt-Rubber Binder

1. Laboratory test results of the proposed blend for test parameters shown in these special provisions.
2. The minimum reaction time and temperature.

The method and equipment for combining the paving asphalt, asphalt modifier, and CRM shall be so designed and accessible that the Engineer can readily determine the percentages by mass for each material being incorporated into the mixture.

The proportions of the materials, by total mass of asphalt-rubber binder, shall be 80 percent ± 2 percent combined paving asphalt and asphalt modifier and 20 percent ± 2 percent CRM. However, the minimum amount of CRM shall not be less than 18.0 percent. Lower values shall not be rounded up. The CRM shall be combined at the production site and shall contain 75 percent ± 2 percent scrap tire CRM and 25 percent ± 2 percent high natural CRM, by mass.

The paving asphalt and asphalt modifier shall be combined into a blended mixture that is chemically compatible with the crumb rubber modifier to be used. The blended mixture shall be considered to be chemically compatible when the mixture meets the requirements for asphalt-rubber binder (after reacting) found in these special provisions.

The blended paving asphalt and asphalt modifier mixture and the CRM shall be combined and mixed together at the production site in a blender unit to produce a homogeneous mixture.

The temperature of the blended paving asphalt and asphalt modifier mixture shall not be less than 190°C nor more than 226°C when the CRM is added. The combined materials shall be reacted for a minimum of 45 minutes after incorporation of the CRM at a temperature of not less than 190°C nor more than 218°C. The temperature shall not be higher than 6°C below the actual flash point of the asphalt-rubber binder.

After reacting, the blended asphalt-rubber binder shall conform to the following requirements:

BLENDED ASPHALT-RUBBER BINDER

Test Parameter	ASTM Test Method	Requirement	
		Minimum	Maximum
Cone Penetration @ 25°C, 1/10 mm	D 217	25	70
Resilience @ 25°C, Percent rebound	D 3407	18	—
Field Softening Point, °C	D 36	52	74
Viscosity @190°C, Pa • s ($x10^{-3}$)	See Note	1500	3000

NOTE: The viscosity test shall be conducted using a hand held Haake Viscometer Model VT-02 with Rotor 1, 24 mm depth x 53 mm height, or equivalent, as determined by the Engineer. The accuracy of the viscometer shall be verified by comparing the viscosity results obtained with the hand held viscometer to 3 separate calibration fluids of known viscosities ranging from 1000 Pa to 5000 Pa • s ($x10^{-3}$). The viscometer will be considered accurate if the values obtained are within 300 Pa • s ($x10^{-3}$) of the known viscosity. The known viscosity value shall be based on the fluid manufacturer's standard test temperature or the test temperature versus viscosity correlation table provided by the fluid manufacturer. All viscometers used on the project shall be verified to be accurate. The test method for determining the viscosity of asphalt-rubber binder using a hand held viscometer is available at the Transportation Laboratory, Office of Pavement Consulting Services, Sacramento, California, Telephone (916) 227-7300. The accuracy verification results shall be provided to the Engineer and shall be certified by a Certificate of Compliance. The Certificate of Compliance shall be furnished to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

The Contractor shall provide a Haake Viscometer, or equivalent, at the production site during the combining of asphalt-rubber binder materials. The Contractor shall take viscosity readings of asphalt-rubber binder from samples taken from the distributor truck a minimum of 45 minutes after incorporation of the CRM. Readings shall be taken at least every hour with not less than one reading for each batch of asphalt-rubber binder. The Contractor shall log these results, including time and asphalt-rubber temperature. A copy of the log shall be submitted to the Engineer on a daily basis. As determined by the Engineer, the Contractor shall either notify the Engineer at least 15 minutes prior to each test or provide the Engineer a schedule of testing times.

The reacted asphalt-rubber binder shall be maintained at a temperature of not less than 190°C nor more than 218°C.

If any of the material in a batch of asphalt-rubber binder is not used within 4 hours after the 45-minute reaction period, heating of the material shall be discontinued. If the asphalt-rubber binder cools below 190°C and is then reheated, it shall be considered a reheat cycle. The total number of reheat cycles shall not exceed 2. The material shall be uniformly reheated to a temperature of not less than 190°C nor more than 218°C prior to use. Additional scrap tire CRM may be added to the reheated binder and reacted for a minimum of 45 minutes. The cumulative amount of additional scrap tire CRM shall not exceed 10 percent of the total binder mass. Reheated asphalt-rubber binder shall conform to the requirements for blended asphalt-rubber binder.

SCREENINGS

Screenings shall conform to the provisions in these special provisions and in Section 37-1.02, "Materials," of the Standard Specifications, except that the third, fourth, eighth, and ninth paragraphs of Section 37-1.02 shall not apply.

Stockpiling of screenings after preheating and precoating with paving asphalt will not be permitted.

Canvas or similar covers that completely cover each load of precoated screenings shall be used during hauling to minimize temperature drop of the precoated screenings.

Screenings shall conform to the following grading requirements prior to precoating with paving asphalt:

SCREENINGS GRADING REQUIREMENTS 9.5-mm Maximum	
Sieve Sizes	Percentage Passing
12.5-mm	100
9.5-mm	70-85
4.75-mm	0-15
2.36-mm	0-5
75-μm	0-1

Screenings shall conform to the following grading requirements prior to precoating with paving asphalt:

SCREENINGS GRADING REQUIREMENTS 12.5-mm Maximum	
Sieve Sizes	Percentage Passing
19-mm	100
12.5-mm	95-100
9.5-mm	70-85
4.75-mm	0-15
2.36-mm	0-5
75-µm	0-1

Screenings shall conform to the following quality requirements immediately prior to preheating:

SCREENINGS QUALITY REQUIREMENTS

Test Parameters	California Test	Requirements
Los Angeles Rattler Loss (100 Revolutions)	211	10 Max.
Los Angeles Rattler Loss (500 Revolutions)	211	40 Max.
Film Stripping	302	25 Max.
Cleanness Value	227	80 Min.
Durability	229	52 Min.

Screenings for asphalt-rubber seal coat shall be preheated to between 127°C and 163°C and uniformly coated at a rate of 0.7-percent to one percent by mass of dry aggregate with any of the asphalts specified in the table "Performance Graded Asphalt Binder" in Section 92, "Asphalts," of the Standard Specifications. Screenings shall be coated at a central mixing asphalt concrete plant that has been approved in conformance with the requirements in California Test 109. The exact rate will be determined by the Engineer.

EQUIPMENT

The Contractor shall utilize the following equipment for asphalt-rubber seal coat operations:

A. Self-propelled power brooms that clean the existing pavement and remove loose screenings without dislodging screenings set in the asphalt-rubber binder. Gutter brooms or steel-tinned brooms shall not be used;
B. Pneumatic tired rollers conforming to the provisions in Section 39-5.02, "Compacting Equipment," of the Standard Specifications, except that the rollers shall have an air pressure of 690 kPa and maintained so that the air pressure will not vary more than ±35 kPa in each tire. A sufficient number of rollers shall be used so that one complete coverage will be provided in one pass;
C. A self-propelled screenings spreader, equipped with a screenings hopper in the rear, belt conveyors to carry the screenings to the front, and a spreading hopper equipped with full-width distribution auger and spread roll. The screenings spreader shall be capable of providing a uniform screening spread rate over the entire width of the traffic lane in one application;
D. An asphalt heating tank equipped to heat and maintain the blended paving asphalt and asphalt modifier mixture at the necessary temperature before blending with the CRM. This unit shall be equipped with a thermostatic heat control device and a temperature reading device and shall be accurate to within ±3°C and shall be of the recording type;
E. A mechanical mixer for the complete, homogeneous blending of paving asphalt, asphalt

modifier, and CRM. Paving asphalt and asphalt modifier shall be introduced into the mixer through meters conforming to the provisions in Section 9-1.01, "Measurement of Quantities," of the Standard Specifications. The blending system shall vary the rate of delivery of paving asphalt and asphalt modifier proportionate with the delivery of CRM. During the proportioning and blending of the liquid ingredients, the temperature of paving asphalt and the asphalt modifier shall not vary more than ±14°C. The paving asphalt feed, the asphalt modifier feed, and CRM feed shall be equipped with devices by which the rate of feed can be determined during the proportioning operation. Meters used for proportioning individual ingredients shall be equipped with rate-of-flow indicators to show the rates of delivery and resettable totalizers so that the total amounts of liquid ingredients introduced into the mixture can be determined. The liquid and dry ingredients shall be fed directly into the mixer at a uniform and controlled rate. The rate of feed to the mixer shall not exceed that which will permit complete mixing of the materials. Dead areas in the mixer, in which the material does not move or is not sufficiently agitated, shall be corrected by a reduction in the volume of material or by other adjustments. Mixing shall continue until a homogeneous mixture of uniformly distributed and properly blended asphalt-rubber binder of unchanging appearance and consistency is produced. The contractor shall provide a safe sampling device that delivers a representative sample of the completed asphalt-rubber binder of sufficient size to permit the required tests;

F. An asphalt-rubber binder storage tank equipped with a heating system to maintain the proper temperature of the asphalt-rubber binder and an internal mixing unit that maintains a homogeneous mixture of blended paving asphalt, asphalt modifier, and CRM;

G. A self-propelled truck or trailer mounted distributor, equipped with an internal mixing unit that maintains a homogeneous mixture of blended paving asphalt, asphalt modifier and CRM. The distributor shall have a pump or pumps that sprays asphalt-rubber binder within ±0.25 L/m^2 of the specified rate. The distributor shall have a fully circulating spray bar that applies the asphalt-rubber binder without a streaked or otherwise irregular pattern. The distributor shall be equipped with a tachometer, pressure gages, volume measuring devices, and thermometer. The distributor shall have a platform on the rear of the vehicle and an observer shall accompany the distributor. The observer shall ride in such a position that all spray nozzles are in full view and readily accessible for unplugging plugged nozzles, should plugging occur; and

H. Tailgate discharge trucks for hauling screenings shall be equipped with a device to lock onto the hitch at the rear of the screenings spreader. Haul trucks shall be compatible with the screenings spreader so that the dump bed will not push down on the spreader when fully raised or have too short a bed which results in screenings spilling while dumping into the receiving hopper.

Equipment shall be approved by the Engineer prior to use.

APPLYING ASPHALT-RUBBER BINDER

Asphalt-rubber binder shall be applied in conformance with these special provisions and with the provisions for applying asphaltic emulsion in Section 37-1.05, "Applying Asphaltic Emulsion," of the Standard Specifications, except that the second, third, fourth, fifth, ninth, and twelfth paragraphs of Section 37-1.05 shall not apply.

Asphalt-rubber binder for asphalt-rubber seal coat shall be applied where shown on the plans at a rate of 2.5 L/m^2 to 3.0 L/m^2. The exact rate will be determined by the Engineer.

Attention is directed to Section 7-1.11, "Preservation Of Property," of the Standard Specifications and "Existing Highway Facilities" of these special provisions regarding protecting highway facilities from seal coat.

Asphalt-rubber binder shall be placed upon a clean, dry surface. The pavement surface temperature shall be a minimum of 13°C where asphalt-rubber binder is to be applied. The atmospheric temperature shall be a minimum of 16°C and a maximum of 43°C.

Distributor bar height, distribution speed, and shielding materials shall be utilized to reduce the effects of wind upon spray distribution as directed by the Engineer. The Engineer will delay or reschedule work when high, gusting or dirty winds prevent or adversely affect binder or screening application operations. Necessary equipment shall be in position and ready to commence placement operations before starting. The Contractor shall comply with Federal, State, and Local environmental laws, rules, regulations, and ordinances including, but not limited to, air quality requirements.

The asphalt-rubber binder shall be applied to the roadway immediately following mixing and reacting and shall be applied at a temperature not less than 196°C nor more than 213°C. Asphalt-rubber binder application shall not be in excess of that which can be covered with screenings within 2 minutes.

When placing asphalt-rubber seal coat at intersections, left turn lanes, gore points, and other irregular areas, asphalt-rubber application shall not be in excess of that which can be covered with screenings within 15 minutes.

When joining edges against areas with screenings, the joint shall be swept clean of excess screenings prior to the adjacent application of asphalt-rubber binder. Transverse joints of this type shall be constructed by placing roofing paper across and over the end of the previous asphalt-rubber seal coat application. Once the spraying has progressed beyond the paper, the paper shall be removed immediately.

The longitudinal joint between adjacent applications of screenings shall coincide with the line between designated traffic lanes. Longitudinal joints shall be overlapped for complete coverage. The overlap shall not exceed 100 mm.

At longitudinal joints with screenings, the edge shall be broomed back and blended to eliminate differences in elevation. The joints shall be free from ridges and depressions and shall have a uniform appearance consistent with the adjacent sealed surface. Defects shall be corrected at the Contractor's expense.

Joints between areas of asphalt-rubber binder without screenings shall be made by overlapping asphalt-rubber binder distributions. The excess material shall be properly dispersed by spreading with a squeegee or rake over a larger area of freshly applied asphalt-rubber binder.

The application of asphalt-rubber binder to areas not accessible with the distributor bar on the distributor truck shall be accomplished by using pressurized hand wands or other means approved by the Engineer.

SPREADING SCREENINGS

Screenings for asphalt-rubber seal coat shall be spread in conformance with the provisions specified for spreading screenings on asphaltic emulsion in these special provisions and in Section 37-1.06, "Spreading Screenings," of the Standard Specifications, except that the first, fifth, sixth, and seventh paragraphs of Section 37-1.06 shall not apply.

Following the application of the asphalt-rubber binder, screenings shall be placed over areas receiving asphalt-rubber binder.

Screenings for asphalt-rubber seal coat shall be applied at a temperature not less than 107°C and

not more than 163°C after applying asphalt-rubber binder.

The Contractor shall prevent any vehicle, including construction equipment, from driving on the asphalt-rubber binder prior to application of screenings.

Screenings shall be applied at a rate of 15 kg/m^2 to 22 kg/m^2. The exact rate will be determined by the Engineer. The completed spread rate shall be within 10 percent of the rate determined by the Engineer. The completed surface shall be free of gaps, ridges, depressions or other irregularities caused by the application of the asphalt-rubber seal coat.

FINISHING

Asphalt-rubber seal coat shall be finished in conformance with the provisions for finishing screenings spread on asphaltic emulsion in these special provisions and in Section 37-1.07, "Finishing," of the Standard Specifications, except that the second, third, seventh, eighth, and ninth paragraphs of Section 37-1.07 shall not apply.

Initial rolling of the asphalt-rubber seal coat shall consist of a minimum of one complete coverage with one or more pneumatic-tired rollers and shall begin within 90 seconds following the placement of the screenings.

The distance between the rollers and the screenings spreader shall not exceed 60 m at any time during the spreading of the screenings operations.

A minimum of 3 complete coverages as defined in Section 39-6.03, "Compacting," of the Standard Specifications with pneumatic tired rollers, after the initial coverage, shall be made on the asphalt-rubber seal coat. When permitted by the Engineer, the final roller coverage may be made with one steel wheel roller weighing 7.25 tonnes minimum and 9 tonnes maximum. If a steel wheel roller is used, the roller shall be operated in the static mode only.

Sweeping shall be a multi-step operation following final rolling of the screenings. Loose screenings shall be removed from the roadway surface and abutting adjacent areas.

Loose screenings shall be disposed of at least 46 m from the nearest waterway.

Initial sweeping shall be completed before controlled traffic is permitted on the asphalt-rubber seal coat. Removal of excess screenings shall be completed before uncontrolled traffic is permitted on the completed asphalt-rubber seal coat. Final sweeping shall be done and loose screenings shall be removed without dislodging the screenings set in the asphalt-rubber binder prior to acceptance.

FLUSH COAT

Flush coat shall consist of an application of a fog seal coat followed by a sand cover to the surface of asphalt-rubber seal coat. Flush coat shall conform to the provisions in Section 37-1, "Seal Coats," of the Standard Specifications and these special provisions.

Flush coat shall be applied to the asphalt-rubber seal coat immediately after initial brooming of the asphalt-rubber seal coat and removal of excess screenings and prior to opening the lane to uncontrolled (not controlled with pilot cars) public traffic.

Fog Seal Coat

Asphaltic emulsion (fog seal coat) shall be grade CSS1 or CSS1h or CQS1 as directed by the Engineer.

The asphaltic emulsion (fog seal coat) shall be applied at a rate of 0.14- to 0.27-L/m^2. The exact rate of application will be determined by the Engineer.

Attention is directed to Section 7-1.11, "Preservation Of Property," of the Standard

Specifications and "Existing Highway Facilities" of these special provisions regarding protecting the highway facilities from the fog seal coat.

During flush coat operations, the surface upon which the flush coat is being applied shall be closed to public traffic. Care shall be taken to avoid tracking fog seal coat material onto existing pavement surfaces beyond the limits of construction.

Sand Cover

Sand cover shall be applied immediately following application of the fog seal coat.

Sand for sand cover shall conform to the provisions for fine aggregate grading in Section 90-3.03, "Fine Aggregate Grading," of the Standard Specifications and these special provisions. Sand shall not contain clay and shall not contain organic material.

Sand shall be spread by means of a self-propelled chip spreader equipped with a mechanical device that will spread the sand at a uniform rate over the full width of a traffic lane in a single application. Sand shall be spread at a rate of 1 kg/m^2 to 2 kg/m^2. The exact rate will be determined by the Engineer.

MEASUREMENT AND PAYMENT

Quantities of asphalt-rubber binder for asphalt-rubber seal coat will be measured in the same manner specified for asphalt in Section 92-1.04, "Measurement," of the Standard Specifications.

Quantities of screenings for asphalt-rubber seal coat to be paid for by the tonne will be determined after preheating and precoating with paving asphalt in the same manner specified for asphalt concrete in Section 39-8.01, "Measurement," of the Standard Specifications.

The contract price paid per tonne for asphalt-rubber binder shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in furnishing and applying asphalt-rubber binder, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per tonne for screenings (hot-applied) shall include full compensation for furnishing all labor, materials (including paving asphalt for precoating screenings), tools, equipment, and incidentals and for doing all the work involved in furnishing and applying screenings, complete in place, including preparation for seal coat and preheating and precoating screenings, furnishing, placing, maintaining, and removing C6 (Loose Gravel) and W6 (35 MPH) signs and temporary supports or barricades for the signs, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Sand cover will be measured and paid for in the same manner specified for screenings in Section 37-1.08, "Measurement," and Section 37-1.09, "Payment," of the Standard Specifications.

No adjustment in compensation will be made for any increase or decrease in the quantities of asphaltic emulsion (fog seal coat) and sand cover required, regardless of the reason for the increase or decrease. The provisions in Section 4-1.03B, "Increased or Decreased Quantities," of the Standard Specifications shall not apply to the items of asphaltic emulsion (fog seal coat) and sand cover.

Appendix G: California Terminal Blend NSSP

The following was an NSSP used in Caltrans D9 SR 203 Mammoth Lakes Project on 2011.

PG-TR Grades posted are Non-Standard Special Provision (NSSP) status only

PROPERTY	Test Method AASHTO or Other	Performance Grade (PG)	
		PG 64-28 TR	PG 76-22 TR
Original Binder:			
Flash Point, Minimum °C	T 48	230	230
Solubility, % minimum [b]	T 44[d]	97.5	97.5[e]
Viscosity at 135°C, [f] Maximum, Pa·s	T 316	3.0	3.0
Dynamic Shear, Test Temp. at 10 rad/s, °C Minimum G*/sin(delta), kPa	T 315	64 1.00	76 1.00
RTFO Test , Mass Loss, Maximum, %	T 240	1.00	1.00
RTFO Test Aged Binder:			
Dynamic Shear, Test Temp. at 10 rad/s, °C Minimum G*/sin(delta), kPa	T 315	64 2.20	76 2.20
Dynamic Shear, Test Temp. at 10 rad/s, °C Maximum (delta), %	T 315	Note g 80	Note g 80
Elastic Recovery[h], Test Temp., °C Minimum recovery, %	T 301	25 75	25 65
PAV[i] Aging, Temperature, °C	R 28	100	110
RTFO Test and PAV Aged Binder:			
Dynamic Shear, Test Temp. at 10 rad/s, °C Maximum G*sin(delta), kPa	T 315	22 5000	31 5000
Creep Stiffness, Test Temperature, °C Maximum S-value, MPa Minimum M-value	T 313	-18 300 0.300	-12 300 0.300

Notes:

a.	Do not modify binder using polyphosphoric acid modification.
b.	Supplier is required to certify 10% minimum tire rubber modifier in binder.
c.	The Engineer waives this specification if the supplier is a Quality Supplier as defined by the Department's "Certification Program for Suppliers of Asphalt."
d.	The Department allows ASTM D 5546 instead of AASHTO T 44
e.	For hot applied chip seal applications the solubility will be a minimum of 93% and a binder profile is required for supplier who is not a Quality Supplier as defined by the Department's "Certification Program for Suppliers of Asphalt."
f.	The Engineer waives this specification if the supplier certifies the asphalt binder can be adequately pumped and mixed at temperatures meeting applicable safety standards.
g.	Test temperature is the temperature at which G*/sin(delta) is 2.2 kPa. A graph of log G*/sin(delta) plotted against temperature may be used to determine the test temperature when G*/sin(delta) is 2.2 kPa. A graph of (delta) versus temperature may be used to determine delta at the temperature when G*/sin(delta) is 2.2 kPa. The Engineer also accepts direct measurement of (delta) at the temperature when G*/sin(delta) is 2.2 kPa.
h.	Tests without a force ductility clamp may be performed.
i.	"PAV" means Pressurized Aging Vessel.

Appendix H: California Rubberized HMA with Warm Mix Technologies

10-1.__ HOT MIX ASPHALT WITH WARM MIX ASPHALT TECHNOLOGY

GENERAL

Summary

This work includes producing and placing hot mix asphalt (HMA) using an approved warm mix asphalt (WMA) technology. Water injection technologies will not be allowed. For Department-approved WMA technologies, go to:

http://www.dot.ca.gov/hq/esc/approved_products_list/

____-WMA must comply with Section 39, "Hot Mix Asphalt," of the Standard Specifications for ____ and must be produced and constructed under the _____ process.

AASHTO T 324 (Modified) is AASHTO T 324, "Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)," with the following parameters:

1. Target air void content is 7 ± 1 percent
2. 4 test specimens
3. 6-inch gyratory compacted test specimen
4. Test temperature is 122 ± 2 °F
5. Impression measurements at every 100 passes
6. Inflection point as the number of wheel passes at the intersection of the creep slope and the stripping slope
7. Testing shut off after 25,000 passes
8. For RHMA test specimens:

    8.1. Superpave Gyratory Compactor ram pressure may be increased to a maximum 825 kPa
    8.2. Specimens may be held at a constant height for a maximum 90 minutes

HMA samples must be prepared under California Test 304, except the samples must be cured in a forced air draft oven at 275 °F for 4 hours ± 10 minutes.

Definitions

WMA: HMA produced at temperatures no greater than 275 °F.

HMA with WMA technology: HMA produced using additives to aid with mixing and compaction of HMA produced at temperatures greater than 275 °F.

Submittals

General

With the job mix formula (JMF) submittal, submit:

1. Name of WMA technology you propose to use
2. Percent admixture by weight of binder and HMA as recommended by the manufacturer
3. Methodology for inclusion of admixture in laboratory-produced HMA
4. Proposed HMA production temperature range
5. California Test 371 test results for dry strength for untreated plant-produced HMA

6. California Test 371 test results for tensile strength ratio for untreated plant-produced HMA
7. California Test 204 test results for plasticity index if untreated plant-produced HMA test result determined under California Test 371 is below the specified HMA mix design requirements
8. California Test 371 test results for treated plant-produced HMA if untreated plant-produced HMA test result determined under California Test 371 is below the specified HMA mix design requirements
9. AASHTO T 324 (Modified) test results data showing number of passes with rut depth for plant-produced HMA
10. AASHTO T 324 (Modified) test results data showing number of passes at inflection point for plant-produced HMA

Prepaving Conference

With the JMF submittal, submit a list of names participating in the prepaving conference. Identify each participant's name, employer, title, and role in the production and placement of HMA with WMA technology.

Tests and Samples

At production start-up and within ±1,000 tons of the halfway point of the production of HMA with WMA technology, submit samples split from your HMA production sample for California Test 371 and AASHTO T 324 (Modified) test to the Engineer and the Transportation Laboratory, Attention: Moisture Test.

With the JMF submittal, at JMF verification, at production start-up, and for each 10,000 tons of HMA produced, submit California Test 371 test results and AASHTO T 324 (Modified) test results for mix design and production to the Engineer and electronically to:

Moisture_Tests@dot.ca.gov

With the JMF submittal, at JMF verification, at production start-up evaluation, and for each 10,000 tons of HMA produced, submit one tested sample set from the AASHTO T 324 (Modified) test to the Engineer.

Daily Production Log

Submit the log of production data, daily and upon request.

Data Cores

Three business days before starting coring, submit proposed methods and materials for backfilling data core holes.

Submit to the Engineer and electronically to Coring@dot.ca.gov:

1. Summary of data cores taken
2. Photograph of each data core

For each data core, the summary must include:

1. Project identification number
2. Date cored
3. Core identification number
4. Type of materials recovered
5. Type and approximate thickness of unstabilized material not recovered
6. Total core thickness
7. Thickness of each individual material to within:

    7.1. For recovered material, 1/2 inch
    7.2. For unstabilized material, 1.0 inch

8. Location including:

    8.1. County
    8.2. Route
    8.3. Post mile
    8.4. Lane number
    8.5. Lane direction
    8.6. Station

Each data core digital photograph must include a ruler laid next to the data core. Each photograph must include:

1. Core
2. Project identification number
3. Core identification number
4. Date cored
5. County
6. Route
7. Post mile
8. Lane number
9. Lane direction

After data core summary and photograph submittal, dispose of cores under Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

Quality Control and Assurance

Technical Representative

A technical representative from the WMA technology supplier must be present during the first 3 days of production and placement of HMA using WMA technology. The technical representative must advise you, the Engineer, and the HMA producer. The technical representative must direct the HMA mix operation as it relates to the WMA technology.

The technical representative must advise the HMA producer regarding HMA plant and HMA plant process-controller modifications necessary for integrating WMA technology with HMA plant. HMA plant modifications and WMA technology equipment, scales, and meters must comply with the Department's Materials Plant Quality Program (MPQP).

Prepaving Conference

Schedule a prepaving conference with the Engineer at a mutually agreed time and place. Make arrangements for the conference facility. Be prepared to discuss:

1. HMA production and placement
2. Method for incorporating WMA technology and any impacts on HMA production and placement including requirements for compaction and workmanship
3. Contingency plan

The following personnel must attend the prepaving conference:

1. Project Manager
2. Superintendent
3. Technical representative for WMA technology
4. Asphalt binder supplier
5. HMA plant manager
6. HMA plant operators
7. HMA paving foreman

Quality Control Testing

Perform sampling and testing at the specified frequency and location for the following additional quality characteristics:

Minimum Quality Control

Quality Characteristic	Test Method	Minimum Sampling and Testing Frequency	Requirement			Sampling Location	Maximum Reporting Time Allowance
			HMA Type				
			A-WMA	B-WMA	RHMA-G-WMA		
Moisture susceptibility (minimum dry strength, psi)	California Test 371	First production day and 1 per every 10,000 tons	120	120	120	Loose mix behind the paver. See California Test 125	15 days
Moisture susceptibility (tensile strength ratio, %)	California Test 371		Report Only	Report Only	Report Only		
Hamburg wheel track (minimum number of passes at 0.5 inch average rut depth) PG-58 PG-64 PG-70 PG-76	AASHTO T 324 (Modified)	First production day and 1 per every 10,000 tons	 10,000 15,000 20,000 25,000	 10,000 15,000 20,000 25,000	 15,000 20,000 25,000 --	Loose mix behind the paver. See California Test 125	7 days[a]
Hamburg wheel track (inflection point minimum number of passes) PG-58 PG-64 PG-70 PG-76	AASHTO T 324 (Modified)		 10,000 10,000 12,500 15,000	 10,000 10,000 12,500 15,000	 10,000 12,500 15,000 --		

[a] Submit test data and 1 tested sample set.

Engineer's Acceptance

The Engineer samples HMA for acceptance testing and tests for the following additional quality characteristic:

HMA Acceptance

Quality Characteristic	Test Method	Requirement			Sampling Location
		HMA Type			
		A-WMA	B-WMA	RHMA-G-WMA	
Moisture susceptibility (minimum dry strength, psi)	California Test 371	120	120	120	Loose mix behind the paver. See California Test 125
Moisture susceptibility (tensile strength ratio, %)	California Test 371	Report Only[a]	Report Only[a]	Report Only[a]	
Hamburg wheel track (minimum number of passes at 0.5 inch average rut depth) PG-58 PG-64 PG-70 PG-76	AASHTO T 324 (Modified)	 10,000 15,000 20,000 25,000	 10,000 15,000 20,000 25,000	 15,000 20,000 25,000 --	Loose mix behind the paver. See California Test 125
Hamburg wheel track (inflection point minimum number of passes) PG-58 PG 64 PG-70 PG-76	AASHTO T 324 (Modified)	 10,000 10,000 12,500 15,000	 10,000 10,000 12,500 15,000	 10,000 12,500 15,000 --	

[a]The Department does not use California Test 371 tensile strength ratio test results from production to determine specification compliance.

MATERIALS

Asphalt Binder

The grade of asphalt binder to be mixed with aggregate for ____-WMA must be PG _____.
The grade of asphalt binder to be mixed with asphalt modifier and crumb rubber modifier (CRM) for RHMA-G-WMA must be PG _____.

Aggregate

The aggregate for HMA Type ____-WMA must comply with the _____ grading.
The aggregate for RHMA-G-WMA must comply with the_____ grading.

Hot Mix Asphalt

Hot Mix Asphalt Mix Design

Produce HMA mix samples for your mix design using WMA technology. For WMA technology, use your methodology for inclusion of admixture in laboratory-produced HMA.

Determine the amount of asphalt rubber binder to be mixed with the aggregate for RHMA-G-WMA under California Test 367 except:

1. Determine the specific gravity used in California Test 367, Section B, "Void Content of Specimen," using California Test 308, Method A.

2. California Test 367, Section C, "Optimum Bitumen Content," is revised as follows:

    2.1. Base the calculations on the average of 3 briquettes produced at each asphalt rubber binder content.
    2.2. Use California Test 309 to determine theoretical maximum specific gravity and density of the RHMA-G-WMA.
    2.3. Plot asphalt rubber binder content versus average air voids content based on California Test 309 for each set of three specimens on Form TL-306 (Figure 3), and connect adjacent points with a best-fit curve.
    2.4. Plot asphalt rubber binder content versus average Hveem stability for each set of three specimens and connect adjacent points with a best-fit curve.
    2.5. Calculate voids in mineral aggregate (VMA) and voids filled with asphalt (VFA) for each specimen, average each set, and plot the average versus asphalt rubber binder content.
    2.6. Calculate the dust proportion and plot versus asphalt rubber binder content.
    2.7. From the curve plotted in Step 2.3, select the theoretical asphalt rubber binder content that has ___ percent air voids.
    2.8. At the selected asphalt rubber binder content, evaluate corresponding voids in mineral aggregate, voids filled with asphalt, and dust proportion to verify compliance with requirements. If necessary, develop an alternate composite aggregate gradation to conform to the RHMA-G-WMA requirements.
    2.9. Record the asphalt rubber binder content in Step 2.7 as the optimum bitumen content (OBC).
    2.10. OBC must be equal or greater than 7.5 percent based as a percentage of dry weight of the aggregate.

3. Laboratory mixing and compaction must comply with California Test 304, except the mixing temperature of the aggregate must be from 300 °F to 325 °F. The mixing temperature of the asphalt-rubber binder must be from 375 °F to 425 °F. The compaction temperature of the combined mixture must be from 290 °F to 300 °F.

HMA mix design must meet the following quality characteristics:

Hot Mix Asphalt Mix Design Requirements

Quality Characteristic	Test Method	HMA Type		
		A-WMA	B-WMA	RHMA-G-WMA
Moisture susceptibility (minimum dry strength, psi)	California Test 371	120	120	120
Moisture susceptibility (tensile strength ratio, %)	California Test 371	70	70	70
Hamburg wheel track (minimum number of passes at 0.5 inch average rut depth)	AASHTO			
PG-58	T 324	10,000	10,000	15,000
PG 64	(Modified)	15,000	15,000	20,000
PG-70		20,000	20,000	25,000
PG-76		25,000	25,000	--
Hamburg wheel track (inflection point minimum number of passes)	AASHTO			
PG-58	T 324	10,000	10,000	10,000
PG 64	(Modified)	10,000	10,000	12,500
PG-70		12,500	12,500	15,000
PG-76		15,000	15,000	--

If the determined test results under California Test 371 or AASHTO T 324 (Modified) for untreated plant-produced HMA are less than the minimum requirement for the mix design, determine the plasticity index of the aggregate blend under California Test 204. Choose from the antistrip treatments based on plasticity index in compliance with:

Hot Mix Asphalt Antistrip Treatment Options

Quality Characteristic	Test Method	Treatment Requirement
Plasticity index from 4 to 10 [a]	California Test 204	Dry hydrated lime with marination Lime slurry with marination
Plasticity index less than 4		Liquid Antistrip Dry hydrated lime without marination Dry hydrated lime with marination Lime slurry with marination

Notes:
[a] If the plasticity index is greater than 10, do not use that aggregate blend.

Mix design for treated plant-produced HMA must meet the mix design requirements, except if the tensile strength ratio test result for treated plant produced RHMA-G-WMA is less than the mix design requirement for tensile strength ratio, the minimum tensile strength ratio requirement is waived, but you must use any of the following antistrip treatments:

1. HMA aggregate lime treatment – slurry method
2. HMA aggregate lime treatment – dry lime method
3. Liquid antistrip treatment using 0.5 percent liquid antistrip

Job Mix Formula Verification

HMA produced for JMF verification must be produced using the WMA technology shown in the JMF submittal.
Use the OBC specified on your CEM-3512. No adjustments are allowed. When RAP is used, the asphalt binder set point for HMA must be the OBC specified on your CEM-3512 minus RAP percentage multiplied by the combined average asphalt binder content of the processed fractioned RAP stockpiles.
Perform the AASHTO T 324 (Modified) test for compliance with the mix design requirements. Submit test data and one tested sample set from the AASHTO T 324 (Modified) test.
The Engineer may verify that the HMA complies with the mix design requirements for AASHTO T 324 (Modified) and California Test 371.
If you request, the Engineer verifies RHMA-G-WMA quality requirements within 5 business days of sampling.

Production

General

HMA and RHMA produced using WMA technology must be produced at a temperature between 290 °F and 325 °F.
Comply with Section 39-1.08A, "General," of the Standard Specifications except the HMA plant asphalt binder set point for HMA production must be the OBC specified on your CEM-3511. When RAP is used, asphalt binder set point for HMA production must be the OBC specified on your CEM-3511 minus RAP percentage multiplied by the combined average binder content of the processed fractioned RAP stockpiles.
HMA additives used for antistrip treatment and WMA technologies may be either in a liquid or dry state.
The HMA plant must have a sampling device in the feed line connecting the additive storage to the additive metering system. The sampling equipment must comply with California Test 125.

Proportioning Warm Mix Asphalt Technologies

HMA plants using WMA technology must comply with the Department's MPQP.
Proportion all ingredients by weight. The HMA plant process controller (PPC) must be the sole source of ingredient proportioning control and be fully interfaced with all scales and meters used in the production process. The addition of the HMA additive must be controlled by the PPC.
Weighing and metering devices used for the production of additive enhanced HMA must meet the requirements of the MPQP. When a loss-in-weight meter is used for dry HMA additive, the meter must:

1. Meet the requirements of the MPQP
2. Have an automatic and integral material delivery control system for the refill cycle

Calibrate the loss-in-weight meter by:

1. Including at least 1 complete system refill cycle during each calibration test run
2. Operating the device in a normal run mode for 10 minutes immediately before starting the calibration process

3. Isolating the scale system within the loss-in-weight feeder from surrounding vibration
4. Checking the scale system within the loss-in-weight feeder for accuracy before and after the calibration process and daily during mix production
5. Using a 15-minute or 250-pound-minimum test run size for a dry ingredient delivery rate of less than 1 ton per hour
6. Complying with the limits of Table B, "Conveyor Scale Testing Extremes," in the MPQP

Produce additive enhanced HMA by using either a continuous mixing or a batch type HMA plant. Liquid ingredient additive, including a normally dry ingredient made liquid, must be proportioned with a mass flow meter at continuous mixing plants. Use a mass flow meter or a container scale to proportion liquid additives at batch mixing plants.
Continuous mixing plants using HMA additives must comply with the following:

1. Dry ingredient additives for continuous production must be proportioned with a conveyor scale or a loss-in-weight meter.
2. HMA PPC and ingredient measuring systems must be capable of varying all ingredient feed rates proportionate with the dry aggregate delivery at all production rates and rate changes.
3. Liquid HMA additive must enter the production stream with the binder. Dry HMA additive must enter the production stream at or before the mixing area.
4. When dry HMA additives are used at continuous mixing HMA plants, baghouse dust systems must return all captured material to the mix.
5. HMA additive must be proportioned to within ±0.3 percent of the target additive rate.

Batch mixing plants using HMA additives must comply with the following:

1. Metered HMA additive must be placed in an intermediate holding vessel before being added to the stream of asphalt binder as it enters the pugmill.
2. When a container scale is used, weigh additive before combining with asphalt binder. Keep the container scale separate from other ingredient proportioning. The container scale capacity must be no more than twice the volume of the maximum additive batch size. The container scale's graduations must be smaller than the proportioning tolerance or 0.001 times the container scale capacity.
3. Dry HMA additive proportioning devices must be separate from metering devices for the aggregates and asphalt binder. Proportion dry HMA additive directly into the pugmill or place in an intermediate holding vessel to be added to the pugmill at the appropriate time in the batch cycle. Dry ingredients for batch production must be proportioned with a hopper scale.
4. Zero tolerance for the HMA additive batch scale is ±0.5 percent of the target additive weight. The indicated HMA additive batch scale weight may vary from the preselected weight setting by up to ±1.0 percent of the target additive weight.

Production Data Collection

The HMA PPC must produce an electronic log of production data consisting of a series of snapshots captured at a maximum of 1-minute intervals throughout daily production. Each snapshot of production data must be a register of production activity at that time and not a summation of the data over the preceding interval to the previous snapshot. The amount of material represented by each snapshot is the amount produced during the 0.5-minute interval before and the 0.5-minute interval after the capture

time. Collect and hold data for the duration of the contract and submit the electronic media, daily and upon request. The snapshot of production data must include the following:

1. Date of production
2. Production location
3. Time of day the data is captured
4. HMA mix type being produced and target binder rate
5. HMA additive type, brand, and target rate
6. Temperature of the binder and HMA mixture
7. For a continuous mix operation, the rate of flow of the dry aggregate calculated from the wet aggregate flow rate as determined by the conveyor scale
8. For a continuous mix plant operation, the rate of flow of the asphalt meter
9. For a continuous mix plant operation, the rate of flow of HMA additive meter
10. For a batch plant operation, actual batch weights of all ingredients
11. Dry aggregate to binder ratio calculated from metered ingredient output
12. Dry aggregate to HMA additive ratio calculated from metered output

Electronic media must be presented in a comma-separated values (CSV) or tab-separated values (TSV) format. Captured data, for the ingredients represented by production snapshot, must have allowances for sufficient fields to satisfy the amount of data required by these specifications and include data titles at least once per report.

CONSTRUCTION

General

You must request adjustments to the plant asphalt binder set point based on new RAP stockpiles average asphalt binder content. Do not adjust the HMA plant asphalt binder set point until approved by the Engineer.
Produce HMA and RHMA at a temperature between 290 °F and 325 °F.

Spreading and Compacting

For Standard and QC/QA processes, spread and compact HMA under the Method process if any of the following applies:

1. Specified paved thickness is less than 0.15 foot.
2. Specified paved thickness is less than 0.20 foot and 3/4-inch aggregate grading is specified and used.
3. You spread and compact at:

    3.1. Asphalt concrete surfacing replacement areas
    3.2. Leveling courses
    3.3. Areas for which the Engineer determines conventional compaction and compaction measurement methods are impeded

Do not allow traffic on new HMA pavement until its mid-depth temperature is below 130 °F.
If the atmospheric temperature is below 60 °F, cover loads in trucks with tarpaulins. When the time for HMA discharge to truck at the HMA plant until transfer to paver's hopper is 90 minutes or greater and

if the atmospheric temperature is below 70 °F, cover loads in trucks with tarpaulins. The tarpaulins must completely cover the exposed load until you transfer the mixture to the paver's hopper or to the pavement surface. Tarpaulins are not required if the time from discharging to the truck until transfer to the paver's hopper or the pavement surface is less than 30 minutes.
For method process, spread HMA Type A-WMA and Type B-WMA when the atmospheric and surface temperatures are above the minimum temperatures shown in the following table:

Minimum Atmospheric and Surface Temperatures

Compacted Layer Thickness	Atomosphere, °F		Surface, °F	
	Unmodified Asphalt Binder	Modified Asphalt Binder	Unmodified Asphalt Binder	Modified Asphalt Binder [a]
< 0.15	45	40	50	45
0.15-0.25	40	40	40	40

Note:
[a] Except asphalt rubber binder.

If the asphalt binder for HMA Type A-WMA and Type B-WMA is unmodified asphalt binder, complete:

1. First coverage of breakdown compaction before the surface temperature drops below 240 °F
2. Breakdown and intermediate compaction before the surface temperature drops below 190 °F
3. Finish compaction before the surface temperature drops below 140 °F

If the asphalt binder for HMA Type A-WMA and Type B-WMA is modified asphalt binder, complete:

1. First coverage of breakdown compaction before the surface temperature drops below 230 °F
2. Breakdown and intermediate compaction before the surface temperature drops below 170 °F
3. Finish compaction before the surface temperature drops below 130 °F

For RHMA-G-WMA:

1. Only spread and compact if the atmospheric temperature is at least 50 °F and the surface temperature is at least 50 °F
2. Complete the 1st coverage of breakdown compaction before the surface temperature drops below 260 °F
3. Complete breakdown and intermediate compaction before the surface temperature drops below 230 °F
4. Complete finish compaction before the surface temperature drops below 180 °F

Material Transfer Vehicle

A material transfer vehicle (MTV) must be used when placing HMA with WMA technologies.
The MTV must:

1. Either receive HMA directly from trucks or use a windrow pickup head to load it from a windrow deposited on the roadway surface
2. Transfer HMA directly into the paver's receiving hopper or feed system
3. Remix the HMA with augers before loading the paver
4. Have sufficient capacity to prevent stopping the paver

HMA deposited in a windrow on the roadway surface must not extend more than 100 feet in front of the MTV.

Rumble Strips

Construct rumble strips in the top layer of new HMA surfacing.

Vertical Joints

If you perform half-width paving, at the end of each day's work, the distance between the ends of adjacent surfaced lanes must not be greater than can be completed in the following day of normal paving.
Before opening the lane to public traffic, pave shoulders and median borders adjacent to a lane being paved.
Do not leave a vertical joint more than 0.15 foot high between adjacent lanes open to public traffic.
Place HMA on adjacent traveled way lanes so that at the end of each work shift, the distance between the ends of HMA layers on adjacent lanes is between 5 feet and 10 feet. Place additional HMA along the transverse edge at each lane's end and along the exposed longitudinal edges between adjacent lanes. Hand rake and compact the additional HMA to form temporary conforms. You may place Kraft paper or another approved bond breaker under the conform tapers to facilitate the taper removal when paving operations resume.

Widening

If widening existing pavement, construct new structural section on both sides of the existing pavement to match the elevation of the existing pavement's edge for the project's entire length before placing HMA over the existing pavement.
If widening existing pavement, construct new structural section on both sides of the existing pavement to match the elevation of the existing pavement's edge at each location before placing HMA over the existing pavement.
If widening existing pavement, construct new structural section on both sides of the existing pavement to match the elevation of the existing pavement's edge in increments of at least _____ feet before placing HMA over the existing pavement.

Conform Tapers

Place shoulder conform tapers concurrently with the adjacent lane's paving.
Place additional HMA along the pavement's edge to conform to road connections and private drives. Hand rake, if necessary, and compact the additional HMA to form a smooth conform taper.

Data Cores

Take data cores that include the completed HMA pavement, underlying base, and subbase material.
Protect data cores and surrounding pavement from damage.
Take 4-inch or 6-inch diameter data cores:

1. At the beginning, end, and every 1/2 mile within the paving limits of each route on the project
2. After all paving is complete

3. From the center of the specified lane

On a 2-lane roadway, take data cores from either lane. On a 4-lane roadway, take data cores from each direction in the outermost lane. On a roadway with more than 4 lanes, take data cores from the median lane and the outermost lane in each direction.
Each core must include the stabilized materials encountered. You may choose not to recover unstabilized material but you must identify the material. Unstabilized material includes:

1. Granular material
2. Crumbled or cracked stabilized material
3. Sandy or clayey soil

PAYMENT

The contract lump sum price paid for data core includes full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in data coring, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.
Full compensation for furnishing all labor and materials for using WMA technology and providing an MTV is included in the contract price paid per ton for the HMA type designated in the verified Bid Item List and no additional compensation will be allowed therefor.

Appendix I: Arizona Asphalt Rubber Specifications

SECTION 1009 ASPHALT-RUBBER MATERIAL:

1009-1 Description:

The work under this section shall consist of furnishing, proportioning and mixing all the ingredients necessary to produce an asphalt-rubber material.

1009-2 Materials:

1009-2.01 Asphalt-Rubber:

(A) Asphalt Cement:

Asphalt cement shall be a performance grade (PG) asphalt binder conforming to the requirements of Section 1005.

(B) Rubber:

Rubber shall meet the following gradation requirements when tested in accordance with Arizona Test Method 714.

Sieve Size	Percent Passing	
	Type A	Type B
No. 8	100	
No. 10	95 - 100	100
No. 16	0 - 10	65 - 100
No. 30		20 - 100
No. 50		0 - 45
No. 200		0 - 5

The rubber shall have a specific gravity of 1.15 ± 0.05 and shall be free of wire or other contaminating materials, except that Type A rubber shall contain not more than 0.1 percent fabric and Type B shall contain not more than 0.5 percent fabric. Calcium carbonate, up to four percent by weight of the granulated rubber, may be added to prevent the particles from sticking together.

Certificates of Compliance conforming to Subsection 106.05 shall be submitted. In addition, the certificates shall confirm that the rubber is a crumb rubber, derived from processing whole scrap tires or shredded tire materials; and the tires from which the crumb rubber is produced are taken from automobiles, trucks, or other equipment owned and operated in the United States. The certificates shall also verify that the processing does not produce, as a waste product, casings or other round tire material that can hold water when stored or disposed of above ground.

1009-2.02 Asphalt-Rubber Proportions:

The asphalt-rubber shall contain a minimum of 20 percent ground rubber by the weight of the asphalt cement.

1009-2.03 Asphalt-Rubber Properties:

Asphalt-rubber shall conform to the following:

Property	Requirement		
	Type 1	**Type 2**	**Type 3**
Grade of base asphalt cement	PG 64-16	PG 58-22	PG 52-28
Rotational Viscosity*: 350 ^{o}F; pascal seconds	1.5 - 4.0	1.5 - 4.0	1.5 - 4.0
Penetration: 39.2 ^{o}F, 200 g, 60 sec. (ASTM D 5); minimum	10	15	25
Softening Point: (ASTM D 36); ^{o}F, minimum	135	130	125
Resilience: 77 ^{o}F (ASTM D 5329); %, minimum	30	25	15
* The viscotester used must be correlated to a Rion (formerly Haake) Model VT-04 viscotester using the No. 1 Rotor. The Rion viscotester rotor, while in the off position, shall be completely immersed in the binder at a temperature from 350 to 355 degrees F for a minimum heat equilibrium period of 60 seconds, and the average viscosity determined from three separate constant readings (± 0.5 pascal seconds) taken within a 30 second time frame with the viscotester level during testing and turned off between readings. Continuous rotation of the rotor may cause thinning of the material immediately in contact with the rotor, resulting in erroneous results.			

1009-2.04 Asphalt-Rubber Design:

At least two weeks prior to the use of asphalt-rubber, the contractor shall submit an asphalt-rubber design prepared by an approved laboratory. Such design shall meet the requirements specified herein. The design shall show the values obtained from the required tests, along with the following information: percent, grade and source of the asphalt cement used; and percent, gradation and source(s) of rubber used.

1009-3 Construction Requirements:

During production of asphalt-rubber, the contractor shall combine materials in conformance with the asphalt-rubber design unless otherwise approved by the Engineer.

1009-3.01 Mixing of Asphalt-Rubber:

The temperature of the asphalt-cement shall be between 350 and 400 degrees F at the time of addition of the ground rubber. No agglomerations of rubber particles in excess of two

inches in the least dimension shall be allowed in the mixing chamber. The ground rubber and asphalt-cement shall be accurately proportioned in accordance with the design and thoroughly mixed prior to the beginning of the one-hour reaction period. The contractor shall document that the proportions are accurate and that the rubber has been uniformly incorporated into the mixture. Additionally, the contractor shall demonstrate that the rubber particles have been thoroughly mixed such that they have been "wetted." The occurrence of rubber floating on the surface or agglomerations of rubber particles shall be evidence of insufficient mixing. The temperature of the asphalt-rubber immediately after mixing shall be between 325 and 375 degrees F. The asphalt-rubber shall be maintained at such temperature for one hour before being used.

Prior to use, the viscosity of the asphalt-rubber shall be tested by the use of a rotational viscotester, which is to be furnished by the contractor or supplier.

1009-3.02 Handling of Asphalt-Rubber:

Once the asphalt-rubber has been mixed, it shall be kept thoroughly agitated during periods of use to prevent settling of the rubber particles. During the production of asphaltic concrete the temperature of the asphalt-rubber shall be maintained between 325 and 375 degrees F. However, in no case shall the asphalt-rubber be held at a temperature of 325 degrees F or above for more than 10 hours. Asphalt-rubber held for more than 10 hours shall be allowed to cool and gradually reheated to a temperature between 325 and 375 degrees F before use. The cooling and reheating shall not be allowed more than one time. Asphalt-rubber shall not be held at temperatures above 250 degrees F for more than four days.

For each load or batch of asphalt-rubber, the contractor shall provide the Engineer with the following documentation:

(1) The source, grade, amount and temperature of the asphalt cement prior to the addition of rubber.

(2) The source and amount of rubber and the rubber content expressed as percent by the weight of the asphalt cement.

(3) Times and dates of the rubber additions and resultant viscosity test.

(4) A record of the temperature, with time and date reference for each load or batch. The record shall begin at the time of the addition of rubber and continue until the load or batch is completely used. Readings and recordings shall be made at every temperature change in excess of 20 degrees F, and as needed to document other events which are significant to batch use and quality.

Appendix J: Arizona Specifications – Gap Graded

SECTION 413 ASPHALTIC CONCRETE (ASPHALT-RUBBER)

413-1 Description:

Asphaltic Concrete (Asphalt-Rubber), hereinafter asphaltic concrete, shall consist of furnishing all materials, mixing at a plant, hauling, and placing a mixture of aggregate materials, mineral admixture, and bituminous material (asphalt-rubber) to form a pavement course or to be used for other specified purposes, in accordance with the details shown on the project plans and the requirements of these specifications, and as directed by the Engineer.

The contractor shall be responsible for all adjustments to its equipment necessary to properly accommodate the use of asphalt-rubber as a bituminous material.

413-2 Asphaltic Concrete Mix Design Criteria:

Mix designs will be performed in accordance with Arizona Test Method 815, modified as necessary for Asphaltic Concrete (Asphalt-Rubber). Mix designs shall meet the criteria in Table 413-1.

TABLE 413-1
ASPHALTIC CONCRETE MIX DESIGN CRITERIA

Criteria	Requirement
1. Effective Voids: %, Range	5.5 ± 1.0
2. Voids in Mineral Aggregate: %, Min.	19.0
3. Absorbed Asphalt-Rubber: %, Range	0 - 1.0

413-3 Materials:

413-3.01 Mineral Aggregate Source:

There is no Department-furnished source of mineral aggregate. The contractor shall provide a source in accordance with the requirements of Section 1001 of these specifications.

When the contractor selects a source or sources, it shall notify the Engineer. The contractor shall be solely responsible for assuring that the mineral aggregate meets all requirements and, when processed, is fully capable of providing asphaltic concrete which meets all the requirements of these specifications.

413-3.02 Mineral Aggregate:

Coarse and intermediate mineral aggregate shall consist of crushed gravel, crushed rock, or other approved inert materials with similar characteristics, or a combination thereof, conforming to the requirements of these specifications.

Fine mineral aggregate shall be obtained from crushed gravel or crushed rock. All uncrushed material passing a No. 4 sieve shall be removed prior to the crushing, screening, and washing operations necessary to produce the specified gradation. The contractor shall notify the Engineer a minimum of 48 hours in advance of crushing the material to be used as mineral aggregate, so all crushing operations are inspected. Existing stockpile material which has not been inspected during crushing will not be permitted for use unless the contractor is able to document to the Engineer's satisfaction that the mineral aggregate has been crushed. Any material inspected by the Department as crushed material shall be separated from the contractors other stockpiles and reserved for use by the Department.

Mineral aggregate shall be separated into stockpiles by the contractor. No individual stockpile usage shall be less than three percent of the total mineral aggregate. No individual stockpile shall be permitted to contain more than 6.0 percent passing the No. 200 sieve when tested in accordance with Arizona Test Method 201. If necessary, the contractor shall wash the mineral aggregate to meet this requirement.

Mineral aggregate furnished for mix designs shall be representative of the source(s), and sampled from the materials stockpiles to be utilized in asphaltic concrete production. Mix designs shall be performed utilizing mineral aggregate which conforms to the grading limits in Table 413-2.

TABLE 413-2
MIX DESIGN GRADING LIMITS FOR MINERAL AGGREGATE (WITHOUT ADMIXTURE)

Sieve Size	Percent Passing
3/4 Inch	100
1/2 Inch	80 - 100
3/8 Inch	65 - 80
No. 4	28 - 42
No. 8	14 - 22
No. 200	0 - 2.5

Mineral aggregate shall conform to the requirements in Table 413-3 when tested in accordance with the applicable test methods.

Tests on aggregates outlined in Table 413-3, other than abrasion, shall be performed on materials furnished for mix design purposes and composited to the mix design gradation. Abrasion shall be performed separately on samples from each source of mineral aggregate. All sources shall meet the requirements for abrasion.

TABLE 413-3 MINERAL AGGREGATE CHARACTERISTICS		
Characteristics	**Test Method**	**Requirement**
Combined Bulk Specific Gravity	Arizona Test Method 815	2.35 - 2.85
Combined Water Absorption	Arizona Test Method 815	0 - 2.5%
Sand Equivalent	AASHTO T 176	Minimum 55
Fractured Coarse Aggregate Particles	Arizona Test Method 212	Minimum 85% (two Fractured Faces determined on plus No. 4 material)
Abrasion	AASHTO T 96	100 Rev., Max 9% 500 Rev., Max 40%

413-3.03 Mineral Admixture:

Mineral admixture will be required. The amount shall be 1.0 percent, by weight of the mineral aggregate, and shall be either Portland Cement type II or hydrated lime, conforming to the requirements of Table 413-4.

TABLE 413-4 MINERAL ADMIXTURE	
Material	**Requirement**
Portland Cement, Type II	ASTM C 150
Hydrated Lime	ASTM C 1097

A Certificate of Analysis conforming to the requirements of Subsection 106.05 shall be submitted to the Engineer.

413-3.04 Bituminous Material:

Bituminous material shall be asphalt-rubber conforming to the requirements of Section 1009 of the specifications. The type of asphalt-rubber shall be as shown in the Special Provisions. The crumb rubber gradation shall be Type B conforming to the requirements of Section 1009.

In no case shall the asphalt-rubber be diluted with extender oil, kerosene, or other solvents. Any asphalt-rubber so contaminated shall be rejected.

Any kerosene or other solvents used in the cleaning of equipment shall be purged from the system prior to any subsequent use of that equipment.

413-3.05 Blotter Material:

An application of blotter material may be required following the placement of the asphaltic concrete and prior to opening the roadway to traffic. The blotter material shall conform to the requirements of Section 404. The blotter material shall be applied in one or more applications for a total application of two pounds per square yard. The Engineer may reduce or eliminate blotter material if deemed to be unnecessary.

413-4 Mix Design:

Approximately 300 pounds of produced mineral aggregate, in proportion to the anticipated percent usage, shall be obtained by the contractor and witnessed by the Engineer so that both parties are satisfied that samples are representative of the mineral aggregate to be utilized in the asphaltic concrete production.

The contractor shall also furnish representative samples of the following materials: a five-pound sample of the crumb rubber proposed for use, one gallon of asphalt cement from the intended supplier, three gallons of the proposed mixture of asphalt and rubber, and a one-gallon can of the mineral admixture to be used in the asphaltic concrete.

Along with the samples furnished for mix design testing, the contractor shall submit a letter explaining in detail its methods of producing mineral aggregate including wasting, washing, blending, proportioning, etc., and any special or limiting conditions it may propose. The contractor's letter shall also state the source(s) of mineral aggregate, the source of asphalt cement and crumb rubber, the asphalt-rubber supplier, and the source and type of mineral admixture.

Within 10 working days of receipt of all samples and the contractor's letter in the Central Laboratory, the Department will provide the contractor with the percentage of asphalt-rubber to be used in the mix, the percentage to be used from each of the stockpiles of mineral aggregate, the composite mineral aggregate gradation, the composite mineral aggregate and mineral admixture gradation, and any special or limiting conditions for the use of the mix.

The Department will provide the contractor with material to be used for calibration of nuclear asphalt content gauges. The material will be fabricated by the Department utilizing asphalt-rubber submitted by the contractor for mix design purposes.

413-5 Mix Design Revisions:

The contractor shall not change its methods of crushing, screening, washing or stockpiling from those used during production of material used for mix design purposes without approval of the Engineer, or without requesting a new mix design.

During production of asphaltic concrete, the contractor, on the basis of field test results, may request a change to the approved mix design. The Engineer will evaluate the proposed changes and notify the contractor of the Engineer's decision within two working days of the receipt of the request.

If, at any time, unapproved changes are made in the source of bituminous material,

source(s) of mineral aggregate, production procedures, or proportional changes in violation of approved mix design stipulations, production shall cease until a new mix design is developed, or the contractor complies with the approved mix design.

At any time after the mix design has been approved, the contractor may request a new mix design.

The costs associated with the testing of materials in the developing of mix designs after a mix design acceptable to the Department has been developed shall be borne by the contractor.

If, during production, the Engineer on the basis of testing determines that a change in the mix design is necessary, the Engineer will issue a revised mix design. Should these changes require revisions to the contractor's operations which result in additional cost to the contractor, the contractor will be reimbursed for these costs. However, the Engineer reserves the right to modify the asphalt-rubber content without compensation being made to the contractor involving additional operation costs.

413-6 Acceptance of Materials:

413-6.01 General:

If the production of asphaltic concrete is stopped either for failure to meet the requirements specified hereinafter under Subsection 413-6.03, or because changes are made in the mix design, samples will be taken for calculating new consecutive averages either after production resumes or after the changes in the mix design have been made. The acceptance of the mineral aggregate gradation and the bituminous material content will be determined on the basis of the tests as hereinafter specified under Subsection 413-6.03. The Engineer reserves the right to increase the frequency of sampling and testing upon the resumption of asphaltic concrete production.

413-6.02 Mineral Aggregate:

Aggregate shall be free of deleterious materials, clay balls, and adhering films or other materials that prevent thorough coating of the aggregate with the bituminous material.

During asphaltic concrete production, the Engineer shall obtain and test samples of mineral aggregate for the determination of the sand equivalent and fractured coarse aggregate particles. The sample shall be obtained either from the cold feed prior to addition of mineral admixture, or from the stockpiles. Should such testing indicate results not meeting the requirements outlined in table 413-3 for sand equivalent and fractured coarse aggregate particles, operations shall cease and the contractor shall have the option of requesting a new mix design or correcting deficiencies in the aggregate stockpiles.

413-6.03 Asphaltic Concrete:

(A) Mineral Aggregate Gradation:

For each approximate 500 tons of asphaltic concrete, at least one sample of mineral aggregate will be taken. Samples will be taken in accordance with the requirements of Arizona Test Method 105 on a random basis just prior to the addition of mineral admixture and bituminous material by means of a sampling device which is capable of producing samples which are representative of the mineral aggregate. The device, which shall be approved by the Engineer, shall be furnished by the contractor. In any shift that the production of asphaltic concrete is less than 500 tons, at least one sample will be taken.

Samples will be tested for conformance with the mix design gradation without mineral admixture in accordance with the requirements of Arizona Test Method 201.

The gradation of the mineral aggregate will be considered to be acceptable unless the average of any three consecutive tests or the result of any single test varies from the mix design gradation percentages as follows:

Passing Sieve	**Number of Tests**	
	3 Consecutive	**One**
3/8 Inch and larger	± 4	± 6
No. 4	± 4	± 6
No. 8	± 3	± 5
No. 200	± 1.0	± 1.5

One hundred percent of the material shall pass the largest sieve size shown in Table 413-2.

At any time that test results indicate that the gradation of the mineral aggregate does not fall within all of the limits indicated, the production of asphaltic concrete shall cease immediately and shall not begin again until a calibration test indicates that the gradation is within the 3-consecutive test limits indicated.

(B) Asphalt-Rubber Content:

During production of asphaltic concrete, the contractor shall maintain at the plant site a nuclear asphalt content gauge calibrated and operated in accordance with Arizona Test Method 421. The calibration shall be performed using material supplied by the Department as stated in Section 413-4. Under the observation of the Engineer, the contractor shall determine the asphalt-rubber content by means of the nuclear asphalt content gauge a minimum of four times per full shift. The contractor's technicians performing the testing, including the calibration of the nuclear gauge, shall meet the technician requirements given in the Department's System for the Evaluation of Testing Laboratories. The requirements may be obtained from ADOT Materials Group, 1221 North 21st Avenue, Phoenix, AZ 85009-3740. Production of asphaltic concrete shall cease immediately and the plant and/or the nuclear asphalt content gauges re-calibrated if the Engineer determines the percent of asphalt-rubber has varied by an amount greater than ± 0.5 percent from the amount directed by the Engineer.

413-7 Construction Requirements:

413-7.01 Quality Control:

Quality control of mineral aggregate production and asphaltic concrete production shall be the responsibility of the contractor. The contractor shall perform sufficient testing to assure that mineral aggregate and asphaltic concrete are produced which meet all specified requirements. The Engineer reserves the right to obtain samples of any portion of any material at any point of the operations for the Engineer's own use.

413-7.02 Stockpiling:

The contractor will not be allowed to feed the hot plant from stockpiles containing less than two full days of production unless only two days production remain to be done or special conditions exist where the Engineer deems this requirement waived.

Mineral aggregate shall be separated and stockpiled so that segregation is minimized. An approved divider of sufficient size to prevent intermingling of stockpiles shall be provided.

413-7.03 Proportioning:

The contractor shall provide documentation by calibration charts or other approved means that the mineral aggregate, asphalt-rubber, and mineral admixture are being proportioned in accordance with the approved mix design.

Unless approved by the Engineer, no individual stockpile usage shall be less than three percent of the total mineral aggregate.

Changes in stockpile/hot bin use in excess of five percent from the approved mix design will not be permitted without the approval of the Engineer.

Mineral admixture shall be mechanically mixed with the mineral aggregate prior to combining the mineral aggregate and asphalt-rubber. The engineer may direct a spray of water be applied either to control the loss of the mineral admixture or to comply with any mix design requirements for wet mixing of the aggregate and admixture.

If a drum mix plant is used, the mineral admixture shall be added and thoroughly mixed by means of a mechanical mixing device prior to the mixture entering the drum drier. The mineral admixture shall be weighed across a weigh belt or an approved alternative weighing system, with a weight totalizer prior to entry into the mechanical mixing device. The mechanical mixing device shall be a pugmill type mixer consisting of at least two motorized shafts with mixing paddles. The mixing device shall be designed such that the mixture of aggregate and admixture is moved in a near horizontal direction by the mixing paddles without the aid of conveyor belts for a distance of at least three feet. Mixing devices which permit the mixture of aggregate and admixture to fall through mixing blades onto a belt or chute are not acceptable. The mixing device’s rated capacity in tons per hour shall not be exceeded by the rate of material feed to the mixer. The mixer shall be constructed to prevent the leakage of the contents. The mixer shall be located in the system at a location

where the mixed material can be readily inspected on a belt prior to entry into the drum. The mixing device shall be capable of effective mixing in the full range of asphaltic concrete production rates.

A positive signal system and a limit switch device shall be installed in the plant at the point of introduction of the admixture. The positive signal system shall be placed between the metering device and the drum drier, and utilized during production whereby the mixing shall automatically be stopped if the admixture is not being introduced into the mixture.

If a batch plant is used, the mineral admixture shall be added and thoroughly mixed in the pugmill prior to adding asphalt-rubber.

The contractor shall furnish daily documentation to the Engineer that the required amount of mineral admixture has been incorporated into the asphaltic concrete.

No fine material which has been collected in the dust collection system shall be returned to the mixture unless the Engineer, on the basis of tests, determines that all or a portion of the collected fines can be utilized. If the Engineer so determines, the Engineer will authorize in writing the utilization of a specific proportion of the fines; however, authorization will not be granted unless the collected fines are uniformly metered into the mixture.

Mineral aggregate, mineral admixture, and asphalt-rubber shall be proportioned by volume, by weight, or by a combination of volume and weight.

When mineral aggregate, mineral admixture, and asphalt-rubber are proportioned by weight, all boxes, hoppers, buckets, or similar receptacles used for weighing materials, together with scales of any kind used in batching materials, shall be insulated against the vibration or movement of the rest of the plant due to the operation of any equipment so that the error in weighing with the entire plant operating shall not exceed two percent for any setting nor one and one half percent for any batch. Bituminous material shall be weighed in a heated, insulated bucket suspended from a springless dial scale system.

When mineral aggregate, mineral admixture, and asphalt-rubber are proportioned by volume, the correct portion of each mineral aggregate size introduced into the mixture shall be drawn from the storage bins by an approved type of continuous feeder which will supply the correct amount of mineral aggregate in proportion to the bituminous material and so arranged that the proportion of each mineral aggregate size can be separately adjusted. The continuous feeder for the mineral aggregate shall be mechanically or electrically actuated.

The introduction of asphalt-rubber shall be controlled by an automated system fully integrated with the controls for mineral aggregate and mineral admixture.

413-7.04 Drying and Heating:

A recording pyrometer or other approved recording thermometric instrument sensitive to a rate of temperature change not less than 10 degrees F per minute shall be so placed at the

discharge chute of the drier in order to record automatically the temperature of the asphaltic concrete or mineral aggregate. A copy of the recording shall be given to the Engineer at the end of each shift.

The moisture content of the asphaltic concrete shall not exceed 0.5 percent. The moisture content will be determined in accordance with Arizona Test Method 406. Drying and heating shall be accomplished in such a manner as to preclude the mineral aggregate from becoming coated with fuel oil or carbon.

413-7.05 Mixing:

The production of the plant shall be governed by the rate required to obtain a thorough and uniform mixture of the materials.

A positive signal system shall be provided to indicate the low level of mineral aggregate in the bins. The plant will not be permitted to operate unless this signal system is in good working condition. Each bin shall have an overflow chute or a divider to prevent material from spilling into adjacent bins.

The temperature of asphaltic concrete upon discharge from the mixer shall not exceed 350 degrees F. If the asphaltic concrete is discharged from the mixer into a hopper, the hopper shall be constructed so that segregation of the asphaltic concrete will be minimized.

413-7.06 Placing and Finishing:

(A) General Requirements:
The handling of asphaltic concrete shall at all times be such as to minimize segregation. Any asphaltic concrete which displays segregation shall be removed and replaced.

Before asphaltic concrete is placed, the surface to be paved shall be cleaned of all objectionable material and tacked with asphalt cement in accordance with the requirements of Section 404 of the specifications. The cleaning of the surface, the tacking of the surface, and the amount and grade of asphalt cement used shall be as directed by and acceptable to the Engineer.

A light coat of asphalt cement shall be applied as directed to edges or vertical surfaces against which asphaltic concrete is to be placed.

The base or subgrade upon which the asphaltic concrete is to be placed shall be prepared in accordance with the applicable requirement for the material involved and maintained in a smooth and firm condition until placement. Asphaltic concrete shall not be placed on a frozen or excessively wet base or subgrade.

Asphaltic concrete shall be placed only when the temperature of the surface on which the asphaltic concrete is to be placed is at least 65 degrees F and the ambient temperature is at least 65 degrees F and rising. The placement shall be stopped when the ambient temperature is at or below 70 degrees F and falling.

At any time the Engineer may require that the work cease or that the work day be reduced in the event of weather conditions which would have an adverse effect upon the asphaltic concrete.

All asphaltic concrete shall be placed either as a leveling course or as a surfacing course. Leveling courses are defined as courses placed for the primary purpose of raising an existing paved or unpaved surface to a smooth plane. Surfacing courses are defined as courses placed to serve either as the traffic surface or as a surface upon which a finishing course or seal coat is to be placed.

Thickness of leveling and surfacing courses will be shown on the project plans. No change in thickness will be allowed without the written approval of the Engineer.

(B) Loading Asphaltic Concrete into the Paving Machine:

If the asphaltic concrete is dumped directly into the paving machine from the hauling trucks, care shall be taken to avoid jarring the machine or moving it out of alignment. No vertical load shall be exerted on the paving machine by the trucks. Trucks, while dumping, shall be securely attached to the paving machine.

If the asphaltic concrete is dumped upon the surface being paved and subsequently loaded into the paving machine, the loading equipment shall be self-supporting and shall not exert any vertical load on the paving machine. Substantially all of the asphaltic concrete shall be picked up and loaded into the paving machine.

(C) Placing and Finishing Asphaltic Concrete by Means of Self-Propelled Paving Machines:

All courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines except under certain conditions or at certain locations where the Engineer deems the use of self-propelled paving machines impractical.

In order to achieve, as far as practical, a continuous operation, the speed of the paving machine shall be coordinated with the production of the plant. If the paving machine is stopped for more than three minutes, or there is a three minute or longer interval between the completion of delivery by one truck and the beginning of delivery by the next truck, the paving machine shall be pulled away from the mat in order for the rollers to compact this area in accordance with the temperature limitations given hereinafter under Subsection 413-7.08(C). A transverse construction joint shall be made by a method approved by the Engineer.

Self-propelled paving machines shall spread the mixture without segregation or tearing within the specified tolerances, true to the line, grade, and crown indicated on the project plans. Pavers shall be equipped with hoppers and augers which will distribute the mixture uniformly in front of adjustable screeds.

Screeds shall include any strike-off device operated by tamping or vibrating action which is effective without tearing, shoving or gouging the mixture and which produces a course with a uniform texture and density for the full width being paved. Screeds shall be adjustable as to height and crown and shall be equipped with a controlled heating device for use when required.

Tapered sections not exceeding eight feet in width, or widened sections not exceeding four feet in width may be placed and finished by other means approved by the Engineer.

(D) Automatically Actuated Control System:

Except under certain conditions or at certain locations where the Engineer deems the use of automatic controls impractical, all courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines equipped with an automatically actuated control system.

The control system shall control the elevation of the screed at each end by controlling the elevation of one end directly and the other end indirectly either through controlling the transverse slope or alternately when directed, by controlling the elevation of each end independently.

The control system shall be capable of working with the following devices which shall be furnished with the machine:

Ski-type device at least 30 feet in length, supported throughout its entire length.

Short ski.

500 feet of control line and stakes.

Joint matcher shoe.

The control line shall be set and maintained taut by the contractor to the grade and alignment established by the Engineer.

Failure of the control system to function properly shall be cause for the suspension of the asphaltic concrete operations.

413-7.07 Joints:

Longitudinal joints of each course shall be staggered a minimum of one foot with relation to the longitudinal joint of the immediate underlying course.

The contractor shall schedule its paving operations to minimize exposed longitudinal edges. Unless otherwise approved by the Engineer, the contractor shall limit the placement of asphaltic concrete courses, in advance of adjacent courses, to one shift of asphaltic concrete production. The contractor shall schedule its paving operations in such a manner

to eliminate exposed longitudinal edges over weekends or holidays.

Longitudinal joints shall be located within one foot of the center of a lane or within one foot of the centerline between two adjacent lanes. Joints shall be formed by a slope shoe or hot lapped, and shall be compacted while the mixture is still hot.

Before a surface course is placed in contact with a cold transverse construction joint, the cold existing asphaltic concrete shall be trimmed to a vertical face by cutting the existing asphaltic concrete back for its full depth and exposing a fresh face. After placement and finishing of the new asphaltic concrete, both sides of the joint shall be dense and the joint shall be well sealed. The surface in the area of the joint shall conform to the requirements hereinafter specified for surface tolerances when tested with the straightedge placed across the joint.

When surfacing courses are placed on ten-foot or wider shoulders that are to receive a rumble strip, any longitudinal joint between the shoulder and the travel lane shall be located at the travel lane edge of the rumble strip.

413-7.08 Compaction:
(A) General Requirements:

The temperature of asphaltic concrete just prior to compaction shall be at least 275 ^{o}F.

The wheels of compactors shall be wetted with water, or if necessary soapy water, or a product approved by the Engineer to prevent the asphaltic concrete from sticking to the steel wheels during rolling. The Engineer may change the rolling procedure if in the Engineer's judgment the change is necessary to prevent picking up of the asphaltic concrete.

(B) Equipment:

For courses greater than one inch in nominal thickness, a minimum of one static steel-wheel compactor and two vibratory steel-wheel compactors shall be provided; however, sufficient vibratory steel-wheel compactors shall be provided to cover the entire width of the paving machine on the initial forward pass.

For courses of one inch or less in nominal thickness, a minimum of three static steel-wheel compactors shall be provided; however, sufficient compactors must be provided to cover the entire width of the paving machine on the initial forward pass while a static compactor remains to complete final rolling. If the asphaltic concrete production rate exceeds 250 tons per hour, an additional static steel-wheel compactor shall be provided.

The compactors shall weigh not less than eight tons.

The compactors shall be self-propelled and shall be operated with the drive wheel in the forward position. Vibratory rollers shall be used in the mode required by the Engineer. Vibratory compactors shall not be used in the vibratory mode for courses of one inch or less

in nominal thickness.

(C) Rolling Procedure:

Vibratory compactors shall be used for initial breakdown on courses greater than one inch in nominal thickness. Static steel wheel compactors, or vibratory compactors in the static mode, shall be used for initial breakdown on courses one inch or less in nominal thickness. Initial breakdown rollers shall be maintained no more than 300 feet behind the paving machine. The roller(s) for final compaction shall follow as closely behind the initial breakdown as possible. As many passes as are possible shall be made with the compactors before the temperature of the asphaltic concrete falls below 220 ^{o}F.

All edges shall be compacted by methods approved by the Engineer, while the mixture is still hot.

413-7.09 Surface Requirements and Tolerances:

All courses of asphaltic concrete shall be compacted as required, smooth and reasonably true to the required lines, grades, and dimensions.

Leveling course surfaces shall not vary more than 1/4 inch from the lower edge of a 10-foot straightedge when the straightedge is placed parallel to the center line of the roadway.

Surfacing course surfaces shall not vary more than 1/8 inch from the lower edge of a ten-foot straightedge when the straightedge is placed parallel to the center line of the roadway, or 1/4 inch when placed in the transverse direction across longitudinal joints.

413-7.10 Acceptance:

Asphaltic concrete will be accepted complete in place, if, in the judgment of the Engineer, the asphaltic concrete reasonably conforms to the requirements specified herein. Asphaltic concrete that is not acceptable and is rejected shall be replaced to the satisfaction of the Engineer and at no expense to the Department.

413-8 Method of Measurement:

Asphaltic concrete will be measured by the ton for the mixture actually used, which will include the weight of mineral aggregate, mineral admixture, and asphalt-rubber. Measurement will include any weight used in construction of intersections, turnouts, or other miscellaneous items or surfaces.

Asphalt-rubber material will be measured by the ton.

The weight of the asphalt-rubber material shall either be determined by weighing directly enroute from the reaction vessel to the point of delivery or be determined from the weight of the asphalt cement and the weight of the rubber minus wastage.

Mineral admixture will be measured by the ton.

413-9 Basis of Payment:

The accepted quantities of asphaltic concrete, measured as provided above, will be paid for at the contract unit price per ton, which price shall be full compensation for the work, complete in place, as specified herein.

Payment for the asphalt-rubber will be made by the ton, including asphalt cement and crumb rubber. The results of a nuclear asphalt content gauge shall not be used to determine the weight of asphalt-rubber material as the basis of payment.

Payment for mineral admixture will be made by the ton.

Appendix K: Arizona Specifications – Open Graded

SECTION 414 ASPHALTIC CONCRETE FRICTION COURSE (ASPHALT-RUBBER):

414-1 Description:

Asphaltic Concrete Friction Course (Asphalt-Rubber), hereinafter asphaltic concrete, shall consist of furnishing all materials, mixing at a plant, hauling, and placing a mixture of aggregate materials, mineral admixture, and bituminous material (asphalt-rubber) to form a pavement course or to be used for other specified purposes, in accordance with the details shown on the project plans and the requirements of these specifications, and as directed by the Engineer.

The contractor shall be responsible for all adjustments to its equipment necessary to properly accommodate the use of asphalt-rubber as a bituminous material.

414-2 Asphaltic Concrete Mix Design Criteria:

Mix designs will be performed in accordance with Arizona Test Method 814, modified as necessary for Asphaltic Concrete Friction Course (Asphalt-Rubber). The allowable range of percent absorbed asphalt-rubber shall be 0-1.0, when tested in accordance with the applicable section of Arizona Test Method 815.

414-3 Materials:

414-3.01 Mineral Aggregate Source:

There is no Department-furnished source of mineral aggregate. The contractor shall provide a source in accordance with the requirements of Section 1001 of these specifications.

When the contractor selects a source or sources, it shall notify the Engineer. The contractor shall be solely responsible for assuring that the mineral aggregate meets all requirements and, when processed, is fully capable of providing asphaltic concrete which meets all the requirements of these specifications.

414-3.02 Mineral Aggregate:

Mineral aggregate shall be separated into at least two stockpiles. No individual stockpile usage shall be less than three percent of the total mineral aggregate.

Coarse mineral aggregate shall consist of crushed gravel, crushed rock, or other approved inert materials with similar characteristics, or a combination thereof, conforming to the requirements of these specifications.

Fine mineral aggregate or blend material shall consist of natural sand, sand prepared from rock, or other approved inert materials, or a combination thereof, conforming to the requirements of these specifications.

Material aggregate furnished for mix designs shall be representative of the source(s) and sampled from the materials stockpiles to be utilized in asphaltic concrete production. Mix designs shall be performed utilizing mineral aggregate which conforms to the grading limits in Table 414-1.

TABLE 414-1
MIX DESIGN GRADING LIMITS FOR MINERAL AGGREGATE
(Without Admixture)

Sieve Size	Percent Passing
3/4 Inch	100
No. 4	30 - 45
No. 8	4 - 8
No. 200	0 - 2.5

Mineral aggregate shall conform to the requirements in Table 414-2 when tested in accordance with the applicable test methods.

Tests on aggregates outlined in Table 414-2, other than abrasion, shall be performed on materials furnished for mix design purposes and composited to the mix design gradation. Abrasion shall be performed separately on samples from each source of mineral aggregate. All sources shall meet the requirements for abrasion.

TABLE 414-2
MINERAL AGGREGATE CHARACTERISTICS

Characteristic	Test Method	Requirement
Combined Bulk Specific Gravity	Arizona Test Method 814	2.35 - 2.85
Combined Water Absorption	Arizona Test Method 814	0 – 2.5%
Sand Equivalent	Arizona Test Method 242	Minimum 55
Fractured Coarse Aggregate Particles	Arizona Test Method 212	Minimum 85% (two fractured faces)
Flakiness Index	Arizona Test Method 233	Maximum 25
Carbonates in Aggregate	Arizona Test Method 238	Maximum 30%
Abrasion	AASHTO T 96	100 Rev., Max. 9% 500 Rev., Max. 40%

414-3.03 Mineral Admixture:

Mineral admixture will be required. The amount shall be 1.0 percent, by weight of the mineral aggregate and shall be either portland cement type II or hydrated lime, conforming to the requirements of Table 414-3.

TABLE 414-3 MINERAL ADMIXTURE	
Material	**Requirement**
Portland Cement, Type II	ASTM C 150
Hydrated Lime	ASTM C 1097

A Certificate of Analysis conforming to the requirements of Subsection 106.05 shall be submitted to the Engineer.

414-3.04 Bituminous Material:

Bituminous material shall be asphalt-rubber conforming to the requirements of Section 1009 of the specifications. The type of asphalt-rubber shall be as shown in the Special Provisions. The crumb rubber gradation shall be Type B conforming to the requirements of Section 1009.

In no case shall the asphalt-rubber be diluted with extender oil, kerosene, or other solvents. Any asphalt-rubber so contaminated shall be rejected.

Any kerosene or other solvents used in the cleaning of equipment shall be purged from the system prior to any subsequent use of that equipment.

414-4 Mix Design:

Approximately 300 pounds of produced mineral aggregate, in proportion to the anticipated percent usage, shall be obtained by the contractor and witnessed by the Engineer so that both parties are satisfied that samples are representative of the mineral aggregate to be utilized in the asphaltic concrete production.

The contractor shall also furnish representative samples of the following materials: a five-pound sample of the crumb rubber proposed for use, one gallon of asphalt cement from the intended supplier, three gallons of the proposed mixture of asphalt and rubber, and a one-gallon can of the mineral admixture to be used in the asphaltic concrete.

Along with the samples furnished for mix design testing, the contractor shall submit a letter explaining in detail its methods of producing mineral aggregate including wasting, washing, blending, proportioning, etc., and any special or limiting conditions it may propose. The contractor’s letter shall also state the source(s) of mineral aggregate, the source of asphalt cement and crumb rubber, the asphalt-rubber supplier, and the source and type of mineral admixture.

Within 10 working days of receipt of all samples and the contractor's letter in the Central Laboratory, the Department will provide the contractor with the percentage of asphalt-rubber to be used in the mix, the percentage to be used from each of the stockpiles of mineral aggregate, the composite mineral aggregate gradation, the composite mineral aggregate and mineral admixture gradation, and any special or limiting conditions for the use of the mix.

The Department will provide the contractor material to be used for calibration of nuclear asphalt content gauges. The material will be fabricated by the Department utilizing asphalt-rubber submitted by the contractor for mix design purposes.

414-5 Mix Design Revisions:

The contractor shall not change its methods of crushing, screening, washing, or stockpiling from those used during production of material used for mix design purposes without approval of the Engineer, or without requesting a new mix design.

During production of asphaltic concrete, the contractor, on the basis of field test results, may request a change to the approved mix design. The Engineer will evaluate the proposed changes and notify the contractor of the Engineer's decision within two working days of the receipt of the request.

If, at any time, unapproved changes are made in the source of bituminous material, source(s) of mineral aggregate, production methods, or proportional changes in violation of approved mix design stipulations, production shall cease until a new mix design is developed, or the contractor complies with the approved mix design.

At any time after the mix design has been approved, the contractor may request a new mix design.

The costs associated with the testing of materials in the developing of mix designs after a mix design acceptable to the Department has been developed shall be borne by the contractor.

If, during production, the Engineer on the basis of testing determines that a change in the mix design is necessary, the Engineer will issue a revised mix design. Should these changes require revisions to the contractor's operations which result in additional cost to the contractor, it will be reimbursed for these costs. However, the Engineer reserves the right to modify the asphalt-rubber content without compensation being made to the contractor involving additional operation costs.

414-6 Acceptance of Materials:

414-6.01 General:

If the production of asphaltic concrete is stopped either for failure to meet the requirements specified hereinafter under Subsection 414-6.03, or because changes are made in the mix design, samples will be taken for calculating new consecutive averages either after production resumes or after the changes in the mix design have been made. The acceptance of the mineral aggregate gradation and the bituminous material content will be determined on the basis of the tests as hereinafter specified under Subsection 414-6.03. The Engineer reserves the right to increase the frequency of sampling and testing upon the resumption of asphaltic concrete production.

414-6.02 Mineral Aggregate:

Aggregate shall be free of deleterious materials, clay balls, and adhering films or other material that prevent thorough coating of the aggregate with the bituminous material.

During asphaltic concrete production, the Engineer shall obtain and test samples of mineral aggregate for the determination of the sand equivalent, fractured coarse aggregate particles, and flakiness index. The sample shall be obtained either from the cold feed prior to addition of mineral admixture, or from the stockpiles. Should such testing indicate results not meeting the requirements of Table 414-2 for sand equivalent, fractured coarse aggregate particles, and flakiness index, operations shall cease and the contractor shall have the option of requesting a new mix design or correcting deficiencies in the aggregate stockpiles.

414-6.03 Asphaltic Concrete:

(A) Mineral Aggregate Gradation:

For each approximate 500 tons of asphaltic concrete, at least one sample of mineral aggregate will be taken. Samples will be taken in accordance with the requirements of Arizona Test Method 105 on a random basis just prior to the addition of mineral admixture and bituminous material by means of a sampling device which is capable of producing samples which are representative of the mineral aggregate. The device, which shall be approved by the Engineer, shall be furnished by the contractor. In any shift that the production of asphaltic concrete is less than 500 tons, at least one sample will be taken.

Samples will be tested for conformance with the mix design gradation without mineral admixture in accordance with the requirements of Arizona Test Method 201.

The gradation of the mineral aggregate will be considered to be acceptable, unless the average of any three consecutive tests or the result of any single test varies from the mix design gradation percentages as follows:

Passing Sieve	Number of Tests	
	3 Consecutive	One
No. 4	± 4	± 6
No. 8	± 3	± 4
No. 200	± 1.0	± 1.5

One hundred percent of the material shall pass the largest sieve size shown in Table 414-1.

At any time that test results indicate that the gradation of the mineral aggregate does not fall within all of the limits indicated, the production of asphaltic concrete shall cease immediately and shall not begin again until a calibration test indicates that the gradation is within the 3-consecutive test limits indicated.

(B) Asphalt-Rubber Content:

During production of asphaltic concrete, the contractor shall maintain at the plant site a nuclear asphalt content gauge calibrated and operated in accordance with Arizona Test Method 421. The calibration shall be performed using material supplied by the Department as stated in Section 414-4. Under the observation of the Engineer, the contractor shall determine the asphalt-rubber content by means of the nuclear asphalt content gauge a minimum of four times per full shift. The contractor's technicians performing the testing, including the calibration of the nuclear gauge, shall meet the technician requirements given in the Department's System for the Evaluation of Testing Laboratories. The requirements may be obtained from ADOT Materials Group, 1221 North 21st Avenue, Phoenix, AZ 85009. Production of asphaltic concrete shall cease immediately and the plant and/or the nuclear asphalt content gauges re-calibrated if the Engineer determines the percent of asphalt-rubber has varied by an amount greater than ± 0.5 percent from the amount directed by the Engineer.

414-7 Construction Requirements:

414-7.01 Quality Control:

Quality control of mineral aggregate production and asphaltic concrete production shall be the responsibility of the contractor. The contractor shall perform sufficient testing to assure that mineral aggregate and asphaltic concrete are produced which meet all specified requirements. The Engineer reserves the right to obtain samples of any portion of any material at any point of the operations for the Engineer's own use.

414-7.02 Stockpiling:

The contractor will not be allowed to feed the hot plant from stockpiles containing less than two full days of production unless only two days production remain to be done or special conditions exist where the Engineer deems this requirement waived.

Mineral aggregate shall be separated and stockpiled so that segregation is minimized. An approved divider of sufficient size to prevent intermingling of stockpiles shall be provided.

414-7.03 Proportioning:

The contractor shall provide documentation by calibration charts or other approved means that the mineral aggregate, asphalt-rubber, and mineral admixture are being proportioned in accordance with the approved mix design.

Unless approved by the Engineer, no individual stockpile usage shall be less than three percent of the total mineral aggregate.

Changes in stockpile/hot bin use in excess of five percent from the approved mix design will not be permitted without the approval of the Engineer.

Mineral admixture shall be mechanically mixed with the mineral aggregate prior to combining the mineral aggregate and asphalt-rubber. The engineer may direct a spray of water be applied either to control the loss of the mineral admixture or to comply with any mix design requirements for wet mixing of the aggregate and admixture.

If a drum mix plant is used, the mineral admixture shall be added and thoroughly mixed by means of a mechanical mixing device prior to the mixture entering the drum drier. The mineral admixture shall be weighed across a weigh belt or an approved alternative weighing system, with a weight totalizer prior to entry into the mechanical mixing device. The mechanical mixing device shall be a pugmill type mixer consisting of at least two motorized shafts with mixing paddles. The mixing device shall be designed such that the mixture of aggregate and admixture is moved in a near horizontal direction by the mixing paddles without the aid of conveyor belts for a distance of at least three feet. Mixing devices which permit the mixture of aggregate and admixture to fall through mixing blades onto a belt or chute are not acceptable. The mixing device's rated capacity in tons per hour shall not be exceeded by the rate of material feed to the mixer. The mixer shall be constructed to prevent the leakage of the contents. The mixer shall be located in the system at a location where the mixed material can be readily inspected on a belt prior to entry into the drum. The mixing device shall be capable of effective mixing in the full range of asphaltic concrete production rates.

A positive signal system and a limit switch device shall be installed in the plant at the point of introduction of the admixture. The positive signal system shall be placed between the metering device and the drum drier, and utilized during production whereby the mixing shall automatically be stopped if the admixture is not being introduced into the mixture.

If a batch plant is used, the mineral admixture shall be added and thoroughly mixed in the pugmill prior to adding asphalt-rubber.

The contractor shall furnish daily documentation to the Engineer that the required amount of mineral admixture has been incorporated into the asphaltic concrete.

No fine material which has been collected in the dust collection system shall be returned to the mixture unless the Engineer, on the basis of tests, determines that all or a portion of the collected fines can be utilized. If the Engineer so determines, the Engineer will authorize in writing the utilization of a specific proportion of the fines; however, authorization will not be granted unless the collected fines are uniformly metered into the mixture.

Mineral aggregate, mineral admixture, and asphalt-rubber shall be proportioned by volume, by weight, or by a combination of volume and weight.

When mineral aggregate, mineral admixture, and asphalt-rubber are proportioned by weight, all boxes, hoppers, buckets, or similar receptacles used for weighing materials, together with scales of any kind used in batching materials, shall be insulated against the vibration or movement of the rest of the plant due to the operation of any equipment so that the error in weighing with the entire plant operating shall not exceed two percent for any setting nor 1-1/2 percent for any batch. Bituminous material shall be weighed in a heated, insulated

bucket suspended from a springless dial scale system.

When mineral aggregate, mineral admixture, and asphalt-rubber are proportioned by volume, the correct portion of each mineral aggregate size introduced into the mixture shall

be drawn from the storage bins by an approved type of continuous feeder which will supply the correct amount of mineral aggregate in proportion to the bituminous material and so arranged that the proportion of each mineral aggregate size can be separately adjusted. The continuous feeder for the mineral aggregate shall be mechanically or electrically actuated.

The introduction of asphalt-rubber shall be controlled by an automated system fully integrated with the controls for mineral aggregate and mineral admixture.

414-7.04 Drying and Heating:

A recording pyrometer or other approved recording thermometric instrument sensitive to a rate of temperature change not less than 10 degrees F per minute shall be so placed at the discharge chute of the drier in order to record automatically the temperature of the asphaltic concrete or mineral aggregate. A copy of the recording shall be given to the Engineer at the end of each shift.

The moisture content of the asphaltic concrete shall not exceed 0.5 percent. The moisture content will be determined in accordance with Arizona Test Method 406. Drying and heating shall be accomplished in such a manner as to preclude the mineral aggregate from becoming coated with fuel oil or carbon.

414-7.05 Mixing:

The production of the plant shall be governed by the rate required to obtain a thorough and uniform mixture of the materials.

A positive signal system shall be provided to indicate the low level of mineral aggregate in the bins. The plant will not be permitted to operate unless this signal system is in good working condition. Each bin shall have an overflow chute or a divider to prevent material from spilling into adjacent bins.

The temperature of asphaltic concrete upon discharge from the mixer shall not exceed 350 degrees F. If the asphaltic concrete is discharged from the mixer into a hopper, the hopper shall be constructed so that segregation of the asphaltic concrete will be minimized.

414-7.06 Placing and Finishing: (A)

General Requirements:

The handling of asphaltic concrete shall at all times be such as to minimize segregation. Any asphaltic concrete which displays segregation shall be removed and replaced.

Before asphaltic concrete is placed, the surface to be paved shall be cleaned of all objectionable material and tacked with asphalt cement in accordance with the requirements of Section 404 of the specifications. The cleaning of the surface, the tacking of the surface, and the amount and grade of asphalt cement used shall be as directed by and acceptable to the Engineer.

Unless otherwise specified on the project plans, asphaltic concrete shall not be placed on the two-foot widened section where guardrail is to be installed.

(1) Dates and Surface Temperature:

Asphaltic concrete shall be placed between the dates specified in the Special Provisions and only when the temperature of the surface on which the asphaltic concrete is to be placed is at least 85 ^{o}F.

Despite a surface temperature of 85 ^{o}F, the Engineer at any time may require that the work cease or that the work day be reduced in the event of weather conditions either existing or expected which would have an adverse effect upon the asphaltic concrete.

(2) Delivery to Screed Unit:

Asphaltic concrete delivered to the screed unit shall be a free flowing, homogeneous mass in which there is no segregation, crusts, lumps, or migration of the asphalt-rubber.

Should any one or more of such conditions be evident in the material delivered to the screed unit, and which cannot be eliminated by one or more of the following methods, the Engineer will order the work to be stopped until conditions are conducive to the delivery of the material in the condition as hereinbefore required:

(a) Covering hauling units with tarpaulins.

(b) Dumping material directly into the paver.

(c) Moving the hot plant nearer to the point of delivery.

Other measures proposed by the contractor which will deliver asphaltic concrete meeting the above requirements will be considered by the Engineer.

(B) Loading Asphaltic Concrete into the Paving Machine:

If the asphaltic concrete is dumped directly into the paving machine from the hauling trucks, care shall be taken to avoid jarring the machine or moving it out of alignment. No vertical load shall be exerted on the paving machine by the trucks. Trucks, while dumping, shall be securely attached to the paving machine.

If the asphaltic concrete is dumped upon the surface being paved and subsequently loaded

into the paving machine, it shall not be dumped at a distance greater than 150 feet in front of the paving machine. The loading equipment shall be self-supporting and shall not exert any vertical load on the paving machine. Substantially all of the asphaltic concrete shall be picked up and loaded into the paving machine.

(C) Placing and Finishing Asphaltic Concrete by Means of Self-Propelled Paving Machines:

All courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines except under certain conditions or at certain locations where the Engineer deems the use of self-propelled paving machines impractical.

In order to achieve, as far as practical, a continuous operation, the speed of the paving machine shall be coordinated with the production of the plant. If the paving machine is stopped for more than three minutes, or there is a three-minute or longer interval between the completion of delivery by one truck and the beginning of delivery by the next truck, the paving machine shall be pulled away from the mat in order for the rollers to compact this area in accordance with the temperature limitations given hereinafter under Subsection 414-7.08(C). A transverse construction joint shall be made by a method approved by the Engineer.

Self-propelled paving machines shall spread the mixture without segregation or tearing within the specified tolerances, true to the line, grade, and crown indicated on the project plans. Pavers shall be equipped with hoppers and augers which will distribute the mixture uniformly in front of adjustable screeds.

Screeds shall include any strike-off device operated by tamping or vibrating action which is effective without tearing, shoving or gouging the mixture and which produces a course with a uniform texture and density for the full width being paved. Screeds shall be adjustable as to height and crown and shall be equipped with a controlled heating device for use when required.

Tapered sections not exceeding eight feet in width, or widened sections not exceeding four feet in width may be placed and finished by other means approved by the Engineer.

(D) Automatically Actuated Control System:

Except under certain conditions or at certain locations where the Engineer deems the use of automatic controls impractical, all courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines equipped with an automatically actuated control system.

The control system shall control the elevation of the screed at each end by controlling the elevation of one end directly and the other end indirectly either through controlling the transverse slope or alternately when directed, by controlling the elevation of each end independently.

The control system shall be capable of working with the following devices which shall be

furnished with the machine:

Ski-type device at least 30 feet in length, supported throughout its entire length.

Short ski.

Failure of the control system to function properly shall be cause for the suspension of the asphaltic concrete operations.

414-7.07 Joints:

If the lift thickness is equal to or greater than one inch, the contractor shall schedule its paving operations to minimize exposed longitudinal edges. Unless otherwise approved by the Engineer, the contractor shall limit the placement of asphaltic concrete courses, in advance of adjacent courses, to one shift of asphaltic concrete production. The contractor shall schedule its paving operations in such a manner to eliminate exposed longitudinal edges over weekends or holidays.

Longitudinal joints shall be located within one foot of the centerline between two adjacent lanes.

Before a surface course is placed in contact with a cold transverse construction joint, the cold existing asphaltic concrete shall be trimmed to a vertical face by cutting the existing asphaltic concrete back for its full depth and exposing a fresh face. After placement and finishing of the new asphaltic concrete, both sides of the joint shall be dense and the joint shall be well sealed. The surface in the area of the joint shall conform to the requirements hereinafter specified for surface tolerances when tested with the straightedge placed across the joint.

414-7.08 Compaction:

(A) General Requirements:

The temperature of asphaltic concrete just prior to compaction shall be at least 275 degrees F.

The wheels of compactors shall be wetted with water, or if necessary soapy water, or a product approved by the Engineer to prevent the asphaltic concrete from sticking to the steel wheels during rolling. The Engineer may change the rolling procedure if in the Engineer's judgment the change is necessary to prevent picking up of the asphaltic concrete.

(B) Equipment:

A minimum of three static steel wheel compactors shall be provided. The drums shall be of sufficient width that when staggered, two compactors can cover the entire width of the ribbon with one pass.

The compactors shall weigh not less than eight tons.

The compactors shall be self-propelled and shall be operated with the drive wheel in the forward position. Vibrator rollers may be used in the static mode only.

(C) Rolling Procedure:

Two compactors shall be used for initial breakdown and be maintained no more than 300 feet behind the paving machine. The roller(s) for final compaction shall follow as closely behind the initial breakdown as possible. As many passes as is possible shall be made with the compactors before the temperature of the asphaltic concrete falls below 220 ^{o}F

414-7.09 Surface Requirements and Tolerances:

Asphaltic concrete shall be compacted as required, smooth and reasonably true to the required lines, grades, and dimensions.

Asphaltic concrete shall not vary more than 1/8 inch from the lower edge of a ten-foot straightedge when the straightedge is placed parallel to the center line of the roadway, or 1/4 inch when placed in the transverse direction across longitudinal joints.

414-7.10 Acceptance:

Asphaltic concrete will be accepted complete in place, if, in the judgment of the Engineer, the asphaltic concrete reasonably conforms to the requirements specified herein. Asphaltic concrete that is not acceptable and is rejected shall be replaced to the satisfaction of the Engineer and at no expense to the Department.

414-8 Method of Measurement:

Asphaltic concrete will be measured by the ton for the mixture actually used, which will include the weight of mineral aggregate, mineral admixture and asphalt-rubber. Measurement will include any weight used in construction of intersections, turnouts, or other miscellaneous items or surfaces.

Asphalt-rubber will be measured by the ton.

The weight of the asphalt-rubber material shall either be determined by weighing directly enroute from the reaction vessel to the point of delivery or be determined from the weight of the asphalt cement and the weight of the rubber minus wastage.

Mineral admixture will be measured by the ton.

414-9 Basis of Payment:

The accepted quantities of asphaltic concrete, measured as provided above, will be paid for at the contract unit price per ton, which price shall be full compensation for the work, complete in place, as specified herein.

Payment for the asphalt-rubber will be made by the ton, including asphalt cement and crumb rubber. The results of a nuclear asphalt content gauge shall not be used to determine the weight of asphalt-rubber material as the basis of payment.
Payment for mineral admixture will be made by the ton.

Appendix L: Arizona Specifications – Chip Seal

SECTION 410 ASPHALT-RUBBER STRESS-ABSORBING MEMBRANE:

410-1 Description:

The work under this section shall consist of furnishing all materials including asphalt-rubber, tack coat and cover material and applying the materials in accordance with the details shown on the project plans and the requirements of these specifications.

410-2 Materials:

410-2.01 Tack Coat:

The existing roadway surface upon which the Asphalt Rubber Membrane is to be placed, shall be first cleaned of potentially detrimental material and tacked with a light coat of bituminous material, conforming to the requirements of Subsection 404-3.12 of the specifications. The cleaning of the surface, the tacking of the surface and the type and amount of bituminous material used shall be as directed by the Engineer.

410-2.02 Asphalt-Rubber:

Asphalt-Rubber shall conform to the requirements of Section 1009. The type of asphalt-rubber shall be as shown in the Special Provisions. The rubber gradation shall be Type A.

410-2.03 Cover Material:

Cover material shall conform to the requirements of Subsection 404-2.02(C). The bulk specific gravity shall be 2.30 to 2.85 as determined in accordance with the requirements of Arizona Test Method 210. The gradation shall meet the following requirements when tested in accordance with Arizona Test Method 201.

Sieve Size	Percent Passing
3/8 inch	100
1/4 inch	0 - 15
No. 8	0 - 5
No. 200	0 - 2.0

410-3 Construction Requirements:

410-3.01 General:

All equipment used to mix and apply asphalt-rubber material shall meet the requirements specified under Subsection 404-3.02(A) of the specifications. The equipment shall also be capable of maintaining a uniform, homogeneous mixture throughout the operation.

410-3.02 Application of the Asphalt-Rubber Stress-Absorbing Membrane:

Asphalt-Rubber Stress-Absorbing Membranes shall be placed between the dates specified in the Special Provisions.

The existing pavement shall be cleaned in accordance with the requirements of Subsection 404-3.04.

After cleaning and prior to the application of the membrane, the existing pavement surface shall be treated with a tack coat as hereinbefore specified.

Placement of the asphalt-rubber membrane shall be made only when all of the following conditions are met:

(1) The ambient air temperature and the pavement surface temperature are both above 65 degrees F.

(2) The pavement is dry.

(3) The wind conditions are such that a satisfactory membrane can be achieved.

(4) All construction equipment such as asphalt rubber distributor, aggregate spreader, haul trucks with cover material, and rollers are in position and ready to commence placement operations.

The distributor shall be capable of spreading the asphalt-rubber mixture in accordance with the tolerances specified in Subsection 404-3.02(A) except that the maximum deviation from the specified rate shall not exceed 0.05 gallons per square yard.

The hot asphalt-rubber mixture shall be applied at the rate of approximately 0.55 ± 0.05 gallons per square yard (based on a unit weight of 7.75 pounds per gallon of hot asphalt-rubber); however, the Engineer will specify the exact rate based on existing surface conditions.

All transverse joints shall be made by placing building paper over the end of the previous application, and the joining application shall start on the building paper. Once the application process has progressed beyond the paper, the paper shall be disposed of as directed by the Engineer.

All longitudinal joints shall be lapped approximately four inches.

Traffic shall not be permitted on the asphalt-rubber membrane prior to the application of cover material.

410-3.03 Application of Cover Material:

Cover material shall be applied in accordance with the requirements of Subsection 404-3.06.

Cover material shall be immediately and uniformly spread over the freshly applied asphalt-rubber at the rate of approximately 0.014 cubic yards per square yard; however, the actual rate of application will be determined by the Engineer.

Cover material shall be precoated with 0.40 to 0.60 percent asphalt cement, by weight of the aggregate, and shall have a minimum temperature of 250 degrees F at the time of application. The asphalt cement shall meet the requirements of Section 1005. The end result shall be a thoroughly and uniformly coated, dust free material.

410-3.04 Rolling:

At least three pneumatic rollers shall be provided to accomplish the required rolling. The rollers shall conform to the requirements of Subsection 406-7.05(A)(2), except that the minimum air pressure in each tire shall be 100 pounds per square inch.

A sufficient number of rollers shall be furnished to cover the width of the spread on the first pass and complete the required number of passes within the time specified hereinafter. The first pass shall be made immediately behind the spreader and if the spreading is stopped for any reason, the spreader shall be moved ahead so that all cover material may be immediately rolled. The rolling shall continue until a minimum of four complete coverages have been made. Final rolling shall be completed in accordance with the following:

Existing Pavement Temperature	Complete Rolling Within
100 ^{o}F and above	20 Minutes
Between 65 and 100 ^{o}F	10 Minutes

410-3.05 Traffic:

Traffic of all types shall be kept off the stress-absorbing membrane until it has had time to set properly. The minimum traffic free period shall be three hours. However, when it is absolutely necessary that hauling equipment or piloted traffic travel on the newly applied membrane and the use is approved in advance by the Engineer, the speed shall not exceed 15 miles per hour. Stress-absorbing membrane operations shall be scheduled so that the normal flow of traffic will be resumed before sunset.

410-3.06 Removing Loose Cover Material:

Loose cover material shall be removed in accordance with the requirements of Subsection 404-3.08. Sweeping shall be completed and all excess cover material removed prior to the placement of any subsequent layers of asphaltic concrete.

410-3.07 Placement of Asphaltic Concrete:

If the asphalt-rubber membrane has been subjected to traffic, a tack coat, as hereinbefore specified, shall be applied at the rate of approximately 0.06 gallons per square yard prior to placement of the asphaltic concrete.

410-4 Method of Measurement:

Asphalt-rubber material will be measured by the ton. Conversion from volume to weight will be calculated on the basis of 7.75 pounds per gallon of hot asphalt-rubber material.

Cover material will be measured by the cubic yard. Cover material will be weighed and the amount in tons of dry material will be converted to cubic yards. The weight of all moisture contained in the cover material will be deducted prior to the conversion of the weight in tons to the volume in cubic yards. The dry weight per cubic foot will be determined in accordance with the requirements of AASHTO T 19.

The quantities of bituminous tack coat and time to apply tack coat will be measured in accordance with the requirements of Section 404.

410-5 Basis of Payment:

The accepted quantity of asphalt-rubber, measured as provided above, will be paid for at the contract unit price for the asphalt-rubber mixture complete in place, including asphalt cement and crumb rubber.

The accepted quantity of cover material, measured as provided above, will be paid for at the contract unit price, complete in place, including precoating material, and rolling and removal of loose cover material.

The accepted quantities of bituminous tack coat and time to apply tack coat will be paid for in accordance with the requirements of Section 404.

The bidding schedule reflects a quantity of bituminous tack coat based on two applications of emulsified asphalt at the specified rate. No adjustment in the contract unit prices will be made because of a variation in the quantities actually required to complete the work.

* USE IN CONJUNCTION WITH STORED SPECIFICATIONS: 1009ASRM *
* 404BITUM *

* FILL IN THE FOLLOWING:
* 410-2.02 ASPHALT-RUBBER TYPE(1 place) *

(410ARSAM, 01/19/06) SECTION 410 ASPHALT-RUBBER STRESS-ABSORBING

MEMBRANE:

410-2.02 Asphalt-Rubber: of the Standard Specifications is revised to read:

Asphalt-Rubber shall conform to the requirements of Section 1009 of the specifications. The asphalt-rubber shall be Type XXXXX. The crumb rubber gradation shall be Type A conforming to the requirements of Section 1009.

410-2.03 Cover Material: of the Standard Specifications is revised to read:

Cover material shall conform to the requirements of Subsection 404-2.02(C).

410-3.02 Application of the Asphalt-Rubber Stress-Absorbing Membrane: the first paragraph of the Standard Specifications is revised to read:

Asphalt-rubber stress-absorbing membranes shall be placed between the dates shown below for the average elevation of the project.

Average Elevation of Project, Feet	Beginning and Ending Dates
0 – 3499	March 15 – May 31
0 – 3499	September 1 – October 31
3500 – 4999	April 15 – October 15
5000 and over	June 1 – September 15

410-3.02 Application of the Asphalt-Rubber Stress-Absorbing Membrane: item (1) of the fourth paragraph of the Standard Specifications is revised to read:

(1) The pavement surface temperature is above 75 degrees F.

410-3.03 Application of Cover Material: the third paragraph of the Standard Specifications are revised to read:

Cover material shall be precoated with 0.40 to 0.60 percent asphalt cement, by weight of the aggregate. The cover material shall have a minimum temperature of 250 degrees F at the time of precoating with asphalt cement. The asphalt cement shall meet the requirements of Section 1005. The end result shall be a dust-free material.

Appendix M: Texas Asphalt Rubber Specifications

ITEM 300

ASPHALTS, OILS, AND EMULSIONS

300.1. Description. Provide asphalt cements, cutback and emulsified asphalts, performance-graded asphalt binders, and other miscellaneous asphalt materials as specified on the plans.

300.2. Materials. Provide asphalt materials that meet the stated requirements when tested in accordance with the referenced Department, AASHTO, and ASTM test methods. Refer to the Material Inspection Guide (maintained by the Construction Division), Section 11. "Asphalt Inspection, Quality Control and Quality Assurance," for sampling and testing requirements.

Acronyms used in this Item are defined in Table 1.

Table 1
Acronyms

Acronym	Definition
Test Procedure Designations	
Tex T or R D	Department AASHTO ASTM
Polymer Modifier Designations	
P SBR or L SBS TR	polymer-modified styrene-butadiene rubber (latex) styrene-butadiene-styrene block co-polymer tire rubber (from ambient temperature grinding of truck and passenger tires)
AC	asphalt cement
AE	asphalt emulsion
AE-P	asphalt emulsion prime
A-R	asphalt-rubber
C	cationic
EAP&T	emulsified asphalt prime and tack
H-suffix	harder residue (lower penetration)
HF	high float
MC	medium-curing

A. Crumb Rubber Modifier. Crumb rubber modifier (CRM) consists of automobile and truck tires processed by ambient temperature grinding.

CRM must be:

- free from contaminants including fabric, metal, and mineral and other nonrubber substances;

- free-flowing; and
- nonfoaming when added to hot asphalt binder.

When tested in accordance with Tex-200-F, Part I, using a 50-g sample, the rubber gradation must meet the requirements of the grades in Table 2.

Table 2
CRM Gradations

Sieve Size (% Passing)	Grade A		Grade B		Grade C		Grade D	Grade E
	Min	Max	Min	Max	Min	Max		
#8	100	–	–	–	–	–	As shown on the plans	As approved
#10	95	100	100	–	–	–		
#16	–	–	70	100	100	–		
#30	–	–	25	60	90	100		
#40	–	–	–	–	45	100		
#50	0	10	–	–	–	–		
#200	–	–	0	5	–	–		

B. Asphalt-Rubber Binders. Asphalt-rubber (A-R) binders are mixtures of asphalt binder and CRM, which have been reacted at elevated temperatures. The A-R binders meet D 6114 and contain a minimum of 15% CRM by weight. Types I or II, containing CRM Grade C, are used for hot mixed aggregate mixtures. Types II or III, containing CRM Grade B, are used for surface treatment binder. Table 3 describes required binder properties.

Table 3
A-R Binders

Property	Test Procedure	Binder Type					
		Type I		Type II		Type III	
		Min	Max	Min	Max	Min	Max
Apparent viscosity, 347°F, cP	D 2196, Method A	1,500	5,000	1,500	5,000	1,500	5,000
Penetration, 77°F, 100 g, 5 sec.	T 49	25	75	25	75	50	100
Penetration, 39.2°F, 200 g, 60 sec.	T 49	10	–	15	–	25	–
Softening point, °F	T 53	135	–	130	–	125	–
Resilience, 77°F, %	D 5329	25	–	20	–	10	–
Flash point, C.O.C., °F	T 48	450	–	450	–	450	–
Tests on residue from Thin-Film Oven Test:	T 179						
Retained penetration ratio, 39.2°F, 200 g, 60 sec., % of original	T 49	75	–	75	–	75	–

C. Performance-Graded Binders. PG binders must be smooth and homogeneous, show no separation when tested in accordance with Tex-540-C, and meet Table 4 requirements.

Separation testing is not required if:

- a modifier is introduced separately at the mix plant either by injection in the asphalt line or mixer,
- the binder is blended on site in continuously agitated tanks, or
- binder acceptance is based on field samples taken from an in-line sampling port at the hot mix plant after the addition of modifiers.

Table 4
Storage and Application Temperatures

Type–Grade	Application		Storage Maximum (°F)
	Recommended Range, °F	Maximum Allowable (°F)	
AC-0.6, AC-1.5, AC-3	200–300	350	350
AC-5, AC-10	275–350	350	350
AC-5 w/2% SBR, AC-10 w/2% SBR, AC-15P, AC-20-5TR	300–375	375	360
RC-250	125–180	200	200
RC-800	170–230	260	260
RC-3000	215–275	285	285
MC-30, AE-P	70–150	175	175
MC-250	125–210	240	240
MC-800, SCM I, SCM II	175–260	275	275
MC-3000, MC-2400L	225–275	290	290
HFRS-2, MS-2, CRS-2, CRS-2H, HFRS-2P, CRS-2P, CMS-2, CMS-2S, AES-300, AES-300S, AES-150P, AES-300P	120–160	180	180
SS-1, SS-1H, CSS-1, CSS-1H, PCE, EAP&T, SS-1P, RS-1P, CRS-1P, CSS-1P, recycling agent, emulsified recycling agent, polymer mod AE crack sealant	50–130	140	140
PG binders	275–350	350	350
Rubber asphalt crack sealers (Class A, Class B)	350–375	400	–
A-R binders Types I, II, and III	325–425	425	425

300.3. Measurement and Payment. The work performed, materials furnished, equipment, labor, tools, and incidentals will not be measured or paid for directly, but is subsidiary or is included in payment for other bid Items.

Appendix N: Texas Specifications – Permeable Friction Course

ITEM 342

PERMEABLE FRICTION COURSE (PFC)

342.1. Description. Construct a surface course composed of a compacted permeable mixture of aggregate, asphalt binder, and additives mixed hot in a mixing plant.

342.2. Materials. Furnish uncontaminated materials of uniform quality throughout that meet the requirements of the plans and specifications.

Notify the Engineer of all material sources. Notify the Engineer before changing any material source or formulation. When the Contractor makes a source or formulation change, the Engineer will verify that the specification requirements are met and may require a new laboratory mixture design, trial batch, or both. The Engineer may sample and test project materials at any time during the project to verify specification compliance.

A. Aggregate. Furnish aggregates from sources that conform to the requirements shown in Table 1, and as specified in this Section, unless otherwise shown on the plans. Provide aggregate stockpiles that meet the definition in this Section for coarse aggregate. Do not use fine aggregate or reclaimed asphalt pavement (RAP) in PFC mixtures. Supply mechanically crushed gravel or stone aggregates that meet the definitions in Tex-100-E. The Engineer will designate the plant or the quarry as the sampling location. Samples must be from materials produced for the project. The Engineer will establish the surface aggregate classification (SAC) and perform Los Angeles abrasion, magnesium sulfate soundness, and Micro-Deval tests. Perform all other aggregate quality tests listed in Table 1.

Document all test results on the mixture design report. The Engineer may perform tests on independent or split samples to verify Contractor test results. Stockpile aggregates for each source and type separately. Determine aggregate gradations for mixture design and production testing based on the washed sieve analysis given in Tex-200-F, Part II. Do not add material to an approved stockpile from sources that do not meet the aggregate quality requirements of the Department's *Bituminous Rated Source Quality Catalog* (BRSQC) unless otherwise approved.

1. **Coarse Aggregate.** Coarse aggregate stockpiles must have no more than 20% material passing the No. 8 sieve. Provide aggregates from sources listed in the BRSQC. Provide aggregate from nonlisted sources only when tested by the Engineer and approved before use. Allow 30 calendar days for the Engineer to sample, test, and report results for nonlisted sources.

   Provide coarse aggregate with at least the minimum SAC as shown on the plans. SAC requirements only apply to aggregates used on the surface of travel lanes, unless otherwise shown on the plans. The SAC for sources on the Department's Aggregate Quality Monitoring Program (AQMP) is listed in the BRSQC.

   Class B aggregate, meeting all other requirements in Table 1, may be blended with a Class A aggregate in order to meet requirements for Class A materials. When blending Class A and B aggregates to meet a Class A requirement, ensure that at least 50% by weight of the material retained on the No. 4 sieve comes from the Class A aggregate source. Blend by volume if the bulk specific gravities of the Class

A and B aggregates differ by more than 0.300. When blending, do not use Class C or D aggregates.

Table 1
Coarse Aggregate Quality Requirements

Property	Test Method	Requirement
SAC	AQMP	As shown on plans
Deleterious material, %, max	Tex-217-F, Part I	1.0
Decantation, %, max	Tex-217-F, Part II	1.5
Micro-Deval abrasion, %, max	Tex-461-A	Note 1
Los Angeles abrasion, %, max	Tex-410-A	30
Magnesium sulfate soundness, 5 cycles, %, max	Tex-411-A	20
Coarse aggregate angularity, 2 crushed faces, %, min	Tex-460-A, Part I	95[2]
Flat and elongated particles @ 5:1, %, max	Tex-280-F	10

1. Not used for acceptance purposes. Used by the Engineer as an indicator of the need for further investigation.
2. Only applies to crushed gravel.

2. RAP. Do not use RAP in PFC mixtures.

B. Baghouse Fines. Fines collected by the baghouse or other dust collecting equipment may be reintroduced into the mixing drum.

C. Asphalt Binder. Furnish performance-graded (PG) asphalt binder and fibers unless the plans specify asphalt-rubber (A-R) binder. Provide asphalt binder that meets requirements of Item 300, "Asphalts, Oils, and Emulsions."

1. PG Binder. When PG binder is specified, provide an asphalt binder with a high-temperature grade of PG 76 and low-temperature grade as shown on the plans in accordance with Section 300.2.J, "Performance-Graded Binders."

2. A-R Binder When A-R binder is specified, provide A-R binder that meets the Type I or Type II requirements of Section 300.2.I, "Asphalt-Rubber Binders," unless otherwise shown on the plans. Use at least 15.0% by weight of Crumb Rubber Modifier (CRM) that meets the Grade B or Grade C requirements of Section 300.2.G, "Crumb Rubber Modifier," unless otherwise shown on the plans.

3. Tack Coat. Unless otherwise shown on the plans or approved, furnish CSS-1H, SS-1H, or a PG binder with a minimum high-temperature grade of PG 58 for tack coat in accordance with Item 300, "Asphalts, Oils, and Emulsions." Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use.

The Engineer will obtain at least 1 sample of the tack coat binder per project and test to verify compliance with Item 300. The Engineer will obtain the sample from the asphalt distributor immediately before use.

D. Additives. When shown on the plans, use the type and rate of additive specified. Other additives that facilitate mixing or improve the quality of the mixture may be allowed when approved.

1. **Fibers.** When PG binder is specified, provide cellulose or mineral fibers. Do not use fibers when A-R binder is specified. Submit written certification to the Engineer that the fibers proposed for use meet the requirements of DMS-9204, "Fiber Additives for Bituminous Mixtures."
2. **Lime Mineral Filler.** When PG binder is specified, add lime as mineral filler at a rate of 1.0% by weight of the total dry aggregate. Do not add lime directly into the mixing drum of any plant where lime is removed through the exhaust stream unless the plant has a baghouse or dust collection system that reintroduces the lime back into the drum.
3. **Antistripping Agents.** If lime or a liquid antistripping agent is used, add in accordance with Item 301, "Asphalt Antistripping Agents." When the plans require lime to be added as an antistripping agent, lime added as mineral filler will count towards the total quantity of lime specified.

342.3. Equipment. Provide required or necessary equipment in accordance with Item 320, "Equipment for Hot-Mix Asphalt Materials." When A-R binder is specified, equip the hot-mix plant with an in-line viscosity measuring device located between the blending unit and the mixing drum.

342.4. Construction. Produce, haul, place, and compact the specified paving mixture. When shown on the plans, schedule and participate in a prepaving meeting with the Engineer as required in the Quality Control Plan (QCP).

A. Certification. Personnel certified by the Department-approved hot-mix asphalt certification program must conduct all mixture designs, sampling, and testing in accordance with Table 2. In addition to meeting the certification requirements in Table 2, all Level II certified specialists must successfully complete an approved Superpave training course. Supply the Engineer with a list of certified personnel and copies of their current certificates before beginning production and when personnel changes are made. Provide a mixture design that is developed and signed by a Level II certified specialist. Provide a Level IA certified specialist at the plant during production operations. Provide a Level IB certified specialist to conduct placement tests.

Table 2
Test Methods, Test Responsibility, and Minimum Certification Levels

1. Aggregate Testing	Test Method	Contractor	Engineer	Level
Sampling	Tex-400-A	✎	✎	IA
Dry sieve	Tex-200-F, Part I	✎	✎	IA
Washed sieve	Tex-200-F, Part II	✎	✎	IA
Deleterious material	Tex-217-F, Part I	✎	✎	II
Decantation	Tex-217-F, Part II	✎	✎	II
Los Angeles abrasion	Tex-410-A		✎	
Magnesium sulfate soundness	Tex-411-A		✎	
Micro-Deval abrasion	Tex-461-A		✎	
Coarse aggregate angularity	Tex-460-A	✎	✎	II

Flat and elongated particles	Tex-280-F	✎	✎	II
2. Mix Design & Verification	**Test Method**	**Contractor**	**Engineer**	**Level**
Design and JMF changes	Tex-204-F	✎	✎	II
Mixing	Tex-205-F	✎	✎	II
Molding (SGC)	Tex-241-F	✎	✎	IA
Laboratory-molded density	Tex-207-F	✎	✎	IA
Rice gravity	Tex-227-F	✎	✎	IA
Ignition oven calibration[1]	Tex-236-F	✎	✎	II
Drain-down	Tex-235-F	✎	✎	IA
Boil test	Tex-530-C	✎	✎	IA
Cantabro loss	Tex-245-F	✎	✎	II

Table 2 (continued)
Test Methods, Test Responsibility, and Minimum Certification Levels

3. Production Testing	**Test Method**	**Contractor**	**Engineer**	**Level**
Control charts	Tex-233-F	✎	✎	IA
Mixture sampling	Tex-222-F	✎	✎	IA
Gradation & asphalt content[1]	Tex-236-F	✎	✎	IA
Moisture content	Tex-212-F	✎	✎	IA
Micro-Deval abrasion	Tex-461-A		✎	
Drain-down	Tex-235-F	✎	✎	IA
Boil test	Tex-530-C	✎	✎	IA
Aging ratio	Tex-211-F		✎	
4. Placement Testing	**Test Method**	**Contractor**	**Engineer**	**Level**
Control charts	Tex-233-F	✎	✎	IA
Ride quality measurement	Tex-1001-S	✎	✎	IB
Thermal profile	Tex-244-F	✎	✎	IB
Tack coat adhesion	Tex-243-F		✎	
Permeability	Tex-246-F	✎	✎	IB

1. Refer to Section 342.4.E for exceptions to using ignition oven**.**

B. Reporting. Use Department-provided software to record and calculate all test data. The Engineer and the Contractor shall provide any available test results to the other party when requested. The Engineer and the Contractor shall immediately report to the other party any test result that requires production to be suspended or fails to meet the specification requirements. Use the approved communication method (e.g., email, diskette, hard copy) to submit test results to the Engineer. When directed, use the procedures described in Tex-233-F to plot the results of all productions and placement testing. Update the control charts as soon as test results for each sublot become available. Make the control charts readily accessible at the field laboratory. The Engineer may

suspend production for failure to update control charts.

C. QCP. Develop and follow the QCP in detail. Obtain approval from the Engineer for changes to the QCP made during the project. The Engineer may suspend operations if the Contractor fails to comply with the QCP.

When directed, submit a written QCP to the Engineer before the mandatory prepaving meeting. Receive the Engineer's approval of the QCP before beginning production. Include the following items in the QCP.

1. **Project Personnel.** For project personnel, include:
   - a list of individuals responsible for quality control (QC) with authority to take corrective action and
   - contact information for each individual listed.
2. **Material Delivery and Storage.** For material delivery and storage, include:
   - the sequence of material processing, delivery, and minimum quantities to assure continuous plant operations;
   - aggregate stockpiling procedures to avoid contamination and segregation;
   - frequency, type, and timing of aggregate stockpile testing to assure conformance of material requirements before mixture production; and
   - procedure for monitoring the quality and variability of asphalt binder.
3. **Production.** For production, include:
   - loader operation procedures to avoid contamination in cold bins,
   - procedures for calibrating and controlling cold feeds,
   - procedures to eliminate debris or oversized material,
   - procedures for adding and verifying rates of each applicable mixture component (e.g., aggregate, asphalt binder, RAP, lime, liquid antistrip),
   - procedures for reporting job control test results, and
   - procedures to avoid segregation and drain-down in the silo.
4. **Loading and Transporting.** For loading and transporting, include:
   - type and application method for release agents and
   - truck loading procedures to avoid segregation.
5. **Placement and Compaction.** For placement and compaction, include:
   - proposed agenda for mandatory prepaving meeting including date and location;
   - type and application method for release agents in the paver and on rollers, shovels, lutes, and other utensils
   - procedures for the transfer of mixture into the paver while avoiding segregation and preventing material spillage;
   - process to balance production, delivery, paving, and compaction to achieve continuous placement operations;
   - paver operations (e.g., operation of wings, height of mixture in auger chamber) to avoid physical and thermal segregation and other surface irregularities; and
   - procedures to construct quality longitudinal and transverse joints.

D. Mixture Design. Unless otherwise shown on the plans, use the PFC design procedure given in Tex-204-F, Part V, to design a mixture meeting the requirements listed in Tables 1, 3 and 4. Use Ndes = 50 as the design number of gyrations.

The Contractor may submit a new mixture design at anytime during the project. The Engineer will approve all mixture designs before the Contractor can begin production.

When shown on the plans, the Engineer will provide the mixture design.

Provide the Engineer with a mixture design report using Department-provided software. Include the following items in the report: the combined aggregate gradation, source, specific gravity, and percent of each material used;

- results of all applicable tests;
- the mixing and molding temperatures;
- the signature of the Level II person or persons that performed the design;
- the date the mixture design was performed; and
- a unique identification number for the mixture design.

Table 3
Master Gradation Band (% Passing by Weight or Volume)
and Binder Content

Sieve Size	PG 76 Mixtures	A-R Mixtures
3/4"	100.0	100.0
1/2"	80.0–100.0	95.0–100.0
3/8"	35.0–60.0	50.0–80.0
#4	1.0–20.0	0.0–8.0
#8	1.0–10.0	0.0–4.0
#200	1.0–4.0	0.0–4.0
Binder Content, %		
	5.5–7.0	8.0–10.0

Table 4
Laboratory Mixture Design Properties

Mixture Property	Test Method	Minimum	Maximum
Drain-down, %	Tex-235-F	–	0.20
Laboratory-molded density, %	Tex-207-F, Part VI	78.0[1]	82.0
Fiber content[2], %	Calculated	0.20	0.50
Lime content[2], %	Calculated	1.0	2.0
CRM content[3], %	Calculated	15.0	
Boil test	Tex-530-C	–	None
Cantabro loss, %	Tex-245-F	–	20.0[1]

1. Suggested limit. Test and report for informational purposes only.
2. By weight of total mixture. Not required when using A-R.
3. By weight of asphalt. Not required when using PG 76 and fibers.

1. **Job-Mix Formula Approval.** The job-mix formula (JMF) is the combined aggregate gradation and target asphalt percentage used to establish target values for hot mix production. JMF1 is the original laboratory mixture design used to produce the trial batch. The Engineer and the Contractor will verify JMF1 based on plant-produced mixture from the trial batch unless otherwise approved. The Engineer may accept an existing mixture design previously used on a Department project and may waive the trial batch to verify JMF1.

   a. Contractor's Responsibilities.

      (1) Providing Superpave Gyratory Compactor. Furnish a Superpave

gyratory compactor (SGC), calibrated in accordance with Tex-241-F, for molding production samples. Locate the SGC at the field laboratory and make the SGC available to the Engineer for use in molding production samples.

(2) Gyratory Compactor Correlation Factors. Use Tex-206-F, Part II, to perform a gyratory compactor correlation when the Engineer uses a different SGC. Apply the correlation factor to all subsequent production test results.

(3) Submitting JMF1. Furnish the Engineer a mix design report (JMF1) and request approval to produce the trial batch.

(4) Supplying Aggregates. Provide the Engineer with approximately 40 lb. of each aggregate stockpile unless otherwise directed.

(5) Supplying Asphalt. Provide the Engineer at least 1 gal. of the asphalt material and sufficient quantities of any additives proposed for use.

(6) Ignition Oven Correction Factors. Determine the aggregate and asphalt correction factors from the ignition oven using Tex-236-F. Provide the Engineer with split samples of the mixtures and blank samples used to determine the correction factors.

(7) Boil Test. Perform the test and retain the tested sample from Tex-530-C. Use this sample for comparison purposes during production. The Engineer may waive the requirement for the boil test. If signs of stripping exist, add lime or liquid antistripping agent as directed.

(8) Trial Batch Approval. Upon receiving conditional approval of JMF1 from the Engineer, provide a plant-produced trial batch for verification testing of JMF1 and development of JMF2.

(9) Trial Batch Production Equipment. To produce the trial batch, use only equipment and materials proposed for use on the project.

(10) Trial Batch Quantity. Produce enough quantity of the trial batch to ensure that the mixture is representative of JMF1.

(11) Number of Trial Batches. Produce trial batches as necessary to obtain a mixture that meets the operational tolerances in Table 5.

(12) Trial Batch Sampling. Obtain a representative sample of the trial batch and split it into 3 equal portions in accordance with Tex-222-F. Label these portions as “Contractor,” “Engineer,” and “Referee.” Deliver samples to the appropriate laboratory.

(13) Trial Batch Testing. Test the trial batch to ensure the mixture produced using the proposed JMF1 meets the verification testing requirements for gradation, binder content, laboratory-molded density, and drain-down listed in Table 5. Provide the Engineer with a copy of the trial batch test results.

(14) Development of JMF2. After the Engineer grants full approval of JMF1 based on results from the trial batch, evaluate the trial batch test results, determine the optimum mixture proportions, and submit as JMF2.

(15) Mixture Production. After receiving approval for JMF2, use JMF2 to produce Lot 1.

(16) Development of JMF3. Evaluate the test results from Lot 1, determine the optimum mixture proportions, and submit as JMF3 for use in Lot 2.

(17) JMF Adjustments. If necessary, adjust the JMF before beginning a new lot. The adjusted JMF must:

- be provided to the Engineer in writing before the start of a new lot,
- be numbered in sequence to the previous JMF,
- meet the master gradation limits shown in Table 3, and
- be within the operational tolerances of JMF2 listed in Table 5.

(18) Requesting Referee Testing. If needed, use the referee testing in accordance with Section 342.4.I.1, "Referee Testing," to resolve testing differences with the Engineer.

b. Engineer's Responsibilities.

(1) Gyratory Compactor. For molding trial batch and production samples, the Engineer will use the Contractor-provided SGC at the Contractor's field laboratory or provide and use a Department SGC, calibrated according to Tex-241-F, at an alternate location.

(2) Conditional Approval of JMF1. Within 2 working days of receiving the mixture design report (JMF1) and all required materials, the Engineer will review the Contractor's mixture design report and verify conformance with all aggregates, asphalt, additives, and mixture specifications. The Engineer may perform tests to verify the aggregates meet the requirements listed in Table 1. The Engineer will grant the Contractor conditional approval of JMF1 if the information provided on the paper copy of JMF1 indicates the Contractor's mixture design meets the specifications. Full approval of JMF1 will be based on the Engineer's test results on mixture from the trial batch.

Table 5
Testing Frequency and Mixture Production Tolerances

Test Descriptionon	Test Method	Minimum Contractor Testing Frequency	Minimum Engineer Testing Frequency	Operational Tolerance from JMF
Individual % retained for sieve sizes larger than #200	Tex-200-F	1 per sublot	1 per 12 sublots	±5.0[1]
% passing the #200				±2.0[1]
Laboratory-molded density, %	Tex-207-F, Part VI	1 per sublot	1 per lot	Table 4
Binder content, %	Tex-236-F	1 per sublot	1 per lot[2]	±0.3
Drain-down, %	Tex-235-F	1 per sublot	1 per 12 sublots	Table 4
Boil test[3]	Tex-530-C	1 per project	1 per project	N/A
Asphalt Binder Sampling[3]	Tex-500-C	1 per sublot (sample only)	1 per project	N/A
Thermal profile	Tex-244-F	1 per sublot	Optional	N/A

1. Aggregate gradation will not exceed limits shown in Table 3.

2. May be obtained from asphalt meter readouts.
3. The Engineer may reduce or waive the sampling and testing requirements based on a satisfactory test history.

(3) Authorizing Trial Batch. After conditionally approving JMF1, the Engineer will authorize the Contractor to produce a trial batch.

(4) Ignition Oven Correction Factor. The Engineer will use the split samples provided by the Contractor to determine the aggregate and asphalt correction factors for the ignition oven in accordance with Tex-236-F.

(5) Testing the Trial Batch. Within 1 full working day, the Engineer will sample and test the trial batch to ensure that the gradation, binder content, and laboratory molded density meet the requirements listed in Table 5.

The Engineer will have the option to perform the following tests on the trial batch:

- Tex-235-F to verify that drain-down meets the requirement shown in Table 4.
- Tex-461-A to determine the need for additional magnesium sulfate soundness testing.
- Tex-530-C to retain and use for comparison purposes during production.
- Tex-245-F to verify the Cantabro loss meets the requirement shown in Table 4.

(6) Full Approval of JMF1. The Engineer will grant full approval of JMF1 and authorize the Contractor to proceed with developing JMF2 if the Engineer's results for gradation, asphalt content, and laboratory-molded density confirm that the trial batch meets the requirements in Table 5.

The Engineer will notify the Contractor that an additional trial batch is required if the trial batch does not meet the requirements in Table 5.

(7) Approval of JMF2. The Engineer will approve JMF2 within 1 working day if it meets the master grading limits shown in Table 3 and is within the operational tolerances of JMF1 listed in Table 5.

(8) Approval of Lot 1 Production. The Engineer will authorize the Contractor to proceed with Lot 1 production after approving JMF2.

(9) Approval of JMF3. The Engineer will approve JMF3 within 1 working day if it meets the master grading limits shown in Table 3 and is within the operational tolerances of JMF2 listed in Table 5.

2. JMF Adjustments. Produce the mixture within the operational tolerances listed in Table 5. The Engineer may suspend production if corrective actions are not taken when operational tolerances are exceeded. With approval from the Engineer, the JMF target values may be adjusted as needed. Document any changes to the JMF with a subsequent JMF number. The Engineer may adjust the target asphalt percentage or fiber percentage within the operational tolerances of the JMF.

E. Production Operations. Perform a new trial batch when the plant or plant location is changed.

Perform QC at the frequency and within the tolerances listed in Table 5. Take corrective action and receive approval to proceed after any production suspension for noncompliance to the specification.

At any time during production, the Engineer may require the Contractor to verify the following based on quantities used:

- lime content (within ±0.1% of JMF), when PG binder is specified;
- fiber content (within ±0.03% of JMF), when PG binder is specified; and
- CRM content (within ±1.5% of JMF), when A-R binder is specified.

When A-R binder is specified, maintain the in-line measuring device to verify the A-R binder viscosity of at least 2,500 centipoise at 350°F unless otherwise approved.

If the aggregate mineralogy is such that Tex-236-F does not yield reliable results, the Engineer may allow alternate methods for determining the asphalt content and aggregate gradation. Unless otherwise allowed, the Engineer will require the Contractor to provide evidence that results from Tex-236-F are not reliable before permitting an alternate method. If an alternate test method is allowed, use the applicable test procedure as directed.

1. **Storage and Heating of Materials.** Do not heat the asphalt binder above the temperatures specified in Item 300, "Asphalts, Oils, and Emulsions" or outside the manufacturer's recommended values. On a daily basis, provide the Engineer with the records of asphalt binder and hot-mix asphalt discharge temperatures in accordance with Item 320, "Equipment for Hot-Mix Asphalt Materials." Unless otherwise approved, do not store mixture for a period long enough to affect the quality of the mixture, nor in any case longer than 12 hr.
2. **Mixing and Discharge of Materials.** Notify the Engineer of the target discharge temperature and produce the mixture within 25°F of the target. Monitor the temperature of the material in the truck before shipping to ensure that it does not exceed 350°F. The Department will not pay for or allow placement of any mixture produced at more than 350°F.

   Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. If requested, determine the moisture content by oven- drying in accordance with Tex-212-F, Part II, and verify that the mixture contains no more than 0.2% of moisture by weight. Obtain the sample immediately after discharging the mixture into the truck and perform the test promptly.

F. Hauling Operations. Before use, clean all truck beds to ensure mixture is not contaminated. When a release agent is necessary to coat the truck bed, use a release agent on the approved list maintained by the Construction Division.

G. Placement Operations. Prepare the surface by removing raised pavement markers and objectionable material such as moisture, dirt, sand, leaves, and other loose impediments from the surface before placing mixture. Remove vegetation from pavement edges. Place the mixture to meet the typical section requirements and produce a smooth, finished surface with a uniform appearance and texture. Offset longitudinal joints of successive courses of hot mix by at least 6 in. Place mixture so longitudinal joints on the surface course coincide with lane lines, or as directed. Ensure that all finished surfaces will drain properly.

1. **Weather Conditions.** Place mixture when the roadway surface temperature is 70°F or higher unless otherwise approved. Measure the roadway surface temperature with a handheld infrared thermometer. Unless otherwise shown on the plans, place

mixtures only when weather conditions and moisture conditions of the roadway surface are suitable in the opinion of the Engineer.

2. **Tack Coat.** Clean the surface before placing the tack coat. Unless otherwise approved, apply tack coat uniformly at the rate directed by the Engineer. The Engineer will set the rate between 0.04 and 0.10 gal. of residual asphalt per square yard of surface area. Apply a thin, uniform tack coat to all contact surfaces of curbs, structures, and all joints. Prevent splattering of tack coat when placed adjacent to curb, gutter, and structures. Roll the tack coat with a pneumatic-tire roller when directed. The Engineer may use Tex-243-F to verify that the tack coat has adequate adhesive properties. The Engineer may suspend paving operations until there is adequate adhesion.

3. **Lay-Down Operations.** Measure the temperature of mixture delivered to the paver and take corrective action if needed to ensure the temperature does not drop below 280°F. For each sublot use a handheld infrared thermometer to obtain a thermal profile of the uncompacted mat immediately behind the paver. Record the information on Department QC/QA forms and submit the forms to the Engineer.

   a. **Thermal Profile.** For each sublot, obtain a thermal profile using Tex-244-F. The Engineer may reduce the testing frequency based on a satisfactory test history. The Engineer may also obtain as many thermal profiles as deemed necessary. If the temperature differential is greater than 25°F, the area will be deemed to have thermal segregation. Take corrective action to eliminate areas that have thermal segregation. Unless otherwise directed, suspend operations if maximum temperature differential exceeds 50°F. Resume operations when the Engineer determines that subsequent production will meet the requirements of this Item.

   b. **Windrow Operations.** When hot mix is placed in windrows, operate windrow pickup equipment so that substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

H. Compaction. Roll the freshly placed PFC with a steel-wheeled roller, operated in static mode, to seat the mixture without excessive breakage of the aggregate and to provide a smooth surface and uniform texture. Do not use pneumatic rollers. Thoroughly moisten the roller drums with a soap-and-water solution to prevent adhesion. Unless otherwise directed, use only water or an approved release agent on rollers, tamps, and other compaction equipment.

The Engineer may use or require the Contractor to use Tex-246-F to test and verify that the compacted mixture has adequate permeability. Adjust the mixture design or construction methods if the compacted mixture does not exhibit adequate permeability.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic unless otherwise directed. When directed, sprinkle the finished mat with water or limewater to expedite opening the roadway to traffic.

I. Acceptance Plan. Sample and test the hot mix on a lot and sublot basis. A production lot consists of 4 equal sublots. Lot 1 will be 1,000 tons. The Engineer will select subsequent lot sizes based on the anticipated daily production. The lot size will be between 1,000 and 4,000 tons. The Engineer may change the lot size before the Contractor begins any lot. If the production or placement test results are not within the

acceptable tolerances listed in Table 5, suspend production until test results or other information indicate to the satisfaction of the Engineer that the next material produced or placed will meet the specified values.

1. **Referee Testing.** The Construction Division is the referee laboratory. The Contractor may request referee testing if the differences between Contractor and Engineer test results exceed the operational tolerances shown in Table 5 and the differences cannot be resolved. Make the request within 5 working days after receiving test results and cores from the Engineer. Referee tests will be performed only on the sublot in question and only for the particular test in question. Allow 10 working days from the time the samples are received at the referee laboratory for test results to be reported. The Department may require the Contractor to reimburse the Department for referee tests if more than 3 referee tests per project are required and the Engineer's test results are closer than the Contractor's test results to the referee test results.
2. **Asphalt Binder Sampling.** Obtain a 1-qt. (1-gal. for A-R binder) sample of the asphalt binder for each sublot of mixture produced. Obtain the sample at approximately the same time the mixture random sample is obtained. Sample from a port located immediately upstream from the mixing drum or pug mill. Take the sample in accordance with the pipeline sampling procedure given in Tex-500-C, Part II. Label the can with the corresponding lot and sublot numbers, and deliver the sample to the Engineer.

   The Engineer may also obtain independent samples. If the Engineer chooses to obtain an independent asphalt binder sample, the Engineer will split a sample of the asphalt binder with the Contractor. The Engineer will test at least 1 asphalt binder sample per project to verify compliance with Item 300, "Asphalts, Oils, and Emulsions."
3. **Operational Tolerances.** Control the production process within the operational tolerances listed in Table 5. When production is suspended, the Engineer will allow production to resume when test results or other information indicates the next mixture produced will be within the operational tolerances.
4. **Recovered Asphalt DSR.** The Engineer may take production samples or cores from suspect areas of the project to determine recovered asphalt properties. Asphalt binders with an aging ratio greater than 3.5 do not meet the requirements for recovered asphalt properties and may be deemed defective when tested and evaluated by the Construction Division. The aging ratio is the dynamic shear rheometer (DSR) value of the extracted binder divided by the DSR value of the original unaged binder. DSR values are obtained according to AASHTO T 315 at the specified high temperature PG of the asphalt. The Engineer may require removal and replacement of the defective material at the Contractor's expense. The asphalt binder will be recovered for testing from production samples or cores using Tex-211-F.
5. **Irregularities.** Immediately take appropriate corrective actions if surface irregularities, including but not limited to segregation, rutting, raveling, flushing, fat spots, mat slippage, color, texture, roller marks, tears, gouges, streaks, or uncoated aggregate particles, are detected. The Engineer may allow placement to continue for at most 1 day of production while taking appropriate action. If the problem still exists after that day, suspend paving until the problem is corrected to the

satisfaction of the Engineer.

At the expense of the Contractor and to the satisfaction of the Engineer, remove and replace any mixture that does not bond to the existing pavement or that has other surface irregularities identified above.

6. **Ride Quality.** Unless otherwise shown on the plans, measure ride quality in accordance with Item 585, "Ride Quality for Pavement Surfaces."

342.5. Measurement. PFC will be measured by the ton of composite PFC. The composite PFC is defined as the asphalt, aggregate, and additives. The weights of asphalt and aggregate will be calculated based on the measured weight of PFC and the target percentage of asphalt and aggregate. Measure the weight on scales in accordance with Item 520, "Weighing and Measuring Equipment."

A. Asphalt. The asphalt weight in tons will be determined from the total weight of PFC. Measured asphalt percentage will be obtained using Tex-236-F or asphalt flow meter readings, as determined by the Engineer.

1. **Target Percentage.** The JMF target asphalt percentage will be used to calculate the weight of asphalt binder unless the measured asphalt binder percentage is more than 0.3 percentage points below the JMF target asphalt percentage. Volumetric meter readings will be adjusted to 140°F and converted to weight.
2. **Measured Percentage.** The measured asphalt percentage will be used for payment for that lot's production when the measured percentage is more than 0.3 percentage points below the JMF target asphalt percentage.

B. Aggregate. The aggregate weight in tons will be determined from the total weight of PFC less the weight of the asphalt.

342.6. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "PFC (Asphalt)" of the binder specified and for "PFC (Aggregate)" of the grade and surface aggregate classification specified. These prices are full compensation for surface preparation, materials including tack coat, placement, equipment, labor, tools, and incidentals.

Trial batches will not be paid for unless they are included in pavement work approved by the Department. Pay adjustment for ride quality will be determined in accordance with Item 585, "Ride Quality for Pavement Surfaces."

Appendix O: Texas Specifications – Stone Matrix

ITEM 346

STONE-MATRIX ASPHALT

346.1. Description. Construct a pavement layer composed of a compacted stone-matrix asphalt (SMA) or stone-matrix asphalt rubber (SMAR) mixture of aggregate, asphalt binder, and additives mixed hot in a mixing plant.

346.2. Materials. Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications.

Notify the Engineer of all material sources. Notify the Engineer before changing any material source or formulation. When the Contractor makes a source or formulation change, the Engineer will verify that the requirements of this Item are met and may require a new laboratory mixture design, trial batch, or both. The Engineer may sample and test project materials at any time during the project to verify compliance.

A. Aggregate. Furnish aggregates from sources that conform to the requirements shown in Table 1, and as specified in this Section, unless otherwise shown on the plans. Provide aggregate stockpiles that meet the definition in this Section for either a coarse aggregate or fine aggregate. When reclaimed asphalt pavement (RAP) is allowed by plan note, provide RAP stockpiles in accordance with this Section. Aggregate from RAP is not required to meet Table 1 requirements unless otherwise shown on the plans. Supply mechanically crushed gravel or stone aggregates that meet the definitions in Tex-100-E. The Engineer will designate the plant or the quarry as the sampling location. Samples must be from materials produced for the project. The Engineer will establish the surface aggregate classification (SAC) and perform Los Angeles abrasion, magnesium sulfate soundness, and Micro- Deval tests. Perform all other aggregate quality tests listed in Table 1. Document all test results on the mixture design report. The Engineer may perform tests on independent or split samples to verify Contractor test results. Stockpile aggregates for each source and type separately. Determine aggregate gradations for mixture design and production testing based on the washed sieve analysis given in Tex-200-F, Part II. Do not add material to an approved stockpile from sources that do not meet the aggregate quality requirements of the Department's *Bituminous Rated Source Quality Catalog* (BRSQC) unless otherwise approved.

1. **Coarse Aggregate.** Coarse aggregate stockpiles must have no more than 20% material passing the No. 8 sieve. Provide aggregates from sources listed in the BRSQC. Provide aggregate from nonlisted sources only when tested by the Engineer and approved before use. Allow 30 calendar days for the Engineer to sample, test, and report results for nonlisted sources.

   Provide coarse aggregate with at least the minimum SAC shown on the plans. SAC requirements only apply to aggregates used on the surface of travel lanes, unless otherwise shown on the plans. The SAC for sources on the Department's Aggregate Quality Monitoring Program (AQMP) is listed in the BRSQC.

   Class B aggregate meeting all other requirements in Table 1 may be blended with a Class A aggregate in order to meet requirements for Class A materials. When blending Class A and B aggregates to meet a Class A requirement, ensure that at least 50% by weight of the material retained on the No. 4 sieve comes from the Class A aggregate source. Blend by volume if the bulk specific gravities of the Class A and B aggregates differ by more than 0.300. When blending, do not use Class C or D aggregates. For blending purposes, coarse aggregate from RAP will be considered as Class B aggregate.

2. **RAP.** RAP is salvaged, milled, pulverized, broken, or crushed asphalt pavement. Crush or break RAP so that 100% of the particles pass the 2-in. sieve.

   RAP from either Contractor- or Department-owned sources, including RAP generated during the project, is permitted only when shown on the plans. Department-owned RAP, if allowed for use, will be available at the location shown on the plans. When RAP is used, determine asphalt content and gradation for mixture design purposes. Perform other tests on RAP when shown on the plans. When RAP is allowed by plan note, use no more than 20% RAP unless otherwise shown on the plans.

Do not use RAP contaminated with dirt or other objectionable materials. Do not use the RAP if the decantation value exceeds 5% and the plasticity index is greater than 8. Test the stockpiled RAP for decantation in accordance with the laboratory method given in Tex-406-A, Part I. Determine the plasticity index using Tex-106-E if the decantation value exceeds 5%. The decantation and plasticity index requirements do not apply to RAP samples with asphalt removed by extraction.

Do not intermingle Contractor-owned RAP stockpiles with Department-owned RAP stockpiles. Remove unused Contractor-owned RAP material from the project site upon completion of the project. Return unused Department-owned RAP to the designated stockpile location.

3. Fine Aggregate. Fine aggregates consist of manufactured sands, screenings, and field sands. Fine aggregate stockpiles must meet the gradation requirements in Table 2. Supply fine aggregates that are free from organic impurities. The Engineer may test the fine aggregate in accordance with Tex-408-A to verify the material is free from organic impurities. At most 15% of the total aggregate may be field sand or other uncrushed fine aggregate. With the exception of field sand, use fine aggregate from coarse aggregate sources that meet the requirements shown in Table 1,unless otherwise approved.

If 10% or more of the stockpile is retained on the No. 4 sieve, test the stockpile and verify that it meets the requirements in Table 1 for coarse aggregate angularity (Tex-460-A) and flat and elongated particles (Tex-280-F).

Table 1
Aggregate Quality Requirements

Property	Test Method	Requirement
Coarse Aggregate		
SAC	AQMP	As shown on plans
Deleterious material, %, max	Tex-217-F, Part I	1.0
Decantation, %, max	Tex-217-F, Part II	1.5
Micro-Deval abrasion, %, max	Tex-461-A	Note 1
Los Angeles abrasion, %, max	Tex-410-A	30
Magnesium sulfate soundness, 5 cycles, %, max	Tex-411-A	20
Coarse aggregate angularity, 2 crushed faces, %, min	Tex 460-A, Part I	95[2]
Flat and elongated particles @ 5:1, %, max	Tex-280-F	10
Fine Aggregate		
Linear shrinkage, %, max	Tex-107-E	3
Combined Aggregate[3]		
Sand equivalent, %, min	Tex-203-F	45

1. Not used for acceptance purposes. Used by the Engineer as an indicator of the need for further investigation.
2. Only applies to crushed gravel.
3. Aggregates, without mineral filler, RAP, or additives, combined as used in the job-mix formula (JMF).

Table 2
Gradation Requirements for Fine Aggregate

Sieve Size	% Passing by Weight or Volume
3/8"	100
#8	70–100
#200	0–30

B. Mineral Filler. Mineral filler consists of finely divided mineral matter such as agricultural lime, crusher fines, hydrated lime, cement, or fly ash. Mineral filler is allowed unless otherwise shown on the plans. Do not use more than 2% hydrated lime or cement, unless otherwise shown on the plans. The plans may require or disallow specific mineral fillers. When used, provide mineral filler that:

- is sufficiently dry, free-flowing, and free from clumps and foreign matter;
- does not exceed 3% linear shrinkage when tested in accordance with Tex-107-E; and
- meets the gradation requirements in Table 3.

Table 3

Gradation Requirements for Mineral Filler

Sieve Size	% Passing by Weight or Volume
#8	100
#200	55–100

C. Baghouse Fines. Fines collected by the baghouse or other dust-collecting equipment may be reintroduced into the mixing drum.

D. Asphalt Binder. For SMA mixtures, furnish the type and grade of PG binder and fibers specified on the plans. For SMAR mixtures, provide the A-R binder specified on the plans. Provide asphalt binder that meets requirements of Item 300, "Asphalts, Oils, and Emulsions."

1. PG Binder. When SMA is specified, provide an asphalt binder with a high-temperature grade of PG 76 and low-temperature grade as shown on the plans in accordance with Section 300.2.J, "Performance-Graded Binders."

2. A-R Binder. When SMAR is specified, provide A-R binder that meets the Type I or Type II requirements of Section 300.2.I, "Asphalt-Rubber Binders," unless otherwise shown on the plans. Use at least 15.0% by weight of Crumb Rubber Modifier (CRM) that meets the Grade B or Grade C requirements of Section 300.2.G, "Crumb Rubber Modifier," unless otherwise shown on the plans.

E. Tack Coat. Unless otherwise shown on the plans or approved, furnish CSS-1H, SS-1H, or a PG binder with a minimum high-temperature grade of PG 58 for tack coat in accordance with Item 300. Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use.

The Engineer will obtain at least 1 sample of the tack coat binder per project and test it to verify compliance with Item 300. The Engineer will obtain the sample from the asphalt distributor immediately before use.

F. Additives. When shown on the plans, use the type and rate of additive specified. Other additives that facilitate mixing or improve the quality of the mixture may be allowed when approved.

1. Fibers. When PG binder is specified, provide cellulose or mineral fibers. Submit written certification to the Engineer that the fibers proposed for use meet the requirements of DMS-9204, "Fiber Additives for Bituminous Mixtures."

2. Antistripping Agents. If lime or a liquid antistripping agent is used, add in accordance with Item 301, "Asphalt Antistripping Agents." Do not add lime directly into the mixing drum of any plant where lime is removed through the exhaust stream unless the plant has a baghouse or dust collection system that reintroduces the lime back into the drum.

346.3. Equipment. Provide required or necessary equipment in accordance with Item 320, "Equipment for Asphalt Concrete Pavement." When A-R binder is specified, equip the hot mix plant with an in-line viscosity-measuring device located between the blending unit and the mixing drum.

346.4. Construction. Produce, haul, place, and compact the specified paving mixture. Schedule and participate in a prepaving meeting with the Engineer as required in the Quality Control Plan (QCP).

A. Certification. Personnel, certified by the Department-approved hot-mix asphalt certification program, must conduct all mixture designs, sampling, and testing in accordance with Table 4. In addition to meeting the certification requirements in Table 4, all Level II certified specialists must successfully complete an approved Superpave training course. Supply the Engineer with a list of certified personnel and copies of their current certificates before beginning production and when personnel changes are made.

Provide the following:

- a mixture design that is developed and signed by a Level II certified specialist,
- a Level IA certified specialist at the plant during production operations, and
- a Level IB certified specialist to conduct placement tests.

B. Reporting. Use Department-provided software to record and calculate all test data. The Engineer and the Contractor shall provide any available test results to the other party when requested. The maximum

allowable time for the Contractor and Engineer to exchange test data is as given in Table 5, unless otherwise approved. The Engineer and the Contractor shall immediately report to the other party any test result that requires production to be suspended, a payment penalty, or fails to meet the specification requirements. Use the approved communication method (e.g., email, diskette, hard copy) to submit test results to the Engineer.

Table 4
Test Methods, Test Responsibility, and Minimum Certification Levels

1. Aggregate Testing	**Test Method**	**Contractor**	**Engineer**	**Level**
Sampling	Tex-400-A	✎	✎	IA
Dry sieve	Tex-200-F, Part I	✎	✎	IA
Washed sieve	Tex-200-F, Part II	✎	✎	IA
Deleterious material	Tex-217-F, Part I	✎	✎	II
Decantation	Tex-217-F, Part II	✎	✎	II
Los Angeles abrasion	Tex-410-A		✎	
Magnesium sulfate soundness	Tex-411-A		✎	
Micro-Deval abrasion	Tex-461-A		✎	
Coarse aggregate angularity	Tex-460-A	✎	✎	II
Flat and elongated particles	Tex-280-F	✎	✎	II
Linear shrinkage	Tex-107-E	✎	✎	II
Sand equivalent	Tex-203-F	✎	✎	II
Organic impurities	Tex-408-A	✎	✎	II
2. Mix Design & Verification	**Test Method**	**Contractor**	**Engineer**	**Level**
Design and JMF changes	Tex-204-F	✎	✎	II
Mixing	Tex-205-F	✎	✎	II
Molding (SGC)	Tex-241-F	✎	✎	IA
Laboratory-molded density	Tex-207-F	✎	✎	IA
VMA	Tex-207-F	✎	✎	II
Rice gravity	Tex-227-F	✎	✎	IA
Ignition oven calibration[1]	Tex-236-F	✎	✎	II
Indirect tensile strength	Tex-226-F	✎	✎	II
Hamburg Wheel test	Tex-242-F	✎	✎	II
Boil test	Tex-530-C	✎	✎	IA
3. Production Testing	**Test Method**	**Contractor**	**Engineer**	**Level**
Random sampling	Tex-225-F		✎	IA
Mixture sampling	Tex-222-F	✎	✎	IA
Molding (SGC)	Tex-241-F	✎	✎	IA
Laboratory-molded density	Tex-207-F	✎	✎	IA
VMA (calculation only)	Tex-207-F	✎	✎	IA
Rice gravity	Tex-227-F	✎	✎	IA
Gradation & asphalt content[1]	Tex-236-F	✎	✎	IA
Control charts	Tex-233-F	✎	✎	IA
Moisture content	Tex-212-F	✎	✎	IA
Hamburg Wheel test	Tex-242-F	✎	✎	II
Micro-Deval abrasion	Tex-461-A		✎	
Boil test	Tex-530-C	✎	✎	IA
Aging ratio	Tex-211-F		✎	
4. Placement Testing	**Test Method**	**Contractor**	**Engineer**	**Level**
Random sampling	Tex-225-F		✎	IA
In-Place air voids	Tex-207-F	✎	✎	IA
Establish rolling pattern	Tex-207-F	✎		IB
Control charts	Tex-233-F	✎	✎	IA
Ride quality measurement	Tex-1001-S	✎	✎	IB

Table 4 (continued)
Test Methods, Test Responsibility, and Minimum Certification Levels

4. Placement Testing	Test Method	Contractor	Engineer	Level
Segregation (density profile)	Tex-207-F, Part V	✎	✎	IB
Longitudinal Joint Density	Tex-207-F, Part VII	✎	✎	IB
Thermal profile	Tex-244-F	✎	✎	IB
Tack coat adhesion	Tex-243-F		✎	IB

1. Refer to Section 344.4.I.2.c for exceptions to using an ignition oven.

Table 5
Reporting Schedule

Description	Reported By	Reported to	To Be Reported Within
Production Quality Control			
Gradation[1] Asphalt content[1] Laboratory-molded density[2] Moisture content[3] Boil test[3]	Contractor	Engineer	1 working day of completion of the sublot
Production Quality Assurance			
Gradation[3] Asphalt content[3] Laboratory-molded density[1] Hamburg Wheel test[2] Boil test[3] Binder tests[2]	Engineer	Contractor	1 working day of completion of the sublot
Placement Quality Control			
In-Place air voids[2] Segregation[1] Longitudinal joint density[1] Thermal profile[1]	Contractor	Engineer	1 hr. of performing the test for segregation, longitudinal joint density, and thermal profile
Placement Quality Assurance			
In-Place Air Voids[1] Segregation[2] Longitudinal joint density[2] Thermal profile[2] Aging ratio[2]	Engineer	Contractor	1 working day of receipt of the trimmed cores for In-Place air voids[4]
Pay Adjustment Summary	Engineer	Contractor	2 working days of performing all required tests and receiving Contractor test data

1. These tests are required on every sublot.
2. Optional test. To be reported as soon as results become available.
3. To be performed at the frequency shown in Table 12.
4. Additional time is allowed if cores cannot be dried to constant weight within 1 day.

The Engineer will use the Department-provided software to calculate all pay adjustment factors for the lot. Sublot samples may be discarded after the Engineer and Contractor sign off on the pay adjustment summary documentation for the lot.

Use the procedures described in Tex-233-F to plot the results of all quality control (QC) and quality assurance (QA) testing. Update the control charts as soon as test results for each sublot become available. Make the control charts readily accessible at the field laboratory. The Engineer may suspend production for failure to update control charts.

C. QCP. Develop and follow the QCP in detail. Obtain approval from the Engineer for changes to the QCP made during the project. The Engineer may suspend operations if the Contractor fails to comply with the QCP.

Submit a written QCP to the Engineer before the mandatory prepaving meeting. Receive the Engineer's approval of the QCP before beginning production. Include the following items in the QCP.

1. **Project Personnel.** For project personnel, include:
   - a list of individuals responsible for QC with authority to take corrective action and
   - contact information for each individual listed.
2. **Material Delivery and Storage.** For material delivery and storage, include:
   - the sequence of material processing, delivery, and minimum quantities to assure continuous

plant operations;

- aggregate stockpiling procedures to avoid contamination and segregation;
- frequency, type, and timing of aggregate stockpile testing to assure conformance of material requirements before mixture production; and
- procedure for monitoring the quality and variability of asphalt binder.

3. **Production.** For production, include:
   - loader operation procedures to avoid contamination in cold bins,
   - procedures for calibrating and controlling cold feeds,
   - procedures to eliminate debris or oversized material,
   - procedures for adding and verifying rates of each applicable mixture component (e.g., aggregate, asphalt binder, RAP, lime, liquid antistrip),
   - procedures for reporting job control test results, and
   - procedures to avoid segregation and drain-down in the silo.
4. **Loading and Transporting.** For loading and transporting, include:
   - type and application method for release agents and
   - truck loading procedures to avoid segregation.
5. **Placement and Compaction.** For placement and compaction, include:
   - proposed agenda for mandatory prepaving meeting including date and location;
   - type and application method for release agents in the paver and on rollers, shovels, lutes, and other utensils;
   - procedures for the transfer of mixture into the paver while avoiding segregation and preventing material spillage;
   - process to balance production, delivery, paving, and compaction to achieve continuous placement operations;
   - paver operations (e.g., operation of wings, height of mixture in auger chamber) to avoid physical and thermal segregation and other surface irregularities; and
   - procedures to construct quality longitudinal and transverse joints.

D. Mixture Design.

1. **Design Requirements.** Unless otherwise shown on the plans, use the SMA or SMAR design procedures given in Tex-204-F, Part VI or Part VII, to design a mixture meeting the requirements listed in Tables 1, 2, 3, 6, 7, and 8. Use an approved laboratory to perform the Hamburg Wheel test and provide results with the mixture design or provide the laboratory mixture and request that the Department perform the Hamburg Wheel test. The Construction Division maintains a list of approved laboratories. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel test results on the laboratory mixture design.

   The Contractor may submit a new mixture design at any time during the project. The Engineer will approve all mixture designs before the Contractor can begin production. When shown on the plans, the Engineer will provide the mixture design.

   The design number of gyrations (N^{des}) may be increased from 75 to 100 when allowed by the Engineer.

   Provide the Engineer with a mixture design report using Department-provided software. Include the following items in the report:
   - the combined aggregate gradation, source, specific gravity, and percent of each material used;
   - results of all applicable tests;
   - the mixing and molding temperatures;
   - the signature of the Level II person or persons that performed the design;
   - the date the mixture design was performed; and
   - a unique identification number for the mixture design.

Table 6
Master Gradation Bands (% Passing by Weight or Volume)
and Volumetric Properties

Sieve Size	SMA-C Coarse	SMA-D Medium	SMA-F Fine	SMAR-C Coarse	SMAR-F Fine
3/4"	100.0	100.0	100.0	100.0	100.0
1/2"	80.0–90.0	85.0–99.0	100.0	72.0–85.0	100.0
3/8"	25.0–60.0	50.0–75.0	70.0–90.0	50.0–70.0	95.0– 100.0
#4	20.0–28.0	20.0–32.0	30.0–50.0	30.0–45.0	40.0–50.0
#8	14.0–20.0	16.0–28.0	20.0–30.0	17.0–27.0	17.0–27.0
#16	8.0–20.0	8.0–28.0	8.0–30.0	12.0–22.0	12.0–22.0
#30	8.0–20.0	8.0–28.0	8.0–30.0	8.0–20.0	8.0–20.0
#50	8.0–20.0	8.0–28.0	8.0–30.0	6.0–15.0	6.0–15.0
#200	8.0–12.0	8.0–12.0	8.0–14.0	5.0–9.0	5.0–9.0
Design VMA[1], % Minimum					
	17.5	17.5	17.5	19.0	19.0
Plant-Produced VMA[1], % Minimum					
	17.0	17.0	17.0	18.5	18.5

1. Voids in mineral aggregates.

Table 7
Laboratory Mixture Design Properties

Mixture Property	Minimum		Maximum		Test
	SMA Mix	SMAR Mix	SMA Mix	SMAR Mix	Procedure
Design gyrations, N_{des}	75	75	75	75	–
Target laboratory-molded density, %	96.0	97.0	96.0	97.0	Tex-207-F
Asphalt binder content[1], %	6.0	7.0	–	10.0	–
Drain-down, %	–	–	0.20	0.20	Tex-235-F
Fiber content, % by wt. of total mixture	0.20	–	0.50	--	Calculated
CRM content, % by wt. of A-R binder	–	15.0	–	–	Calculated
Hamburg Wheel test[2], rut depth @ 20,000 passes tested @ 122ºF, in.	–	–	0.50	0.50	Tex-242-F
Tensile strength (dry), psi (molded to 93% ±1% density)	85	85	200[3]	200	Tex-226-F

Boil test[4] Tex-530-C

1. When SMA mix cannot be designed with a minimum asphalt content of 6.0%, using the available aggregates, follow the guidelines in Table 8 to establish a minimum asphalt content requirement based on the combined aggregate bulk specific gravity.
2. For SMAR mixes, the number of passes required for the Hamburg Wheel test may be decreased. Other tests may be required for SMAR mixes instead of or in addition to the Hamburg Wheel test, when shown on the plans.
3. May exceed 200 psi when approved and may be waived when approved.
4. Used to establish baseline for comparison to production results. May be waived when approved.

Table 8
Guide to Adjust Minimum Asphalt Content
Based on Bulk Specific Gravity of Aggregates

Combined Aggregate Bulk Specific Gravity	Minimum Asphalt Content %
δ 2.75	6.0
2.80	5.9
2.85	5.8
2.90	5.7
2.95	5.6
3.00	5.5

2. Job-Mix Formula Approval. The job-mix formula (JMF) is the combined aggregate gradation and target asphalt percentage used to establish target values for hot mix production. JMF1 is the original laboratory mixture design used to produce the trial batch. The Engineer and the Contractor will verify JMF1 based on plant-produced mixture from the trial batch unless otherwise approved. The Engineer may accept an existing mixture design previously used on a Department project and may waive the trial batch to verify JMF1.

a. Contractor's Responsibilities.

(1) Providing Superpave Gyratory Compactor. Furnish a Superpave gyratory compactor (SGC), calibrated in accordance with Tex-241-F, for molding production samples. Locate the SGC at the Engineer's field laboratory and make the SGC available to the Engineer for use in molding production samples.

(2) Gyratory Compactor Correlation Factors. Use Tex-206-F, Part II, to perform a gyratory compactor correlation when the Engineer uses a different SGC. Apply the correlation factor to all subsequent production test results.

(3) Submitting JMF1. Furnish the Engineer a mix design report (JMF1) and request approval to produce the trial batch. If opting to have the Department perform the Hamburg Wheel test on the laboratory mixture, provide the Engineer with approximately 10,000 g of the design mixture and request that the Department perform the Hamburg Wheel test.

(4) Supplying Aggregates. Provide the Engineer with approximately 40 lb. of each aggregate stockpile unless otherwise directed.

(5) Supplying Asphalt. Provide the Engineer at least 1 gal. of the asphalt material and sufficient quantities of any additives proposed for use.

(6) Ignition Oven Correction Factors. Determine the aggregate and asphalt correction factors from the ignition oven using Tex-236-F. Provide the Engineer with split samples of the mixtures and blank samples used to determine the correction factors.

(7) Boil Test. Perform the test and retain the tested sample from Tex-530-C. Use this sample for comparison purposes during production. The Engineer may waive the requirement for the boil test.

(8) Trial Batch Approval. Upon receiving conditional approval of JMF1 from the Engineer, provide a plant-produced trial batch for verification testing of JMF1 and development of JMF2.

(9) Trial Batch Production Equipment. To produce the trial batch, use only equipment and materials proposed for use on the project.

(10) Trial Batch Quantity. Produce enough quantity of the trial batch to ensure that the mixture is representative of JMF1.

(11) Number of Trial Batches. Produce trial batches as necessary to obtain a mixture that meets the requirements in Table 9.

(12) Trial Batch Sampling. Obtain a representative sample of the trial batch and split it into 3 equal portions in accordance with Tex-222-F. Label these portions as "Contractor," "Engineer," and "Referee." Deliver samples to the appropriate laboratory as directed.

(13) Trial Batch Testing. Test the trial batch to ensure the mixture produced using the proposed JMF1 meets the verification testing requirements for gradation, asphalt content, laboratory-molded density, and VMA listed in Table 9 and is in compliance with the Hamburg Wheel test requirement in Table 7. Use a Department-approved laboratory to perform the Hamburg Wheel test on the trial batch mixture or request that the Department perform the Hamburg Wheel test. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel test results on the trial batch. Provide the Engineer with a copy of the trial batch test results.

(14) Development of JMF2. After the Engineer grants full approval of JMF1 based on results from the trial batch, evaluate the trial batch test results, determine the optimum mixture proportions, and submit as JMF2.

(15) Mixture Production. After receiving approval for JMF2 and receiving a passing result from the Department's or a Department-approved laboratory's Hamburg Wheel test on the trial batch, use JMF2 to produce Lot 1 as described in Section 346.4.I.3.a(1), "Lot 1 Placement." As an option, once JMF2 is approved, proceed to Lot 1 production at the Contractor's risk without receiving the results from the Department's Hamburg Wheel test on the trial batch.

If electing to proceed without Hamburg Wheel test results from the trial batch, notify the Engineer. Note that the Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test be removed and replaced at the Contractor's expense.

(16) Development of JMF3. Evaluate the test results from Lot 1, determine the optimum mixture proportions, and submit as JMF3 for use in Lot 2.

(17) JMF Adjustments. If necessary, adjust the JMF before beginning a new lot. The adjusted JMF must:

- be provided to the Engineer in writing before the start of a new lot,
- be numbered in sequence to the previous JMF,
- meet the master gradation limits shown in Table 6, and
- be within the operational tolerances of JMF2 listed in Table 9.

(18) Requesting Referee Testing. If needed, use referee testing in accordance with Section 346.4.I.1, "Referee Testing," to resolve testing differences with the Engineer.

Table 9
Operational Tolerances

Description	Test Method	Allowable Difference from Current JMF Target	Allowable Difference Between Contractor and Engineer[1]
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	±5.0[2]	±5.0
Individual % retained for sieves smaller than #8 and larger than #200		±3.0[2]	±3.0
% passing the #200 sieve		±2.0[2]	±1.6
Binder content, %	Tex-236-F	±0.3[3]	±0.3
Laboratory-molded density, %	Tex-207-F	±1.0	±0.5
In-Place air voids, %		N/A	±1.0
Laboratory-molded bulk specific gravity		N/A	±0.020
VMA, % Min		Note 4	Note 4
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	±0.020
Drain-down	Tex-235-F	Note 4	Note 4

1. Contractor may request referee testing only when values exceed these tolerances.
2. When within these tolerances, mixture production gradations may fall outside the master grading limits; however, the % passing the #200 will be considered out of tolerance when outside the master grading limits.
3. Tolerance between JMF1 and JMF2 may exceed ±0.3%.
4. Test and verify that Table 6 requirements are met.

b. Engineer's Responsibilities.

(1) Gyratory Compactor. The Engineer will use a Department SGC, calibrated according to Tex-241-F, to mold samples for laboratory mixture design verification. For molding trial

batch and production specimens, the Engineer will use the Contractor-provided SGC at the field laboratory or provide and use a Department SGC at an alternate location. The Engineer will make the Contractor-provided SGC in the Department field laboratory available to the Contractor for molding verification samples.

(2) Conditional Approval of JMF1. Within 2 working days of receiving the mixture design report (JMF1) and all required materials and Contractor-provided Hamburg Wheel test results, the Engineer will review the Contractor's mix design report and verify conformance with all aggregates, asphalt, additives, and mixture specifications. The Engineer may perform tests to verify the aggregates meet the requirements listed in Table 1. The Engineer will grant the Contractor conditional approval of JMF1 if the information provided on the paper copy of JMF1 indicates the Contractor's mixture design meets the specifications. When the Contractor does not provide Hamburg Wheel test results with laboratory mixture design, a total of 10 working days is allowed for conditional approval of JMF1. Full approval of JMF1 will be based on the Engineer's test results on mixture from the trial batch.

(3) Hamburg Wheel Testing of JMF1. If the Contractor requests the option to have the Department perform the Hamburg Wheel test on the laboratory mixture, the Engineer will mold samples in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 7.

(4) Authorizing Trial Batch. After conditionally approving JMF1, which will include either Contractor- or Department-supplied Hamburg Wheel test results, the Engineer will authorize the Contractor to produce a trial batch.

(5) Ignition Oven Correction Factors. The Engineer will use the split samples provided by the Contractor to determine the aggregate and asphalt correction factors for the ignition oven in accordance with Tex-236-F.

(6) Testing the Trial Batch. Within 1 full working day, the Engineer will sample and test the trial batch to ensure that the gradation, asphalt content, laboratory-molded density, and VMA meet the requirements listed in Table 9. If the Contractor requests the option to have the Department perform the Hamburg Wheel test on the trial batch mixture, the Engineer will mold samples in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 7.

The Engineer will have the option to perform the following tests on the trial batch:

- Tex-226-F to verify that the indirect tensile strength meets the requirement shown in Table 7,
- Tex-461-A to determine the need for additional magnesium sulfate soundness testing, and
- Tex-530-C to retain and use for comparison purposes during production.

(7) Full Approval of JMF1. The Engineer will grant full approval of JMF1 and authorize the Contractor to proceed with developing JMF2 if the Engineer's results for gradation, asphalt content, laboratory-molded density, and VMA confirm that the trial batch meets the requirements in Table 9.

The Engineer will notify the Contractor that an additional trial batch is required if the trial batch does not meet the requirements in Table 9.

(8) Approval of JMF2. The Engineer will approve JMF2 within 1 working day if it meets the master grading limits shown in Table 6 and is within the operational tolerances of JMF1 listed in Table 9.

(9) Approval of Lot 1 Production. The Engineer will authorize the Contractor to proceed with Lot 1 production as soon as a passing result is achieved from the Department's or an approved laboratory's Hamburg Wheel test on the trial batch. As an option, the Contractor may at their own risk, proceed with Lot 1 production without the results from the Hamburg Wheel test on the trial batch.

If the Department's or Department-approved laboratory's sample from the trial batch fails the Hamburg Wheel test, the Engineer will suspend production until further

Hamburg Wheel tests meet the specified values. The Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test to be removed and replaced at the Contractor's expense.

(10) Approval of JMF3. The Engineer will approve JMF3 within 1 working day if it meets the master grading limits shown in Table 6 and is within the operational tolerances of JMF2 listed in Table 9.

E. Production Operations. Perform a new trial batch when the plant or plant location is changed. Take corrective action and receive approval to proceed after any production suspension for noncompliance to the specification.

1. **Storage and Heating of Materials.** Do not heat the asphalt binder above the temperatures specified in Item 300, "Asphalts, Oils, and Emulsions" or outside the manufacturer's recommended values. On a daily basis, provide the Engineer with the records of asphalt binder and hot-mix asphalt discharge temperatures in accordance with Item 320, "Equipment for Hot-Mix Asphalt Materials." Unless otherwise approved, do not store mixture for a period long enough to affect the quality of the mixture, nor in any case longer than 12 hr.

2. **Mixing and Discharge of Materials.** Notify the Engineer of the target discharge temperature and produce the mixture within 25°F of the target. Monitor the temperature of the material in the truck before shipping to ensure that it does not exceed 350°F. The Department will not pay for or allow placement of any mixture produced at more than 350°F.

   Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. If requested, determine the moisture content by oven-drying in accordance with Tex-212-F, Part II, and verify that the mixture contains no more than 0.2% of moisture by weight. Obtain the sample immediately after discharging the mixture into the truck, and perform the test promptly.

F. Hauling Operations. Before use, clean all truck beds to ensure mixture is not contaminated. When a release agent is necessary, use a release agent on the approved list maintained by the Construction Division to coat the inside bed of the truck.

G. Placement Operations. Prepare the surface by removing raised pavement markers and objectionable material such as moisture, dirt, sand, leaves, and other loose impediments from the surface before placing mixture. Remove vegetation from pavement edges. Place the mixture to meet the typical section requirements and produce a smooth, finished surface with a uniform appearance and texture. Offset longitudinal joints of successive courses of hot mix by at least 6 in. Place mixture so longitudinal joints on the surface course coincide with lane lines, or as directed. Ensure that all finished surfaces will drain properly. Place mixture within the compacted lift thickness shown in Table 10 unless otherwise shown on the plans or allowed.

Table 10
Compacted Lift Thickness and Required Core Height

Mixture Type	Compacted Lift Thickness		Minimum Untrimmed Core Height (in.) Eligible for Testing
	Minimum (in.)	Maximum (in.)	
SMA-C	2.25	4.00	2.00
SMA-D	1.50	3.00	1.25
SMA-F	1.25	2.50	1.25
SMAR-C	2.00	4.00	1.75
SMAR-F	1.50	3.00	1.25

1. **Weather Conditions.** Place mixture when the roadway surface temperature is 70°F or higher unless otherwise approved. Measure the roadway surface temperature with a handheld infrared thermometer. Unless otherwise shown on the plans, place mixtures only when weather conditions and moisture conditions of the roadway surface are suitable in the opinion of the Engineer.

2. **Tack Coat.** Clean the surface before placing the tack coat. Unless otherwise approved, apply tack coat uniformly at the rate directed by the Engineer. The Engineer will set the rate between 0.04 and 0.10 gal. of residual asphalt per square yard of surface area. Apply a thin, uniform tack coat to all contact surfaces of curbs, structures, and all joints. Prevent splattering of tack coat when placed

adjacent to curb, gutter, and structures. Roll the tack coat with a pneumatic-tire roller when directed. The Engineer may use Tex-243-F to verify that the tack coat has adequate adhesive properties. The Engineer may suspend paving operations until there is adequate adhesion.

3. **Lay-Down Operations.** Use the guidelines in Table 11 to establish the temperature of mixture delivered to the paver. Record the information on Department QC/QA forms and submit the forms to the Engineer.

   a. **Thermal Profile.** For each sublot, obtain a thermal profile using Tex-244-F. The Engineer may reduce the testing frequency based on a satisfactory test history. The Engineer may also obtain as many thermal profiles as deemed necessary. If the temperature differential is greater than 25°F, the area will be deemed as having thermal segregation. Evaluate areas with thermal segregation by performing a density profile in accordance with Section 346.4.I.3.c(2), "Segregation (Density Profile)." Take corrective action to eliminate areas that have thermal segregation. Unless otherwise directed, suspend operations if the maximum temperature differential exceeds 50°F. Resume operations when the Engineer determines that subsequent production will meet the specifications.

   b. **Windrow Operations.** When hot mix is placed in windrows, operate windrow pickup equipment so that substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

Table 11
Suggested Minimum Mixture Placement Temperature

High-Temperature Binder Grade	Minimum Placement Temperature (Before Entering Paver)
PG 76 and A-R	280°F
PG 82 or higher	290°F

H. Compaction. Uniformly compact the pavement to the density requirements of the specification. Use the control strip method given in Tex-207-F, Part IV, to establish the rolling pattern. Do not use pneumatic-tire rollers if excessive pickup of fines by roller tires occurs. Unless otherwise directed, use only water or an approved release agent on rollers, tamps, and other compaction equipment.

Where specific air void requirements are waived, furnish and operate compaction equipment as approved. Use tamps to thoroughly compact the edges of the pavement along curbs, headers, and similar structures and in locations that will not allow thorough compaction with rollers. The Engineer may require rolling with a trench roller on widened areas, in trenches, and in other limited areas.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic unless otherwise directed. When directed, sprinkle the finished mat with water or limewater to expedite opening the roadway to traffic.

I. Acceptance Plan. Sample and test the hot mix on a lot and sublot basis. If the production pay factor for 3 consecutive lots or the placement pay factor for 3 consecutive lots is below 1.000, suspend production until test results or other information indicate, to the satisfaction of the Engineer, that the next material produced or placed will meet the specified values. Pay adjustments for the material will be in accordance with Article 346.6, "Payment."

1. **Referee Testing.** The Construction Division is the referee laboratory. The Contractor may request referee testing if a "remove and replace" condition is determined based on the Engineer's test results, or if the differences between Contractor and Engineer test results exceed the maximum allowable difference shown in Table 9 and the differences cannot be resolved. Make the request within 5 working days after receiving test results and cores from the Engineer. Referee tests will be performed only on the sublot in question and only for the particular test in question. Allow 10 working days from the time the samples are received at the referee laboratory for test results to be reported. The Department may require the Contractor to reimburse the Department for referee tests if more than 3 referee tests per project are required and the Engineer's test results are closer than the Contractor's test results to the referee test results.

   The Construction Division will determine the laboratory-molded density based on the molded specific gravity and the maximum theoretical specific gravity of the referee sample. The In-Place

air voids will be determined based on the bulk specific gravity of the cores, as determined by the referee laboratory, and the Engineer's average maximum theoretical specific gravity for the lot. With the exception of remove and replace conditions, referee test results are final and will establish pay adjustment factors for the sublot in question. Sublots subject to be removed and replaced will be further evaluated in accordance with Article 346.6, "Payment."

2. Production Acceptance.

a. Production Lot. A production lot consists of 4 equal sublots. Lot 1 will be 1,000 tons. The Engineer will select subsequent lot sizes based on the anticipated daily production. The lot size will be at least 1,000 tons, but no greater than 4,000 tons. The Engineer may change the lot size before the Contractor begins any lot.

(1) Small Quantity Production. When the anticipated daily production is less than 500 tons or the total production for the project is less than 5,000 tons, the Engineer may waive all quality control and quality assurance (QC/QA) sampling and testing requirements. If the Engineer waives QC/QA sampling and testing, both production and placement pay factors will be 1.000. However, the Engineer will retain the right to perform random acceptance tests for production and placement and may reject objectionable materials and workmanship.

When the Engineer waives all QC/QA sampling and testing requirements:

- produce, haul, place and compact the mixture as directed by the Engineer;
- control mixture production to yield a laboratory-molded density of 96.0% ±1.0% for SMA mixtures and 97.0% ±1.0% for SMAR mixtures if tested by the Engineer; and
- compact the mixture to yield In-Place air voids that are greater than or equal to 2.7% and less than or equal to 8.0% as tested by the Engineer.

(2) Incomplete Production Lots. If a lot is begun but cannot be completed, such as on the last day of production or in other circumstances deemed appropriate, the Engineer may close the lot. Adjust the payment for the incomplete lot in accordance with Section 346.6.A, "Production Pay Adjustment Factors."

b. Production Sampling.

(1) Mixture Sampling. At the beginning of the project, the Engineer will select random numbers for all production sublots. Determine sample locations in accordance with Tex-225-F.

Obtain hot mix samples from trucks at the plant in accordance with Tex-222-F. For each sublot, take 1 sample at the location randomly selected. For each lot, the Engineer will randomly select and test a "blind" sample from at least 1 sublot. The location of the Engineer's "blind" sample will not be disclosed to the Contractor. The Engineer will use the Contractor's split sample for sublots not sampled by the Engineer.

The sampler will split each sample into 3 equal portions in accordance with Tex-200-F, and label these portions as "Contractor," "Engineer," and "Referee." Deliver the samples to the appropriate party's laboratory. Deliver referee samples to the Engineer. Discard unused samples after accepting pay adjustment factors for that lot.

(2) Asphalt Binder Sampling. Obtain a 1-qt. (1-gal. for A-R binder) sample of the asphalt binder for each sublot of mixture produced. Obtain the sample at approximately the same time the mixture random sample is obtained. Sample from a port located immediately upstream from the mixing drum or pug mill. Take the sample in accordance with the pipeline sampling procedure given in Tex-500-C, Part II. Label the can with the corresponding lot and sublot numbers, and deliver the sample to the Engineer.

The Engineer may also obtain independent samples. If the Engineer chooses to obtain an independent asphalt binder sample, the Engineer will split a sample of the asphalt binder with the Contractor. The Engineer will test at least 1 asphalt binder sample per project to verify compliance with Item 300, "Asphalts, Oils, and Emulsions."

c. Production Testing. The Contractor and Engineer must perform production tests in accordance with Table 12. The Contractor has the option to verify the Engineer's test results on split samples provided by the Engineer. Determine compliance with operational tolerances

listed in Table 9 for all sublots.

At any time during production the Engineer may require the Contractor to verify the following based on quantities used:

- lime content (within ±0.1% of JMF), when PG binder is specified;
- fiber content (within ±0.03% of JMF), when PG binder is specified; and
- CRM content (within ±1.5% of JMF), when A-R binder is specified.

When A-R binder is specified, maintain the in-line measuring device to verify the A-R binder viscosity of at least 2,500 centipoise at 350°F unless otherwise approved.

If the aggregate mineralogy is such that Tex-236-F does not yield reliable results, the Engineer may allow alternate methods for determining the asphalt content and aggregate gradation. Unless otherwise allowed, the Engineer will require the Contractor to provide evidence that results from Tex-236-F are not reliable before permitting an alternate method. If an alternate test method is allowed, use the applicable test procedure as directed.

Table 12
Production and Placement Testing Frequency

Description	Test Method	Minimum Contractor Testing Frequency	Minimum Engineer Testing Frequency
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	1 per sublot	1 per 12 sublots
Individual % retained for sieves smaller than #8 and larger than #200 % passing the #200 sieve			
Laboratory-molded density VMA Laboratory-molded bulk specific gravity In-Place air voids	Tex-207-F	N/A	1 per sublot
Segregation (density profile)	Tex-207-F, Part V	1 per sublot	1 per project
Longitudinal joint density	Tex-207-F, Part VII		
Moisture content	Tex-212-F, Part II	When directed	
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	1 per sublot
Drain-down	Tex-235-F	1 per sublot	1 per 12 sublots
Asphalt content	Tex-236-F		1 per lot
Hamburg Wheel test	Tex-242-F	N/A	1 per project
Thermal profile	Tex-244-F	1 per sublot	
Asphalt binder sampling[1]	Tex-500-C	1 per sublot (sample only)	
Boil test[1]	Tex-530-C	1 per lot	

1. The Engineer may reduce or waive the sampling and testing requirements based on a satisfactory test history.

d. Operational Tolerances. Control the production process within the operational tolerances listed in Table 9. When production is suspended, the Engineer will allow production to resume when test results or other information indicates the next mixture produced will be within the operational tolerances.

(1) Gradation. Unless otherwise directed, suspend production when either the Contractor's or the Engineer's test results for gradation exceed the operational tolerances for 3 consecutive sublots on the same sieve or 4 consecutive sublots on any sieve. The consecutive sublots may be from more than 1 lot.

(2) Asphalt Content. No production or placement bonus will be paid for any lot that has 2 or more sublots within a lot that are out of operational tolerance for asphalt content based on either the

Contractor's or the Engineer's test results. Suspend production and shipment of mixture if the asphalt content deviates from the current JMF by more than 0.5% for any sublot.

(3) Fibers. Suspend production if fiber content varies from the design target value by more than 10% on 2 consecutive tests.

(4) Hamburg Wheel Test. The Engineer may perform a Hamburg Wheel test at any time during production including when the boil test indicates a change in quality from the materials submitted for JMF1. In addition to testing production samples, the Engineer may obtain cores and perform Hamburg Wheel tests on any area of the roadway where rutting is observed. When the production or core samples fail the Hamburg Wheel test criteria in Table 8, suspend production until further Hamburg Wheel tests meet the specified values. Core samples if taken will be obtained from the center of the finished mat or other areas excluding the vehicle wheel path. The Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test to be removed and replaced at the Contractor's expense.

If the Department's or Department-approved laboratory's Hamburg Wheel test results in a "remove and replace" condition, the Contractor may request the Department confirm the results by retesting the failing material. The Construction Division will perform the Hamburg Wheel tests and determine the final disposition of the material in question based on the Department's test results.

e. Individual Loads of Hot Mix. The Engineer can reject individual truckloads of hot mix. When a load of hot mix is rejected for reasons other than temperature, the Contractor may request that the rejected load be tested. Make this request within 4 hr. of rejection. The Engineer will sample and test the mixture. If test results are within the operational tolerances shown in Table 9, payment will be made for the load. If test results are not within operational tolerances, no payment will be made for the load and the Engineer may require removal.

3. Placement Acceptance.

a. Placement Lot. A placement lot consists of 4 placement sublots. A placement sublot consists of the area placed during a production sublot.

(1) Lot 1 Placement. Placement bonuses for Lot 1 will be in accordance with Section 346.6.B, "Placement Pay Adjustment Factors." However, no placement penalty will be assessed for any sublot placed in Lot 1, when the In-Place air voids are greater than or equal to 2.7% and less than or equal to 8.0%. Remove and replace any sublot with In-Place air voids less than 2.7% or greater than 8.0%.

(2) Incomplete Placement Lots. An incomplete placement lot consists of the area placed as described in Section 346.4.I.2.a(2), "Incomplete Production Lot," excluding miscellaneous areas as defined in Section 346.4.I.3.a(4), "Miscellaneous Areas." Placement sampling is required if the random sample plan for production resulted in a sample being obtained from an incomplete production sublot.

(3) Shoulders and Ramps. Shoulders and ramps are subject to In-Place air void determination and pay adjustments, unless otherwise shown on the plans.

(4) Miscellaneous Areas. Miscellaneous areas include areas that are not generally subject to primary traffic, such as driveways, mailbox turnouts, crossovers, gores, spot level-up areas, and other similar areas. Miscellaneous areas also include level-ups and thin overlays if the layer thickness designated on the plans is less than the compacted lift thickness shown in Table 10. Miscellaneous areas are not eligible for random placement sampling locations, and will receive a 1.000 placement pay factor. Compact areas that are not subject to In-Place air void determination in accordance with Section 346.4.H, "Compaction."

b. Placement Sampling. At the beginning of the project, the Engineer will select random numbers for all placement sublots. The Engineer will provide the Contractor with the placement random numbers immediately after the sublot is completed. Mark the roadway location at the completion of each sublot and record the station number. Determine 1 random sample location for each placement sublot in accordance with Tex-225-F. If the randomly generated sample location is within 2 ft. of a joint or pavement edge, adjust the location by no more than necessary to achieve a 2-ft. clearance.

Shoulders and ramps are always eligible for selection as a random sample location. However, if a random sample location falls on a shoulder or ramp that is designated on the plans as not subject to In-Place air void testing, cores will not be taken for the sublot and a 1.000 pay factor will be assigned to that sublot.

Unless otherwise determined, the Engineer will witness the coring operation and measurement of the core thickness. Unless otherwise approved, obtain the cores within 1 working day of the time the placement sublot is completed. Obtain two 6-in.-diameter cores side-by-side from within 1 ft. of the random location provided for the placement sublot. Mark the cores for identification. Visually inspect each core and verify that the current paving layer is bonded to the underlying layer. If an adequate bond does not exist between the current and underlying layer, take corrective action to insure that an adequate bond will be achieved during subsequent placement operations.

Immediately after obtaining the cores, dry the core holes and tack the sides and bottom. Fill the hole with the same type of mixture and properly compact the mixture. Repair core holes with other methods when approved.

If the core heights exceed the minimum untrimmed values listed in Table 10, trim and deliver the cores to the Engineer within 1 working day following placement operations unless otherwise approved.

If the core height before trimming is less than the minimum untrimmed value shown in Table 10, decide whether or not to include the pair of cores in the air void determination for that sublot. If the cores are to be included in air void determination, trim the cores before delivering to the Engineer. If the cores will not be included in air void determination, deliver untrimmed cores to the Engineer. The placement pay factor for the sublot will be 1.000 if cores will not be included in air void determination.

c. Placement Testing. Perform placement tests in accordance with Table 12. After the Engineer returns the cores, the Contractor has the option to test the cores to verify the Engineer's test results for in-place air voids. Re-dry the cores to constant weight before testing. The allowable differences between the Contractor's and Engineer's test results are listed in Table 9.

(1) In-Place Air Voids. The Engineer will measure in-place air voids in accordance with Tex-207-F and Tex-227-F. Before drying to a constant weight, cores may be predried using a Corelok or similar vacuum device to remove excess moisture. The Engineer will average the values obtained for all sublots in the production lot to determine the theoretical maximum specific gravity. The Engineer will use the average air void content of the 2 cores to calculate a placement pay adjustment factor.

The Engineer will use paraffin coating or vacuum methods to seal the core if required by Tex-207-F. The Engineer will use the test results from the unsealed core to determine the placement pay adjustment factor if the sealed core yields a higher specific gravity than the unsealed core. After determining the in-place air void content, the Engineer will return the cores and provide test results to the Contractor.

(2) Segregation (Density Profile). Test for segregation using density profiles in accordance with Tex-207-F, Part V. Provide the Engineer with the results of the density profiles as they are completed. Areas defined in Section 346.4.I.3.a(4), "Miscellaneous Areas," are not subject to density profile testing.

Unless otherwise approved, perform a density profile every time the screed stops, on areas that are identified by either the Contractor or the Engineer as having thermal segregation, and on any visibly segregated areas. If the screed does not stop, and there are no visibly segregated areas or areas that are identified as having thermal segregation, perform a minimum of 1 profile per sublot. Reduce the test frequency to a minimum of 1profile per lot if 4 consecutive profiles are within established tolerances. Continue testing at a minimum frequency of 1 per lot unless a profile fails, at which point resume testing at a minimum frequency of 1 per sublot. The Engineer may further reduce the testing frequency based on a consistent pattern of satisfactory results.

The density profile is considered failing if it exceeds the tolerances in Table 13. No production or placement bonus will be paid for any sublot that contains a failing density profile. The Engineer

may make as many independent density profile verifications as deemed necessary. The Engineer's density profile results will be used when available.

Investigate density profile failures and take corrective actions during production and placement to eliminate the segregation. Suspend production if 2 consecutive density profiles fail, unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

Table 13
Segregation (Density Profile) Acceptance Criteria

Mixture Type	Maximum Allowable Density Range (Highest to Lowest)	Maximum Allowable Density Range (Average to Lowest)
SMA-C & SMAR-C	8.0 pcf	5.0 pcf
SMA-D, SMA-F & SMA-F	6.0 pcf	3.0 pcf

(3) Longitudinal Joint Density.

(a) Informational Tests. While establishing the rolling pattern, perform joint density evaluations and verify that the joint density is no more than 3.0 pcf below the density taken at or near the center of the mat. Adjust the rolling pattern if needed to achieve the desired joint density. Perform additional joint density evaluations at least once per sublot unless otherwise directed.

(b) Record Tests. For each sublot, perform a joint density evaluation at each pavement edge that is or will become a longitudinal joint. Determine the joint density in accordance with Tex-207-F, Part VII. Record the joint density information and submit results, on Department forms, to the Engineer. The evaluation is considered failing if the joint density is more than 3.0 pcf below the density taken at the core random sample location and the correlated joint density is less than 90.0%. The Engineer may make independent joint density verifications at the random sample locations. The Engineer's joint density test results will be used when available.

Investigate joint density failures and take corrective actions during production and placement to improve the joint density. Suspend production if 2 consecutive evaluations fail unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

(4) Recovered Asphalt DSR. The Engineer may take production samples or cores from suspect areas of the project to determine recovered asphalt properties. Asphalt binders with an aging ratio greater than 3.5 do not meet the requirements for recovered asphalt properties and may be deemed defective when tested and evaluated by the Construction Division. The aging ratio is the dynamic shear rheometer (DSR) value of the extracted binder divided by the DSR value of the original unaged binder (including RAP binder). DSR values are obtained according to AASHTO T 315 at the specified high temperature PG of the asphalt. The binder from RAP will be included proportionally as part of the original unaged binder. The Engineer may require removal and replacement of the defective material at the Contractor's expense. The asphalt binder will be recovered for testing from production samples or cores using Tex-211-F.

(5) Irregularities. Immediately take appropriate corrective action if surface irregularities, including but not limited to segregation, rutting, raveling, flushing, fat spots, mat slippage, color, texture, roller marks, tears, gouges, streaks, or uncoated aggregate particles are detected. The Engineer may allow placement to continue for at most 1 day of production while taking appropriate action. If the problem still exists after that day, suspend paving until the problem is corrected to the satisfaction of the Engineer.

At the expense of the Contractor and to the satisfaction of the Engineer, remove and replace any mixture that does not bond to the existing pavement or has other surface irregularities identified above.

4. Ride Quality. Unless otherwise shown on the plans, measure ride quality in accordance with Item 585, "Ride Quality for Pavement Surfaces."

346.5. Measurement. Hot mix will be measured by the ton of composite hot mix. The composite hot mix is the asphalt, aggregate, and additives. Measure on scales in accordance with Item 520, "Weighing and Measuring Equipment."

346.6. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under Article 346.5, "Measurement," will be paid for at the unit bid price for "Stone Matrix Asphalt," of the mixture type, surface aggregate classification, and binder specified. Pay adjustments for bonuses and penalties will be applied as determined in this Item. These prices are full compensation for surface preparation, materials including tack coat, placement, equipment, labor, tools, and incidentals.

Trial batches will not be paid for unless they are included in pavement work approved by the Department. Pay adjustment for ride quality will be determined in accordance with Item 585, "Ride Quality for Pavement Surfaces."

A. Production Pay Adjustment Factors. The production pay adjustment factor is based on the laboratory-molded density using the Engineer's test results. A pay adjustment factor will be determined from Table 14 for each sublot using the deviation from the target laboratory-molded density defined in Table 7. The production pay adjustment factor for completed lots will be the average of the pay adjustment factors for the 4 sublots sampled within that lot.

Table 14
Production Pay Adjustment Factors for Laboratory-Molded Density

Absolute Deviation from Target Laboratory-Molded Density	Production Pay Adjustment Factor
0.0	1.100
0.1	1.100
0.2	1.100
0.3	1.086
0.4	1.075
0.5	1.063
0.6	1.050
0.7	1.038
0.8	1.025
0.9	1.013
1.0	1.000
1.1	0.900
1.2	0.800
1.3	0.700
> 1.3	Remove and replace

1. **Incomplete Production Lots.** Production pay adjustments for incomplete lots, described under Section 346.4.I.2.a(2), "Incomplete Production Lots," will be calculated using the average production pay factors from all sublots sampled. A production pay factor of 1.000 will be assigned to any lot when the random sampling plan did not result in collection of any samples.
2. **Production Sublots Subject to Removal and Replacement.** If after referee testing, the laboratory-molded density for any sublot results in a "remove and replace" condition as listed in Table 14, the Engineer may require removal and replacement, or may allow the sublot to be left in place without payment. Replacement material meeting the requirements of this Item will be paid for in accordance with this Article.

B. Placement Pay Adjustment Factors. The placement pay adjustment factor is based on in-place air voids using the Engineer's test results. A pay adjustment factor will be determined from Table 15 for each sublot that requires in-place air void measurement. A placement pay adjustment factor of 1.000 will be assigned to the entire sublot when the random sample location falls in an area on a ramp or shoulder not subject to in-place air void testing. A placement pay adjustment factor of 1.000 will be assigned to quantities placed in miscellaneous areas as described in Section 346.4.I.3.a(4), "Miscellaneous Areas." The placement pay adjustment factor for completed lots will be the average of the placement pay adjustment factors for the 4 sublots within that lot.

Table 15
Placement Pay Adjustment Factors for In-Place Air Voids

In-Place Air Voids	Placement Pay Adjustment Factor	In-Place Air Voids	Placement Pay Adjustment Factor
< 2.7	Remove and Replace	5.4	1.030
2.7	0.700	5.5	1.025
2.8	0.740	5.6	1.020
2.9	0.780	5.7	1.015
3.0	0.820	5.8	1.010
3.1	0.860	5.9	1.005
3.2	0.900	6.0	1.000
3.3	0.940	6.1	0.985
3.4	0.980	6.2	0.970
3.5	1.020	6.3	0.955
3.6	1.060	6.4	0.940
3.7	1.100	6.5	0.925
3.8	1.100	6.6	0.910
3.9	1.100	6.7	0.895
4.0	1.100	6.8	0.880
4.1	1.095	6.9	0.865
4.2	1.090	7.0	0.850
4.3	1.085	7.1	0.835
4.4	1.080	7.2	0.820
4.5	1.075	7.3	0.805
4.6	1.070	7.4	0.790
4.7	1.065	7.5	0.775
4.8	1.060	7.6	0.760
4.9	1.055	7.7	0.745
5.0	1.050	7.8	0.730
5.1	1.045	7.9	0.715
5.2	1.040	8.0	0.700
5.3	1.035	> 8.0	Remove and Replace

1. **Incomplete Placement Lots.** Pay adjustments for incomplete placement lots described under Section 346.4.I.3.a(2), "Incomplete Placement Lots," will be calculated using the average of the placement pay factors from all sublots sampled and sublots where the random location falls in an area on a ramp or shoulder not eligible for testing. A placement pay adjustment factor of 1.000 will be assigned to any lot when the random sampling plan did not result in collection of any samples.

2. **Placement Sublots Subject to Removal and Replacement.** If after referee testing the placement pay adjustment factor for any sublot results in a "remove and replace" condition as listed in Table 15, the Engineer will choose the location of 2 cores to be taken within 3 ft. of the original failing core location. The Contractor will obtain the cores in the presence of the Engineer. The Engineer will submit the cores to the Materials and Pavements Section of the Construction Division where they will be tested for bulk specific gravity within 10 working days of receipt. The average bulk specific gravity of the cores will be divided by the Engineer's average maximum theoretical specific gravity for that lot to determine the new pay adjustment factor of the sublot in question. If the new pay adjustment factor is 0.700 or greater, then the new pay adjustment factor will apply to that sublot. If the new pay adjustment factor is less than 0.700, no payment will be made for the sublot. Remove and replace the failing sublot. Replacement material must meet the requirements of this specification with payment made accordingly.

C. Total Adjustment Pay Calculation. Total adjustment pay (TAP) will be based on the applicable pay adjustment factors for production and placement of each lot.

$$TAP = (A + B)/2$$

where:

A = Bid price × production lot quantity × average pay adjustment factor for the production lot
B = Bid price × placement lot quantity × average pay adjustment factor for the placement lot + (bid price × miscellaneous quantities × 1.000)

Appendix P: Texas Asphalt Rubber Chip Seal Specifications

ITEM 318

HOT ASPHALT-RUBBER SURFACE TREATMENTS

318.1. Description.
Construct a surface treatment consisting of 1 or more applications of a single layer of hot asphalt-rubber (A-R) binder covered with a single layer of aggregate.

318.2. Materials.

A. Asphalt-Rubber Binder. Furnish Type II or Type III A-R binder in accordance with Section 300.2.I, "Asphalt-Rubber Binders," as shown on the plans. Furnish a blend design for approval. Include in the design, at a minimum, the following:

- manufacturer and grade of asphalt cement;
- manufacturer and grade of crumb rubber;
- manufacturer, type, and percentage of extender oil, if used;
- test report on crumb rubber gradation in accordance with Tex-200-F, Part I;
- design percentage of crumb rubber versus asphalt content;
- blending temperature; and
- test results on the properties at reaction times of 60, 90, 240, 360, and 1,440 min. in accordance with Section 300.2.I, "Asphalt-Rubber Binders."

Furnish a new blend design if the grade or source for any of the components changes.

B. Tack Coat. Unless otherwise shown on the plans or approved, furnish CSS-1H, SS-1H, or a performance grade (PG) binder with a minimum high temperature grade of PG 58 for tack coat binder in accordance with Item 300, "Asphalts, Oils, and Emulsions." Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use. If required, verify that emulsified asphalt proposed for use meets the minimum residual asphalt percentage specified in Item 300.

C. Aggregate. Furnish aggregate meeting Item 302, "Aggregates for Surface Treatments," of the type and grade shown on plans. For final surfaces, unless otherwise shown on the plans, furnish aggregate with a minimum B surface aggregate classification.

318.3. Equipment.

A. Distributor. Furnish a distributor calibrated in accordance with Article 316.3, "Equipment," capable of keeping the rubber in uniform suspension and adequately mixing the asphalt, rubber, and any additional additives. If equipped with an onboard scale system or micro-motion meters for proportioning or payment, they must weigh or measure the load within a 0.4% accuracy in accordance with Item 520, "Weighing and Measuring Equipment."

B. Aggregate Spreader. Use a continuous-feed, self-propelled spreader to apply aggregate uniformly at the specified rate or as directed.

C. Rollers. Unless otherwise shown on the plans, furnish medium pneumatic rollers in accordance with Item 210, "Rolling."

D. Broom. Furnish rotary self-propelled power brooms.

E. Asphalt Storage and Handling Equipment. Furnish a recording thermometer in each tank to indicate the asphalt temperature continuously. Keep equipment clean and free of leaks.

F. Hot Asphalt-Rubber Blending and Storage Equipment. Provide a mechanical blender for proper proportioning and thorough mixing of the asphalt and rubber. Use proportioning, weighing, and measuring devices meeting the requirements of Item 520, "Weighing and Measuring Equipment." If an A-R binder storage tank is used, equip it with:

- a heating system to maintain the proper temperature of the binder,
- recording thermometer in each tank to indicate the asphalt-rubber binder temperature continuously,
- an internal mixing unit capable of maintaining a homogeneous mixture of asphalt and rubber, and

- a sampling port.

Keep A-R binder free of contamination.

G. Aggregate Haul Trucks. Unless otherwise authorized, use trucks of uniform capacity to deliver the aggregate. Provide documentation showing measurements and calculation in cubic yards. Clearly mark the calibrated level. Truck size may be limited when shown on the plans.

H. Digital Measuring Instrument. Furnish a vehicle with a calibrated, digital measuring instrument, accurate to ±6 ft. per mile.

I. Truck Scales. Provide standard platform scales in accordance with Item 520, "Weighing and Measuring Equipment." Truck scales will not be required if the distributor has an adequate calibrated scale system.

J. Aggregate Heating System. If required, furnish a heating system that will:

- heat aggregate to the specified temperature,
- not damage aggregate,
- not leave fuel residue on heated aggregate, and
- provide a continuous recording thermometer to indicate aggregate temperature as it leaves the system.

318.4. Construction.

A. General. Asphalt application season will be as shown on the plans. Asphalt and aggregate rates shown on the plans are for estimating purposes only. The Engineer will adjust the rates for the existing conditions.

B. Temporary Aggregate Stockpile. The Engineer will approve the location of temporary aggregate stockpiles on the right of way before delivery. Place stockpiles in a manner that will not:

- obstruct traffic or sight distance,
- interfere with the access from abutting property, or
- interfere with roadway drainage.

Locate stockpiles a minimum of 30 ft. from the roadway when possible. Sign and barricade as shown on the plans.

C. Department-Furnished Aggregate. When shown on the plans, the Department will furnish aggregate to the Contractor without cost. Stockpile locations will be shown on the plans.

D. Adverse Weather Conditions. Do not place hot asphalt-rubber surface treatment when, in the Engineer's opinion, general weather conditions are unsuitable. Apply surface treatment when the air temperature is 80°F and above, or above 70°F and rising. In all cases, do not apply surface treatment when surface temperature is below 70°F.

E. Mixing Hot A-R Binder. Mix in accordance with the approved blend design required in Section 318.2.A, "Asphalt-Rubber Binder."

At the end of each shift, provide the Engineer with production documentation, which includes the following:

- amount and temperature of asphalt cement before addition of rubber,
- amount of rubber and any extender added,
- viscosity of each hot A-R batch just before roadway placement, and
- time of the rubber additions and viscosity tests.

F. Surface Preparation. Remove existing raised pavement markers in accordance with the plans. Remove dirt, dust, or other harmful material. When directed by the Engineer, apply a tack coat before applying the hot asphalt-rubber treatment on an existing wearing surface in accordance with Section 340.4.G.2, "Tack Coat."

G. Rock Land and Shot.

1. Definitions.

- A "rock land" is the area covered at the aggregate rate, as directed, with 1 truckload of aggregate.
- A "shot" is the area covered by 1 distributor load of asphalt material.

2. Setting Lengths. Calculate the lengths of each. Adjust shot length to be an even multiple of the rock land. Verify that the distributor has enough asphalt material to complete entire shot length. Mark shot length

before applying hot A-R. When directed, mark length of each rock land to verify the aggregate rate.

H. Hot A-R Binder Placement.

1. **General.** Adjust the application temperature, not exceeding 425°F, to obtain the proper application characteristics. Uniformly apply at the rate specified or as directed.

   The maximum shot width is 13 ft. Adjust the shot width as directed so operations do not encroach on traffic or interfere with the traffic control plan. Use paper or other approved material at the beginning and end of each shot to construct a straight transverse joint and to prevent overlapping of the asphalt. Unless otherwise approved, longitudinal joints must match lane lines.

2. **Limitations.** Do not apply asphalt to the roadway until:
   - traffic control methods and devices are in place as shown on the plans or as directed,
   - the loaded aggregate spreader is in position and ready to begin,
   - haul trucks are loaded with enough aggregate to cover the shot area, and
   - haul trucks are in place behind the spreader box.

3. **Test Sections.** Place a test section at an approved location to demonstrate that equipment is capable of uniformly mixing and placing the A-R binder. The Engineer may stop work at any time and require additional test sections to be shot if:
   - the application is not uniform;
   - on 3 consecutive shots, application rate differs by more than 0.03 gal. per square yard from the rate directed; or
   - any shot differs by more than 0.05 gal. per square yard from the rate directed.

4. **Nonuniform Application.** Stop application if not uniform due to streaking, ridging, puddling, or flowing off the roadway surface. Verify equipment condition, operating procedures, application temperature, and material properties. Determine the cause of nonuniform application and correct it.

I. Aggregate Placement. The aggregate must be surface dry before application. When shown on the plans, preheat aggregate to between 250°F and 350°F. Cover each load with tarping material to minimize the temperature drop of the preheated aggregate. Immediately after the distributor has started spraying the hot asphalt-rubber, uniformly apply the aggregate at the rate specified by the Engineer.

J. Rolling. Start the rolling operation on each shot as soon as aggregate is applied. Use sufficient rollers to cover entire mat width in 1 pass (1 direction). Roll in a staggered pattern. Unless otherwise shown on the plans, make at least 5 passes.

If rollers are unable to keep up with spreader box, stop application until rollers have caught up, or furnish additional rollers. Keep roller tires free of asphalt.

K. Repair. Repair areas where coverage is incomplete. Make repairs by patching, hand spotting, or other method, as approved. When necessary, apply additional hot A-R binder to embed the aggregate.

L. Brooming. After rolling, sweep away excess as soon as aggregate has sufficiently bonded.

M. Final Acceptance. Maintain surface treatment until the Engineer accepts the work. Repair any surface failures. Before final project acceptance, remove all temporary stockpiles and restore the area to the original contour and grade.

318.5. Measurement.

A. A-R Binder. A-R binder, including all components, will be measured in tons just before delivery to the point of application.

B. Aggregate. Contractor-supplied aggregate will be measured by the cubic yard in the trucks as applied to the road.

C. Loading, Hauling, and Distributing Aggregate. If the Department furnishes the aggregate, the loading, hauling, and distributing will be measured by the cubic yard in the trucks as applied on the road.

318.6. Payment.

The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit prices bid for "A-R Binder" of the type specified; "Aggregate" of the

type, grade and surface aggregate classification specified; or “Loading, Hauling, and Distributing Aggregate.” These prices are full compensation for surface preparation, tack coat, heating and mixing, hauling and placing all materials, rolling and removing excess aggregate, cleaning up stockpiles, test sections, equipment, labor, tools, and incidentals.

Appendix Q: Florida Asphalt Rubber Specifications

SECTION 336
ASPHALT RUBBER BINDER

336-1 Description.

Produce asphalt rubber binder for use in Asphalt Concrete Friction Courses and Asphalt Rubber Membrane Interlayers.

336-2 Materials.

336-2.1 Superpave PG Asphalt Binder: For the particular grade of asphalt as specified in Table 336-1, meet the requirements of Section 916.

336-2.2 Ground Tire Rubber: For the type of ground tire rubber, meet the requirements of Section 919.

336-3 Asphalt Rubber Binder.

Thoroughly mix and react the asphalt binder and ground tire rubber in accordance with the requirements of Table 336-1. Use a rubber type that is in accordance with the verified mix design. Accomplish blending of the asphalt binder and ground tire rubber at the supplier's terminal or at the project site.

336-4 Equipment.

Use blending equipment that is designed for asphalt rubber binder and capable of producing a homogeneous mixture of ground tire rubber and asphalt binder meeting the requirements of Table 336-1. Use a batch type or continuous type blending unit that provides for sampling of the blended and reacted asphalt rubber binder material during normal production and provides for accurate proportioning of the asphalt binder and ground tire rubber either by weight or volume.

In order to meet specification requirements, keep the asphalt rubber uniformly blended while in storage. Equip storage tanks with a sampling device.

336-5 Testing and Certification Requirements.

336-5.1 Blending at Project Site: Monitor the ground tire rubber content in the asphalt rubber binder on a daily basis based on the following:

(1) the weight of the ground tire rubber used and the gallons of asphalt rubber binder produced, or

(2) the weight of the ground tire rubber used and the number of gallons of asphalt binder used. Use the weight per gallon for the various types of asphalt rubber binder shown in Table 336-1 for the calculations in (1) above.

336-5.2 Blending at Supplier's Terminal: Where blending the asphalt rubber binder at the supplier's terminal, the supplier shall furnish certification on the bill of lading for each load delivered to the project site that includes: the quantity, the asphalt rubber binder type, the customer name, the delivery location, and a statement that the asphalt rubber binder has been produced in accordance with and meets the requirements of 336. In addition, include, with the certification, copies of the certifications for the asphalt binder and ground tire rubber, as specified in 916-1.3.6 and 919-6, respectively.

336-5.3 Asphalt Rubber Binder Blending Quality Control Records: Maintain adequate Quality Control records for the Engineers review of all blending activities. The Quality

Control records shall include at a minimum the following information (for each batch of asphalt rubber binder produced): financial project number, shipping date, customer name and delivery location, asphalt rubber binder type, asphalt binder supplier (including QPL number and LOT), asphalt binder quantity in gallons, ground tire rubber supplier (including QPL number and LOT), ground tire rubber quantity in pounds, and viscosity results.

336-5.4 Testing of Asphalt Rubber Binder:

336-5.4.1 Quality Control Requirements: Test the asphalt rubber binder for the viscosity requirement of Table 336-1 at the following frequencies and situations:

1. One per batch (for batch blending) or two per day (for continuous blending) during blending at the project site or suppliers terminal.
2. Each load delivered to the project site when blended at the supplier's terminal.
3. Beginning of each day from the storage tank when storing the asphalt rubber binder at the project site, obtain the sample for testing from the discharge piping exiting the storage tank. Obtain the viscosity testing equipment specified in FM 5-548 and make it available to the Engineer for verification purposes.

If the asphalt rubber binder does not meet the minimum viscosity requirement, make the appropriate adjustments in order to (1) correct the viscosity of the blended material, and (2) correct the blending operation. These corrective actions within the requirements of Table 336-1 may include increasing the ground tire rubber content, lowering the blending temperature, changing the supply of ground tire rubber or increasing the reaction time. In the event that the corrective actions taken fail to correct the problem, or the material consistently fails to meet the minimum viscosity requirement, stop all asphalt rubber production operations and solve the problem. Do not resume production operations until the Engineer grants approval. The Engineer may require that any mix placed with low viscosity asphalt rubber binder be evaluated in accordance with 334-5.1.9.5. In the event that the viscosity of the asphalt rubber binder increases to the extent that plant production or paving operations of the mixture are adversely affected (i.e. density or texture problems occur), stop plant operations and resolve the problem to the Engineer's satisfaction.

336-5.4.2 Verification Requirements: The Engineer will test the asphalt rubber in accordance with FM 5-548 randomly on an as needed basis to ensure conformance with the minimum viscosity requirement as specified in Table 336-1.

Table 336-1

Asphalt Rubber Binder

Binder Type	ARB 5	ARB 12	ARB 20
Rubber Type	TYPE A (or B)*	TYPE B (or A)**	TYPE C (or B or A)**
Minimum Ground Tire Rubber (by weight of asphalt binder)	5%	12%	20%
Binder Grade	PG 67-22	PG 67-22	PG 64-22
Minimum Temperature	300°F	300°F	335°F
Maximum Temperature	335°F	350°F	375°F
Minimum Reaction Time	10 minutes	15 minutes (Type B)	30 minutes (Type C)

Table 336-1			
Asphalt Rubber Binder			
Binder Type	ARB 5	ARB 12	ARB 20
Rubber Type	TYPE A (or B)*	TYPE B (or A)**	TYPE C (or B or A)**
Unit Weight @ 60ºF***	8.6 lbs/gal	8.7 lbs/gal	8.8 lbs/gal
Minimum Viscosity ****	4.0 Poise @ 300°F	10.0 Poise @ 300°F	15.0 Poise @ 350°F

* Use of Type B rubber may require an increase in the mix temperature in order to offset higher viscosity values.
** Use of finer rubber could result in the reduction of the minimum reaction time.
*** Conversions to standard 60ºF are as specified in 300-9.3.
**** FM 5-548, Viscosity of Asphalt Rubber Binder by use of the Rotational Viscometer.
NOTE: The Contractor may adjust the minimum reaction time if approved by the Engineer depending upon the temperature, size of the ground tire rubber and viscosity measurement determined from the asphalt rubber binder material prior to or during production. Apply the asphalt rubber binder for use in membrane interlayers within a period of six hours, unless some form of corrective action such as cooling and reheating is approved by the Engineer.

336-6 Use of Excess Asphalt Rubber.

The Contractor may use excess asphalt rubber in other asphalt concrete mixes requiring the use of a PG 67-22 binder by blending with straight PG 67-22 binder so that the total amount of ground tire rubber in the binder is less than 2.0%. The Contractor may use excess asphalt rubber in asphalt concrete mixtures requiring the use of a recycling agent in a recycled mixture by blending with a recycling agent in such proportions that the total amount of ground tire rubber in the recycling agent is less than 1.0%.

336-7 Basis of Payment.

Payment for Asphalt Rubber Binder will be included in Sections 337 and 341, as appropriate.

Appendix R: Florida Asphalt Rubber Interlayer Specifications

SECTION
341
ASPHALT RUBBER MEMBRANE
INTERLAYER

341-1 Description.

Construct an asphalt rubber membrane interlayer composed of a separate application of asphalt rubber binder covered with a single application of aggregate.

341-2 Materials.

341-2.1 Asphalt Rubber Binder: Use ARB-20 meeting the requirements of Section 336.

341-2.2 Cover Material: Use Size No. 6 stone, slag, or gravel meeting the requirements of Section 901.

341-3 Equipment.

341-3.1 Power Broom: Provide a power broom for cleaning the existing pavement capable of removing all loose material from the surface.

341-3.2 Spreading Equipment: Provide a self-propelled aggregate spreader that can be adjusted to accurately apply the cover material at the specified rate and that spreads the material uniformly.

341-3.3 Rollers: Provide self-propelled, pneumatic-tired traffic type rollers equipped with at least 7 smooth-tread, low-pressure tires, and capable of carrying a gross load of at least 8 tons. Maintain a minimum tire inflation pressure of 90 psi, or as specified by the manufacturer, such that in no two tires the air pressure varies more than 5 psi. Load the traffic roller as directed by the Engineer.

341-3.4 Mixing Equipment: Use mixing equipment for asphalt rubber binder designed for that purpose and capable of producing and maintaining a homogeneous mixture of rubber and asphalt cement at the specified temperature.

341-3.5 Pressure Distributor: Use a pressure type distributor to apply asphalt rubber binder capable of maintaining a homogeneous mixture of rubber and asphalt cement at the specified temperature and consistently apply the material in a uniform manner.

341-4 Contractor's Quality Control.

Provide the necessary quality control of the asphalt rubber binder and construction in accordance with the Contract requirements. Provide in the Quality Control Plan procedures for monitoring and controlling of rate of application. If the rate of application varies by more than 5% from the rate set by the Engineer in accordance with 341-6, immediately make all corrections necessary to bring the spread rate into the acceptable range. The Engineer may take additional measurements at any time. The Engineer will randomly check the Contractor's measurement to verify the spread rate.

341-5 Preparation of Asphalt Rubber Binder.

Combine the materials as rapidly as possible for such a time and at such a temperature that the consistency of the binder approaches that of a semi-fluid material. Use the time and

temperature for blending of the asphalt rubber binder as specified in Table 336-1. The Engineer will be the sole judge of when the material has reached application consistency and will determine if an extender oil or diluent is needed for that purpose. After reaching the proper consistency, proceed with application immediately. Never hold the mixture at temperatures over 350ºF for more than six hours after reaching that temperature.

341-6 Construction Procedure.

341-6.1 Preparation of Surface: Prior to application of the asphalt rubber binder, clean the existing pavement as specified in 300-5.

341-6.2 Application of Asphalt Rubber Binder: Apply the asphalt rubber binder only under the following conditions:

a. The air temperature is above 50ºF and rising.
b. The pavement is absolutely dry.
c. The wind conditions are such that cooling of the asphalt rubber binder will not be so rapid as to prevent good bonding of the aggregate.

Uniformly apply the asphalt rubber binder, at the rate of 0.6 to 0.8 gal/yd^2 as directed by the Engineer. Use an application rate based on the unit weight as shown in Table 336-1. For conversions to standard 60ºF, refer to 300-9.3. Determine the rate of application after each application operation.

341-6.3 Application of Cover Material: Immediately after application of the asphalt rubber binder, uniformly spread the cover material at a rate of 0.26 and 0.33 ft^3/yd^2. The Engineer will set the exact rate. Determine the application rate at the beginning of each day's production, and as needed to control the operation, a minimum of twice per day. Maintain an application rate such that the pavement is covered uniformly with aggregate, and is one aggregate layer thick. For the cover material, use aggregate that is reasonably free of any adherent coatings and that does not contain excessive moisture. Immediately after the application of cover material, check the surface to ensure a uniform distribution of cover material and a smooth surface. Do not separate the application of the asphalt rubber binder and the application of the cover material by more than 300 feet, unless approved by the Engineer.

341-6.4 Rolling: In order to ensure maximum embedment of the aggregate, cover the entire width of the mat immediately by traffic rollers. For the first coverage, provide a minimum of three traffic rollers in order to accomplish simultaneous rolling in echelon of the entire width of the spread. After initial rolling, immediately correct all portions of the completed surface, that the Engineer deems are defective (not properly covered by aggregates, fat spots, excessive free aggregate, etc.). Following the first coverage, make additional coverages with traffic rollers as directed by the Engineer.

341-6.5 Traffic Control: For the normal sequence of construction operations, place the first course of asphalt concrete overlay over the membrane prior to opening to traffic.

341-7 Unacceptable Asphalt Rubber Membrane Interlayer.

If the asphalt rubber membrane interlayer is unacceptable due to incorrect blending, application rate, or not meeting the requirements of this Section, or damaged prior to placement of the asphalt concrete layer, remove and replace it as directed by the Engineer at no additional cost to the Department. Do not apply excessive amounts of asphalt rubber binder.

341-8 Placement of Asphalt Concrete Overlay.

Ensure that the thickness and temperature of the initial layer of asphalt concrete placed on top of the asphalt rubber membrane interlayer are such that the overlay bonds to the interlayer and the underlying layer without voids or excessive binder. Core the asphalt overlay as directed by the Engineer to evaluate the binder and aggregate spread rates, as well as the effectiveness of the asphalt concrete overlay in producing a well-bonded interlayer.

341-9 Method of Measurement.

341-9.1 Asphalt Rubber Membrane Interlayer: The quantity to be paid for will be plan quantity, in square yards, completed and accepted.

341-9.2 Bituminous Material (Asphalt Rubber Binder-Interlayer): The quantity will be the volume, in gallons, determined as provided in 300-8.

341-9.3 Submittal of Certification of Quantities for Bituminous Material: Prepare a Certification of Quantities, using the Department's current approved form, for the quantity of bituminous material placed and accepted. Submit this certification to the Engineer no later than Twelve O'clock noon Monday after the monthly estimate cutoff date or as directed by the Engineer. The certification must include the Contract Number, FPID Number, State Project Number, Certification Number and period represented by the Certification.

341-10 Basis of Payment.

341-10.1 Asphalt Rubber Membrane Interlayer: Price and payment will be full compensation for all work specified in this Section, including furnishing cover materials, handling, spreading, rolling, bituminous material, and other incidental work necessary to complete this item.

341-10.2 Bituminous Material (Asphalt Rubber Binder-Interlayer): Payment will be included in the price of the asphalt rubber membrane interlayer and will be full compensation for furnishing asphalt cement, ground tire rubber, blending and handling.

341-10.3 Payment Items: Payment will be made under:

Item No. 341- 70- Asphalt Rubber Membrane Interlayer - per square yard.

Appendix S: New Jersey Asphalt Rubber Specifications

SECTION 402 –HMA FRICTION COURSE

402.01 DESCRIPTION

SECTION 402.01 IS CHANGED TO:

This Section describes the requirements for constructing open-graded friction courses (OGFC), modified open-graded friction courses (MOGFC) and asphalt-rubber open-graded friction courses (AR-OGFC).

402.02 MATERIALS

402.02.01 Materials

THE FOLLOWING IS ADDED: Provide materials as specified:

Asphalt-Rubber Open-Graded Friction Course..... 902.07

402.02.02 Equipment

THE FOLLOWING IS ADDED: Provide equipment as specified:

Asphalt-Rubber Binder Blending Equipment..... 1009.03

402.03 CONSTRUCTION

THE FOLLOWING IS ADDED AFTER 402.03.01:

402.03.02 AR-OGFC

A. Paving Plan. At least 20 days before beginning placing the AR-OGFC, submit to the RE for approval a detailed plan of operation as specified in 401.03.03.A.

Do not begin paving until the RE approves this plan. Submit an adjusted paving plan before making adjustments to the paving operation.

B. Weather Limitations. If within the 12 hours before paving the National Weather Service locally forecasts a 50 percent chance or greater of precipitation during the scheduled placement, postpone the placement of AR-OGFC. Do not place AR-OGFC if it is precipitating and do not allow trucks to leave the plant when precipitation is imminent. The Contractor may resume paving operations when the chance of precipitation is less than 50 percent and the surface is dry.

Do not pave if the surface temperature of the underlying pavement is below 50 °F.

C. Test Strip. Construct a test strip as specified in 401.03.03.C. The Department will not require quality control cores or nuclear density testing.

D. Transportation and Delivery of AR-OGFC. Transport and deliver AR-OGFC as specified in 401.03.03.D.

E. Spreading and Grading. Apply tack coat as specified in 401.03.02. Place AR-OGFC at a laydown temperature between 275 °F and 330 °F maximum. Spread and grade

AR-OGFC as specified in 401.03.03.E, except do not apply polymerized joint adhesive or tack coat to longitudinal joints.

F. Compacting. Immediately after spreading and strike-off, compact AR-OGFC with a minimum of 1 pass of a non-vibratory, 2-axle roller. The RE may direct additional passes to eliminate roller marks. The Contractor may use a vibratory roller if it is operated in static mode.

Orient the drive axles of the roller towards the paver during the compaction operation. Operate rollers at a slow, uniform speed not exceeding 2-1/2 miles per hour. If necessary to prevent adhesion of the AR-OGFC to the rollers, keep the wheels moistened with water mixed with small quantities of detergent or fabric softener.

Remove and replace AR-OGFC that becomes loose, broken, or otherwise defective or that shows an excess or deficiency of asphalt-rubber binder material.

When paving in echelon, keep the rollers for the first lane approximately 6 inches from the unconfined edge adjacent to the second paving operation. After AR-OGFC from the second paver is placed against the uncompacted edge of the mat from the first paver, compact the AR-OGFC on both sides of the joint.

Prevent lateral or vertical displacement of the unconfined edge during the compaction operation. Ensure that the edge of the drums of the rollers extends over the free edge of the mat by at least 6 inches.

When compacting the butt joint, while paving the adjacent lane, place the roller on the newly placed AR-OGFC and overlap the joint by approximately 6 inches.

G. Curing. Following compaction, spray 1 to 3 applications of lime water (a minimum of 50 pounds of pulverized limestone per 2,000 gallons of water) to prevent material pick-up. Lime water shall be applied in a manner that uniformly covers the entire surface of the paving pass. Prior to applying the lime water, do not allow traffic on the AR-OGFC, including the lime water applicator, except as absolutely necessary for construction and emergency.

H. Opening to Traffic. Remove loose material from the traveled way, shoulder, and auxiliary lanes before opening to traffic. Before opening AR-OGFC to traffic or construction equipment, ensure that the lime water has been applied, the surface is tack free and the surface temperature is less than 140 °F.

I. Ride Quality Requirements. The Department will evaluate the AR-OGFC as specified in 401.03.03.J.

402.04 MEASUREMENT AND PAYMENT

THE FOLLOWING IS ADDED:

The Department will measure and make payment for Items as follows:

Item	*Pay Unit*
ASPHALT-RUBBER OPEN-GRADED FRICTION COURSE	TON

The Department will measure ASPHALT-RUBBER OPEN -GRADED FRICTION COURSE by the ton as indicated on the certified weigh tickets, excluding unused material.

The Department will make payment for TACK COAT and TACK COAT 64-22 as specified in 401.04.

SECTION 902 – ASPHALT

THE FOLLOWING SUBSECTION IS ADDED TO **SECTION 902**:

902.07 Asphalt-Rubber Open-Graded Friction Course (AR-OGFC) 902.07.01 Composition of Mixture

Mix AR-OGFC in a plant listed on the QPL and conforming to the requirements for HMA plants specified in 1009.01. Ensure the HMA plant is equipped with asphalt-rubber binder blending equipment as specified in 1009.03.

Composition of mixture for AR-OGFC is coarse aggregate, fine aggregate and asphalt-rubber binder. Ensure that the mixture conforms to the following requirements:

1. Use aggregates that conform to 901.05. Use fine aggregate that is manufactured stone sand and conforms to Table 902.02.02-2.
2. Do not use RAP, CRCG, GBSM, or RPCSA.
3. Use asphalt-rubber binder that conforms to 902.07.02.

902.07.02 Asphalt-Rubber Binder.

A. **Materials.** Use the following materials:

1. Ground Crumb Rubber. Ensure that the ground crumb rubber has a specific gravity of 1.15 ± 0.05, is free of wire or other contaminating materials, and contains not more than 0.5 percent fabric. Use crumb rubber that is ambient ground and conforms to the gradation requirements specified in Table 902.07.02-1. Ensure that the moisture content is less than 0.75 percent. The Contractor may add up to four percent calcium carbonate by weight of the granulated rubber, to prevent the particles from sticking together.

Table 902.07.02-1 Ground Crumb Rubber Gradation

Sieve Size	Percent Passing[1, 2]
No. 8	100
No. 16	65 – 100
No. 30	20 – 100
No. 50	0 – 45
No. 200	0 – 5

1. Perform gradation according to AASHTO T 27 using a minimum 50 gram sample.
2. Ensure that the gradation is performed as specified in NJDOT B-11.

Submit to the ME a certification of compliance, as specified in 106.07, for the ground crumb rubber. In addition, ensure that the certificates confirm that the rubber is a crumb rubber, derived from processing whole scrap tires or shredded tire materials; and the tires from which the crumb rubber is produced are taken from automobiles, trucks, or other equipment owned and operated in the United States. Include with the certifications verifications that the processing did not produce, as a waste product, casings, or other round tire material that can hold water when stored or disposed of above ground.

2. **Asphalt Binder.** Use asphalt binder that conforms to AASHTO M 320, Table 1; PG 64-22, PG 58-28 or an approved blend of both grades.

   The asphalt binder producer shall provide the asphalt binder quality control plan annually to the ME for approval. Ensure that the quality control plan conforms to AASHTO R 26.

   Submit to the ME a certification of compliance, as specified in 106.07, for the asphalt binder. The ME will perform quality assurance sampling and testing of each asphalt binder lot as defined in the approved quality control plan.

B. **Mixing.** Using the asphalt-rubber binder blending equipment in 1009.03, produce the asphalt-rubber binder to contain at least 17 percent ground rubber by the weight of total asphalt binder (asphalt + crumb rubber). Ensure that the temperature of the asphalt cement is between 350 and 400 °F at the time of addition of the ground rubber. Ensure that there are no agglomerations of rubber particles in excess of two inches in the least dimension in the mixing chamber.

   Document that the proportions are accurate and that the rubber has been uniformly incorporated into the mixture. Report as directed by the ME. Ensure that the crumb rubber and asphalt-cement are thoroughly mixed before beginning the one-hour reaction period. Rubber floating on the surface or agglomerations of rubber particles is evidence of insufficient mixing. Maintain the temperature of the asphalt-rubber binder immediately after mixing between 325 and 375 °F. Maintain the temperature of the asphalt-rubber binder for at least one hour before using.

C. **Properties.** Prepare asphalt-rubber binder using the "wet process." Physical properties shall comply with the requirements of ASTM D 6114, Type II, except for the properties specified in Table 902.07.02-2.

Table 902.07.02-2 Asphalt-Rubber Binder Properties

Property	Test Procedure	Requirement
Resilience: 77 °F; %, minimum	ASTM D 5329	25
Rotational Viscosity[1] 350 °F; cP	NJDOT B-12	2000 – 4000

1. The viscotester used must be correlated to a Rion (formerly Haake) Model VT-04 viscotester using the No. 1 Rotor. The Rion viscotester rotor, while in the off position, shall be completely immersed in the binder at a temperature from 350±

3°F for a minimum heat equilibrium period of 60 seconds, and the average viscosity determined from three separate constant readings (± 500 cP) taken within a 30 second time frame with the viscotester level during testing and turned off between readings. Continuous rotation of the rotor may cause thinning of the material immediately in contact with the rotor, resulting in erroneous results.

D. **Handling and Testing.** Once the asphalt-rubber binder has been mixed, thoroughly agitate during periods of use to prevent settling of the rubber particles. During production, maintain asphalt-rubber binder between 325 and 375 °F. Ensure that asphalt-rubber binder is not held at 325 °F or higher for more than 16 hours. Allow asphalt-rubber binder held for more than 16 hours to cool. To reuse, gradually reheat to between 325 and 375 °F. Do not cool and reheat more than one time. Do not store asphalt-rubber binder above 250 °F for more than four days.

For each load or batch of asphalt-rubber binder, provide the RE with the following:

1. The source, grade, amount, and temperature of the asphalt cement before the addition of rubber.
2. The source and amount of rubber and the rubber content expressed as percent by the weight of the asphalt cement.
3. Times and dates of the rubber additions and resultant viscosity test.
4. A record of the temperature, with time and date reference for each load or batch. The record shall begin at the time of the addition of rubber and continue until the load or batch is completely used. Take readings and record every temperature change in excess of 20 °F, and as needed to document other events that are significant to batch use and quality.

902.07.3 Mix Design.

Submit binder and mix designs including JMF for each mixture performed by an AASHTO accredited lab with at least five successfully completed asphalt- rubber open-graded friction course projects greater than 5,000 tons each. Include a statement naming the source of each component and a report with the results for the criteria specified in Table 902.07.03-1. Include a report detailing the rotational viscosity of the asphalt-rubber binder at 60, 90, 135, 240, and 1440 minutes. Submit lab qualifications and references to the ME for approval prior to beginning work.

Design the mix to meet the criteria in Table 902.07.03-1.

Table 902.07.03-1 JMF Master Ranges and Mixture Requirements AR-OGFC

	Mixture Designations (% Passing[1])
Sieve Sizes	**AR-OGFC**
1/2"	100
3/8"	90 – 100
No. 4	20 – 40
No. 8	5 – 10
No. 200	0 – 3.0
Minimum asphalt-rubber binder, %[1]	8.4
Minimum % Air Voids, design	15

1. Aggregate percent passing to be determined based on dry aggregate weight. Asphalt-rubber binder content to be determined based on total weight of mix.

Determine and verify the JMF according to NJDOT B-8. Ensure that the JMF is within the master range specified in Table 902.07.03-1.

Prepare compacted test specimens for submittal to the ME at least 30 days before the initial production date. Prepare these specimens from material mixed according to the final JMF, using 50 gyrations of the Superpave gyratory compactor according to AASHTO T 312.

The ME will test 2 specimens to verify stone-on-stone contact according to NJDOT B-8 and that the final JMF produces a mixture that has a minimum void content as specified in Table 902.07.03-1. The ME will determine percent air voids according to AASHTO T 209 and AASHTO T 331.

The ME will test 2 test specimens for abrasion and impact resistance using a modified L.A. Abrasion Test according to NJDOT B-8. The maximum allowable loss as calculated by this method is 30 percent.

Do not modify, which includes changing the asphalt cement supplier, the JMF unless the ME approves the modification.

902.07.04 Sampling and Testing

A. **General Acceptance Requirements.** The RE or ME may reject and require disposal of any batch or shipment that is rendered unfit for its intended use due to contamination, segregation, improper temperature, lumps of cold material, or incomplete coating of the aggregate. For other than improper temperature, visual inspection of the material by the RE or ME is considered sufficient grounds for such rejection.

For asphalt-rubber binder, ensure that the temperature of the mixture at discharge from

the plant or surge and storage bins is at least 290 °F but not greater than 330 °F.

Combine and mix the aggregates and asphalt-rubber binder to ensure that at least 95 percent of the coarse aggregate particles are entirely coated with asphalt-rubber binder as determined according to AASHTO T 195. If the ME determines that there is an on-going problem with coating, the ME may obtain random samples from 5 trucks and will determine the adequacy of the mixing on the average of particle counts made on these 5 test portions. If the requirement for 95 percent coating is not met on each sample, modify plant operations, as necessary, to obtain the required degree of coating.

B. **Quality Control Testing**. The HMA producer shall provide a quality control (QC) technician who is certified by the Society of Asphalt Technologists of New Jersey as an Asphalt Technologist, Level 2. The QC technician may substitute equivalent technician certification by the Mid-Atlantic Region Technician Certification Program (MARTCP). Ensure that the QC technician is present during periods of mix production for the sole purpose of quality control testing and to assist the ME. The ME will not perform the quality control testing or other routine test functions in the absence of, or instead of, the QC technician.

   The QC technician shall perform sampling and testing according to the approved quality control plan, to keep the mix within the limits specified for the mix being produced. The QC technician may use acceptance test results or perform additional testing as necessary to control the mix.

   For each acceptance test, perform maximum specific gravity testing according to AASHTO T 209 on a test portion of the sample taken by the ME. Sample and test coarse aggregate, fine aggregate and mineral filler according to the approved quality control plan for the plant.

C. **Acceptance Testing.** During production, the ME will take one random acceptance sample from each 500 tons of production to verify composition. The ME will perform sampling according to NJDOT B-2 or ASTM D 3665, and will perform testing for composition according to AASHTO T 308 or NJDOT B-5. Perform testing for air voids according to T 209 and either B-6 or T 331. Perform testing for draindown according to NJDOT B-8.

   Conduct air voids and draindown tests as directed by the ME.

   If the composition testing results are outside of the production control tolerances specified in Table 902.07.04-1 for an acceptance sample, determine if a plant adjustment is needed and immediately run a quality control sample. If the quality control sample is also outside of the control tolerances in Table 902.07.04-1, immediately take corrective action to bring the mix into compliance. Take additional quality control samples after the corrective action to ensure that the mix is within the production control tolerances. If two consecutive acceptance samples are outside the tolerances specified in Table 902.07.04-1, immediately stop production. Obtain ME approval of a plant correction plan before resuming production. Upon restarting production, do not transport mixture to the Project Limits before the results of a QC sample from the mixture indicate that the mixture meets JMF tolerances. The ME will reject mixture produced at initial restarting that does not meet tolerances.

Table 902.07.04-1 Production Control Tolerances for AR-OGFC Mixtures	
Sieve Sizes	**Production Control Tolerances from JMF[1]**
1/2"	±6.0
3/8"	±5.5
No. 4	±5.5
No. 8	±4.5
No. 200	±2.0
Asphalt-rubber binder, % (AASHTO T 308)	±0.40
Asphalt-rubber binder, % (NJDOT B-5)	±0.15
Minimum % Air Voids	1.0% less than design requirement

1. Production tolerances may fall outside of the wide band gradation limits in Table 902.07.03-1.

SECTION 1009 – HMA PLANT EQUIPMENT

THE FOLLOWING IS ADDED AFTER 1009.02:

1009.03 Asphalt-Rubber Binder Blending Equipment

Provide equipment for preparation of Asphalt-Rubber Binder. Ensure that the unit is equipped with a crumb rubber feed system capable of continuously supplying the asphalt cement feed system, and is capable of fully blending the individual crumb rubber particles with the asphalt cement. Use an asphalt-rubber binder storage tank that is equipped with a heating system capable of maintaining the temperature of the binder between 325 and 375 °F during the reaction. Ensure the asphalt-rubber binder storage tank is also equipped with an internal auger mixing device, oriented horizontally in the tank, capable of maintaining a uniform mixture of the asphalt-rubber binder.

Ensure that the tanks for storage of asphalt-rubber binder are equipped to uniformly heat the material to the required temperature under effective and positive control at all times. Ensure that heating is accomplished so that no flame comes in contact with the heating tank.

Provide a circulating system of sufficient capacity for the binder to ensure continuous circulation between the storage tank and proportioning units during the entire operating period. Ensure that the discharge end of the binder circulating pipe is maintained below the surface of the binder in the storage tank to prevent discharge of hot binder into the open air.

Ensure that pipe lines and fittings are steam or oil jacketed, electrically or otherwise heated, and insulated to prevent heat loss.

Provide valves according to AASHTO T 40, except ensure that a sampling valve is also located

in the lowest third of each storage tank.

If the plant has been equipped with a water injection type asphalt foaming system, ensure that the system will allow the proper amount of asphalt rubber binder to be supplied continuously or provide a by-pass to ensure that the proper amount of asphalt rubber binder is supplied to the mix.

Appendix T: Massachusetts Asphalt Rubber Specifications

SECTION 466

STRESS ABSORBING MEMBRANE INTERLAYER

DESCRIPTION

466.20 General.

This work consists of the application of hot, rubberized asphalt to a paved surface and immediately embedding aggregate therein by spreading and rolling in accordance with these specifications. This item may also be referred to as SAMI.

MATERIALS

466.40 General.

Asphalt: Asphalt cement for the asphalt rubber mixture shall be AC-10 or AC-20, complying with the requirements of M3.01.0. If AC-10 is used, the SAMI shall be overlayed within ten (10) days.

Rubber: The granulated rubber shall be a vulcanized rubber product from the ambient temperature processing of pneumatic tires.

The granulated rubber type shall meet the following gradation:

Sieve Designation	Percent Passing
2.36 mm	100
2.00 mm	95-100
1.18 mm	-
600 •m	0-10
300 •m	0-5

Aggregate shall conform to the requirements of M2.01.0 for crushed stone. Crushed gravel stone will not be permitted. Gradation requirements will conform to M2.01.6. Percentage of wear as determined by the Los Angeles Abrasion Test (AASHTO T 96) shall be a maximum of 30.

CONSTRUCTION METHODS

466.60 General.

Preparation of Existing Surface.
Prior to application of the rubberized asphalt, the entire paved surface to be treated shall be cleaned by sweeping, blowing and other methods until free of dirt and loose particles. Pot holes, depressions, cracks larger than 20 millimeters and other irregularities will be patched with hot bituminous mix and compacted. No water shall be present on the surface. A levelling course shall be placed on planed, milled or existing surface if required.

Seasonal and Weather Limitations.
Construction shall not proceed when the ambient temperature has been below 10 °C within the previous 12 hours, when rain is falling, or when conditions are unfavorable to obtaining a uniform spread.

466.61 Asphalt Rubber Mixing and Reaction
The percent of rubber shall be 23 ± 2% as indicated by the mixture design for specific project

requirements by weight of total mixture, that is, by total weight of asphalt cement, plus granulated rubber. The temperature of the asphalt shall be between 175 °C and 220 °C at the time of addition of the vulcanized rubber. The asphalt and rubber shall be combined and mixed together in a blender unit and reacted in the distributor for a period of time as required by the Engineer which shall be based on laboratory testing by the rubberized asphalt supplier. The temperature of the rubberized asphalt mixture shall be above 160 °C during the reaction period.

After the reaction between asphalt and rubber has occurred, the viscosity of the hot rubberized asphalt mixture may be adjusted for spraying and/or better "wetting" of the cover material by the addition of a diluent. The diluent shall comply with the requirements of ASTM D 369, Grade #1 Fuel Oil and shall not exceed 7.5 percent by volume of the hot asphalt rubber mixture.

When a job delay occurs after full reaction, the rubberized asphalt may be allowed to cool. The rubberized asphalt shall be reheated slowly just prior to application, but not to a temperature exceeding 160 °C. An additional quantity of diluent not exceeding 3 percent by volume of the hot rubberized asphalt mixture may be added after reheating.

Viscosities shall be run, by the applicator, on each blended load of rubberized asphalt rubber using a Haake Field viscometer. One viscosity prior to the induction of the diluent and one after the induction of the diluent blended into the asphalt and rubber mixture. The viscosity of the final product shall be in the range of 2 to 5 Pascal seconds.

466.62 Equipment.

1. Distributor Truck.
At least two pressure-type bituminous semi-distributor trucks in good condition will be required. The distributor shall be equipped with an internal heating device capable of heating the material evenly up to 200 °C; have adequate pump capacity to maintain a high rate of circulation in the tank; have adequate pressure devices and suitable manifolds to provide constant positive cut off to prevent dripping from the nozzles. The distribution bar on the distributor shall be fully circulating. Any distributor that produces a streaked or irregular distribution of the material shall be promptly repaired or removed from the project.
Distributor equipment shall include a tachometer, pressure gauges, volume measuring devices, a thermometer for reading temperature of tank contents, and an internal auger to maintain proper mixture and blending of asphalt and rubber. Controls for spray bar shall be located in cab of truck, for controlling width and rate of spray of product.
It shall be so constructed that uniform applications may be made at the specified rate per square meter within a tolerance of plus or minus 0.20 liters per square meter.

2. Brooms.
Revolving brooms shall be so constructed as to sweep clean or redistribute aggregate without damage to the rubberized-asphalt membrane or surface treatment.

3. Pneumatic-Tired Roller.
There shall be at least two multiple wheel self-propelled pneumatic-tired rollers with provisions for loading 7 to 11 metric tons as deemed necessary. Pneumatic-tired rollers shall have a total compacting width of at least 1.5 meters and shall have a minimum tire pressure of 415 kiloPascals. A minimum of three rollers are required, two pneumatic and one steel.

4. Power Rollers.
Shall be self-propelled steel rollers weighing between 1.5 and 5 metric tons.

5. Asphalt Heating Tank.
To heat the asphalt cement to the necessary temperature for blending with the rubber, tank shall be a minimum 10 cubic meter capacity and capable of heating product at a minimum rate of 15

°C per hour.

6. Mechanical Blender.
For proper proportioning and thorough mixing of the asphalt and rubber together to produce the specified rubber content material. This unit shall have both an asphalt totalizing meter (liters) and a flow rate meter (liters per minute), positive placement auger to feed rubber properly to mix chamber at the specified rate, and an auger in mixing chamber running through a static motionless mixer.

7. Distributor.
Shall include a tachometer, pressure gauges, volume measuring devices, a thermometer, a300 millimeter auger capable of blending and maintaining proper blending of material and an 200 millimeter dual positive placement gear head pump capable of spraying the rubberized asphalt at a viscosity of 2 to 5 Pascal seconds. A "bootman" shall accompany the distributor and ride in a position so that all spray bar nozzles are in his/her full view and readily accessible for unplugging.

8. Chip Spreader.
This equipment shall be self-propelled and be adjustable to control and spread accurately the given amounts of cover aggregate per square meter. It shall have a width of spread of not less than 3.75 meters. Cut off plates shall be provided to permit the width of spread to be reduced in increments of 125 millimeters from the maximum width specified. The spreader shall be equipped with a hitch at the rear so it can lock onto the hauling trucks while they are discharged into the spreader. Two (2) conveyor belts shall supply aggregate from the hopper to the element which spreads the cover aggregate over the road surface. Screen below screw auger at bottom of hopper shall be in place.

466.63 Construction Requirements.

The rubberized asphalt mixture shall be applied at a temperature of 140°C to 170°C at a rate of2.75 ± 0.25 liters per square meter. Transverse joints shall be constructed by placing building paper across and over the end of the previous rubberized asphalt application. Once the spraying has progressed beyond the paper, the paper shall be removed immediately and disposed of as directed by the Engineer. Longitudinal joints shall be overlapped from 100 to 150 millimeters.

If rubberized asphalt is applied directly to an old existing Portland Cement Concrete pavement, band-aid strips shall be placed prior to the rubberized asphalt treatment on all transverse and longitudinal joints. The strips shall be Pave-Prep, Polygard, Rol-Glas or equal and shall be placed 500 millimeters wide. The SAMI shall be applied within four days of the placement of the band-aid strips.

1. Application.
No application shall be made to any area which cannot immediately be covered with aggregate. The application from the distributor shall be stopped before the tank is empty to be sure the application does not run light. At all starts, intersections, junctions at transverse joints with previous spreads or other pavements, provision shall be made to ensure that the distributor nozzles are operated at full force when the application begins. Building paper or other suitable devices shall be used to receive the initial application from the nozzle before any material reaches the surface at the transverse joint. The paper shall be removed immediately after use without spilling surplus material on the surface. Longitudinal joints shall be reasonably true to line and parallel to centerline. The overlap in application of asphalt-rubber material shall be minimum to assure complete coverage. Where any construction joint occurs, the edges shall be broomed back and blended so there are no gaps and the elevations are the same, and free from ridges and depressions.

During application, adequate provision shall be made to prevent marring and discoloration of adjacent pavements, structures, vehicles, foliage or personal property.

2. Aggregate Application.
The application of aggregate shall follow as close as possible behind the application of the hot rubberized asphalt which shall not be spread further in advance of the aggregate spread that can be immediately covered. Construction equipment or other vehicles shall not drive on the uncovered rubberized asphalt.

The dry aggregate, pre-coated with 0.5 to 1.0% of AC-20, shall be spread uniformly by a self-propelled spreader at a rate of spread directed by the Engineer, generally between 15 and 20 kilograms per square meter.

Any deficient areas shall be covered with additional material.
Prior to application, the aggregate shall be pre-heated to a temperature between 120°C to 150°Cand coated with 0.5 to 1.0% of asphalt, grade AC-20.

3. Rolling.
Rolling shall commence immediately following spread of aggregate. There shall be at least three complete passes by the pneumatic tired rollers to embed the aggregate particles firmly into the rubberized asphalt, followed by an additional pass of the steel roller.

4. Sweeping.
When the maximum of aggregate has been embedded into the rubberized asphalt and the pavement has cooled, all loose material shall be swept or otherwise removed at such time and in such a manner as will not displace any embedded aggregate or damage the rubberized asphalt.

5. Curing.
The rubberized asphalt surface treatment should be overlaid immediately following completion of sweeping. If traffic must travel over the surface treatment, it shall be allowed to cool and speed controlled so as not to exceed 40 kilometers per hour.

COMPENSATION

466.80 Method of Measurement.
Stress Absorbing Membrane Interlayer will be measured by the square meter and shall be the actual number of square meters applied as directed by the Engineer.

466.81 Basis of Payment.
Stress Absorbing Membrane Interlayer shall be paid at the contract unit price per square meter and payment shall be full compensation for all labor, materials and equipment required to complete the work to the satisfaction of the Engineer.

466.82 Payment Items.
460.Class I Bituminous Concrete Pavement Type I-1

Metric Ton
466.Stress Absorbing Membrane Interlayer

Square Meter

Appendix U: China Asphalt Rubber Specifications

橡胶沥青上面层AR-AC13施工要点

Rubberized Asphalt Concrete AR-AC13 Constructions Specifications

依据交通部《公路沥青路面施工技术规范》（JTG F40-2004），结合美国Arizona Test Method 815及前期关于间断级配橡胶沥青混凝土（AR-AC13）的研究成果及施工经验，提出如下施工要点。

矿料级配应符合表1的规定。

The gradation of aggregates should meet the requirement in Table 1.

表1 橡胶沥青混凝土AR-AC13矿料级配范围（不含外掺剂）

Table 1. Rubberized Asphalt Concrete AR-AC13 Aggregate Gradation Requirement (not including additives)

层次Layer / 类型Type / 方筛孔尺寸 Sieve Opening (mm）	上面层(Surface layer)
	AR-AC13
16.0	100
13.2	90～100
9.5	45～65
4.75	12～32
2.36	8～18
0.075	0～3.0

一、准备工作 Preparation Work

1、原材料Materials

（1）基质沥青Base Asphalt Cement

橡胶沥青所用的基质沥青采用70号道路石油沥青，其技术要求见表2。基质沥青检测频率参考省高指规定的检测频率。

表2 道路石油沥青技术要求

Table 2. Base Asphalt Cement Technical Requirement

检　验　项　目Test Parameter	技术要求

		Requirement
针入度 Cone Penetration（25°C，100g, 5S）(0.1mm)		60～80
延度 Ductility(5cm/mim, 15°C)（cm）Not less than 不小于		100
延度 Ductility(5cm/mim, 10°C)（cm） Not less than 不小于		20
软化点（环球法）Softening Point（°C）Not less than 不小于		46
溶解度（三氯乙烯）类型Solubility in trichloroethylene（%） 不小于Not less than		99.5
针入度指数PI		-1.5～+1.0
薄膜加热试验 Thin Film Oven Test 163°C，5h	质量损失（%）Mass Loss 不大于Not more than	0.6
	针入度比（%）Penetration Ratio 不小于Not less than	65
	延度（15°C）（cm） 不小于	100
	延度（10°C）（cm） 不小于	6
闪点 Flash Point（COC）（°C） 不小于		260
含蜡量（蒸馏法）Wax content（%） 不大于Not more than		2
密度 Density（15°C）(g/cm3) 不小于Not less than		1.01
动力粘度 Kinematic Viscosity （绝对粘度，60°C）(Pa.s) 不小于Not less than		180
PG等级PG grading		PG64-22

(2) 橡胶粉Crumb Rubber Modifier

橡胶粉颗粒规格应符合表3要求。橡胶粉筛分应采用水筛法进行试验。橡胶粉密度应为1.15±0.05 g/cm^3，应无铁丝或其它杂质，纤维比例应不超过0.5%，要求含有橡胶粉重量4%的碳酸钙，以防止胶粉颗粒相互粘结。The Crumb Rubber Modifier should meet the requirement of Table 3. The gradation analysis should use wet sieve method. The density of CRM should be 1.15±0.05

g/cm^3. It should not contain steel wires or other contaminants. The fiber should be less than 0.5%. About 4% of Calcium carbonate can be added to the CRM to prevent foaming when add it to base binder.

供应商应提供橡胶粉质量保证书，说明橡胶粉规格、加工方式、加工的废旧轮胎类型、橡胶粉的储存方式等。The CRM vendor should provide the certificate of compliance and describe the gradation of CRM, manufacture method, type of waste tires, storage of CRM, etc.

表3 橡胶粉筛分规格

Table 3. Gradation requirement of CRM

筛孔尺寸Sieve Sizes（mm）	通过率 Percent Passing（%）
2.00	100
1.18	65～100
0.6	20～100
0.3	0～45
0.075	0～5

（3）橡胶沥青Asphalt Rubber Cement

橡胶沥青应满足表4技术要求。橡胶沥青现场改性完成后应及时使用，如遇特殊情况需要现场存贮，橡胶沥青不能超过两个加热循环，同时应在使用前对橡胶沥青质量进行检测，检测合格后才能使用。

Asphalt Rubber cement should meet the requirement shown in Table 4. The asphalt rubber binder should be used after proper mixing and reaction time. If storage on site are necessary due to special situation, asphalt rubber binder can be reheated. However, it shall not exceed two heating cycles. At mean time, the asphalt rubber binder should be retested to meet the specification before usage.

表4 橡胶沥青技术要求

Table 4. Technical requirement for asphalt rubber cement

检测项目Test Parameters	技术指标Technical Requirement
粘度Rotational Viscosity，177℃，Pa.S	1.5～4.0
针入度 Cone Penetration (25^{o}C,100g,5 s)	25

0.1mm，最小Minimum	
软化点Ring and Ball Softening Point，℃，最小 Minimum	54
弹性恢复Elastic Recovery，25℃，最小 Minimum	60

（4）粗集料Coarse Aggregate

应采用石质坚硬、清洁、不含风化颗粒、近似立方体颗粒的破碎石，粒径大于4.75mm。宜采用玄武岩集料和辉绿岩集料，粗集料技术要求见表5。

表5 沥青上面层用粗集料质量技术要求

检验项目		单位	技术要求	
石料压碎值	不大于	%	常温	20
			高温	24
洛杉矶磨耗损失	不大于	%	28	
视密度	不小于	t/m^3	2.6	
吸水率	不大于	%	2.0	
对橡胶沥青的粘附性	不小于		5级	
坚固性	不大于	%	12	
针片状颗粒含量	不大于	%	12	
水洗法<0.075 mm颗粒含量	不大于	%	1号料	0.6
			2号料	0.8
			3号料	1.0
软石含量	不大于	%	3	
上面层石料磨光值	不小于	BPN	42	
抗压强度	不小于	MPa	120	

注：（1）有1个或以上破碎面为黄色节理面的集料颗粒含量应不大于5%；

（5）细集料Fine Aggregate

采用坚硬、洁净、干燥、无风化、无杂质并有适当级配的人工轧制的机制砂，石质宜与粗集料相同，不用山场的下脚料。细集料的尺寸规格列于表6。

表6 细集料规格

规格	公称粒径（mm）	通过下列筛孔（mm）的质量百分率（%）						
		4.75	2.36	1.18	0.6	0.3	0.15	0.075

S16	0～3	100	80～100	50～80	25～60	8～45	0～25	0～15

注：（1）中下面层视密度不小于2.5g/cm^3，上面层视密度不小于2.6g/cm^3；

（2）砂当量应不小于60%（宜控制在70%以上）；亚甲兰值不大于25g/kg；

（3）小于0.075mm质量百分率宜不大于12.5%；

（4）棱角性不小于30s。

橡胶沥青混凝土AR-AC13不使用矿粉填料。

（6）外掺剂 Additives

ARAC13橡胶沥青混凝土需要掺入必要的外掺剂以改善橡胶沥青与集料的粘附性及混凝土的水稳定性能，掺量为混合料重量1～2%。适宜的外掺剂为普通硅酸盐水泥或消石灰。

Additives are required to improve the adhesion between AR binder and aggregates and reduce moisture susceptibility. The amount of additive should be 1-2%. The proper additives are cement or hydrated lime.

2、施工机械与质量检测仪器 Equipment for Construction and Quality Control

（1）必须配备齐全施工机械和配件，做好开工前的保养、调试和试机，并保证在施工期间一般不发生有碍施工进度和质量的故障。沥青上面层宜采用机械化连续摊铺作业，对于单幅双车道面层，应实施两台摊铺机梯队作业，以确保摊铺面的质量。因而必须配备以下主要施工机械。

a、橡胶沥青生产设备一套，用管道与拌和楼直接连接，生产经过调试确保沥青泵送系统正常；

b、间歇式沥青混合料拌和机。拌和机应配备良好的二级除尘装置；

c、沥青混合料摊铺机两台以上；

d、非接触式平衡梁装置两套（4只）；

e、12T以上双钢轮振动压路机4台；

f、载重量15T以上的自卸汽车；

g、洒水车。

（2）必须配备性能良好、精度符合规定的质量检测仪器，并配备足够的易损部件。主要仪器设备如下：

a、针入度仪

b、Brookfield 粘度计

c、软化点仪

d、标准筛（方筛孔）

e、集料压碎值试验仪

f、砂当量仪

g、烘箱

h、试模（不少于10只）

i、脱模器

j、试验室用沥青混合料拌和机

k、马歇尔试件击实仪

l、沥青混合料马歇尔试验仪

m、恒温水浴

n、冰箱

o、沥青混合料离心抽提仪

p、路面取芯机

q、平整度仪

r、砂当量仪

二、配合比设计 Mix Design

1、AR-AC13间断级配橡胶沥青混凝土的技术标准

根据课题研究成果，参考美国Arizona Test Method 815，AR-AC13应符合表7规定的马歇尔试验技术标准。进行配合比设计时，沥青混合料动稳定度不应小于3000次/mm，小梁低温抗裂试验的弯曲破坏应变不小于2000με。

表7 热拌橡胶沥青混凝土马歇尔试验技术标准

Table 7. Rubberized Hot Mix Asphalt Marshall Mix Design Standard

试验项目	沥青混凝土类型	技术标准
击实次数（次）	AR-AC13	两面各75次
稳定度（kN） 不小于		8.0
流值（0.1mm）		20～50
空隙率（%）		5.5±1.0
沥青饱和度（%）		70～85

矿料间隙率VMA (%)　不小于		19.0
浸水马歇尔试验 残留稳定度（%）　不小于		85
冻融劈裂试验 残留强度比（%）　不小于		80

2、AR-

AC沥青混凝土配合比设计过程主要包括目标配合比设计、生产配合比设计和生产配合比验证三个阶段。遵照下列步骤进行:

（1）目标配合比设计

a、原材料检测

从工程实际使用的材料中取各种代表性原材料，分别按照现行《公路工程沥青和沥青混合料试验规程》和《公路工程集料试验规程》对各类矿料进行筛分，并对基质沥青、胶粉、橡胶沥青、各类矿料和外掺剂进行检测，确保原材料的质量。

b、矿料配比设计

矿料配合比设计宜利用矿料筛分结果借助电子表格通过试配法进行，矿料级配曲线按《公路工程沥青及沥青混合料试验规程》T 0725

的方法绘制。设计矿料配比时，在表1的级配范围内调整各种矿料的比例设计三组粗细不同的设计级配。

根据实践经验选择适宜的橡胶沥青用量，分别制作上述三组不同粗细级配的马歇尔试件，测定试件体积指标，初选一组满足或接近设计要求的级配作为设计级配。

c、确定设计橡胶沥青用量

根据b中矿料设计级配和初试橡胶沥青用量试验结果，按0.5%间隔变化，根据经验取四个不同的橡胶沥青用量，制备马歇尔试件，计算各组试件密度、空隙率、矿料间隙率、沥青饱和度、稳定度和流值等，分别绘制各项体积指标的曲线。根据设计空隙率并综合考虑其他各项体积指标是否满足表7的技术要求，确定设计沥青用量。

d、配合比设计检验。

按以上设计矿料配合比和设计橡胶沥青用量制备马歇尔试件，进行浸水马歇尔试验，冻融劈裂试验、高温动稳定度试验和低温抗裂性能试验，试验结果必须满足表7的要求。不符合要求必须重新进行配合比设计。

符合要求的配合比可以作为目标配合比，供拌和楼确定各冷料仓的供料比例、进料速度及试拌使用。

（2）生产配合比设计

a、确定各种热料仓矿料的用量。

对间歇式拌和楼，应从二次筛分后进入各热料仓的矿料取样进行筛分，根据筛分结果，通过计算，使混合料的级配符合目标配合比设计级配和表1的规定，以确定各热料仓的用料比例，供拌和楼控制室使用。同时反复调整冷料仓进料比例，以达到供料均衡。同时选择适宜的筛孔尺寸和安装角度，尽量使各热料仓的供料大体平衡。

b、确定最佳橡胶沥青用量。

取目标配合比设计的最佳橡胶沥青用量和设计最佳沥青用量±0.3%，进行马歇尔试验，按目标配合比设计方法绘图，根据设计空隙率和其他体积指标综合确定生产配合比的设计橡胶沥青用量。按以上方法确定的设计橡胶沥青用量可能与目标配合比的设计橡胶沥青用量不一致，如相差不超过0.2％，应按生产配合比确定的设计橡胶沥青用量进行试拌和试铺，或分析确定试拌试铺用橡胶沥青用量；如相差超过0.2％，应找出原因，进一步试验分析后确定试拌试铺用橡胶沥青用量。

c、生产配合比设计检验。

按以上生产配合比，用室内小型拌和机拌制橡胶沥青混合料，进行马歇尔试验，检验浸水残留稳定度和冻融残留强度比，结果必须满足表7的规定。

（3）生产配合比验证

用生产配合比进行试拌，橡胶沥青混合料的技术指标合格后铺筑试铺段。取试铺用的沥青混合料进行马歇尔试验检验和橡胶沥青含量、矿料筛分试验，检验生产配合比矿料合成级配，由此确定正常生产用的标准配合比。对确定的标准配合比需再次进行高温车辙试验和水稳定性检验。

3、关于AR-AC13橡胶沥青混凝土马歇尔室内试验中几点统一做法

⑴进行目标配合比设计和生产配合比设计时，制备试件的混合料，需采用小型沥青混合料拌和机拌和，以模拟生产实际情况。

⑵每组试件个数4～6个。

⑶试件成型温度：对于AR-AC13橡胶沥青混合料，拌和压实温度参照表8温度成型。

表8 AR-AC13沥青混合料室内拌和与击实温度（℃）

矿料	170～175
沥青加热温度	170～180
沥青混合料拌和温度	165～175
试模预热温度	165～175

试件击实温度	160～170
试件成型终了温度	不低于145

（4）橡胶沥青混合料试件密度试验方法：AR-AC13橡胶沥青混合料统一用表干法的毛体积相对密度。

（5）橡胶沥青AR-AC13的最大理论密度采用计算法确定。

三、铺筑试铺路面 Construction of Trial Section

AR-AC13抗滑磨耗层施工开工前，需先做试铺路面。试铺路面宜选在直线段，长度为200m左右。

试铺路面施工分为试拌和试铺两个阶段，需要决定的内容包括：

1、根据各种机械的施工能力相匹配的原则，确定适宜的施工机械，按生产能力决定机械数量与组合方式。

2、通过试拌决定：

（1）拌和楼的操作方式——如上料速度、拌和数量与拌和时间、拌和温度等。

（2）验证橡胶沥青混合料的配合比设计和沥青混合料的技术性能，决定正式生产用的矿料配合比和橡胶沥青用量。

3、通过试铺决定：

（1）摊铺机的操作方式——摊铺温度、摊铺速度、初步振捣夯实的方法和强度、自动找平方式等。

（2）压实机具的选择、组合、压实顺序、碾压温度、碾压速度及遍数。

（3）施工缝处理方法。

（4）用水准仪定点测量高程的方法确定沥青上面层的松铺系数。

4、确定施工产量及作业段的长度，修订施工组织计划。

5、全面检查材料及施工质量是否符合要求。

6、确定施工组织及管理体系、质保体系、人员、机械设备、检测设备、通讯及指挥方式。

试铺路面的质量检查频率应根据需要比正常施工时适当增加（一般增加一倍）。试铺结束后，试铺路面应基本上无离析和石料压碎现象，经检测各项技术指标均符合规定，施工单位应立即提出试铺总结报告，由驻地监理工程师审查，总监代表确认，经总监批准后即可作为申报正式开工的依据。

四、橡胶沥青混凝土（AR-AC13）施工 Rubberized Asphalt Concrete Construction

1、把好原材料质量关

⑴要注意粗细集料和填料的质量，应从源头抓起，对不合格的矿料，不准运进拌和厂。

⑵堆放各种矿料的地坪必须硬化，并具有良好的排水系统，避免材料被污染；各品种材料间应用墙体隔开，以免相互混杂。

⑶细集料及矿粉宜覆盖，细料潮湿将影响喂料数量和拌和楼产量。

⑷橡胶沥青应严格按照省高指有关沥青留样的规定做好沥青留样工作。

2、关于沥青混凝土配合比设计的统一规定

⑴目标配合比需经驻地监理工程师审查，报总监代表批准确认后才能进行生产配合比设计。如果某种矿料产地、品种发生变化，必须重新进行目标配合比设计。

⑵每台拌和楼均应进行生产配合比设计，由驻地监理工程师审查，总监代表确认，经总监批准后，才能进行试拌与试铺。

3、沥青混合料的拌制

⑴严格掌握沥青和集料的加热温度以及沥青混合料的出厂温度。AR-AC13沥青混合料的施工温度控制范围见表9。

表9 AR-AC13沥青混合料的施工温度（℃）

Table 9. AR-AC13 Rubberized Asphalt Concrete Construction Temperatures

橡胶沥青加热温度Asphalt Rubber Cement Temperature	180-190
矿料温度Aggregate Temperature	170-180
混合料出厂温度temperature after mixing	170-180，超过195废弃, discard if over 195
混合料运输到现场温度temperature at the job site	不低于165, not less than 165
摊铺温度paving temperature	不低于160，低于140废弃, not less than 160. Discard if less than 140.

初压开始温度breakdown roller temperature	不低于155, not less than 155
复压最低温度intermediate roller temperature	不低于130, not less than 130
碾压终了温度, finish roller temperature	不低于100, not less than 100

注：①所有检测用温度计应采用半导体数显温度计并及时送当地计量部门检定，或在监理监督下用标准温度计标定；②所有温度检测均应按正确的方法操作，避免温度计探头位置不当使测得温度不真实。③碾压温度是指碾压层内部温度。

⑵拌和楼控制室要逐盘打印沥青及各种矿料的用量和拌和温度，并定期对拌和楼的计量和测温进行校核。

⑶拌和时间由试拌确定。必须使所有集料颗粒全部裹复沥青结合料，并以沥青混合料拌和均匀为度，建议外掺剂水泥加入拌和仓后先与矿料干拌5s，再加入橡胶沥青湿拌40s。

⑷要注意目测检查混合料的均匀性，及时分析异常现象。如混合料有无花白、冒青烟和离析等现象。如确认是质量问题，应作废料处理并及时予以纠正。在生产开始以前，有关人员要熟悉本项目所用各种混合料的外观特征，这要通过细致地观察室内试拌的混合料而取得。

⑸每台拌和楼每天上午、下午各取一组混合料试样做马歇尔试验和抽提筛分试验，检验油石比、矿料级配和沥青混凝土的物理力学性质。每周应检验1～2次残留稳定度。

橡胶沥青用量与设计值的允许误差-0.1%至+0.2%。

0.075mm ±2%

≤2.36mm ±4%

≥4.75mm ±5%

⑹每天结束后，用拌和楼打印的各仓料数量，进行总量控制。以各仓用量及各仓筛分结果，在线检查矿料级配；计算平均施工级配和油石比，与设计结果进行校核；以每天产量计算平均厚度，与路面设计厚度进行校核。

4、沥青混合料的运输Transportation of Hot Mix

⑴采用数字显示插入式热电偶温度计检测沥青混合料的出厂温度和运到现场温度。插入深度要大于150 mm。在运料卡车侧面中部设专用检测孔，孔口距车箱底面约300mm。

⑵拌和楼向运料车卸料时，汽车应前后移动三次装料，以减少粗集料的离析现象。

⑶沥青混合料运输车的运量应较拌和能力和摊铺速度有所富余，根据工程规模摊铺机前方应有3～5辆运料车等候卸料。

⑷运料车应有良好的篷布覆盖设施，卸料过程中继续覆盖，直到卸料结束取走篷布，以资保温并避免污染环境。

⑸连续摊铺过程中，运料车在摊铺机前10～30cm处停住，不得撞击摊铺机。卸料过程中运料车应挂空档，靠摊铺机推动前进。

5、沥青混合料的摊铺Paving Operation

⑴连续稳定地摊铺，是提高路面平整度最主要措施。对于橡胶沥青混凝土，摊铺机的摊铺速度应根据拌和楼的产量、施工机械配套情况及摊铺厚度、摊铺宽度，按1～3m/min予以调整选择，做到缓慢、均匀、不间断地摊铺。用餐应分批轮换交替进行，切忌停铺用餐，争取做到每天收工停机一次。

⑵用机械摊铺的混合料未压实前，施工人员不得进入踩踏。一般情况下不得采用人工整修。

⑶AR-AC沥青混合料上面层采用非接触式平衡梁装置控制摊铺厚度。两台摊铺机距离不应超过10m，以形成良好的热接缝。

⑷摊铺机应调整到最佳工作状态，调好螺旋布料器两端的自动料位器，并使料门开度、链板送料器的速度和螺旋布料器的转速相匹配。螺旋布料器中的混合料以略高于螺旋布料器2/3为度，使熨平板的挡板前混合料的高度在全宽范围内保持一致，避免摊铺层出现离析现象。

⑸检测松铺厚度是否符合规定，以便随时进行调整。摊前熨平板应预热至规定温度。摊铺机熨平板必须拼接紧密，不许存有缝隙，防止卡入粒料将铺面拉出条痕。

⑹摊铺遇雨时，立即停止施工，并清除未压实成型的混合料。遭受雨淋的混合料应废弃，不得卸入摊铺机摊铺。

6、沥青混合料的压实成型

（1）沥青混合料的压实是保证沥青面层质量的重要环节，应选择合理的压路机组合方式及碾压步骤。为保证压实度和平整度，初压应尽量在摊铺后较高温度下及时进行。**为防止橡胶沥青粘结橡胶轮胎，AR-AC沥青混凝土不宜使用胶轮压路机。Penumatic roller is not allowed to prevent pick up.**

⑵橡胶沥青混合料压实工艺分为初压、复压和终压。碾压工艺通过试铺段确定。

⑶压路机应以缓慢而均匀的速度碾压，压路机的适宜碾压速度建议按表10选用。

表10 压路机碾压速度（km/h）

Table 10. Speed of Roller (km/hr)

压路机类型 Type of Roller	初压 Breakdown	复压 Intermediate	终压 Finish
静载钢轮压路机 Static Steel Drum Roller	2～3	——	3～6
钢轮振动压路机 Vabratory Steel Drum Roller	2～4	3～5	——

（4）为避免碾压时混合料推挤产生拥包，碾压时应将驱动轮朝向摊铺机；碾压路线及方向不应突然改变；压路机起动、停止必须减速缓行，不准刹车制动。压路机折回不应处在同一横断面上。

（5）初压应紧跟摊铺机进行碾压，随摊铺机逐步推进。复压、终压应分清段落，设置明显标志，便于司机辨认。对松铺厚度、碾压顺序、压路机组合、碾压遍数、碾压速度及碾压温度应设专岗管理和检查，使面层做到既不漏压也不超压。

（6）压实完成12小时后，方能允许施工车辆通行。

7、施工接缝的处理

（1）纵向施工缝。对于采用两台摊铺机成梯队联合摊铺方式的纵向接缝，应在前部已摊铺混合料部份留下10～20cm宽暂不碾压作为后高程基准面，并有5～10cm左右的摊铺层重叠，以热接缝形式在最后作跨接缝碾压以消除缝迹。上中层纵缝应错开15cm以上。

（2）横向施工缝。全部采用平接缝。用三米直尺沿纵向位置，在摊铺段端部的直尺呈悬臂状，以摊铺层与直尺脱离接触处定出接缝位置，用锯缝机割齐后铲除；继续摊铺时，应将摊铺层锯切时留下的灰浆冲洗干净，涂上少量粘层沥青，摊铺机熨平板从接缝处起步摊铺；碾压时用钢筒式压路机进行横向压实，从先铺路面上跨缝逐渐移向新铺面层。

8、施工阶段的质量管理Quality Control during Construction

检查项目、检查方法、检查频率和质量要求列于表11。本表所列为施工阶段的质量检验标准，交工验收按国家相关标准进行。

压实度采用双控指标，要求马歇尔标准密度的压实度不小于98%，最大理论密度压实度为94%~96.5%。

上面层平整度要求连续平整度仪100m标准差的合格标准不大于0.8mm。

渗水系数应作为常规试验进行检测，应使用改进型渗水仪（着地环状宽度35mm、装有渗水仪开关），施工单位自检和监理组抽检，可按取芯压实度检验频率随机选点。渗水系数要求不大于50ml/min，渗水系数合格率宜不小于80%，当合格率小于80%时应加倍频率检测，如检测结果仍小于80%，需对该段面层进行处理。同时应加强薄弱环节的渗水系数的控制，渗水系数极值不超过150 ml/min（不参与合格率控制）。The permeability should be less than 50 ml/min.

面层混合料的离析包括沥青混合料的温度离析和沥青混合料的级配离析，离析可以暂时作如下控制：

（1）施工过程中采用红外温度探测器检测的温度差不应超过20℃；

（2）核子密度仪检测的密度差不应超过0.075g/cm^3（大体上相当于空隙率相差3%）；

（3）构造深度的最大值与平均值之比不应超过1.5。

表11 AR-AC13沥青混合料上面层施工阶段的质量检查标准

项目	检查频率	质量要求或允许差	试验方法
橡胶沥青177℃粘度（Pa·s）	每生产一批检查一次（每1小时检测1次）	1.5～4.0	旋转粘度计
施工温度：沥青混合料出厂温度	每车料一次	符合表9的规定	温度计测定
运输到现场温度			
初压温度			
碾压终了温度			

矿料级配，与生产设计标准级配的差（%）	0.075mm	逐盘在线检测	±2	计算机采集数据计算
	≤2.36mm		±5	
	≥4.75mm		±6	
	0.075mm	逐盘检查，每天汇总1次，取平均值评定	±1	总量检验
	≤2.36mm		±2	
	≥4.75mm		±2	
	0.075mm	每台拌和机每天上、下午各1次	±2	拌和厂取样，用抽取后的矿料筛分
	≤2.36mm		±4	
	≥4.75mm		±5	
沥青含量（油石比），与生产设计的差（%）		逐盘在线检测	±0.3	计算机采集数据计算
		逐盘检查，每天汇总1次，取平均值评定	±0.1	总量检验
		每日每机上、下午各1次）	–0.1，+0.2	拌和厂取样，离心法抽提
马歇尔试验： 稳定度（kN）不小于		每日每机上、下午各1次	8.0	拌和厂取样， 室内成型试验
流值（0.1mm）			20～50	
空隙率（%）			4.5～6.5	
压实度（%）		每层1次/200m/车道	不小于98（马歇尔密度），94～96.5（最大理论密度）	现场钻孔试验（用核子密度仪随时检查）
厚度	不超过	1次/200m/车道	–4mm	钻孔检查并铺筑时随时插入量取，每日用混合料数量校核
平整度	不大于	每车道连续检测	0.8mm	用连续式平整度仪检测
宽度		2处/100m	不小于设计宽	用尺量
纵断面高度		3处/100m	±15 mm	用水准仪或全站仪
横坡度		3处/100m	±0.3%	用水准仪检测
中线平面偏位	不大于	4点/200m	20mm	用经纬仪检测
渗水系数	不大于	1次/200m/车道	50ml/min	改进型渗水仪
摩擦系数		1处/200m	符合设计要求	摆式仪
构造深度				铺砂法

注：检查频率为单幅双车道。

Appendix V: Rhode Island AR Gap Graded Superpave Mix Design

MassHighway ARGG (Asphalt Rubber Gap Graded) Mix Design

I. Design Criteria

Superpave Design Gyrations (N_{design})	100
Percent Air Voids	3-6%
Voids in Mineral Aggregate (VMA)	18-23%

II. Material Sources

Coarse Aggregate – Aggregate Industries Quarry Wrentham, MA
12.5 mm & 9.5 mm Crushed Stone

Fine Aggregate - Aggregate Industries Quarry Taunton, MA
Stone Dust

Fine Aggregate – G. Lopes Raynham, MA
Natural Sand

Fine Aggregate - Aggregate Industries Quarry Wrentham, MA
Baghouse Fines

Binder – All States Asphalt Inc. Sunderland, MA
PG58-28 with 20% Rubber

III. Gradation, Blend Composition & Aggregate Properties

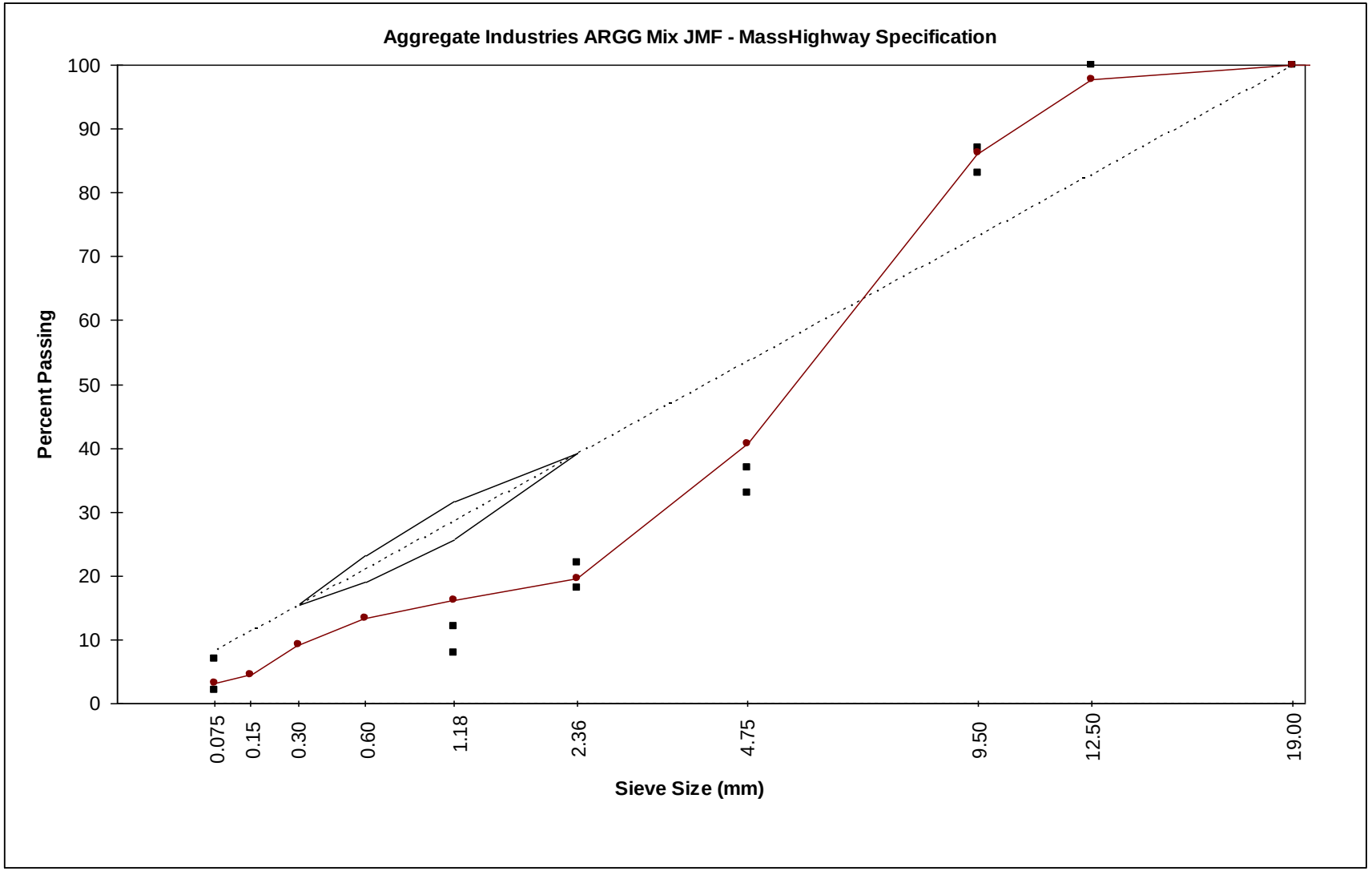
Job Mix Formula (JMF)

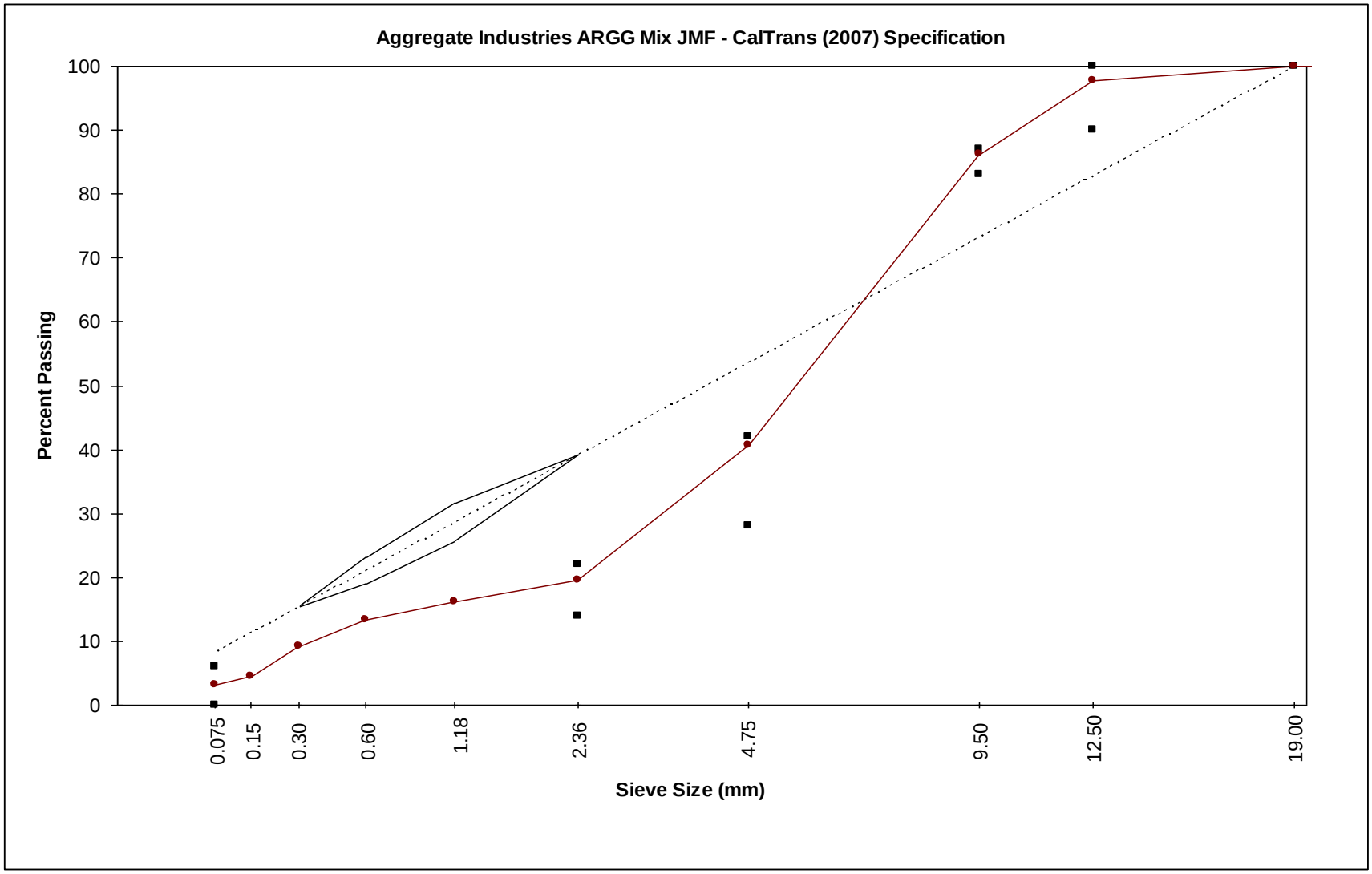
Sieve Size	Aggregate Industries ARGG JMF	MassHighway ARGG Specification	CalTrans (2007) Specification
19.0 mm	100.0	100	100
12.5 mm	97.7	100	90-100
9.5 mm	86.2	83-87	83-87
No. 4	40.6	33-37	28-42
No. 8	19.6	18-22	14-22
No. 16	16.2	8-12	-
No. 30	13.4	-	-
No. 50	9.2	-	-
No. 100	4.5	-	-
No. 200	3.1	2-7	0-6
% PG58-28 w/20% Rubber Asphalt	7.5%	6.5% min.	-

Blend Composition:
13.0% - 12.5mm Aggregate
67.0% - 9.5 mm Aggregate
9.0% - Stone Dust
10.0% - Natural Sand
1.0% - Baghouse Fines

Aggregate Properties for Aggregate Industries ARGG JMF

Item	Result
Combined Bulk Specific Gravity of Aggregate of JMF (Gsb)	2.650


Aggregate Industries ARGG Mix JMF - MassHighway Specification
Percent Passing
100
90
80
70
60
50
40
30
20
10
0
0.075
0.15
0.30
0.60
1.18
2.36
4.75
9.50
12.50
19.00
Sieve Size (mm)


Aggregate Industries ARGG Mix JMF - CalTrans (2007) Specification
Percent Passing
100
90
80
70
60
50
40
30
20
10
0
0.075
0.15
0.30
0.60
1.18
2.36
4.75
9.50
12.50
19.00
Sieve Size (mm)

IV. Temperatures

Mixing Temperature Range: 177°C (350°F)
Compaction Temperature Range: 154-157°C (310-315°F)

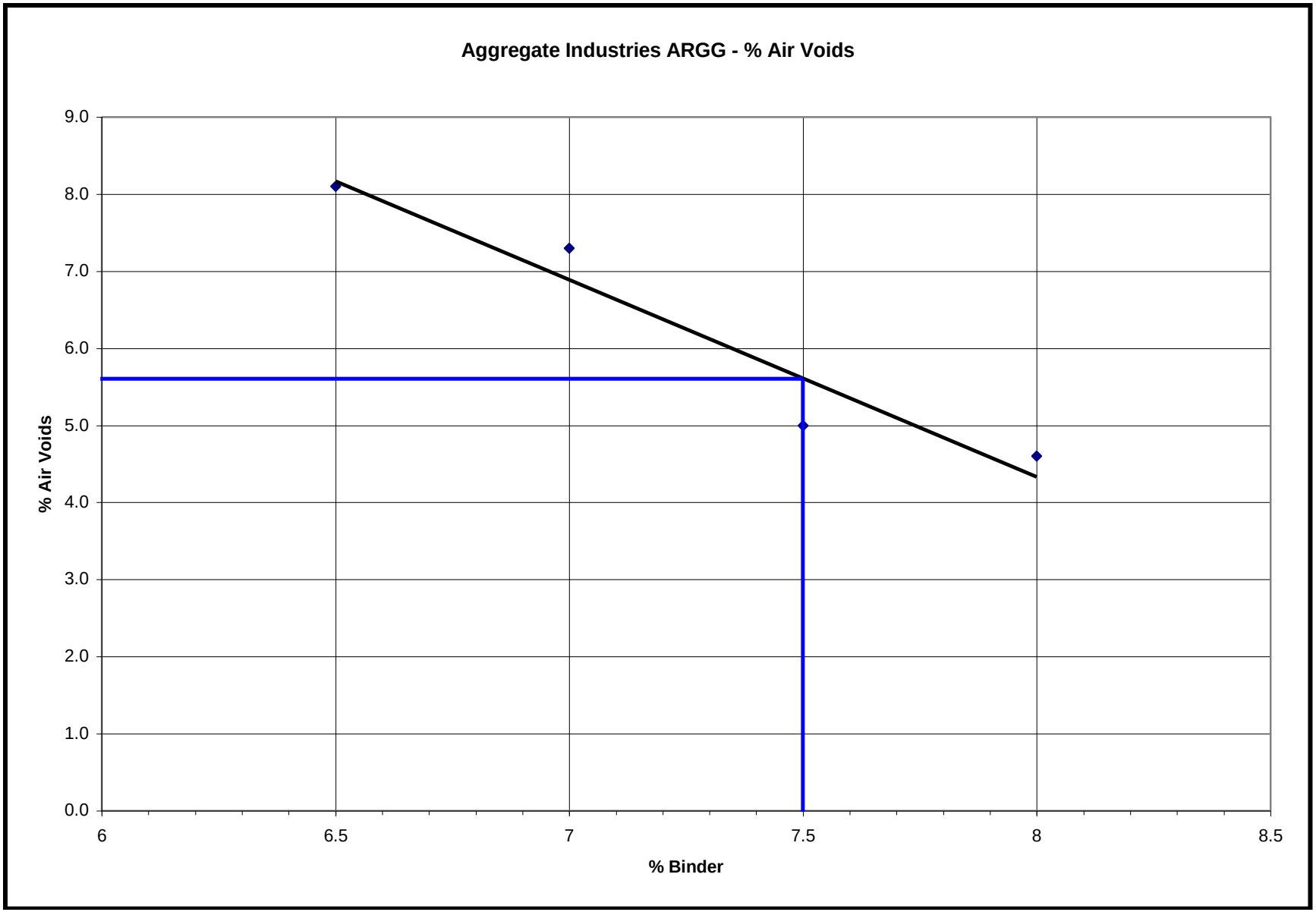
V. Superpave Volumetric Trial Test Results

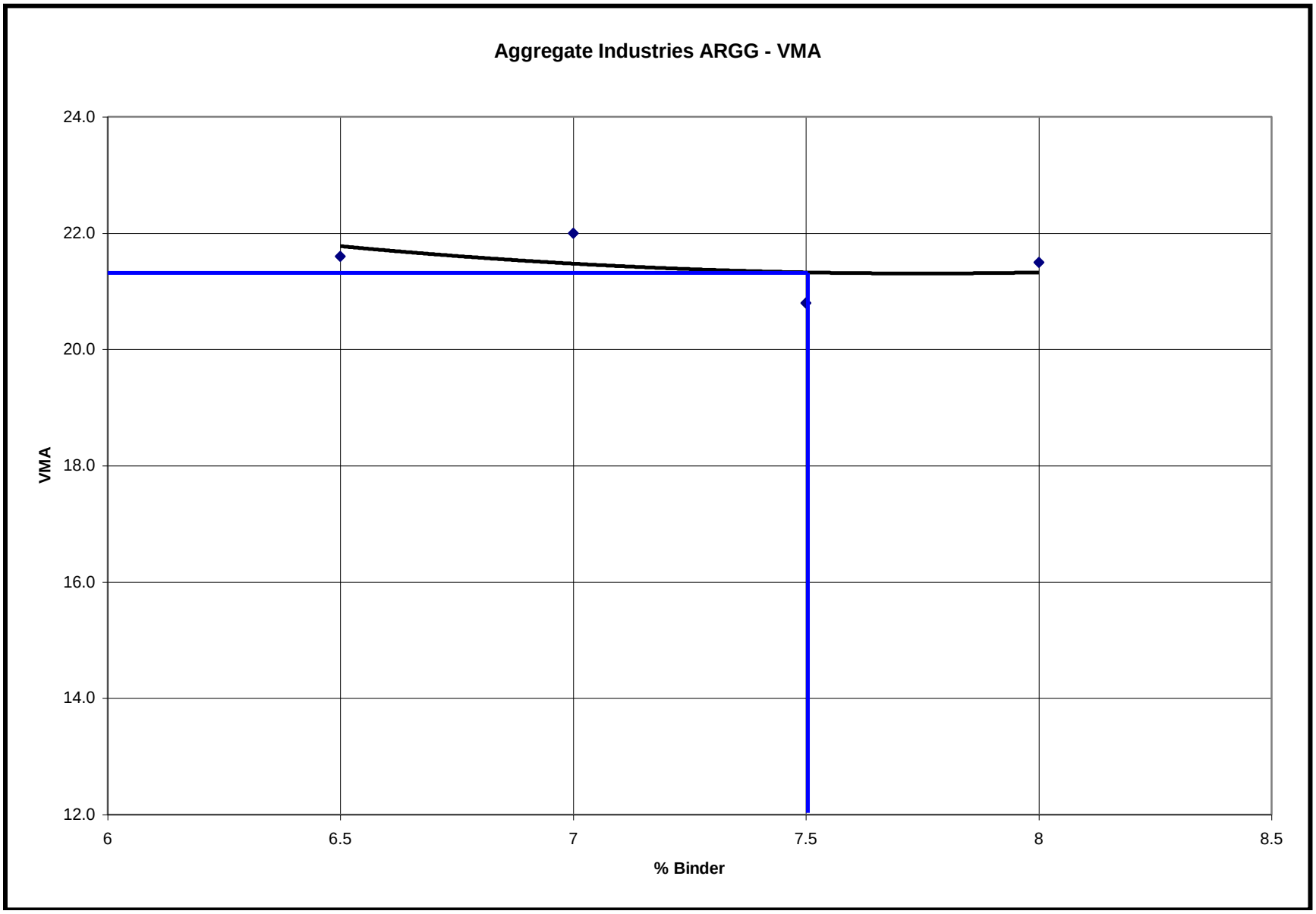
Aggregate Industries ARGG – Average Properties Trial Mixes

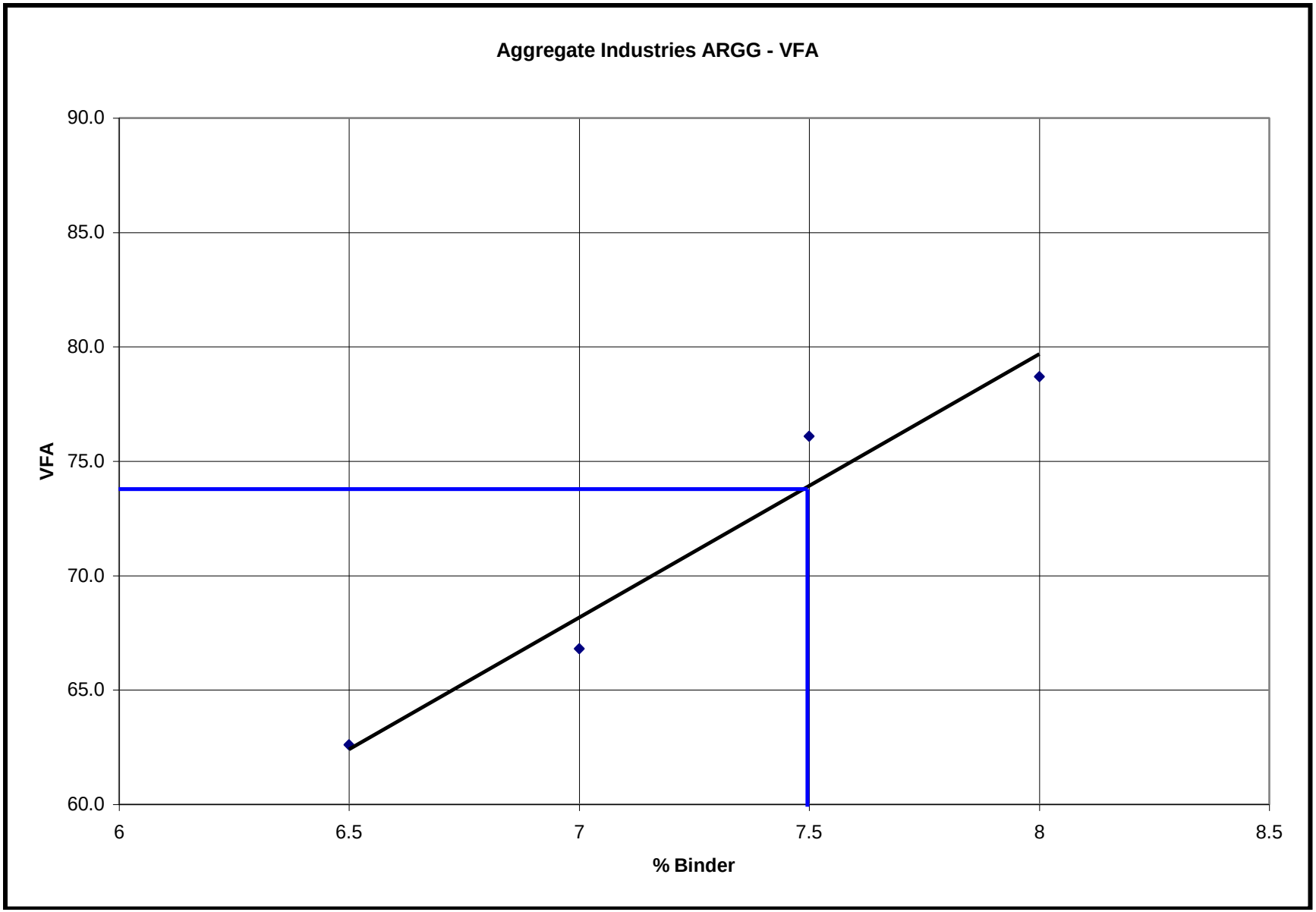
	Trial Asphalt Contents				MassHighway ARGG Specification Range	CalTrans (2007) Specification Range
% Asphalt	6.5%	7.0%	7.5%	8.0%	6.5% min.	-
Air Voids, %	8.1	7.3	5.0	4.6	3.0 - 6.0%	-
VMA, %	21.6	22.0	20.8	21.5	18-23%	18-23%
VFA, %	62.6	66.8	76.1	78.7	-	-
Dust to Binder Ratio	0.50	0.46	0.43	0.40	-	-

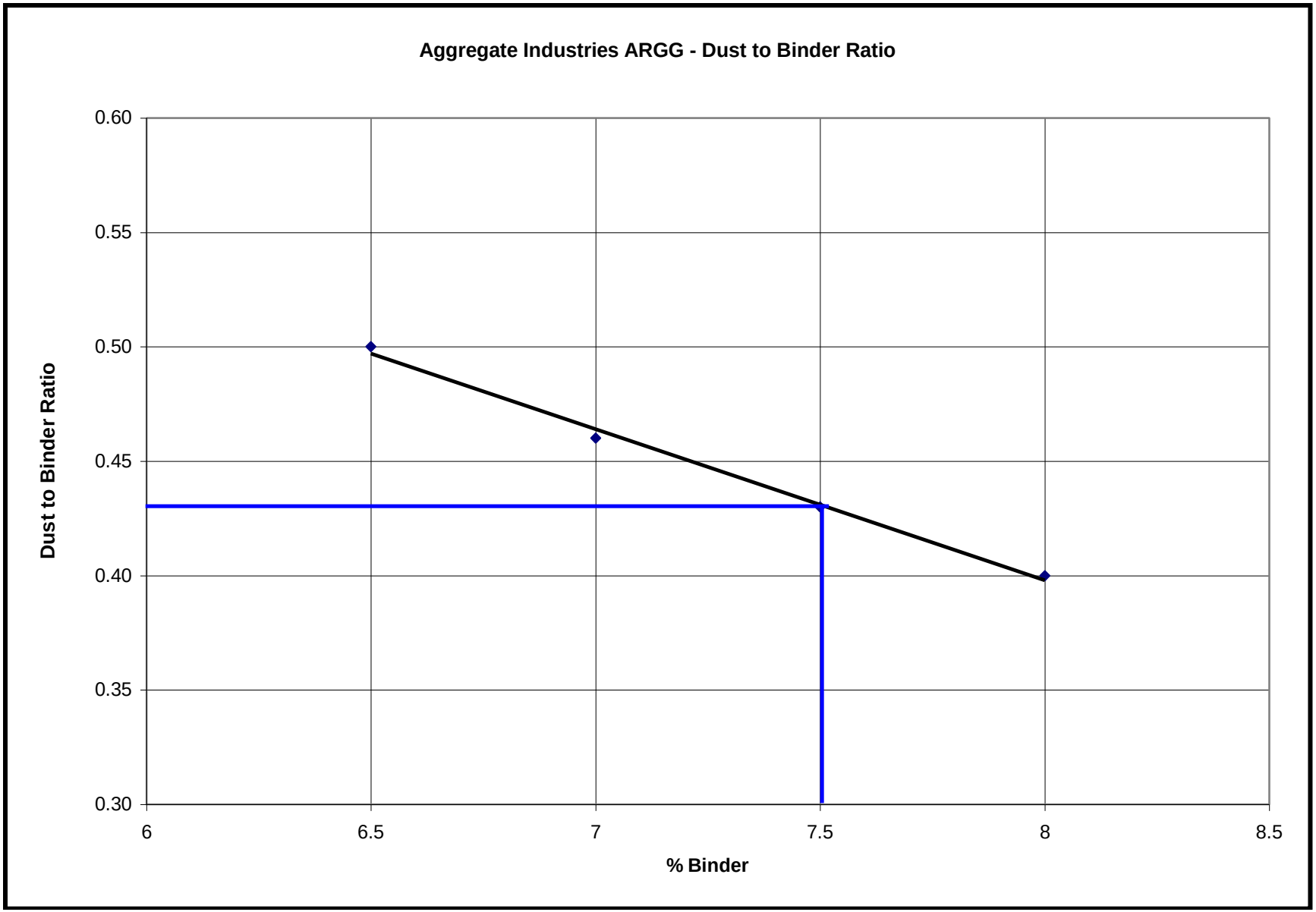
Aggregate Industries ARGG – Properties at Optimum Binder Content

Property	Property Result at Optimum	MassHighway ARGG Specification Range	CalTrans (2007) Specification Range
% Asphalt	7.5%	6.5% min.	-
Air Voids, %	5.6%	3.0 - 6.0%	-
VMA, %	21.3%	18-23%	18-23%
VFA, %	73.8%	-	-
Dust to Binder Ratio	0.43	-	-


Aggregate Industries ARGG - % Air Voids
% Air Voids
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
6
6.5
7
7.5
8
8.5
% Binder


Aggregate Industries ARGG - VMA
24.0
22.0
20.0
18.0
16.0
14.0
12.0
VMA
6
6.5
7
7.5
8
8.5
% Binder


Aggregate Industries ARGG - VFA
90.0
85.0
80.0
75.0
70.0
65.0
60.0
VFA
6
6.5
7
7.5
8
8.5
% Binder


Aggregate Industries ARGG - Dust to Binder Ratio
Dust to Binder Ratio
0.60
0.55
0.50
0.45
0.40
0.35
0.30
6
6.5
7
7.5
8
8.5
% Binder