INTERIM REPORT

CONSTRUCTION GUIDELINES FOR CRUMB RUBBER MODIFIED HOT MIX ASPHALT

Prepared for:

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### Abstract

In recent years there has been increased interest in the use of crumb rubber modified hot mix asphalt (CRM HMA) pavements. This report presents the current technology for the construction of CRM HMA pavements.

The major component of CRM is scrap tire rubber. The agencies currently specifying CRM HMA pavements generally agree on the chemical and foreign matter requirements for the CRM, but differ on the CRM gradation. The gradation chosen will impact the end result of the material and the level of modification of the asphalt cement.

There are two processes for manufacturing CRM HMA mixtures - the wet process and the dry process. The wet process is any process where the CRM is blended with the asphalt cement before the modified binder is added to the heated aggregate. The dry process is where the CRM is mixed with the aggregate before the asphalt cement is added.

Both “on site” and terminal systems are being used to blend the asphalt rubber for the wet process. A field blending system is a portable system where the asphalt cement and CRM are mixed at the contractor’s HMA mixing plant. On the terminal blending system, the CRM and asphalt cement are mixed at a central fixed location and the resultant binder is transported to the HMA mixing plant.

The construction process for CRM HMA is much the same as for conventional HMA. The major difference is the increased viscosity of the binder. Thus, mixing, laydown and compaction temperatures must be increased. The quality control/quality assurance program for CRM HMA is similar to conventional HMA. The key to a good CRM HMA pavement is proper control of the percentages of CRM and asphalt cement, time and temperature reaction, and the use of volumetric controls for the mix properties.
EXECUTIVE SUMMARY

The major component of CRM is scrap tire rubber. There are many sources of ground tire rubber or CRM throughout the United States and Canada. The scrap tires are delivered to the processing plant as whole, cut or shredded tires or buffing waste where they are processed into CRM using one or more combinations of four processes: crackermill, granulator, wet-grinding, and/or cryogenic process. To control the quality of the CRM, it is necessary to insure that certain chemical properties and the required gradation are provided and that the CRM is free of foreign material. The agencies currently specifying CRM generally agree on the chemical and foreign material requirements. There is wide variation in the gradation being used. Different user agencies specify different gradations. The gradation chosen depends on the end use of the material (wet or dry process, and dense, open or gap graded aggregate gradation) and the level of modification of the asphalt cement required.

Aggregates used for CRM HMA should conform to the general source requirements for aggregates used by each agency. Generally, CRM HMA has been most successful with either gap or open graded aggregates.

There are two processes for manufacturing CRM HMA mixtures - the wet process and the dry process. The wet process is any process where the CRM is blended with the asphalt cement before the modified binder is added to the heated aggregate. The dry process is any process where the CRM is mixed with the aggregate before the asphalt cement is added.

There are many systems currently being used to blend asphalt rubber for the wet process. On-site and terminal systems are used. An on-site system is a portable system in which the asphalt cement and CRM are blended at the contractor's HMA mixing plant. A terminal system blends the asphalt cement and CRM at a central fixed location and the resultant binder is transported to different HMA mixing plants. Each of these systems must provide a uniform, thoroughly blended mixture. The key to insuring that this occurs is to require a properly calibrated feeder systems, tight control on temperatures and blending, mixing and holding tanks without dead zones. The report provides details on many of the blending systems being used throughout the United States and Canada. Systems described in this report are the most common ones currently used.

In the dry process with drum plants, the CRM can be added with the baghouse fines and fed into a mixing chamber where the asphalt cement is added. Or be fed into the outer drum of a double drum plant. With batch plants, the CRM is added to the pugmill and the mixing time is increased before the asphalt cement is added.
The construction process is much the same for CRM HMA as it is for conventional HMA. A major difference is dealing with the increased viscosity of the binder. Therefore, the mixing laydown and compaction temperatures must be increased. This applies to both the wet and dry processes. Because of the sticky nature of the material, hand work and raking is more difficult.

The quality control/quality assurance process for CRM HMA should be similar to that used for conventional HMA. The contractor must control the gradation of the aggregate and the amount of binder being introduced using either standard extraction procedures or the NCAT ignition method. Either the contractor or the agency should verify that the volumetric properties of the CRM HMA mixture are within the specification requirements.
ACKNOWLEDGMENTS

The Federal Highway Administration acknowledges the many contributions of both public and private sector individuals in the States of Arizona, California, and Florida in preparation of this report. In addition, this report was prepared as part of the State’s Planning and Research program study entitled “Evaluation of Crumb Rubber Modifiers in Asphalt Pavements” SP&R-(2)166. The Federal Highway Administration would like to acknowledge the following states for supporting this pooled fund study effort: Alabama, Arizona, Arkansas, California, Connecticut, Delaware, Florida, Georgia, Illinois, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Tennessee, Utah, Virginia, Washington, Wisconsin, and Wyoming.
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#### APPROXIMATE CONVERSIONS TO SI UNITS

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**NOTE:** Volumes greater than 1000 L shall be shown in m³.

**MASS**

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**TEMPERATURE (exact)**

| °F | Fahrenheit | (°F-32)/1.8 | Celsius | °C |
| °C | Celsius | 1.8°C + 32 | Fahrenheit | °F |

**ILLUMINATION**

| fc | foot-candles | 10.76 | lux | lx |
| lL | foot-Lamberts | 3.426 | candela/m² | cd/m² |

**FORCE and PRESSURE or STRESS**

| lbf | poundforce | 4.45 | newtons | N |
| lbf/in² | poundforce per square inch | 6.89 | kilopascals | kPa |

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

(Revised September 1993).
CHAPTER 1: INTRODUCTION AND BACKGROUND

INTRODUCTION

Each year the United States discards about 285 million tires (1). Of that figure, 33 million tires are retread, 22 million tires are reused (resold), and 42 million tires are diverted to other uses. The remaining tires are placed in stockpiles, landfills or illegal dumps across the country (1). The EPA estimates that two to three billion tires are stockpiled or landfilled throughout the United States (2). There are environmental risks associated with these scrap tire stockpiles and landfills. It has been shown that there is fire hazard associated with tire stockpiles as demonstrated by well publicized tire stockpile fires. Stockpiles also provide ideal places for breeding mosquitoes and other disease carrying animals.

Land-filling of scrap tires presents several obstacles. Tires use a disproportionate amount of space (tires resist compaction). This is due to their geometry and other physical properties. Scrap tires trap gases and become buoyant, penetrating the covering membrane of the landfill and eventually migrating to the surface (3).

Researchers have identified many uses for disposed tires. One is the use of scrap tires as a tire derived fuel (TDF) in cement kilns, pulp and paper mills, utility boilers and dedicated tire-to-energy facilities. Approximately 57 million scrap tires are used annually for energy recovery. By 1997 it is anticipated that the TDF rate will increase to 185 million tires annually (1). TDF contains about 14,000 to 16,000 BTUs per pound. This is a higher heat energy by weight than most types of coal. In 1991, approximately 90 million pounds of ground rubber was made into rubber products such as athletic fields, railroad crossing pads, drip irrigation pipes, etc. Another use is in hot mix asphalt (HMA) paving mixtures. Highway applications presently utilize 5 million tires annually (3).

BACKGROUND

The concept of adding tire rubber (referred here as crumb rubber modifier or CRM) to asphalt started in the 1950's. In 1959, Mankowich had a patent for rubber modified asphalt in Canada. Flinsteal Corporation dissolved CRM in asphalt in the early 1960's. The New York DOT specified a rubber modified hot mix asphalt (RMHMA) in 1962. In the early 1960's, Charles H. McDonald incorporated CRM into asphalt cement instead of using expensive natural rubber material. McDonald's rubber modified asphalt patches were placed in the Phoenix area to stop asphalt pavement cracking with promising results. The success of using a more rubber modified asphalt as a patching material in the Phoenix area led to its use for other applications. In 1968 the Arizona Department of Transportation (ADOT) placed its first Stress Absorbing Membrane (SAM), a surface treatment using rubber modified binder (4). Later in 1972, ADOT placed its first Stress Absorbing Membrane Interlayer (SAMI), which is a SAM placed before an overlay. Asphalt rubber binder was used in an open graded friction course in 1975 (1,5).
The environmental risk associated with land-filling tires and the early success of incorporated CRM into asphalt pavements has initiated action at the state and national level. Section 1038d of the Intermodal Surface Transportation Efficiency Act of 1991 legislatively addresses the study and use of scrap tires in hot mix asphalt (HMA) by highway agencies (1).

Description of the Technologies

CRM is added to HMA using two basic processes: a wet and a dry process. The difference between the two processes is the point in the production process the CRM is added to the HMA mixture. In the wet process, CRM is added to the asphalt cement to produce a rubber modified binder. This modified binder added to the aggregate to form HMA. There are many technologies available for blending the CRM and the asphalt cement. Always the result is a rubber modified binder. In the dry process, the CRM is added directly to the HMA mixing process. This is accomplished by preblending the CRM with the heated aggregate or fines before charging the mix with the asphalt cement. Figure 1 shows the relationship between CRM terminology and the technology now in use.

Objective

The objective of this report is to provide detailed information about the construction of crumb rubber modified hot mix asphalt pavements. This report is an interim report. As new construction technology is developed and as research data becomes available it will be updated and included in the final report.

Scope

A review of agency and contractor practices currently in use in the United States and Canada are presented in this report. This report is based on interviews with agency and industry personnel and a review of the existing literature on crumb rubber modifier (CRM) construction technology.
Figure 1. The relationship between crumb rubber modified (CRM terminology and technology (6).
CHAPTER 2: MATERIALS

This chapter provides the reader with a background on the materials used in crumb rubber modified hot mix asphalt pavements and the specifications for those materials. Specific topics will include a discussion of the production and properties of CRM, the shipping and handling of CRM, the properties of the asphalt cement as they relate to asphalt rubber and the aggregates used in crumb rubber modified HMA.

Crumb Rubber

Production

The major component of crumb rubber modifier (CRM) is scrap tire rubber which is primarily natural and synthetic rubbers and carbon black. Automobile tires have more synthetic rubber than truck tires. Truck tires contain a higher percentage of natural rubber than automobile tires. Advances in tire manufacturing technology have decreased the difference in chemical composition between the types of tire rubber. The typical bulk CRM produced in today’s market is uniform in composition (5). According to Schnormeier (5) the average car tire contains: ten types of synthetic rubber, four types of natural rubber, four types of carbon black, steel cord, bead wire, and 40 kinds of chemicals, waxes, oils, pigments, etc. The average tire contains the following rubber contents (5):

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<td>85% synthetic</td>
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<td>Bias</td>
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CRM is not produced based on a specific blend of tires. Instead the size, shape and texture and chemistry of the CRM particles are specified. These properties are important because they control the relative surface area of the rubber that may influence the asphalt rubber interaction. The size, shape and texture of the particle largely determine the type of processing required.

The scrap tires are delivered to a processing plant as whole, cut, or shredded tires or buffing waste. CRM is produced using one or more combinations of the four processes: crackermill, granulator, wet grindings, and cryogenic process (8).
The most common method is the crackermill process (figure 2). The scrap tires are pre-processed by shredding to remove steel cord and bead wire. Rotating corrugated steel drums are used to tear the scrap tires into smaller ground CRM. The ground CRM has irregular torn shapes with large surface areas and sizes ranging from 4.75 mm to 425 μm (No. 4 to No. 40 sieve).

In the granulator process, steel cord and bead wire are removed and close tolerance revolving steel plates are used to cut the scrap tires into granulated CRM. The granulated CRM is cubical, uniformly shaped with a low surface area with sizes ranging from 9.5 mm to 2.0 mm (3/8 inch to No. 10 sieve).

In the wet-grinding process, ground or granulated CRM is mixed with water and forced between rotating discs to reduce the CRM to sizes ranging from 425 μm to 75 μm (No. 40 to No. 200 sieve). Before the material is processed in the wet grinding process, it must be reduced in size using another process. Figure 3 presents a schematic of the wet grinding system.

FIGURE 2: Typical crackermill grinding system (9)
FIGURE 3: Schematic of wet grinding system (9)
In the cryogenic process, the pre-chipped scrap tires are cooled with liquid nitrogen. The brittle tire rubber is easily fractured with a hammer mill (figure 4). The process uses a cooler to chill the material, a grinder, appropriate screens and conveyors and steel and fiber separation systems. Usually, the cryogenic process is used as a preliminary step to the other processes which will reduce the particles to the desired size.

In most tire grinding plants, these processes are used in combination with each other to produce the desired end product. A listing of U. S. rubber producers is given in Appendix B.

Physical/chemical properties

Specifying CRM may be done in terms of physical and/or chemical properties. Commonly specified properties include: size/gradation, specific gravity, acetone extract, ash, carbon black, rubber hydrocarbon, and natural rubber content.

The size/gradation of the ground CRM influences the interaction of the asphalt rubber blend. A coarser CRM gradation requires a longer time to react than a fine grind CRM. When
a coarse CRM gradation is used, it is desirable that the aggregate gradation should be either gap or open graded to allow room for the coarser rubber particles. The dense graded mixtures placed in recent years have used a finer gradation of rubber. The finer the gradation the more expensive the CRM. The rubber gradations used by selected agencies are shown in Table 1.

When crumb rubber is added to asphalt cement there is an initial increase in viscosity. The viscosity is constant for a period of time and if the asphalt rubber blend is held at this elevated temperature for a period of time the viscosity will decrease. This is due to a degradation of the rubber. Figure 5 shows a typical viscosity versus time curve. The data shown in this figure if for an AC-10 with 18% ambient ground CRM.

![FIGURE 5. Typical Viscosity versus Time Curve](image)

Chemical properties of the rubber are important and requirements have been established to chemically define the CRM material. These requirements were developed to prevent the supplier’s use of sources other than automobile/truck tires in CRM material. The inclusion of specification requirements for ash, carbon black and rubber hydrocarbon (three definitive components of tires) prohibits the substitution of unacceptable materials such as conveyor belts. Two agencies include a chemical requirement in their specifications: the Florida DOT and the Southern California Chapter of the APWA (see Table 2).

**Shipping, Storage and Handling of CRM Materials**

The CRM is shipped to the asphalt rubber blending operations in either 453 kg. to 906 kg. (1000 to 2000 lb.) gaylord boxes, super sacks (approximately 1 metric ton (2200 lb.)), bulk tanker trucks (similar to cement or lime bulk trucks) or in bags weighing 11 kg. to 27 kg. (25 to 60 lb.). The most economical size of shipment is in truck load quantities, usually 18,140 kg.
to 20,400 kg. (40,000 to 45,000 lb.). Figure 6 shows a super sack storage area on a project in Southern California.

After shipment to the project site, the rubber must be kept dry because moisture in the rubber can cause foaming of the asphalt/rubber during the blending process. The crumb rubber can be loaded directly into a crumb rubber hopper on the blending equipment at the project site. It can also be blown from the bulk tanker truck into a silo from which it can be augured into the asphalt rubber blending unit.

Clumping of CRM in the large containers, such as the gaylord boxes, or supersacks has been reported. Some rubber suppliers (generally at the request of the asphalt rubber blender) add 2 to 4 percent calcium carbonate or talc to the CRM to prevent the CRM from sticking together and to improve free flow characteristics.
TABLE 1: Crumb Rubber Gradations Being Used by Selected Agencies

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>International Surfacing Incorporated</th>
<th>APWA So. Calif. Chapter</th>
<th>City of Phoenix</th>
<th>Florida</th>
<th>Arizona DOT</th>
<th>California DOT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type 1</td>
<td>Type 2</td>
<td>Type D-I</td>
<td>Type D-II</td>
<td>Type D-III</td>
<td>Type B &amp; C(1)</td>
</tr>
<tr>
<td>2.36 mm (No. 8)</td>
<td>100</td>
<td>-</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>2.00 mm (No.10)</td>
<td>95-100</td>
<td>100</td>
<td>95-100</td>
<td>100</td>
<td>-</td>
<td>98-100</td>
</tr>
<tr>
<td>1.18 mm (No.16)</td>
<td>40-60</td>
<td>70-100</td>
<td>40-60</td>
<td>70-100</td>
<td>45-85</td>
<td>50-85</td>
</tr>
<tr>
<td>.85 mm (No. 20)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.60 mm (No. 30)</td>
<td>0-20</td>
<td>25-60</td>
<td>0-20</td>
<td>25-60</td>
<td>5-35</td>
<td>5-30</td>
</tr>
<tr>
<td>.425 mm (No. 40)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.300 mm (No. 50)</td>
<td>0-10</td>
<td>0-20</td>
<td>0-10</td>
<td>0-20</td>
<td>0-15</td>
<td>0-15</td>
</tr>
<tr>
<td>.180 mm (No. 80)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.150 mm (No.100)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0-10</td>
<td>0-10</td>
</tr>
<tr>
<td>.075 mm (No.200)</td>
<td>-</td>
<td>0-5</td>
<td>0-5</td>
<td>0-5</td>
<td>0-1</td>
<td>0-1</td>
</tr>
<tr>
<td>Max Particle Size</td>
<td>4.69 mm (3/16&quot;)</td>
<td>4.69 mm (3/16&quot;)</td>
<td>6.25 mm (1/4&quot;)</td>
<td>6.25 mm (1/4&quot;)</td>
<td>6.25 mm (1/4&quot;)</td>
<td>6.25 mm (1/4&quot;)</td>
</tr>
</tbody>
</table>

(1) shall contain 25% natural rubber.
Quality Control/Quality Assurance of CRM

The CRM supplier typically provides the agency with certified test results to prove that the CRM meets the chemical and foreign matter requirements. The purchasing agency or the HMA contractor may choose to have this checked either by its laboratory or an independent laboratory. Foreign matter requirements are of more interest to the HMA contractor than to the purchasing agency because if foreign material is in the CRM the contractor's equipment may be damaged (pumps for example). The CRM supplier should also provide certified gradation test results. The agency should verify that the material being provided does meet the specified gradation. There have been verified instances of material being supplied that does not meet the gradation requirements.
TABLE 2: Physical & Chemical Requirements of Crumb Rubber Modifier

<table>
<thead>
<tr>
<th>Property</th>
<th>Florida</th>
<th>APWA (So. Calif. Chapter)</th>
<th>Type D</th>
<th>Type B &amp; C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Whole Tire</td>
<td>Natural Rubber</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.10 ± 0.06</td>
<td>1.1-1.2</td>
<td>1.1-1.2</td>
<td>1.1-1.2</td>
</tr>
<tr>
<td>Moisture</td>
<td>≤ 0.75%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal Contaminants</td>
<td>≤ 0.01%</td>
<td>&lt; 0.01%</td>
<td>&lt; 0.01%</td>
<td>&lt; 0.01%</td>
</tr>
<tr>
<td>Chemical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetone Content</td>
<td>&lt; 25%</td>
<td>11-19%</td>
<td>4-10%</td>
<td>9.5-14%</td>
</tr>
<tr>
<td>Hydrocarbon Content</td>
<td>40-55%</td>
<td>42-52%</td>
<td>-</td>
<td>30-55%</td>
</tr>
<tr>
<td>Ash Content</td>
<td>≤ 8%</td>
<td>≤ 8%</td>
<td>≥ 35%</td>
<td>≤ 18.5%</td>
</tr>
<tr>
<td>Carbon Black</td>
<td>20-40%</td>
<td>28-38.8%</td>
<td>≤ 15%</td>
<td>20-38%</td>
</tr>
<tr>
<td>Natural Rubber</td>
<td>16-45% (2)</td>
<td>16-34%</td>
<td>40% Min.</td>
<td>21-42%</td>
</tr>
</tbody>
</table>

(1) From specifications - see Appendix D
(2) Type A ≥ 10%
Asphalt Cement

There are many ways in which the asphalt cement can affect the final asphalt rubber binder product. The first is that the asphalt cement chosen must be compatible with the ground crumb rubber. Compatibility is governed by the chemical composition of both the CRM and the asphalt cement and is demonstrated by an increase in the viscosity of the asphalt rubber blend with time. Many other factors are also involved in the interaction between the CRM and the asphalt cement such as blending temperature, relative surface area (gradation) of the rubber chemistry of the asphalt cement and rubber and time allowed for reaction. As the CRM is blended into the asphalt cement, the viscosity rises to a certain level and stabilize. This stabilization should occur within the first few hours. If the hydrocarbon content of the asphalt cement is high, the CRM particle will swell more readily (7). Most of the CRM produced today from scrap tires is a homogeneous blend of different rubber polymers. Therefore, compatibility is primarily dependent on the chemical and physical properties of the asphalt cement rather than the composition of the CRM material.

The asphalt cement chemical composition can vary greatly depending on the crude source. Asphalt cement is composed of various amounts of asphaltenes, aromatics, and saturates. During the reaction between the asphalt cement and the CRM the aromatics are absorbed into the CRM. If the crude source is low in aromatics, compatibility problems can develop because of an insufficient amount of aromatics for the CRM to absorb. There is also a concern that if few aromatics remain in the asphalt cement, the cold temperature flexibility of the blend is decreased. At times, extender or flux oils are used to provide the required aromatics. The California Department of Transportation requires that a flux or extender oil be added to the asphalt rubber binder. They require a resinous, high flash point, aromatic hydrocarbon conforming to the requirements listed in Table 3 and that 2 to 6 percent extender oil by weight of asphalt cement is added to their Type 2 asphalt rubber binder.

The agency should require that the asphalt rubber supplier furnish a CRM asphalt cement design that includes the quantity of the CRM and the viscosity of the asphalt rubber blend versus time (up to a minimum of 24 hrs) and temperatures. This will allow the agency and the paving contractor to evaluate the time/temperature stability of the blend.

The grade of the asphalt cement is also important. Both the low and high temperature properties are affected by the grade of asphalt cement selected; however, the low temperature properties are most affected by the grade of asphalt cement. The softer the grade of the base asphalt cement (AC-5 versus an AC-20), the better will be the low temperature properties of the resultant asphalt rubber binder. The rubber increases the high temperature viscosity. This increase can be significant.
TABLE 3: Flux Oil Requirements (CalTrans)

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Designation</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, SSU at 37.7°C (100°F)</td>
<td>D 88</td>
<td>2,500 min</td>
</tr>
<tr>
<td>Flash Point, COC. °F</td>
<td>D 92</td>
<td>198.8°C (390°F)</td>
</tr>
<tr>
<td>Asphaltenes, by Weight</td>
<td>D 2007</td>
<td>0.1% max</td>
</tr>
<tr>
<td>Aromatics, by Weight</td>
<td>D 2007</td>
<td>55% min</td>
</tr>
</tbody>
</table>

Polymers (either SBS or SBR materials) are sometimes added by the CRM supplier to enhance the properties of the asphalt rubber blend. Proprietary stabilizers or thickeners are also added to the blended asphalt rubber to reduce or prevent settlement or separation during transport or storage.

Aggregates

The aggregates used in crumb rubber modified hot mix asphalt pavements should conform to the general source requirements for aggregates being used by the agency. Table 4 (wet process) and table 5 (dry process) present the gradation requirements for many of the agencies currently specifying crumb rubber modified hot mix asphalt pavements. The type of rubber (gradation) used with each aggregate gradation is also shown. Generally, the coarse rubber is used with gap and open-graded aggregate mixes and the fine rubber is used with dense graded mixtures.
### TABLE 4: Aggregate Gradations Being Used by Selected Agencies (Wet Process)

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>APWA So. Calif Chapter</th>
<th>Arizona</th>
<th>Florida</th>
<th>California</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ARHM-GG-B</td>
<td>ARHM-GG-C</td>
<td>ARHM-GG-D</td>
<td>Gap Graded</td>
</tr>
<tr>
<td>25 mm (1&quot;)</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>19 mm (3/4&quot;)</td>
<td>90-100</td>
<td>100</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td>12.5 mm (1/2&quot;)</td>
<td>-</td>
<td>98-100</td>
<td>100</td>
<td>80-100</td>
</tr>
<tr>
<td>9.5 mm (3/8&quot;)</td>
<td>60-75</td>
<td>78-92</td>
<td>78-92</td>
<td>65-80</td>
</tr>
<tr>
<td>4.75 mm (No. 4)</td>
<td>28-42</td>
<td>28-42</td>
<td>28-42</td>
<td>28-42</td>
</tr>
<tr>
<td>2.00 mm (No. 10)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.60 mm (No. 30)</td>
<td>5-15</td>
<td>5-15</td>
<td>5-15</td>
<td>-</td>
</tr>
<tr>
<td>.425 mm (No. 40)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.075 mm (No. 200)</td>
<td>0.5</td>
<td>2-7</td>
<td>2-7</td>
<td>0-2.5</td>
</tr>
<tr>
<td>Typical CRM Percentage by Weight of AC</td>
<td>17-22</td>
<td>17-22</td>
<td>17-22</td>
<td>Min 20%</td>
</tr>
</tbody>
</table>
TABLE 5: Aggregate Gradations Being Used by Selected Agencies (Dry Process)

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Oklahoma</th>
<th>Kansas</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARM</td>
<td>BRM</td>
<td>ARS</td>
</tr>
<tr>
<td>25 mm (1&quot;)</td>
<td>90-100</td>
<td>-</td>
</tr>
<tr>
<td>19 mm (3/4&quot;)</td>
<td>75-90</td>
<td>100</td>
</tr>
<tr>
<td>12.5 mm (1/2&quot;)</td>
<td>57-72</td>
<td>85-95</td>
</tr>
<tr>
<td>9.5 mm (3/8&quot;)</td>
<td>-</td>
<td>70-85</td>
</tr>
<tr>
<td>4.75 mm (No. 4)</td>
<td>25-40</td>
<td>25-40</td>
</tr>
<tr>
<td>2.35 mm (No. 8)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.00 mm (No. 10)</td>
<td>15-25</td>
<td>15-25</td>
</tr>
<tr>
<td>1.18 mm (No. 16)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.60 mm (No. 30)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.425 mm (No. 40)</td>
<td>7-17</td>
<td>7-17</td>
</tr>
<tr>
<td>.30 mm (No. 50)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.150 mm (No. 100)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.075 mm (No. 200)</td>
<td>3-7</td>
<td>3-7</td>
</tr>
<tr>
<td>Typical CRM Gradation</td>
<td>40 Mesh</td>
<td>40 Mesh</td>
</tr>
<tr>
<td>Typical CRM Percentage by Weight of HMA</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

(1) By wt of dry aggregate
CHAPTER 3: MIX DESIGN

This chapter provides information on the Marshall and Hveem mix design procedures as they currently apply to CRM-HMA construction. As a part of this overall FHWA study on CRM, an improved mix design procedure is being developed.

Wet Process

Crumb rubber modified asphalt cement can be used for open, gap, and HMA dense-graded mixtures. The use of asphalt rubber requires that the binder be correctly designed and formulated (considering the asphalt grade, CRM gradation, and CRM concentration) for the specific application and that the final aggregate gradation be correctly selected. The different physical properties of the CRM modified binder require that the standard mixture design procedures be modified. Some of these modifications are discussed below.

Preparation of CRM binder

The first step in the development of the laboratory mix design is to manufacture a sufficient supply of CRM modified binder to provide binder for the mixture analysis. The general procedure is to heat the asphalt cement to about 25°C above the desired temperature (176°C (350°F)) and then add the CRM material (10). The mixture is stirred with mechanical mixing equipment and monitored with a Brookfield or Haake viscometer for approximately one hour. When the viscosity of the mixture has stabilized, the asphalt rubber binder can be mixed with the aggregate. The increased viscosity of the asphalt rubber will have an effect on both the mixing and compaction temperatures. The asphalt rubber may be stored overnight if needed by allowing it to cool. When needed, it may be reheated. When it is reheated, it must be thoroughly stirred to ensure uniformity.

Dense graded mixtures

When using high CRM content (10-25 percent) asphalt rubber binder it is recommended that the asphalt rubber be heated to approximately 177°C (350°F) and the aggregate to approximately 149°C (300°F). When using a low CRM content (5-10 percent) the temperature can be reduced to 166°C (325°F) and 135°C (275°F) respectively (10). Care should be taken to insure that the consistency of the asphalt rubber binder is uniform before adding to the aggregates. Mixing of the asphalt rubber with the aggregate can be accomplished using standard mechanical mixers. Mixing should be accomplished immediately after addition of the asphalt rubber.
rubber to the aggregate. Mixing should continue for at least 30 seconds beyond the time required to obtain complete coating and mixing. The compaction of the mixtures with either Marshall or Hveem procedures should follow standard procedures. Work is currently underway to evaluate the use of the SUPERPAVE Gyratory compactor for asphalt rubber hot mix asphalt.

For both Marshall and Hveem procedures, standard testing procedures should be followed. Typically for dense graded mixtures, the recommended air void content is set at the 3 to 4 percent rather than the customary 3 to 5 percent. Marshall flow values are established at 24 for light traffic, 22 for medium traffic and 20 for high traffic. This is due to the flatter slope of the load versus deformation Marshall curve. Hveem stabilometer results for high CRM dense graded HMA mixture ranges from 20 to 30 versus 35 to 40 with a conventional asphalt cement binder (11).

Gap Graded Mixtures

Both Marshall and Hveem procedures can be used to design gap-graded mixtures. Gap graded mixtures are used because of their relatively high VMA. This allows room for the CRM particles. These mixes are used with flakier coarser CRM gradations and higher CRM concentrations. California designs their mixes using Hveem procedures and selects the binder content at void contents (VTM) of 5 percent in hot desert climates and 3 percent in mountain climates. Arizona designs their mixes using the Marshall procedures. They establish their binder content based on 5 percent air voids (11).

Open Graded Mixtures

The increased viscosity of asphalt rubber binder allows for open graded mixtures to be placed at relatively high binder contents without experiencing excessive drain off during construction. The higher binder contents produce thicker, binder films. This provides increased aging resistance and durability.

Florida determines the binder content for their open graded mixtures using the FHWA OGFC (7) procedure with an unmodified AC-30 and then increasing the binder content by 12 percent for the CRM (they use an asphalt rubber with 12 percent CRM for their OGFC). For example, if the binder content for a conventional OGFC is 6.5 percent the binder content for an OGFC with CRM is 7.28 percent (6.5 + .12(6.5)).
Arizona selects the binder content for open graded mixtures using the following equation:

$$Binder\ Content = [0.38(ABS) - 0.4 + 9.0 \cdot (2.620/G_{sb})]$$

where:
- $G_{sb} = $ bulk specific gravity of the aggregate blend
- $ABS = $ water absorption of aggregate blend

**Dry Process**

In the dry process for gap graded and dense graded mixtures, the CRM is added to a heated aggregate and the combined materials are mixed with the asphalt cement. The dry process has limited use for open-graded mixtures. The laboratory mix design process should duplicate the field process as much as possible. Each agency should use its standard mix design procedures whether they are Hveem or Marshall. The samples should be compacted following the temperature requirements of The Asphalt Institute's MS-2. When CRM is added to the mix the Marshall and Hveem stabilities will be lower than they would be for a conventional HMA. The states now using the dry process (Kansas, Oklahoma, Iowa, etc.) are all using a fine graded rubber (80 mesh).
CHAPTER 4: WET PROCESS

This chapter provides a discussion of the various blending systems used to manufacture CRM modified asphalt binder, and the operation of the HMA mixing facility when CRM is used.

Blending

Charles H. McDonald (12) pioneered the U.S. development of the wet process. His work began in the mid 1960s, when he applied asphalt-rubber patching materials. McDonald's experimental work with Altos Rubber, Arizona DOT, and Sahuaro Petroleum and Asphalt Company resulted in the development of commercial binder systems. In the mid 1970s, Arizona Refining Company (ARCO) also developed a CRM modified asphalt binder system. Crafco, Inc. purchased Sahuaro and ARCO technology in the 1980s and continued developing wet process products. Different types and sizes of rubber, polymers, diluents, aromatic oils, and base asphalt cements were evaluated by these companies and others.

From the middle 1970s to the early 1980s, the Arizona DOT sponsored comprehensive research programs to develop an understanding of wet process or asphalt-rubber binders. Because these binders are reacted before being combined with aggregate, binder properties can be determined directly. The research has shown that the properties of asphalt rubber mixtures vary depending on rubber type, gradation, and concentration; asphalt cement type and concentration; diluent type, and concentration reaction time and temperature, and curing or holding time.

The early technologies for asphalt rubber were covered by a series of patents. These patents expired in 1991 and since the expiration of the patents, many different processes have been developed for blending asphalt cement and CRM. The key is that the asphalt cement and the crumb rubber modifier should be uniformly blended into a homogeneous asphalt rubber system. The time required to disperse, blend and react or melt the CRM into the asphalt cement is dependent on the particle size and texture of the rubber, the temperature of the blended material and the physical /chemical properties of the asphalt cement. The finer the material the quicker it will "react." For a given weight of CRM, the reaction time is directly proportional to the diameter squared of the CRM particles.
The reaction time is inversely proportional to the temperature of the material and will generally double with every 10°C decrease in asphalt cement temperature (13). When CRM is added to the asphalt cement there is a drop in the temperature of the combined material due to the addition of the ambient temperature CRM. For example, the addition of 20 percent CRM to an asphalt cement at 204°C (400°F) will cause the combined temperature to drop to about 177°C (350°F) after the addition of the CRM.

Currently used blending systems are discussed in the following paragraphs. Systems in use that are in the early stages of development or not used extensively are not discussed. Figure 7 shows a generalized schematic of a rubber blending system. Most systems in use are variations of this theme. Any system used for blending asphalt rubber should be evaluated for its ability to produce a uniform, "reacted" product.

![General Schematic of CRM Blending System](image)

**FIGURE 7** General Schematic of CRM Blending System (8)
Field Blending Systems

Features of the various field blending systems and the typical formulations are summarized in Tables 6 and 7. A detailed discussion of the various systems is provided below.

**CEI Blending System.** FNF Construction of Tempe, AZ, and Granite Construction of Indio, CA, use a CRM blending system manufactured by CEI Enterprises in Albuquerque, NM. The CRM is fed from a hopper that is fed from superbags. The feeder system for the CRM is an auger system that is electronically linked to the asphalt cement supply. A set of load cells on the hopper provide feedback to control the flow rate for the CRM. The asphalt cement is stored in the contractor’s asphalt tanks. A computer is used to control the CRM and asphalt cement feeder systems to provide precise batch ratios. The blending tank is a 1700 liter (450 gallons) tank and may be equipped with a twin-bladed shaft driven by a 3-hp vertical mixer. One mixing blade is at the bottom of the tank and the second in the middle. The mixing shaft operates at 2500 rpm. The asphalt cement is introduced at 204°C (400°F). During the blending process the temperature of the blended material will drop to approximately 177°C (350°F). After the asphalt cement and the CRM are blended, the modified binder is fed into a double compartment, hot oil heated, horizontal agitation tank. The tank has a 113,562 liter (30,000 gal.) capacity and each compartment is 56,780 liters (15000 gallons). A turbine mixer (operated at 56 rpm) is located in each compartment to keep the crumb rubber in suspension. It is held in the agitation tank for 45 to 60 minutes prior to use. This system can produce approximately 45 metric tons (50 tons) of asphalt rubber binder per hour.
TABLE 6: Field Blending Techniques - Equipment

<table>
<thead>
<tr>
<th>Product/Company</th>
<th>Asphalt Preheater</th>
<th>Rubber Storage</th>
<th>Reaction Vessel</th>
<th>Storage Tank</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEI</td>
<td>Yes</td>
<td>Bags, supersacks</td>
<td>Yes</td>
<td>Yes</td>
<td>Combined reaction &amp; storage tank</td>
</tr>
<tr>
<td>ISI</td>
<td>Yes</td>
<td>Bags, supersacks</td>
<td>Yes</td>
<td>Yes</td>
<td>Combined reaction &amp; storage tank</td>
</tr>
<tr>
<td>Manhole Adjusting</td>
<td>Yes</td>
<td>Bags</td>
<td>Yes</td>
<td>Yes</td>
<td>Combined reaction &amp; storage tank</td>
</tr>
<tr>
<td>Heatec</td>
<td>Yes</td>
<td>Bags, supersacks</td>
<td>No</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Rouse Rubber</td>
<td>Yes</td>
<td>Bags</td>
<td>No</td>
<td>No</td>
<td>-</td>
</tr>
</tbody>
</table>
### TABLE 7: Field Blending Techniques - Formulations

<table>
<thead>
<tr>
<th>Product/Company</th>
<th>CRM, % by total wt of Binder&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Flux</th>
<th>Chemical Stabilizer</th>
<th>Other Polymers</th>
<th>Typical Size of CRM, Mesh&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Past Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEI</td>
<td>15+</td>
<td>When Required</td>
<td>No</td>
<td>No</td>
<td>Minus 8 to 10</td>
<td>Arizona California Nevada New Mexico</td>
</tr>
<tr>
<td>ISI</td>
<td>15+</td>
<td>When Required</td>
<td>No</td>
<td>No</td>
<td>Minus 8 to 10</td>
<td>Arizona California Nevada New Mexico</td>
</tr>
<tr>
<td>Manhole Adjusting</td>
<td>15+</td>
<td>When Required</td>
<td>No</td>
<td>No</td>
<td>Minus 8 to 10</td>
<td>Arizona California Nevada New Mexico</td>
</tr>
<tr>
<td>Heatec</td>
<td>5 &amp; 12</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>40 &amp; 80</td>
<td>Florida</td>
</tr>
<tr>
<td>Rouse Rubber</td>
<td>5 &amp; 12</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>40 &amp; 80</td>
<td>Florida Alabama Mississippi Kansas</td>
</tr>
</tbody>
</table>

Note 1 - The percent CRM and the typical size represents what is being produced with that equipment where it is currently being operated. This does not imply that other percentages or sizes can not be used with the system being described.
International Surfacing Incorporated (ISI). ISI located in Chandler, AZ., uses a blending system that they developed based on the original McDonald process (see Figure 8). The CRM is fed by auger from the hopper that is fed either by breaking individual bags or by superbags. The CRM used with this system is typically a 10 mesh material. It has been used extensively in the Southwest (California, Arizona, New Mexico, and Nevada) and to a lesser extent throughout the United States. The system is a batch process. The amount of CRM and asphalt cement is determined by weight and are fed into a blender unit. The temperature of the asphalt cement at the time the CRM is added is between 190°C (375°F) and 232°C (450°F). This allows for a temperature drop caused by adding the ambient temperature rubber. After blending, the asphalt rubber is held at 162°C (325°F) to 190°C (375°F) during the reaction period. The material is reacted for 30 to 60 minutes depending on specification requirements. After the blended material is reacted the asphalt rubber can be metered into the HMA mixing facility or pumped into an agitated holding tank. The material is blended in 15,142 liter (4000 gallon) batches. This system can produce 15.2 to 31.2 metric tons (17 to 35 tons) of asphalt rubber per hour.

Manhole Adjusting Contractors, Inc. Manhole Adjusting Contractors, Inc. uses a blending system that they have developed and refined based on the original Arizona Refining Co. system (Figure 9) and work primarily in the Los Angeles area. They use a combination of natural rubber (from ground tennis balls) and ground rubber buffings. The CRM used is generally a 10-mesh material. The CRM is fed into the blending unit by breaking individual bags. The asphalt cement is preblended with a high resin, high flash point, aromatic flux or extender oil. The CRM [1 part (or 1 bag) natural rubber and 3 parts (or 3 bags) of ground tire rubber] is fed into a blending chamber (a vertical tank) that contains a high speed turbine where it is mixed with the asphalt cement at 90 gallons per minute. The mixing process is continuous. The asphalt cement and modifier are introduced into the blending chamber at between 190°C (375°F) and 232°C (450°F). After blending the asphalt rubber is fed into a reaction trailer where it is held for a minimum of 30 minutes prior to use. After reaction, the asphalt rubber binder is either fed into the contractor's HMA facility for use or into an agitated storage tank where it is held until ready for use. The system produces approximately 22 metric tons (25 tons) of asphalt rubber binder per hour.

Heatec. Heatec, Inc., a Division of Astec Industries of Chattanooga, TN has developed a portable blending system that is being used primarily in Florida by Martin Paving in Daytona Beach and Bitcom in Coral Springs. It has also been used on a project for the Kansas DOT. The system provides a continuous mixing process. The CRM is loaded into a crumb rubber hopper (see figure 10 for a schematic). The hopper can be loaded from super sacks or with an auger system from a storage silo. The CRM is augured into a 1892 liter (500 gallon) pre-wet mixing tank where it is blended with the asphalt cement. The mixing paddles in this tank operate at 50-70 rpm. The asphalt cement is preheated to 204°C to 232°C (400°F to 450°F) prior to mixing with the CRM. The pre-wetted material is pumped into another 1892 liter (500 gallon) mixing
tank for further blending. Heatec also manufactures a unit with one 3028 liter (800 gallon) mixing tank for blending, rather than the two tanks. Heatec also manufactures a unit with one 3028 liter (800 gallon) mixing tank rather than two 1892 liter (500 gallon) tanks. The CRM and asphalt cement are metered into the tanks using calibrated pumps and auger systems. They are interlocked to insure accurate feed. From these tanks the asphalt rubber is pumped into a 11,356 liter (30,000 gallon) holding tank where it is held until it is needed by the HMA contractor. The mixing paddles in this tank operate at 350-400 rpm. The tanks are vertical tanks with two mixing paddles, one near the bottom and one near the middle of the tanks. The system can be used to produce approximately 13.7 metric ton (15 tons) of asphalt rubber per hour.

Rouse Rubber Industries, Inc. Rouse Rubber Industries, located in Vicksburg, MS, has developed a portable blending and metering unit on a trailer (see figure 10 for schematic and figure 11 for a photo). It can be set up easily at an asphalt terminal, refinery, or HMA plant and interlocked into the existing system. They have done work throughout the south and use primarily 40 and 80 mesh CRM. The CRM is fed into the blending unit by filling the rubber hopper. It is augured into a vertical primary blending tank where it is mixed with the asphalt cement that is supplied at 162°C (325°F). The turbines in the primary tank are operated at 70 to 80 rpm. A secondary tank is used to increase the reaction time. It is a tank of about 1514 liters (400 gallons) and the turbines operate at 90 to 100 rpm. The process is a continuous process. The asphalt cement is preheated and is fed at the rate of 282 liters per minute (75 gal/min). The percent rubber is controlled by adjusting the rate of the auger that feeds the rubber. The residence time for the asphalt rubber blend is approximately 15 minutes. After blending the asphalt and rubber the blended binder is fed directly into the contractor’s HMA mixing facility or into a storage tank for use later. The system can produce approximately 15.6 metric tons (17 tons) of asphalt rubber per hour.
Step 1. Addition of either extender oil or diluant (if ether is used).

Step 2. Addition of rubber.
Crumb rubber is meter into system and pumped directly to the reaction tank.

Step 3. Reaction of Rubber
Tank is equipped with agitation system at the bottom of the tank.
AR is then metered into plant.

Figure 8 Schematic of ISI System (11)

Figure 9 Photo of Manhole Adjusting Blending System.
Figure 10 Heatec Blending System
Figure 11. Schematic of Rouse Blending System

Figure 12. Rouse Blending System
Central Blending Systems

Features of the various terminal blending systems and the typical formulations are summarized in tables 8 and 9. A detailed discussion of the various systems is provided below.

Anderson-Columbia Construction Co. Anderson-Columbia has established centralized blending facilities in Lake City, and Chipley, FL. These facilities are used to blend and supply asphalt rubber of their HMA plant sites located throughout north Florida and South Georgia. The plant is shown schematically in figure 12. The CRM is delivered to the site in bulk tank trucks and blown into one of two 71 metric ton (80 ton) storage silos. The asphalt cement is metered into a 45,425 liter (12,000 gallon) vertical blending tank. This tank is equipped with two turbines located at third points in the tank. The rubber is weighed into the tank and blended for a minimum of 15 minutes at 171°C (340°F). The process is a batch process. After blending the asphalt rubber is held until it is pumped into 22,722 liter (6000 gallon) transport trucks for delivery to one of Anderson-Columbia's HMA mixing plants. The tanker trucks are specially equipped with heating systems and high viscosity pumps for circulation.

Blacklidge Emulsions. Blacklidge Emulsions, Inc. developed their own batch blending systems. These systems are located in Tampa, Florida, and Gulfport, Mississippi. BEI also has a portable blending unit that is utilized on test projects and in areas where transporting the finished product would be unfeasible.

The Tampa Operation utilizes two 26,515 liter (7,000 gallon) vertical units to heat the asphalt cement, as well as blend it with the crumb rubber. Each of these tanks are equipped with vertical blenders, having a series of three different types of paddles. These blenders working with strategically placed baffles, create an environment suitable for the crumb rubber's reaction with the asphalt cement and also create a homogenous blend. A silo equipped with an auguring system and placed on load-cells is used for bulk rubber storage. The crumb rubber is augured into the blending unit as needed.

The Pensacola plant, unlike the Tampa facility, has two horizontal units with 151,515 liter (40,000 gallon) total capacity. These units are each equipped with three vertical blenders rotating at various speeds. The vertical blenders, working with a series of baffles and a pump circulation system, are able to create the environment needed for the asphalt cement reaction with the crumb rubber and at the same time create a homogenous blend. At this location the crumb rubber is manually loaded through a loading chute using fifty pound bags.

The Gulfport, Mississippi facility is equipped with a single 37,878 liter (10,000 gallon) vertical unit similar to the 26,515 liter units located at the Tampa terminal. The crumb rubber is loaded into a hopper out of fifty pound bags and augured into the unit.
### TABLE 8: Terminal Blending Techniques - Basic Equipment

<table>
<thead>
<tr>
<th>Product/Company</th>
<th>Asphalt Preheater</th>
<th>Rubber Storage</th>
<th>Blending Equipment</th>
<th>Reaction Vessel</th>
<th>Storage Tank</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dura-Tirephalt</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Combined Reaction/Storage Tank</td>
</tr>
<tr>
<td>Neste</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Blackidge Emulsions</td>
<td>No</td>
<td>Storage Silos</td>
<td>Vertical Tank</td>
<td>No</td>
<td>Yes</td>
<td>Combined Reaction &amp; Storage Tank</td>
</tr>
<tr>
<td>Anderson-Columbia</td>
<td>No</td>
<td>Bags</td>
<td>Vertical Tank</td>
<td>No</td>
<td>Yes</td>
<td>Combined Reaction &amp; Storage Tank</td>
</tr>
<tr>
<td>Cortland</td>
<td>No</td>
<td>Silos</td>
<td>Mixing Chamber</td>
<td>No</td>
<td>Yes</td>
<td>Combined Reaction &amp; Storage Tank</td>
</tr>
</tbody>
</table>
TABLE 9: Terminal Blending Techniques - Formulations

<table>
<thead>
<tr>
<th>Product/Company</th>
<th>CRM, % by Total Wt of Binder</th>
<th>Flux</th>
<th>Chemical Stabilizer</th>
<th>Other Polymers</th>
<th>Typical Size of CRM, Mesh</th>
<th>Past Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecoflex Bitumar Group</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10-20</td>
<td>Maryland, New Hampshire, New York, No. Carolina, Vermont, Ontario, Quebec</td>
</tr>
<tr>
<td>Dura-Tirephalt McAsphalt</td>
<td>7-15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30-40</td>
<td>Ontario</td>
</tr>
<tr>
<td>Neste</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
<td>-</td>
<td>Arizona, Louisiana, Nevada, Texas, Utah</td>
</tr>
<tr>
<td>Blacklidge Emulsions</td>
<td>5 &amp; 12</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>80 &amp; 40</td>
<td>Florida</td>
</tr>
<tr>
<td>Anderson-Columbia</td>
<td>5 &amp; 12</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>80 &amp; 40</td>
<td>Florida</td>
</tr>
<tr>
<td>Cortland</td>
<td>10-15</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>80 &amp; 40</td>
<td>New York, New Hampshire</td>
</tr>
</tbody>
</table>

Note 1 - The percent CRM and the typical size represents what is being produced with that equipment where it is currently being operated. This does not imply that other percentages or sizes can not be used with the system being described.
The portable unit is mounted on a tandem axle truck and has a capacity of 17,045 liter (4,500 gallon). This unit uses a system much like the horizontal units at the Pensacola facility. The crumb rubber is loaded into a hopper from fifty pound bags and augured into a direct feed port located at the top of the unit. A 24,621 liter (6,500 gallon) heated storage tank with agitators is used when needed.

**McAsphalt Engineering**

McAsphalt Engineering Services is a Canadian company that has developed a patented product being with a trade name of Dura-Tirephall. It uses a minimum of 15 percent of a 40 mesh cryogenically produced CRM plus a patented stabilizer.

**Bitumar**

Bitumar is a Canadian company that produces a product with a trade name of ECOFLEX. It is a patented product that uses a minimum of 10 percent 10 to 20 mesh rubber. It is a homogeneous product and is supplied to the contractor's HMA mixing facility. The suppliers indicate that it has unlimited shelf life. It is being supplied to the Northeastern states as PG graded binder (PG 64-34).

**Neste/Wright**

Neste/Wright of Channelview, TX has developed a patented process that they call Tire Rubber Modified Asphalt Cement (TRMAC). They blend crumb rubber into the asphalt to make a homogeneous, storage stable product.

**Suit-Kote**

Cortland Asphalt in Cortland, NY has established a terminal blending operator from which they are supplying asphalt rubber product to the Northeastern states. The terminal consists of asphalt cement feeder tanks, a mixing chamber and a storage or reaction tank. The tank has two mixing turbines that are run at 100 rpm. The CRM is added to the blending equipment from 22.6 kg (50 lb) bags. It is a batch type process. The blended asphalt rubber is trucked to the project site. Cortland insures that the HMA contractor has equipment to mix the asphalt and the rubber at the HMA plant. If they do not, Cortland will supply the mixing equipment.
General Comments on the Blending Process

Whatever the type of blending operation used, the plant must be operated in a way to obtain a thorough and uniform mixture of the materials. This requires attention to the detail by the asphalt rubber blender and the HMA contractor.

When the use of the reacted asphalt rubber is expected to be delayed by more than 6 hours, the binder should be allowed to cool to 110 to 121°C (225 to 250°F). It can be reheated slowly prior to its use to a temperature of between 150°C (300°F) and 190°C (375°F). It must be thoroughly mixed before pumping and metering into the HMA plant. The viscosity of the asphalt rubber binder should be checked. If it is out of the desired range, the asphalt-rubber blend can be adjusted by the addition of asphalt cement and/or ground tire rubber to provide the proper viscosity. If the asphalt rubber blender uses a bin type feed system for the crumb rubber modifier, steps must be taken to insure that the material is free flowing. As discussed earlier, the rubber can clump up and the chunks can plug up the gates and auger systems used to feed the mixing operation. Possible actions include a vibration of the bin or to have an individual periodically jab the material in the bin with a stick to keep the CRM free flowing.
Operation of the HMA Mixing Facility

The operation of the HMA mixing facility for the construction of wet processed asphalt rubber HMA mixes is unchanged from that used for conventional mixes, with exception that the mix is produced at higher temperatures. The blending equipment and/or agitated nurse tanks can easily be hooked up to both the drum and batch plants. When a drum plant is used, a two or three way valve can be installed in the existing feed line on the output side of the asphalt pump. The asphalt rubber metering equipment is attached to the valve to feed the asphalt rubber accurately. When a batch plant is used, the valve is installed directly onto the supply line leading to the weigh bucket. Often a separate supply line to the weigh bucket is installed. Separate pumps are used by the blending contractor to prevent damage to the HMA contractor's pumps. The asphalt rubber is generally more viscous than the asphalt cement and thus these pumps are generally larger than the standard pumps used on an HMA facility. Also, the pipes and supply lines need to be of sufficient diameter to allow the movement of a more viscous fluid. It may be necessary to employ jacketed and heated lines. There appears to be no problem with the asphalt rubber material building up in lines or any requirements for unusual cleaning or flushing of equipment when asphalt rubber HMA mixes are produced.
CHAPTER 5: DRY PROCESS

This chapter presents background and information on the dry process and presents information of how the CRM is added to the aggregate.

Background

The dry process adds crumb rubber to the aggregate in a hot-mix central plant operation before adding the asphalt cement. The dry process is used in HMA dense- and gap-graded mixtures. Other names for this mixture are:

- Rubber modified hot mix asphalt (RUMAC),
- Asphalt concrete, rubber- filled,
- Non-reacted system

The dry or non-reacted process was used in the 1960s to produce mixtures for athletic field surfaces and pavements (14,15). This process was developed by U.S. Rubber Reclaiming of Vicksburg, Mississippi. Pavement projects were placed in Mississippi in 1968 (16) and in the Lake Tahoe area by the California DOT in the 1970s.

The dry process used most frequently in the United States was developed in Sweden in the late 1960s and marketed under the name of Rubit. It was patented and marketed in the United States under the name of PlusRide™ (7). This process uses a gap-graded aggregate mixtures and coarse rubber particles (1/4 inch top size) that comprise about three percent by weight of mixture. The claim for this material was increased durability, increased rut resistance and resistance to ice formation. The performance of the PlusRide™ system has been spotty. There have been many reports of severe raveling problems. Thus, the process is now in very limited use.

Other dry process techniques include those used in New York and Kansas and developed by the Army Corps of Engineers at the Cold Regions Research and Engineering Laboratory (USA-CRREL) (6).

The dry process mixes the crumb rubber, asphalt cement, and aggregate at the same time, making it impossible to determine the binder properties directly. Binder extraction and recovery tests alter the CRM binders. Tests performed on the mixture provide only indirect data on binder properties. Research has been conducted only on binders produced by the wet process or reacted system, but binders produced by the dry process will be affected by the same variables.
In the dry process the CRM is blended with the aggregate or the aggregate fines before the addition of the asphalt cement. This limits the length of time for reaction to take place. Whereas in the wet process the CRM is fully "reacted", in the dry process there is some reaction between the asphalt and the CRM. The amount of reaction that occurs depends on the size of the CRM, on the time that it takes to mix the HMA in the drum or batch tower, storage, transportation, laydown, compaction at higher temperature and also provide, some reaction time and on the temperature at time of mixing. Some reaction does occur and therefore there is some modification of the binder with the dry process.

Plant Operations

A separate crumb rubber feed system is needed for either batch or drum plants. Manual bag feeding is common at batch plants. In drum plants the CRM has been added using the recycled asphalt concrete hoppers to feed the crumb rubber. It has also been blown in with the baghouse fines and has been fed into the outer drum of a double drum plant. The hopper or belt feeder should be tied electronically to the plant proportioning control system. It is essential that this feeder system be calibrated before production begins and checked periodically during production. Batch plants require a dry mix cycle to ensure that the heated aggregate is mixed with the crumb rubber before the introduction of the asphalt cement.

On four Kansas projects, the bulk CRM was blown from a truck into a mineral filler silo. It was then metered and conveyed into the mixing chamber of a drum plant. Double-drum mixers were used for the first three projects, where the CRM was discharged into the outside drum. Iowa also used a double-drum mixer for their 1993 project with this system. The last Kansas project used a single-drum mixer where the CRM was blown into a coater at the discharge end of the drum. On these projects the CRM was blown in the drum immediately after the AC. There was some concern that if the CRM is introduced close to the dryer flame in a drum, the CRM may blow out, or burn causing smoking problems.

On two Oklahoma projects the bulk CRM was blown into a filler/lime storage silo. It was metered and blown into the baghouse fines return line. The baghouse dust and the CRM material are feed into a mixing device where the asphalt cement was added (figure 14). There were problems with correctly metering the CRM material into the drum.

On one Florida project the CRM was added to the dry aggregate in a pugmill just prior to asphalt cement being added. In South Carolina they built a project with four pounds of rubber per ton of mix. The contractor had a 3-ton batch plant. The rubber supplier provided him with 12 lb. bags of rubber and the contractor's employee added one bag of rubber for every batch.
FIGURE 14 Feed system used by the Oklahoma DOT.
CHAPTER 6: PLACEMENT

The placement, handling and compaction of hot mix asphalt using either the wet or the dry process differs little from the conventional HMA. The following paragraphs present general information about the field construction process.

Hauling/Transporting of Material

The transportation of the asphalt rubber HMA mixture can be accomplished in any truck typically used for the transportation of conventional HMA. There has been no indication of sticking or other problems associated with the trucking. Wetting agents for the truck beds should be either soapy water or silicone emulsions. Solvent based wetting agents should not be used. Asphalt rubber HMA sticks to tires. It will track further and hang on longer than conventional HMA.

Placement/Handwork

The asphalt rubber HMA mixture must be placed only when the surface temperature and weather conditions are optimum. The material is more viscous than conventional HMA; therefore, the placement temperature of the surface on which it is placed should be warm. ADOT requires that the surface be at least 26°C (80°F). Even if the surface temperature requirement is met, it may be necessary to cease work due to existing or expected weather conditions that could have an adverse effect upon the rubber modified HMA mixture.

The CRM modified HMA mixture delivered to the screed unit must be a free flowing, homogeneous mass in which there is no segregation, crusts, lumps, or migration of the asphalt-rubber. It may be necessary to cover the hauling units with tarpaulins, and/or dump the material directly into the paver rather than using pick up devices. Pick up devices have been used but because of the temperature sensitivity of the material they should be used with caution. One contractor suggested that the screed unit may need to be heated periodically to prevent build up of the mix on the screed.

There can be pick up of the HMA mixture when the roadway is turned over to traffic. This can be addressed by lightly sanding the mixture or by applying lime water to the surface.
Compaction

The viscosity and amount of asphalt binder in an HMA mixture (among other factors) will affect the compatibility of the mix. The higher the viscosity of the binder the stiffer the mix at a given temperature. The asphalt rubber binder is a high viscosity material. Asphalt rubber mixtures must be compacted while they are hot. Compaction is generally not a problem if the temperature is maintained. The criticality of the temperature increases as the rubber content increases. The Arizona DOT requires that the temperature of the rubber modified HMA should be at least 135°C (275°F) just before compaction and that compaction must be completed before the temperature of the mixture reaches 104°C (220°F).

Compaction can be accomplished with either a vibratory or static steel wheel rollers. Pneumatic rollers should not be used. The rubber modified binder can pick up on the pneumatic wheels.
CHAPTER 7: RECYCLING

This chapter provides background on the use of asphalt rubber for HMA recycling projects and the recycling of HMA containing CRM.

CRM Plus RAP

The use of asphalt rubber for the binder in a recycled asphalt rubber binder has been accomplished in a few instances. For example, the Georgia DOT constructed a project in south central Georgia where they added asphalt rubber (16.6 percent by weight of asphalt cement with an 80 mesh CRM). The New Hampshire DOT constructed a project near Manchester where they added asphalt rubber (10.0 percent by weight of asphalt cement with 80 mesh CRM).

It does not appear to be a problem to use asphalt rubber as a binder with RAP. The RAP behaves like an aggregate in the mixing process. The only concern might be the need to obtain a specific viscosity for the binder after mixing. It will be difficult to determine the actual viscosity of the binder in the recycled mixture.

Recycling CRM

New Jersey, Texas, Ontario, and Idaho and others have recycled CRM modified HMA mixes. The project in Idaho was a hot in place recycling project. The others were hot central plant recycling projects. None of these agencies reported any mix design or mix production problems.
CHAPTER 8: SPECIFICATION GUIDELINES

Appendixes D and E contain the specifications for asphalt rubber hot mix asphalt that are being used by various agencies. A specification for an asphalt rubber hot mix asphalt pavement should contain the following besides the information in the agency's standard specification:

General Requirements

1. The requirements for the physical and chemical properties of the crumb rubber to be met should include the rubber gradation. The choice of gradation will depend on whether the ultimate hot mix asphalt is to be a gap graded, open, or dense gradation and the rubber concentration. (See Tables 2 and 3 for requirements being used by various agencies.)

2. A requirement should be included that the rubber supplier provide certification that the CRM material meets the physical and chemical requirements of the specification should be met.

3. The sampling and testing procedures to be used for the crumb rubber, and the asphalt rubber should be delineated.

4. The asphalt rubber supplier should be required to provide a design for the asphalt rubber binder.

5. The contractor should be required to provide a job mix formula that will specify the source, composition and proportion of the aggregates, mineral filler, asphalt rubber binder and additives for each mixture supplied to the contract.

6. The aggregate gradation desired should be discussed. (See Table 5 for the gradations being used by various agencies.)

7. In general, higher weather temperatures are required for both the dry and wet processes.

8. A requirement that pneumatic rollers not be used to compact the mixture should be included.

9. The method of mixing and blending the asphalt cement and the CRM material should be delineated.
Wet Process

1. The aggregate gradation desired (see table 5 for the gradation being used by various agencies).

2. Any special requirements for the mixing plant especially methods that will be used for calibrating and controlling the flow of CRM for dry projects and asphalt rubber for the wet projects must be discussed.

3. The method of mixing and blending the asphalt cement and the CRM material should be spelled out.

Dry Process

1. A requirement that the system being used for the addition of the CRM to the mix be properly calibrated before the plant is put into production.
CHAPTER 9: QUALITY CONTROL/QUALITY ASSURANCE

This chapter provides a discussion of the quality control/quality assurance process to be used.

General

The purchasing agency (DOT or city or county) can use its standard HMA acceptance procedures with a few modifications. The source acceptance for the asphalt cement and the mineral aggregates will remain the same. Good volumetric quality control procedures should be followed. Some modifications will need to be made for the rubber, the asphalt-rubber binder and the rubber modified HMA mixture.

Crumb Rubber

The purchasing agency should require that the CRM supplier furnish certified test results covering each shipment of material to the project. The agency may wish to verify those results in their laboratory. To verify the chemical testing requires special equipment. The agency can easily verify the gradation of the material.

Mix Design

Many purchasing agencies require that the supplier furnish the agency with binder formulation and samples of all the materials to be used on the project. These samples are to be provided at least 15 working days before construction. This binder formulation should include:

1. The source and paving grade of the asphalt cement.
2. The source and grade of any additives added to the asphalt cement for example antistripping agents, extender oils, etc.
3. Percentages of the asphalt cement and additives being used by total weight of the asphalt-rubber blend.
4. Source and grade of CRM.
5. Percentage of CRM by total weight of the asphalt rubber blend.
6. Brookfield viscosity of the blended material at 177°C (350°F).
Asphalt rubber.

The production of asphalt rubber should be closely monitored. Many agencies and many contractors will monitor the production of the asphalt-rubber blend using a portable viscometer (Figure 15). When it is a batch process the test will be run on each batch. When it is a continuous process it will be run at least once per day. In Arizona and with some of the contractors in California the trend is to run the ring and ball softening point (AASHTO Test Method T53-89), cone penetration (ASTM Test Method D3407) and resilience tests (ASTM Test Method D3407) on the blended asphalt-rubber. The key to running the viscosity tests in the field is good temperature control on the tests. A small variation in the temperature could cause inaccurate test results which may result in changes in the process that are not required. Insufficient data exists at this time to be able to quantify the variation in the test results.
There is currently no accepted procedure for finding the actual percent CRM in the asphalt rubber binder. NCAT is evaluating a chemical procedure for determining the percent rubber.

**Asphalt rubber content.**

A nuclear asphalt content gauge that has been properly calibrated can be used to monitor and control the asphalt rubber binder content. Calibration problems have been reported. The Florida DOT and the California DOT have conducted a study to evaluate the use of the extraction test to find the binder content in an asphalt rubber mixture. They concluded that since some rubber passes through the filter (the amount cannot be determined) the calculated binder content from the extraction test is not accurate (16). NCAT has determined that the newly developed ignition method can be utilized to accurately determine the asphalt rubber content in the HMA mixture.

**Aggregate Gradation.**

Standard extraction procedures (using either chlorinated or biodegradable solvents) can be used to determine the gradation of the aggregate. The Florida DOT found that even though some rubber particles are left in the extracted aggregate, their weight contribution to any particular sieve is small (16).

**Mixture Properties, Volumetrics - etc.**

Testing of the crumb rubber modified hot mix asphalt mixture is essential to ensuring that a satisfactory product is produced. A significant difference may occur between the properties of HMA mixtures prepared in the laboratory and those "same" asphalt concrete mixtures manufactured in an HMA plant. Changes in the characteristics of the mix are caused by one or more of many factors encountered in the manufacture of HMA such as: the type of plant used, changes in the aggregate properties, or changes in the binder. This is especially true when the binder is field mixed (such as asphalt rubber) and may not have the same properties as the laboratory prepared binder. Thus, the contractor and the specifying agency should control the field mixture on the basis of volumetric properties, such as air voids and voids in mineral aggregate. The air voids in the field produced mix should match the design requirements.
Lot size, sample size and testing frequency for the control and acceptance of the HMA mixture varies from agency to agency. Some agencies use an area of length basis as a unit for determining lot size, while others use a day's production or a tonnage basis. The number of tons included can be dependent on the mix property or the layer type. Typically the lot sizes defined can range from 500 to 4,000 tons.

CHAPTER 10 - CONCLUSIONS & RECOMMENDATIONS

Conclusions

Based on the review of CRM construction practices currently in use, the following conclusions are made:

- CRM HMA pavements can be successfully constructed.
- The viscosity of the asphalt rubber binder needs to be closely monitored.
- Proper HMA volumetric concepts need to be followed.

Recommendations

The following recommendations are made:

- There is a need to standardize the terminology with regard to the gradation of the crumb rubber. Nearly every agency uses a different terminology with regard to gradation.
- There is a need to determine the proper testing frequencies for monitoring the physical properties of the asphalt rubber.
- The construction of CRM HMA pavements should be monitored and the new advances included in the final report.
REFERENCES


APPENDIX A -GLOSSARY

**Ambient ground rubber** - processing where scrap tire rubber is ground or processed at or above ordinary room temperature.

**Asphalt rubber** - asphalt cement modified with crumb rubber modifier.

**Asphalt-rubber concrete** - implies the use of an asphalt-rubber blend (binder) with dense-graded aggregates in a hot-mix application.

**Asphalt-rubber friction course** - implies the use of an asphalt-rubber blend (binder) with open-graded aggregates in a hot-mix application.

**Automobile tires** - tires with an outside diameter less than 26 in (66 cm) used on automobiles, pickups, and light trucks.

**Buffing waste** - high quality scrap tire rubber which is a by-product from the conditioning of tire carcasses in preparation for retreading.

**Crackmill** - process that tears apart scrap tire rubber by passing the material between rotating corrugated steel drums, reducing the size of the rubber to a crumb particle (generally 4.75-mm to 425-micron (No. 4 to No. 40) sieve).

**Crumb rubber modifier** - a general term for scrap tire rubber that is reduced in size and is used as modifier in asphalt paving material.

**Cryogenically ground rubber** - process that freezes the scrap tire rubber and crushes the rubber to the particle size desired.

**Devulcanized rubber** - rubber that has been subjected to treatment by heat, pressure, or the addition of softening agents after grinding to alter properties of the recycled material.

**Diluent** - a lighter petroleum product (typically kerosene) added to asphalt-rubber binder just before the binder is sprayed on the pavement surface.

**Extender oil** - an aromatic oil used to supplement the reaction of the asphalt and the crumb rubber modifier.

**Granulated crumb rubber modifier** - cubical, uniformly shaped, cut crumb rubber particle with a low surface area, which are generally produced by a granulator.

**Granulator** - process that shears apart the scrap tire rubber, cutting the rubber with revolving steel plates that pass at close tolerance, reducing the rubber to particles generally 9.5-mm to 2.0-
mm (3/8 in to No. 10) sieve) in size.

**Ground crumb rubber modifier** - irregularly shapes, torn crumb rubber particles with a large surface area, generally produced by a crackermill.

**Micro-mill** - process that further reduces a crumb rubber to a very fine ground particle, reducing the size of the crumb rubber below a 425-micron (No. 40) sieve.

**Reaction** - the interaction between asphalt cement and crumb rubber modifier when blended together. The reaction, more appropriately defined as polymer swell, is not a chemical reaction. It is the absorption of aromatic oils from the asphalt cement into the polymer chains of the crumb rubber.

**Recycled tire rubber** - rubber obtained by processing used automobile, truck, or bus tires (note: solid tires; tires from fork lifts, aircraft, and earthmoving equipment; other non-automotive tires; and nontire rubber sources are excluded.

**Rubber aggregate** - crumb rubber modifier added to hot-mix asphalt mixture using the dry process, which retains its physical shape and rigidity.

**SAM** - the abbreviation for a stress-absorbing membrane. A SAM is used primarily to mitigate reflective cracking of an existing distressed asphaltic or rigid pavement. It comprises an asphalt-rubber blend sprayed on the existing pavement surface followed immediately by an application of a uniform aggregate which is then rolled and embedded into the binder layer. Its nominal thickness generally ranges between 6 and 9 mm (1/4 and 3/8 in).

**SAMI** - the abbreviation for a stress-absorbing membrane interlayer. The interlayer may be an asphalt-rubber chip seal, fabric, fine unbound aggregate, or an open-graded asphalt layer. A SAM I is a SAM that is applied beneath an asphalt overlay (which may or may not contain rubber in the mix).

**Shredding** - process that reduces scrap tires to pieces 0.15 m (6 in) square and smaller.

**Stress-absorbing membrane (SAM)** - surface treatment using an asphalt-rubber spray application and cover aggregate.

**Stress-absorbing membrane interlayer (SAMI)** - a membrane beneath an overlay designed to resist the stress and strain of reflective cracks and delay the propagation of the cracks through the new overlay. The membrane is often a spray application of asphalt-rubber binder and cover aggregate.

**Tread rubber** - rubber that consists primarily of tread rubber with less than approximately 5 percent sidewall rubber.
**Truck tires** - tires with an outside diameter greater than 26 in (66 cm) and less than 60 in (152 cm) used on commercial trucks and buses.

**Vulcanized rubber** - rubber that has not been subjected to treatment by heat, pressure, or the addition of softening agents after grinding to alter properties of the recycled material.

**Wet process** - any method that blends crumb rubber modifier with the asphalt cement before incorporating the binder in the asphalt paving project.

**Whole tire rubber** - rubber that includes tread and sidewalls in proportions that approximate the respective weights in an average tire.

**West process** - Any method that mixes and reacts the crumb rubber modifier with the asphalt cement prior to the modified binder being added to the aggregate.
APPENDIX B - SUPPLIERS OF CRUMB RUBBER

Arizona/California

Altos Rubber, Inc
1522 Fishburn Avenue
Los Angeles, CA 90063
213-266-4570

Baker Rubber Southwest
11400 E. Pecos Road
Queen Creek, AZ 85242
602-987-3006

BAS Recycling, Inc
1400 N. "H" Street
San Bernardino, CA 92405
909-383-7050

Florida

American Tire Recyclers, Inc.
302 N. Lane Ave.
Jacksonville, FL 32254
904-786-5200

Mississippi

Rouse Rubber Industries, Inc
1000 Rubber Way
Vicksburg, MS 38182-0369
601-636-7141

Indiana

Baker Rubber, Inc
131 S. Taylor Street
P.O. Box 2438
South Bend, IN 46680-2438
219-237-6293

53
Texas

Granulator Products & Services
6205 Airport Freeway
Fort Worth, Texas 76117
817-831-3294

New York

Poly-Tech Recycling Corp
RR1, Box 134
Route 22
Wingdale, NY 12594
APPENDIX C - FIELD AND TERMINAL ASPHALT RUBBER BLENDING SYSTEM CONTRACTORS

Arizona

FNF Construction (Field System)
P.O. Box 5005
Tempe, AZ 85280-5005
602-784-2910

ISI
6751 W. Galveston (Field System)
Chandler, AZ 85226
602-268-0874

Neste-Vinzoyd Petroleum Company (Terminal System)
3731 E. University Drive
Phoenix, AZ 85034
602-437-8068

California

Manhole Adjusting (Field System)
P.O. Box 250
Monterey Park, CA 91754
213-725-1387

Silvia Construction, Inc. (Field System)
9007 Center Avenue
Rancho Cucamonga, CA 91729
909-949-1127

Granite Construction Co. (Field System)
38-000 Monroe Street
Indio, CA 92203
619-775-7500
Florida

Anderson Columbia Co., Inc. (Terminal System)
P.O. Box 1829
Lake City, FL 32056-1829
904-752-7585

Blacklidge Emulsions (Terminal System)
P.O. Box 76799
Tampa, FL 33675
813-247-5699

Martin Paving (Field System)
1801 S. Nova Road
South Daytona, FL 32119

Bitcom (Field System)
3111 University Drive
Suite 1000
Coral Springs, FL 33065
305-753-6501

New York

Cortland Asphalt (Terminal System)
P. O. Box 5160
1911 Lorings Crossing
Cortland, NY 13045

Texas

Cox Paving Company, Inc. (Field System)
Box 519
Blanco, TX 78606
210-833-4547

Neste/Wright Asphalt Products
704 Sheldon Road, Suite B
Channelview, TX 77530
800-882-6541
Washington

U.S. Oil and Refining Co.
3001 Marshall Avenue
Tacoma, WA 98401
206-383-1651

Canada

McAsphalt Industries Limited (Terminal System)
8800 Sheppard Avenue East
Scarborough, Ontario M1B 5R4

Polyphalt (Terminal System)
4 Lansing Square, Suite 119
Willowdale, Ontario M2J 5A2
APPENDIX C - SPECIFICATIONS BEING USED BY VARIOUS AGENCIES - WET PROCESS

(ACRSM487, 4053/M, 04/15/94)

ITEM 4070040 - ASPH. CONC. FRICITION COURSE (ASPHALT-RUBBER):

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 if required, 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 his equipment necessary to properly accommodate the use of asphalt-rubber as a bituminous material.

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.

Materials:

For comparative purposes, quantities shown in the bidding schedule have been calculated based on the following data:

| Spread Rate, Pounds per Square Yard | XXX |
| Percent, Bituminous Material        | X.X |

The spread rate specified includes XX percent for leveling to provide a minimum 1/2 inch thickness; however, the exact spread rate will be determined by the Engineer.
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 the Standard Specifications.

When the contractor selects a source or sources, he 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.

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 shall be obtained from crushed gravel or crushed rock. All uncrushed material passing the 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. Any material inspected by the Department as crushed material shall be separated from the contractor's other stockpiles and reserved for use by the Department.

Mineral aggregate shall be separated into two stockpiles. The Engineer may approve changes to the specified stockpile gradations, provided he determines that a suitable composite gradation is obtainable. The gradation of each stockpile shall conform to the requirements in Table 1.
Table 2. Mineral aggregate characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Bulk Specific Gravity</td>
<td>Arizona Test Method 814</td>
<td>2.35-2.85</td>
</tr>
<tr>
<td>Combined Water Absorption</td>
<td>Arizona Test Method 814</td>
<td>0-2.5</td>
</tr>
<tr>
<td>Sand Equivalent</td>
<td>Arizona Test Method 242</td>
<td>Minimum 55</td>
</tr>
<tr>
<td>Crushed Faces</td>
<td>Arizona Test Method 212</td>
<td>Minimum 70%</td>
</tr>
<tr>
<td>Flakiness Index</td>
<td>Arizona Test Method 233</td>
<td>Maximum 25</td>
</tr>
<tr>
<td>Percent Carbonates in Aggregate</td>
<td>Arizona Test Method 238</td>
<td>Maximum 30%</td>
</tr>
<tr>
<td>Abrasion</td>
<td>AASHTO T-96</td>
<td>100 Rev., Max. 9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500 Rev., Max. 40%</td>
</tr>
</tbody>
</table>

Tests on aggregates outlined in Table 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.

**Mineral Admixture:**

Where the average elevation of the project is over 3500 feet, an approved mineral admixture will be required. The amount shall be one percent, by weight of the mineral aggregate and shall be either portland cement type II or hydrated lime, conforming to the requirements of Table 3.

Table 3. Mineral admixture.

<table>
<thead>
<tr>
<th>Material</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland Cement, Type II</td>
<td>ASTM C-150</td>
</tr>
<tr>
<td>Hydrated Lime</td>
<td>ASTM C-1097</td>
</tr>
</tbody>
</table>

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Bituminous Material:

Bituminous material shall be asphalt-rubber (vulcanized) conforming to the requirements of Section 1009 of the Standard Specifications, except for the following:

The rubber shall conform to the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 10</td>
<td>100</td>
</tr>
<tr>
<td>No. 16</td>
<td>75-100</td>
</tr>
<tr>
<td>No. 30</td>
<td>25-100</td>
</tr>
<tr>
<td>No. 50</td>
<td>0-45</td>
</tr>
<tr>
<td>No. 100</td>
<td>0-10</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-5</td>
</tr>
</tbody>
</table>

The asphalt-rubber shall conform to the following:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, Haake, 350°F</td>
<td>1500-4000 centipoise</td>
</tr>
<tr>
<td>Cone Penetration, 77°F (ASTM D-1191)</td>
<td>20 minimum</td>
</tr>
<tr>
<td>Softening Point, °F, (ASTM D-36)</td>
<td>125°F minimum</td>
</tr>
<tr>
<td>Resilience, 77°F (ASTM D-3407)</td>
<td>15% minimum</td>
</tr>
</tbody>
</table>
The asphalt cement shall be modified by the addition of a minimum of 20 percent of granulated rubber, by weight of the asphalt, unless otherwise approved by the Department’s Central Laboratory.

During the production of asphalt-rubber, the contractor shall maintain at the plant site equipment necessary to measure the viscosity. The asphalt-rubber shall be maintained between 1500 and 4000 centipoise at 350°F. The viscosity shall be checked at the direction of the Engineer.

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.

The asphalt cement and rubber shall be blended for a period of at least one hour prior to mixing with the mineral aggregate and mineral admixture; however, the mixture of asphalt cement and rubber shall not be held at temperatures over 350°F for a period over 10 hours. The temperature of the asphalt cement shall be between 350 and 400°F at the addition of the granulated rubber. Temperature of the asphalt-rubber shall be maintained between 325 and 375°F during the one-hour reaction period.

At the end of each shift, the contractor shall provide the Engineer with documentation on the production of asphalt-rubber, which includes the following:

1. The amount and temperature of the asphalt cement prior to the addition of rubber.
2. The amount (bags) of rubber added.
3. The viscosity of the asphalt-rubber just prior to the mixing with the aggregate and mineral admixture.
4. The time of the rubber additions and viscosity tests.

Mix Design:

- Approximately 200 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 one full bag (as packaged by the supplier) of the granulated rubber proposed for use, one gallon of asphalt cement from the intended supplier, two gallons of the proposed mixture of asphalt and rubber, and, if mineral admixture is required, 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 his methods of producing mineral aggregate including wasting, washing, blending, proportioning, etc., and any special or limiting conditions he may propose. His letter shall also state the source(s) of mineral aggregate, the source of asphalt cement and granulated rubber, the asphalt-rubber supplier, and, if required, 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, and any special or limiting conditions for the use of the mix.

**Mix Design Revisions:**

The contractor shall not significantly change his methods of crushing, screening, or stockpiling from that used during production of material used for mix design purposes without approval of the Engineer, or requesting a new mix design. Significant changes may include changes in the amount or type of materials rejected or wasted, changes in the amount of materials crushed, or reduction in the amount of crushed fines.

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 his 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, 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, he will issue a revised mix design. Should these changes require revisions to the contractor’s operations which result in additional cost to the contractor, he 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.

Acceptance of Materials:

General:

The contractor’s attention is directed to the requirements of the Standard Specifications under Subsection 105.12 - Removal of Unacceptable and Unauthorized Work.

If the production of asphaltic concrete is stopped either for failure to meet the requirements specified hereinafter under Asphaltic Concrete, 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 Asphaltic Concrete. The engineer reserves the right to increase the frequency of sampling and testing upon the resumption of asphaltic concrete production.

Mineral Aggregate:

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

At the direction of, and witnessed by an authorized representative of the Engineer, the contractor shall secure one representative sample of each day's production from each stockpile.

These samples will be tested for conformance with the mineral aggregate gradation in accordance with the requirements of Arizona Test Method 201. These samples will also be composited to the specified stockpile percentages by the Engineer and tested for sand equivalent in accordance with Arizona Test Method 242, the percent of crushed faces in accordance with the requirements of Arizona Test Method 212, and flakiness index in accordance with the requirements of Arizona Test Method 233.

Should testing indicate results not meeting the requirements of Table 1 for gradation, and Table 2 for sand equivalent, crushed faces, and flakiness index, material represented by failing test results will be rejected.
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, 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 in accordance with the requirements of Arizona Test Method 201. If mineral admixture is required, and the sample does not include mineral admixture, the gradation results will be adjusted to reflect the addition of mineral admixture.

The gradation of the mineral aggregate, including mineral admixture if required, 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:

<table>
<thead>
<tr>
<th>Passing Sieve</th>
<th>3 Consecutive</th>
<th>One</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>± 4</td>
<td>± 6</td>
</tr>
<tr>
<td>No. 8</td>
<td>± 3</td>
<td>± 4</td>
</tr>
<tr>
<td>No. 200</td>
<td>± 1.0</td>
<td>± 1.5</td>
</tr>
</tbody>
</table>

One hundred percent of the material shall pass the largest sieve size shown in Table 1.

At any time that test results indicate that the gradation of the mineral aggregate, including mineral admixture if required, does not fall within any 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.
Arizona Department of Transportation

(B) Asphalt-Rubber Content:

During production of asphaltic concrete, the contractor shall maintain at the plant site a nuclear asphalt content gauge calibrated in accordance with the gauge manufacturer's recommendations, on the material being tested. Asphalt-rubber content shall be measured by the contractor by means of the nuclear asphalt content gauge a minimum of four times per 8-hour shift. Production of asphaltic concrete shall cease immediately and the plant 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.

Construction Requirements:

Quality Control:

Quality control shall be the responsibility of the contractor. The Engineer reserves the right to obtain samples of any portion of any material at any point of the operations for his own use.

Stockpiling:

The contractor shall not be allowed to feed the hot plant from stockpiles containing less than two 8-hour 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.

Proportioning:

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

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

Mineral admixture, if required, 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 3 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 devices 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 plant 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, he 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 fury integrated with the controls for mineral aggregate and mineral admixture.

**Drying and Heating:**

A recording pyrometer or other approved recording thermometric instrument sensitive to a rate of temperature change not less than 10°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 immediately behind the paver shall not exceed one 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.

**Mixing:**

The production of the plant shall be governed by the rate required to obtain a thorough and uniform mixture of the materials. Mixing shall continue until the uniformity of coating, when tested in accordance with the requirements of AASHTO T-195, is at least 95 percent.

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 spiking into adjacent bins.

The temperature of asphaltic concrete upon discharge from the mixer shall not exceed 350°F. If the asphaltic concrete is discharged from the mixer into a hopper, the hopper shall be constructed so the segregation of the asphaltic concrete will be minimized.
Placing and finishing:

(A) General Requirements:

The handling of asphaltic concrete shad at an times be such as to minimize segregation. Any asphaltic concrete which displays segregation shad be removed and replaced.

Before asphaltic concrete is placed, the surface to be paved shall be cleaned of all objectionable material and tacked in accordance with the requirements of Section 404 of the Standard 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 guard rail is to be installed.

Dates and Surface Temperature:

Asphaltic concrete shall be placed between the dates shown as applicable to the average elevation of the project and within these dates only when the temperature of the surface on which the asphaltic concrete is to be placed is at least 80°F.

Despite a surface temperature of 80°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.

Average Elevation of Project, feet

<table>
<thead>
<tr>
<th>Average Elevation</th>
<th>Beginning and Ending Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 3499</td>
<td>February 15 - May 31</td>
</tr>
<tr>
<td>0 - 3499</td>
<td>September 1 - December 15</td>
</tr>
<tr>
<td>3500 - 4999</td>
<td>April 1 - October 31</td>
</tr>
<tr>
<td>5000 and over</td>
<td>May 1 - September 30</td>
</tr>
</tbody>
</table>

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.
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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:

1) Covering hauling units with tarpaulins.
2) Dumping material directly into the paver.
3) 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 from the hauling vehicles directly into the paving machine from trucks, care shall be taken to avoid jarring the machine or moving it out of alignment. No vertical load shall be exerted on the paver 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 an 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 pucked away from the mat in order for the ropers to compact this area in accordance with the temperature limitations given hereinafter under Compaction, (C) Rolling Procedure. 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 impracticable, 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.

**Joints:**

The contractor shall schedule his 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 his 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 traverse 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.

Compaction:

(A) General Requirements:

The temperature of asphaltic concrete just prior to compaction shall be at least 275°F. The wheels of compactors shall be wetted with water or, if necessary, soapy water to prevent mix pick-up during rolling. The Engineer may change the rolling procedure if in his judgement 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. Vibratory rollers may be used in the static mode only. All rollers shall be equipped with pads and a watering system to prevent sticking of the asphaltic concrete mix to the steel wheels.

(C) Rolling Procedure:

Two compactors shall be used for initial breakdown and be maintained no more than 300 feet behind the paving machine. The remaining compactor 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°F.

Pavement Smoothness Requirements and Tolerances:

(A) General:

Asphaltic concrete shall be compacted as required, smooth and reasonably true to the required lines, grades, and dimensions.

The final pavement surface shall be evaluated for smoothness by testing.

Past experiences have shown that the following practices have contributed to smooth pavements:

Keeping a constant head of hot mix material in front of the screed. Not letting the truck bump the paver. Running the paver continuously at a speed which matches the asphalt delivery. Avoid stopping the paver. Exercising care in making transverse joints. Using a uniform, consistent mix, and avoiding segregation at any point.

Some newer techniques and systems for placing the material that can improve pavement smoothness are:

Precision controls to maintain a proper head of material, maintaining uniformity in consistency and volume. Infinitely variable auger-conveyor speeds to match paver speed and thickness requirements. Power adjustable auger height to provide “on-the-go” control. Ultrasonic sensing systems to check automatically for material height and signal the auger and conveyor drive to keep correct head of material. Three point suspension systems and hydraulic drives. Mix temperatures maintained within a narrow range.

Some compaction techniques and systems for improving smoothness include:

Edge compactors to compact mat edges more efficiently. Edge cutters to trim mat edges in preparation for paving additional lanes, thereby promoting smoother longitudinal joints. Heavier/larger roppers to “break down” thicker lifts. Solid state controls for speed, direction, frequency and amplitude to promote more efficient compaction and smoother surfaces. Use of higher frequency ranges and the ability to match amplitude and frequency to production densification at higher production rates.
However, the contractor may need to adopt innovative or state-of-the-art techniques to achieve an incentive payment.

The U.S. Army Corps of Engineers distributes the Handbook of Hot-Mix Asphalt Paving which presents some advanced pavement techniques the contractor may elect to use to achieve greater smoothness. The handbook was jointly prepared by the American Association of State Highway and Transportation Officials (AASHTO), the Federal Aviation Administration (FAA), Federal Highway Administration (FHWA), National Asphalt Pavement Association, U.S. Army Corps of Engineers, American Public Works Association (APWA), and National Association of County Engineers. A copy is available for reference at the ADOT Materials Section, 1221 North 21st Avenue, Phoenix, Arizona, 85009-3740.

This document is available from the Federal Aviation Administration Advisory Circular AC 150/5370-14 and from the U.S. Army Corps of Engineers Publication UN-13 (CEMP-ET).

In addition, the National Asphalt Pavement Association has available information on Pavement smoothness, including information series 111, Pavement Smoothness.

(B) Testing:

Testing will be performed by the Department in accordance with the provisions of Arizona Test Method 829. At the completion of mainline paving, the contractor shall notify the Engineer in writing that the pavement is ready for testing. The Engineer will then evaluate the roadway. If the Engineer determines that additional roadway preparation is required, the contractor shall perform such preparation as directed by the Engineer. The contractor shall ensure that the road can be driven safely at the design speed. If requested by the Engineer, the contractor shall broom the pavement immediately prior to testing. No measurement or direct payment will be made for preparing the roadway, the cost being considered as included in the price of contract items.

The testing will be performed within seven days after the Engineer has accepted the roadway for testing. The Engineer will notify the contractor of the test results no later than 7 days after the testing has been performed.

Testing will be done on mainline traffic lanes only, and will include the full length of the pavement placed under the contract. Distress lanes, shoulders, ramps, tapers, cross roads, and frontage roads will not be tested. Testing will not be performed on any portions that cannot be made safe for testing at the design speed, or on any lanes of less than 0.30 mile in length.
Testing will not be done when the ambient air temperature is less than 40°F or during rain or other weather conditions determined to be inclement by the Engineer.

The existing roadway has the following smoothness values (Mays-Meter inches per mile):

**Substitute headings and 0.1 Mile Profilometer***

**Survey Data if Available***

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<thead>
<tr>
<th></th>
<th>XXXXbound</th>
<th>XXXXbound</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Low</td>
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<td>XX</td>
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<tr>
<td>Average</td>
<td>XX</td>
<td>XX</td>
</tr>
</tbody>
</table>

Any 0.1 lane-mile increment having an actual Smoothness (AS) equal to or greater than the Correction Value (CV) shall be repaired. Upon completion of the repairs, the 0.1 lane-mile increment containing the repaired area will be re-tested.

The Correction Value (CV) for this contract is 100 inches per mile.

If repairs are required, the contractor shall prepare a written repair proposal detailing corrective actions and submit the proposal to the Engineer within 10 working days after the contractor’s receipt of test results. Within three working days, the Engineer will review the submitted proposal and either accept it or reject it and ask for a new proposal. If rejected, the contractor shall prepare a new proposal for corrective action, within 10 working days, based on discussions with the Engineer.

If, after the first attempt to repair the pavement, the actual Smoothness (AS) is still equal to or greater than the Correction Value (CV), additional repairs and testing shall be performed as directed by the Engineer.

The contractor shall perform remedial work, including furnishing materials, required to correct pavement smoothness deficiencies such that the correction value (CV) is less than 100 inches per mile. Remedial work shall be performed by the contractor at no additional cost to the Department.

Traffic control costs during the initial smoothness testing period will be reimbursed under the provisions of Section 701 of the Specifications. Any additional traffic control costs incurred, outside the normal scope of work, due to pavement repairs and subsequent
pavement smoothness measurements shall be borne solely by the contractor.

In addition to the smoothness requirements, 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.

**Acceptance:**

Asphaltic concrete will be accepted complete in place, if, in the judgement of the Engineer, the asphaltic concrete reasonable 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.

**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 if required, and asphalt-rubber. Measurement will include any weight used in construction of intersections, turnouts, or other miscellaneous temps or surfaces.

Asphalt-Rubber will be measured by the ton in accordance with the requirements of Section 1009 of the Standard Specifications.

Mineral admixture will be measured by the ton.

**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 granulated rubber.

Payment for mineral admixture will be made by the ton.

An Incentive/Disincentive Value will be added or subtracted from the contract monies due the contractor based on the following:

The Incentive Disincentive Value (IDV), plus or minus, for each 0.1 lane-mile shall be determined from the following formulas:
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When AS < XX.0:

Incentive Value = ((XX - AS) / XX + 2) * 2500

When AS > YY.0:

Disincentive Value = ((YY - AS) / (XX + 2)) * 1000

The Actual Smoothness Value (AS) shall be determined in accordance with Arizona Test Method 829.

The Incentive Base for this contract is $2,500.00 for each 0.1 lane-mile increment or fraction thereof. The Disincentive Base for this contract is $1,000.00 for each 0.1 lane-mile increment or fraction thereof.

The total Incentive/Disincentive Value, plus or minus, for the contract shall be the summation of the individual Incentive/Disincentive Values for the respective 0.1 lane-mile segments.

Incentive/Disincentive Value will not be applied to pavement in distress lanes, shoulders, ramps, tapers, cross roads, or frontage roads.

For projects where pavement is removed and replaced to grade, followed by an ACFC overlay, no smoothness measurements will be made for the following areas:

Pavement placed within 35 feet of the termini of the project.

Pavement placed within 35 feet of the approaches and departures for bridge structures not being overlain as part of the project.

For projects where pavement is removed and replaced to grade, followed by an overlay, followed by an ACFC overlay, no smoothness measurements will be made for the following areas:

Pavement placed within 100 feet of the termini of the project.

Pavement placed within 100 feet of the approaches and departures for bridge structures not being overlain as part of the project.

Bridges and their approaches and departures which are overlain with this project will be subject to the smoothness requirements.
10-1. RUBBERIZED ASPHALT CONCRETE (TYPE G-ASPHALT RUBBER).—
Rubberized asphalt concrete (Type G asphalt Rubber) shall be asphalt rubber hot mix-gap graded (ARHM-GG) and shall consist of furnishing and mincing gap graded aggregate and asphalt-rubber binder and spreading and compacting the mixture. Type G rubberized asphalt concrete shall conform to the requirements specified for Type A asphalt concrete in Section 39, “Asphalt Concrete,” of the Standard Specifications and these special provisions.

The last sentence of the first paragraph in Section 39-2.01, “Asphalts,” of the Standard Specifications and the fifth, sixth, seventh and eighth paragraphs of Section 39-3.03, Proportioning,” of the Standard Specifications shall not apply to Type G rubberized asphalt concrete. The swell, moisture vapor susceptibility, and stabilimeter value requirements in Section 39-2.02, “Aggregate,” of the Standard Specifications shall not apply to Type G rubberized asphalt concrete.

The second paragraph in Section 39-3.05, “Asphalt Concrete and Asphalt Concrete Base Storage,” of the Standard Specifications is amended to read:

Storage silos shall be equipped with a surge-batcher sized to hold a minimum of 4,000 pounds of material. A surge-batcher consists of equipment placed at the top of the storage silo which catches the continuous delivery of the completed mix and changes it to individual batch delivery and prevents the segregation of product ingredients as the completed mix is placed into storage. The surge-batcher shall be center loading and shall be thermally insulated or heated or thermally insulated and heated to prevent material buildup. Rotary chutes shall not be used as surge-batchers.

The surge-batcher shall be independent and distinct from conveyors or chutes used to collect or direct the completed mixture being discharged into storage silos and shall be the last device to handle the material before it enters the silo. Multiple storage silos shall be served by an individual surge-batcher for each silo. Material handling shall be free of oblique movement between the highest elevation (conveyor outfall) and subsequent placement in the silo. Discharge gates on surge-batchers shall be automatic in operation and shall discharge only after a minimum of 4,000 pounds of material has been collected and shall close before the last collected material leaves the device. Discharge gate design shall prevent the deflection of material during the opening and closing operation.

GENERAL.—Binder for Type G rubberized asphalt concrete shall be, at the Contractors option, either Type 1 or Type 2 asphalt-rubber binder conforming to the requirements of these special provisions.
The amount of asphalt-rubber binder to be mixed with the aggregate for Type G rubberized asphalt concrete will be determined by the Engineer using the samples of aggregates furnished by the Contractor in conformance with Section 39-3.03, “Proportioning,” of the Standard Specifications. The Engineer will determine the amount of asphalt-rubber binder to be mixed with the aggregate in accordance with California Test 367, except as follows:

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

Section “C. Optimum Bitumen Content” of California Test 367 shall be as follows:

1. Using Figure 2 record in Step 1 of the pyramid the asphalt content of the four specimens with the maximum asphalt content used in the square farthest to the right.

2. Plot asphalt content versus void content for each specimen on Form TL-306 (Figure 3), and connect adjacent points with straight lines.

3. From Figure 3 select the theoretical asphalt content that has 3.0 percent voids. Record this amount in Step 4 of the pyramid.

4. Record the asphalt content in Step 4 as the Optimum Bitumen Content (OBC).

5. To establish a recommended range, use the Optimum Bitumen Content (OBC) as the high value and 0.3 percent less as the low value.

The temperature of the aggregate at the time the asphalt-rubber binder is added shall be not more than 325°F.

ASPHALT-RUBBER BINDER.—The grade of paving asphalt to be used in asphalt-rubber binder will be either grade AR-1000, AR-2000 or AR 4000, as determined by the Engineer from recommendation by the asphalt-rubber binder supplier.

The reclaimed vulcanized rubber shall be produced primarily from the processing of automobile and truck tires. The rubber shall be produced by ambient temperature grinding processes only.

The specific gravity of reclaimed vulcanized ground rubber shall be not less than 1.10 nor more than 1.20, and shall conform to the following gradation when tested in accordance with ASTM Designation: C 136:
Rubber for use in asphalt-rubber binder shall be free of loose fabric, wire and other contaminants except that up to 4 percent (by weight of rubber) calcium carbonate or talc may be added to prevent caking or sticking of the particles together. The rubber shall be sufficiently dry so as to be free flowing and not produce foaming when blended with the hot paving asphalt.

At least two weeks before its intended use, the Contractor shall furnish samples of the asphalt-rubber binder proposed for use on the project. The samples shall consist of 4 one quart size cans of the asphalt-rubber binder, together with the formulation and the grade of paving asphalt used.

The method and equipment for combining the rubber and paving asphalt shall be so designed and accessible that the Engineer can readily determine the percentage by weight for each material being incorporated into the mixture.

Equipment utilized in the production and proportioning of asphalt-rubber binder shall include the following:

An asphalt heating tank with hot oil heat transfer to heat the paving asphalt to the necessary temperature before blending with the granulated rubber. This unit shall be equipped with a thermostatic heat control device.

A mechanical blender for proper proportioning and thorough mixing of the paving asphalt and rubber. This unit shall have both an asphalt totalizing meter (gallons or liters) and a flow rate meter (gallons per minute or liters per minute).

An asphalt-rubber binder storage tank equipped with a heating system to maintain the proper temperature of the bind and an internal mixing unit capable of maintaining a homogeneous mixture of asphalt and rubber.

The asphalt-rubber mixture shall not be used as a binder after it has been retained for more than 48 hours.
TYPE 1 BINDER.—Type 1 asphalt-rubber binder shall be a uniform and reacted mixture of compatible paving grade asphalt and reclaimed vulcanized rubber. The length of the individual rubber particles shall not exceed 3/16 inch.

Type 1 asphalt-rubber binder shall contain not less than 14 percent nor more than 20 percent rubber, by weight of the total asphalt-rubber binder.

The temperature of the paving asphalt shall be between 350°F and 425°F at the time the rubber is blended with the paving asphalt. The paving asphalt and rubber shall be combined and mixed together in a blender unit, pumped into the agitated storage tank, and then reacted for a minimum of 45 minutes from the time the rubber is added to the paving asphalt. The asphalt-rubber binder shall be maintained at a temperature of not less than 325°F nor more than 375°F during the reaction period.

The viscosity of the asphalt-rubber binder after the reaction period, when tested in accordance with ASTM Designation: D 2196, shall be not less than 1,500 centipoise nor more than 3,000 centipoise at 350°F (Brookfield).

The asphalt-rubber binder, after reaching the desired consistency, shall not be held at temperatures over 325°F for more than 4 hours.

TYPE 2 BINDER.—Type 2 asphalt-rubber binder shall be a uniform and reacted mixture of compatible paving grade asphalt, extend oil, natural rubber and reclaimed vulcanized rubber.

Extender oil shall be a resinous, high flash point, aromatic hydrocarbon conforming to the following:

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Designation</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, SSU, at 100°F</td>
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<tr>
<td>Flash Point, COC, °F</td>
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<td>Molecular Analysis</td>
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<tr>
<td>Asphaltenes, percent by weight</td>
<td>D 2007</td>
<td>0.1 max.</td>
</tr>
<tr>
<td>Aromatics, percent by weight</td>
<td>D 2007</td>
<td>55 min.</td>
</tr>
</tbody>
</table>
The paving asphalt and extender oil, when combined, shall form a material that is chemically compatible with the rubber.

The extender oil shall be added to the paving asphalt at a rate of not less than 2 percent nor more than 6 percent by weight of the paving asphalt, the exact amount to be as determined by the Engineer from recommendation by the asphalt-rubber binder supplier. The asphalt shall be at a temperature of not less than 350°F nor more than 425°F when the extender oil is added.

Rubber for use in Type 2 asphalt-rubber binder shall consist of reclaimed vulcanized rubber and shall contain not less than 20 percent nor more than 30 percent, by weight, natural rubber, when tested in accordance with ASTM Designation D 297. The rubber shall contain no particles longer than 1/4 inch in length.

The paving asphalt-extender oil blend and rubber shall be combined and mixed together in the blender unit to produce a homogeneous mixture.

The amount of rubber to be added to the paving asphalt-extender oil blend shall be not less than 17 percent nor more than 23 percent by weight of the combined mixture of paving asphalt, extender oil, and rubber. The exact amount will be as determined by the Engineer from recommendation by the asphalt-rubber binder supplier. The paving asphalt-extender oil blend shall be at a temperature of not less than 350°F nor more than 425°F when the rubber is added.

The asphalt-rubber binder shall be reacted for a minimum of 45 minutes from the time the rubber is added to the paving asphalt-extender oil blend. The asphalt-rubber binder shall be maintained at a temperature between 375°F and 425°F during the reaction period.

The viscosity of the asphalt-rubber binder after the reaction period, when tested in accordance with ASTM Designation: D 2196, shall be not less than 1,500 centipoise nor more than 3,000 centipoise at 375°F (Brookfield).

The asphalt-rubber binder, after reaching the desired consistency, shall not be held at temperatures over 375°F for more than 4 hours.

AGGREGATE. -The aggregate for Type G rubberized asphalt concrete shall conform to the following grading and shall meet the quality requirements specified for Type A asphalt concrete in Section 39-2.02, "Aggregate," of the Standard Specifications, except the loss at 500 revolutions from the Los Angeles Rattler test shall be 40 percent maximum.

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
1/2" maximum

Limits of

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Proposed Gradation</th>
<th>Operating Range</th>
<th>Compliance</th>
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</thead>
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<tr>
<td>3/4&quot;</td>
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<tr>
<td>90-100</td>
<td>79-87</td>
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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
3/4" maximum
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<tr>
<th>Sieve Size</th>
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<th>Contract Compliance</th>
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<tr>
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<td>100</td>
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<tr>
<td>1/2&quot;</td>
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<td>90-100</td>
<td>90-100</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>60-68</td>
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<td>9-12</td>
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<td>X±5</td>
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<tr>
<td>No. 200</td>
<td>2 - 7</td>
<td></td>
<td>0 - 8</td>
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</tbody>
</table>

CONSTRUCTION.—After the material has reacted for at least 45 minutes, the asphalt-rubber binder shall be metered into the mixing chamber of the asphalt concrete production plant at the percentage determined by the Engineer.

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 weight.

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 be calibrated in accordance with California Test 109.

Type G rubberized asphalt concrete shall be spread at a temperature of not less than 275°F nor more than 325°F, measured in the hopper of the paving machine.

Pneumatic tired rollers shall not be used to compact Type G rubberized asphalt concrete. Alternative compacting equipment as specified 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 for at least one hour after final rolling operations have been completed.

When ordered by the Engineer to prevent tracking by public traffic from the surface of Type G rubberized asphalt concrete, prior to opening a traffic lane, sand shall be spread on the surface at the approximate rate of from one to two pounds per square yard. Sand shall be free from clay or organic material and shall be of such gradation that at least 90 percent will pass the No. 4 sieve and not more than 5 percent will pass a No. 200 sieve. When ordered by the Engineer excess sand shall be removed from the pavement surface by sweeping.
MEASUREMENT AND PAYMENT.—Rubberized asphalt concrete (Type G-asphalt rubber) will be measured and paid for by the ton in the same manner specified for asphalt concrete in Section 39-8, "Measurement and Payment," of the Standard Specifications.

Full compensation for furnishing, spreading and sweeping sand cover shall be considered as included in the contract price paid per ton for rubberized asphalt concrete (Type G-asphalt rubber) and no separate payment will be made therefore.

10-1.- RUBBERIZED ASPHALT CONCRETE (TYPE D-ASPHALT RUBBER)—Rubberized asphalt concrete (Type D-Asphalt Rubber) shall be asphalt rubber hot mix-dense graded (ARHM-DG) and shall consist of furnishing and mixing dense graded aggregate and asphalt-rubber binder and spreading and compacting the mixture. Type D rubberized asphalt concrete shall conform to the requirements specified for Type A asphalt concrete in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.


The second paragraph in Section 39-3.05, "Asphalt Concrete and Asphalt Concrete Base Storage," of the Standard Specifications is amended to read:

Storage silos shall be equipped with a surge-batcher sized to hold a minimum of 4,000 pounds of material. A surge-batcher consists of equipment placed at the top of the storage silo which catches the continuous delivery of the completed mix and changes it to individual batch delivery and prevents the segregation of product ingredients as the completed mix is placed into storage. The surge-batcher shall be center loading and shall be thermally insulated or heated or thermally insulated and heated to prevent material buildup. Rotary chutes shall not be used as surge-batchers.

The surge-batcher shall be independent and distinct from conveyors or chutes used to collect or direct the completed mixture being discharged into storage silos and shall be the last device to handle the material before it enters the silo. Multiple storage silos shall be served by an individual surge-batcher for each silo. Material handling shall be free of oblique movement between the highest elevation (conveyor outfall) and subsequent placement in the silo. Discharge gates on surge-batchers shall be automatic in operation and shal discharge only after a minimum of 4,000 pounds of material has been collected and shall close before the last
collected material leaves the device. Discharge gate design shall prevent the deflection of material during the opening and closing operation.

**GENERAL.**—Binder for Type D rubberized asphalt concrete shall be, at the Contractor’s option, either Type 1 or Type 2 asphalt-rubber binder conforming to the requirements of these special provisions.

The amount of asphalt-rubber binder to be mixed with the aggregate for Type D rubberized asphalt concrete will be determined by the Engineer using the samples of aggregates furnished by the Contractor in conformance with Section 39-3.03, Proportioning, of the Standard Specifications. The Engineer will determine the amount of asphalt-rubber binder to be mixed with the aggregate in accordance with California Test 367, except as follows:

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

Section “C. Optimum Bitumen Content” of California Test 367 shall be as follows:

1. Using Figure 2 record in Step 1 of the pyramid the asphalt content of the four specimens with the maximum asphalt content used in the square farthest to the right.

2. Plot asphalt content versus void content for each specimen on Form TL-306 (Figure 3), and connect adjacent points with straight lines.

3. From Step 1 of the pyramid, select the three highest asphalt contents that do not exhibit moderate or heavy surface flushing, and record these asphalt contents in Step 2. See Note 1.

4. From Figure 2 select the theoretical asphalt content that has 3.0 percent or more voids and is within the asphalt range listed in Step 2 of the pyramid. Always stay as close to 3.0 percent voids as possible. Record this amount in Step 4 of the pyramid.

5. Record the asphalt content in Step 4 as the Optimum Bitumen Content (OBC).

6. To establish a recommended range, use the Optimum Bitumen Content (OBC) as the high value and 0.3 percent less as the low value.

The temperature of the aggregate at the time the asphalt-rubber binder is added shall be not more than 325°F.

**ASPHALT-RUBBER BINDER.**—The grade of paving asphalt to be used in asphalt-rubber binder will be either grade AR-1000, AR-2000 or AR-4000, as determined by the Engineer.
from recommendation by the asphalt-rubber binder supplier.

The reclaimed vulcanized rubber shall be produced primarily from the processing of automobile and truck tires. The rubber shall be produced by ambient temperature grinding processes only.

The specific gravity of reclaimed vulcanized ground rubber shall be not less than 1.10 nor more than 1.20, and shall conform to the following gradation when tested in accordance with ASTM Designation: C 136:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 8</td>
<td>100</td>
</tr>
<tr>
<td>No. 10</td>
<td>95-100</td>
</tr>
<tr>
<td>No. 16</td>
<td>40-80</td>
</tr>
<tr>
<td>No. 30</td>
<td>5-30</td>
</tr>
<tr>
<td>No. 50</td>
<td>0-15</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-3</td>
</tr>
</tbody>
</table>

Rubber for use in asphalt-rubber binder shall be free of loose fabric, wire and other contaminants except that up to 4 percent (by weight of rubber) calcium carbonate or talc may be added to prevent caking or sticking of the particles together. The rubber shall be sufficiently dry so as to be free flowing and not produce foaming when blended with the hot paving asphalt.

At least two weeks before its intended use, the Contractor shall furnish samples of the asphalt-rubber binder proposed for use on the project. The samples shall consist of 4 one-quart size cans of the asphalt-rubber binder, together with the formulation and the grade of paving asphalt used.

The method and equipment for combining the rubber and paving asphalt shall be so designed and accessible that the Engineer can readily determine the percentage by weight for each material being incorporated into the mixture.

Equipment utilized in the production and proportioning of asphalt-rubber binder shall include the following:

An asphalt heating tank with hot oil heat transfer to heat the paving asphalt to the necessary temperature before blending with the granulated rubber. This unit shall be equipped with a
thermostatic heat control device.

A mechanical blender for proper proportioning and thorough mixing of the paving asphalt and rubber. This unit shall have both an asphalt totaling meter (gallons or liters) and a flow rate meter (gallons per minute or liters per minute).

An asphalt-rubber binder storage tank equipped with a heating system to maintain the proper temperature of the binder and an internal mixing unit capable of maintaining a homogeneous mixture of asphalt and rubber.

The asphalt-rubber mixture shall not be used as a binder after it has been retained for more than 48 hours.

**TYPE 1 BINDER.**—Type 1 asphalt-rubber binder shall be a uniform and reacted mixture of compatible paving grade asphalt and reclaimed vulcanized rubber. The length of the individual rubber particles shall not exceed 3/16 inch.

Type 1 asphalt-rubber binder shad contain not less than 14 percent nor more than 20 percent rubber, by weight of the total asphalt-rubber binder.

The temperature of the paving asphalt shall be between 350°F and 425°F at the time the rubber is blended with the paving asphalt. The paving asphalt and rubber shad be combined and mixed together in a blender unit, pumped into the agitated storage tank, and then reacted for a minimum of 45 minutes from the time the rubber is added to the paving asphalt. The asphalt-rubber binder shall be maintained at a temperature of not less than 325°F nor more than 375°F during the reaction period.

The viscosity of the asphalt-rubber binder after the reaction period, when tested in accordance with ASTM Designation: D 2196, shad be not less than 1,500 centipoise at 350°F (Brookfield).

The asphalt-rubber binder, after reaching the desired consistency, shad not be held at temperatures over 325°F for more than 4 hours.

**TYPE 2 BINDER.**—Type 2 asphalt-rubber binder shad be a uniform and reacted mixture of compatible paving grade asphalt, extender oil, natural rubber and reclaimed vulcanized rubber.

Extender oil shall be a resinous, high flash point, aromatic hydrocarbon conforming to the following:
The paving asphalt and extender oil, when combined, shall form a material that is chemically compatible with the rubber.

The extender oil shall be added to the paving asphalt at a rate of not less than 2 percent nor more than 6 percent by weight of the paving asphalt, the exact amount to be as determined by the Engineer from recommendation by the asphalt-rubber binder supplier. The asphalt shall be at a temperature of not less than 350°F nor more than 425°F when the extender oil is added.

Rubber for use in Type 2 asphalt-rubber binder shall consist of reclaimed vulcanized rubber and shall contain not less than 20 percent nor more than 30 percent, by weight, natural rubber, when tested in accordance with ASTM Designation D 297. The rubber shall contain no particles longer than 1/4 inch in length.

The paving asphalt-extender oil blend and rubber shall be combined and mixed together in the blender unit to produce a homogeneous mixture.

The amount of rubber to be added to the paving asphalt-extender oil blend shall be not less than 17 percent nor more than 23 percent by weight of the combined mixture of paving asphalt, extender oil, and rubber. The exact amount will be as determined by the Engineer from recommendation by the asphalt-rubber binder supplier. The paving asphalt-extender oil blend shall be at a temperature of not less than 350°F nor more than 425°F when the rubber is added.

The asphalt-rubber binder shall be reacted for a minimum of 45 minutes from the time the rubber is added to the paving asphalt-extender oil blend. The asphalt-rubber binder shall be maintained at a temperature between 375°F and 425°F during the reaction period.
The viscosity of the asphalt-rubber binder after the reaction period, when tested in accordance with ASTM Designation: D 2196, shall be not less than 1,500 centipoise nor more than 3,000 centipoise at 375°F (Brookfield).

The asphalt-rubber binder, after reaching the desired consistency, shall not be held at temperatures over 375°F for more than 4 hours.

**AGGREGATE.**—The aggregate for Type D rubberized asphalt concrete shall conform to the 3/4” maximum, medium grading and shall meet the quality requirements specified for Type A asphalt concrete in Section 39-2.02, "Aggregate," of the Standard Specifications, except the loss at 500 revolutions from the Los Angeles Rattler test shall be 40 percent maximum.

**CONSTRUCTION.**—After the material has reacted for at least 45 minutes, the asphalt-rubber binder shall be metered into the mixing chamber of the asphalt concrete production plant at the percentage determined by the Engineer.

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

When continuous mixing type asphalt concrete plants are used to produce Type D rubberized asphalt concrete, the asphalt-rubber binder shall be proportioned by an asphalt meter of the mass flow, coriolis effect type. The meter shall be calibrated in accordance with California Test 109.

Type D rubberized asphalt concrete shall be spread at a temperature of not less than 275°F nor more than 325°F, measured in the hopper of the paving machine.

Pneumatic tired rollers shall not be used to compact Type D rubberized asphalt concrete. Alternative compacting equipment as specified in Section 39-6.03, "Compacting," of the Standard Specifications shall be used to compact the Type D rubberized asphalt concrete.

Traffic shall not be allowed on the Type D rubberized asphalt concrete for at least one hour after final rolling operations have been completed.

When ordered by the Engineer to prevent tracking by public traffic from the surface of Type D rubberized asphalt concrete, prior to opening a traffic lane, sand shall be spread on the surface at the approximate rate of from one to two pounds per square yard. Sand shall be free from clay or organic material and shall be of such gradation that at least 90 percent will pass the No. 4 sieve and not more than 5 percent will pass a No. 200 sieve. When ordered by the Engineer excess sand shall be removed from the pavement surface by sweeping.
MEASUREMENT AND PAYMENT.—Rubberized asphalt concrete Type D-asphalt rubber) will be measured and paid for by the ton in the same manner specified for asphalt concrete in Section 39-8, "Measurement and Payment," of the Standard Specifications.

Full compensation for furnishing, spreading and sweeping sand cover shall be considered as included in the contract price paid per ton for rubberized asphalt concrete (Type D-asphalt rubber) and no separate payment will be made therefore.

10-1. RUBBERIZED ASPHALT CONCRETE (TYPE O-ASPHALT RUBBER).—Rubberized asphalt concrete (Type O-Asphalt Rubber) shall be asphalt rubber hot mix-open graded (ARXM-OG) and shall consist of furnishing and mixing open graded aggregate and asphalt-rubber bind and spreading and compacting the mixture. Type O rubberized asphalt concrete shall conform to the requirements specified for open graded asphalt concrete in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.


The second paragraph in Section 39-3.05, "Asphalt Concrete and Asphalt Concrete Base Storage," of the Standard Specifications is amended to read:

Storage silos shall be equipped with a surge-batcher sized to hold a minimum of 4,000 pounds of material. A surge-batcher consists of equipment placed at the top of the storage silo which catches the continuous delivery of the completed mix and changes it to individual batch delivery and prevents the segregation of product ingredients as the completed mix is placed into storage. The surge-batcher shall be center loading and shall be thermally insulated or heated or thermally insulated and heated to prevent material buildup. Rotary chutes shall not be used as surge-batchers.

The surge-batcher shall be independent and distinct from conveyors or chutes used to collect or direct the completed mixture being discharged into storage silos and shall be the last device to handle the material before it enters the silo. Multiple storage silos shall be served by an individual surge-batcher for each silo. Material handling shall be free of oblique movement between the highest elevation (conveyor outfall) and subsequent placement in the silo. Discharge gates on surge-batchers shall be automatic in operation and shall discharge only after a minimum of 4,000 pounds of material has been collected and shall close before the last collected material leaves the device. Discharge gate design shall prevent the deflection of material during the opening and closing operation.
GENERAL.—Binder for Type O rubberized asphalt concrete shall be, at the Contractor’s option, either Type 1 or Type 2 asphalt-rubber binder conforming to the requirements of these special provisions.

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 Section 39-3.03, Proportioning of the Standard Specifications. The Engineer will determine the amount of asphalt-rubber binder to be mixed with the aggregate in accordance with California Test 368, except the test temperature in Section “D. Test Procedures shall be 325°F.

The temperature of the aggregate at the time the asphalt-rubber binder is added shall be not more than 325°F.

ASPHALT-RUBBER BINDER.—The grade of paving asphalt to be used in asphalt-rubber binder will be either grade AR-1000, AR-2000 or AR-4000, as determined by the Engineer from recommendation by the asphalt-rubber binder supplier.

The reclaimed vulcanized rubber shall be produced primarily from the processing of automobile and truck tires. The rubber shall be produced by ambient temperature grinding processes only.

The specific gravity of reclaimed vulcanized ground rubber shall be not less than 1.10 nor more than 1.20, and shall conform to the following gradation when tested in accordance with ASTM Designation: C 136:

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<tr>
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<th>Percent Passing</th>
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<tr>
<td>No. 50</td>
<td>0-15</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-3</td>
</tr>
</tbody>
</table>

Rubber for use in asphalt-rubber binder shall be free of loose fabric, wire and other contaminants except that up to 4 percent (by weight of rubber) calcium carbonate or talc may
be added to prevent caking or sticking of the particles together. The rubber shall be sufficiently dry so as to be free flowing and not produce foaming when blended with the hot paving asphalt.

At least two weeks before its intended use, the Contractor shall furnish samples of the asphalt-rubber binder proposed for use on the project. The samples shall consist of 4 one quart size cans of the asphalt-rubber binder, together with the formulation and the grade of paving asphalt used.

The method and equipment for combining the rubber and paving asphalt shall be so designed and accessible that the Engineer can readily determine the percentage by weight for each material being incorporated into the mixture.

Equipment utilized in the production and proportioning of asphalt-rubber binder shall include the following:

An asphalt heating tank with hot oil heat transfer to heat the paving asphalt to the necessary temperature before blending with the granulated rubber. This unit shall be equipped with a thermostatic heat control device.

A mechanical blender for proper proportioning and thorough mixing of the paving asphalt and rubber. This unit shall have both an asphalt totaling meter (gallons or liters) and a flow rate meter (gallons per minute or liters per minute).

An asphalt-rubber binder storage tank equipped with a heating system to maintain the proper temperature of the binder and an internal mixing unit capable of maintaining a homogeneous mixture of asphalt and rubber.

The asphalt-rubber mixture shall not be used as a binder after it has been retained for more than 48 hours.

**TYPE 1 BINDER.**—Type 1 asphalt-rubber binder shall be a uniform and reacted mixture of compatible paving grade asphalt and reclaimed Vulcanized rubber. The length of the individual rubber particles shall not exceed 3/16 inch.

Type 1 asphalt-rubber binder shall contain not less than 14 percent nor more than 20 percent rubber, by weight of the total asphalt-rubber binder.

The temperature of the paving asphalt shall be between 350°F and 425°F at the time the rubber is blended with the paving asphalt. The paving asphalt and rubber shall be combined and mixed together in a blender unit, pumped into the agitated storage tank, and then reacted for a minimum of 45 minutes from the time the rubber is added to the paving asphalt. The
asphalt-rubber bind shall be maintained at a temperature of not less than 325°F nor more than 375°F during the reaction period.

The viscosity of the asphalt-rubber binder after the reaction period, when tested in accordance with AS1Bl Designation: D 2196, shall be not less than 1,500 centipoise nor more than 3,000 centipoise at 350°F (Brookfield).

The asphalt-rubber binder, after reaching the desired consistency, shall not be held at temperatures over 325°F for more than 4 hours.

**TYPE 2 BINDER.**—Type 2 asphalt-rubber binder shall be a uniform and reacted mixture of compatible paving grade asphalt, extender oil, natural rubber and reclaimed vulcanized rubber.

Extender oil shall be a resinous, high flash point, aromatic hydrocarbon conforming to the following:

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Designation</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, SSU, at 100°F</td>
<td>D 88</td>
<td>2500 min.</td>
</tr>
<tr>
<td>Flash Point, COC, °F</td>
<td>D 92</td>
<td>390 min.</td>
</tr>
<tr>
<td>Molecular Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphaltenes, percent by</td>
<td>D 2007</td>
<td>0.1 max.</td>
</tr>
<tr>
<td>weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatics, percent by</td>
<td>D 2007</td>
<td>55 min.</td>
</tr>
<tr>
<td>weight</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The paving asphalt and extender oil, when combined, shall form a material that is chemically compatible with the rubber.

The extender oil shall be added to the paving asphalt at a rate of not less than 2 percent nor more than 6 percent by weight of the paving asphalt, the exact amount to be as determined by the Engineer from recommendation by the asphalt-rubber binder supplier. The asphalt shall be at a temperature of not less than 350°F nor more than 425°F when the extender oil is added.
Rubber for use in Type 2 asphalt-rubber binder shall consist of reclaimed vulcanized rubber and shall contain not less than 20 percent nor more than 30 percent, by weight, natural rubber, when tested in accordance with ASTM Designation D 297. The rubber shall contain no particles longer than 1/4 inch in length.

The paving asphalt-extender oil blend and rubber shall be combined and mixed together in the blender unit to produce a homogeneous mixture.

The amount of rubber to be added to the paving asphalt-extender oil blend shall be not less than 17 percent nor more than 23 percent by weight of the combined mixture of paving asphalt, extender oil, and rubber. The exact amount will be as determined by the Engineer from recommendation by the asphalt-rubber binder supplier. The paving asphalt-extender oil blend shall be at a temperature of not less than 350°F nor more than 425°F when the rubber is added.

The asphalt-rubber binder shall be reacted for a minimum of 45 minutes from the time the rubber is added to the paving asphalt-extender oil blend. The asphalt-rubber binder shall be maintained at a temperature between 375°F and 425°F during the reaction period.

The viscosity of the asphalt-rubber binder after the reaction period, when tested in accordance with ASTM Designation: D 2196, shall be not less than 1,500 centipoise nor more than 3,000 centipoise at 375°F (Brookfield).

The asphalt-rubber binder, after reaching the desired consistency, shall not be held at temperatures over 375°F for more than 4 hours.

AGGREGATE.—The aggregate for Type O rubberized asphalt concrete shall conform to 1/2 inch maximum open graded asphalt concrete aggregate specified in Section 39-2.02, aggregate,” of the Standard Specifications.

CONSTRUCTION.—After the material has reacted for at least 45 minutes, the asphalt-rubber binder shall be metered into the mixing chamber of the asphalt concrete production plant at the percentage determined by the Engineer.

If the Contractor selects the batch mixing method, asphalt concrete shall be produced by the automatic batch mixing method as provided in Section 39-3.03A(lb), automatic Proportioning,” of the Standard Specifications.

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 weight.
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 be calibrated in accordance with California Test 109.

Type O rubberized asphalt concrete shall be spread at a temperature of not less than 275°F nor more than 325°F, measured in the hopper of the paving machine. Type O rubberized asphalt concrete shall be placed only when the atmospheric temperature is above 45°F.

The area to which paint binder has been applied shall be closed to public traffic. Care shall be taken to avoid tracking binder material onto existing pavement surfaces beyond the limits of construction.

In addition to the requirements in Section 39-5.01, “Spreading Equipment,” of the Standard Specifications, asphalt paving equipment shall be equipped with automatic screed controls and a sensing device or devices.

When paving contiguously with previously placed mats, the end of the screed adjacent to the previously placed mat shall be controlled by a sensor that responds to the grade of the previously placed mat and will reproduce the grade in the new mat within a 0.01-foot tolerance.

Should the methods and equipment furnished by the Contractor fail to produce a layer of asphalt concrete conforming to the requirements, including straightedge tolerance, of Section 39-6.03, “Compacting,” of the Standard Specifications, the paving operations shall be discontinued and the Contractor shall modify his equipment or furnish substitute equipment.

Should the automatic screed controls fail to operate properly during any day’s work, the Contractor may use manual control of the spreading equipment for the remainder of that day, however, the equipment shall be corrected or replaced with alternative automatically controlled equipment conforming to the requirements in this section before starting another day’s work.

Traffic shall not be allowed on the Type O rubberized asphalt concrete for at least one hour after final rolling operations have been completed.

When ordered by the Engineer to prevent tracking by public traffic from the surface of Type O rubberized asphalt concrete, prior to opening a traffic lane, sand shall be spread on the surface at the approximate rate of from one to two pounds per square yard. Sand shall be free from clay or organic material and shall be of such gradation that at least 90 percent will pass the No. 4 sieve and not more than 5 percent will pass a No. 200 sieve. When ordered by the Engineer excess sand shall be removed from the pavement surface by sweeping.
MEASUREMENT AND PAYMENT.—Rubberized asphalt concrete (Type G asphalt rubber) will be measured and paid for by the ton in the same manner specified for asphalt concrete in Section 39-8, "Measurement and Payment," of the Standard Specifications.

Full compensation for furnishing, spreading and sweeping sand cover shall be considered as included in the contract price paid per ton for rubberized asphalt concrete (Type O asphalt rubber) and no separate payment will be made therefore.
337 ASPHALTIC CONCRETE FRICTION COURSES (FA 10-24-94)
(REV 5-25-94)

SECTION 337 (Pages 265-271) is deleted and the following substituted:

SECTION 337
ASPHALTIC CONCRETE FRICTION COURSES
(ASPHALT RUBBER BINDER)

337-1 Description.

This Section specifies the materials, composition, mix design and compensation for Asphaltic Concrete Friction Courses containing asphalt rubber binder. The requirements for plant and equipment for this pavement are specified in Section 320. General construction requirements for all asphaltic concrete pavements as specified in Section 330 are applicable to this Section subject to any exceptions contained herein.

The work will be accepted on a LOT by LOT basis in accordance with the applicable requirements of Sections 5, 6, and 9. The size of the LOT for the bituminous mix accepted at the plant will be as specified in 331-5 and for the material accepted on the roadway as stipulated in 330-10 and 330-12.

The mixes covered by this Section are designated as Friction Course 2 (FC-2), and Friction Course 3 (FC-3).

337-2 Materials.

337-2.1 General: The materials used shall conform with the requirements specified in Division m as modified herein.

337-2.2 Asphalt Rubber Binder: The asphalt rubber binder material for friction courses shall be an ARO12 for FC-2 and an ARB 5 for FC-3, both meeting the requirements of Section 336. In addition, the asphalt rubber binder shall contain 0.5 percent heat stable anti-stripping additive from an approved source. This amount may be varied based on tests performed by the State Materials Office. When the amount is varied in excess of the 0.5 percent, the Contractor will be compensated at the invoice price for the additive. When the amount is varied less than 0.5 percent, the Department shall be reimbursed at the invoice price of the additive.
The heat stable anti-stripping additive shall be introduced and mixed into the asphalt cement at the asphalt terminal during loading or by the Contractor at fee asphalt plant in a manner satisfactory to the Engineer. Addition of the additive at the asphalt terminal shall be certified by the supplier.

337-2.3 Coarse Aggregate: Except as modified herein, all coarse aggregate shall meet the requirements of Section 901.

337-2.4 Fine Aggregate: Fine aggregates shall meet all applicable requirements of Section 902.

337-3 General Composition of Mixes.

337-3.1 General: The bituminous mix shall be composed of a combination of aggregate (coarse, fine, or a mixture thereof), mineral filler if required, and asphalt rubber binder. The several aggregate fractions shall be sized, uniformly graded and combined in such proportions that the resulting mix will meet the grading and physical properties of the approved job mix formula.

337-3.2 Aggregate Components: The aggregate components of the various mixes set out in this Section shall be as follows:

**FC-2**

The coarse aggregate component of FC-2 shall be either crushed granite, crushed slag, or lightweight aggregates (that have been approved for this use). Crushed limestone from the Uletic formation will also be permitted if the coarse aggregate contains a minimum of twelve percent non carbonate material as determined by FM 5-510 and approval of the source is granted by the State Materials Office prior to its use. In addition, use of aggregates other than those listed above may be permitted if approved by the State Materials Office.

**FC-3**

The coarse aggregate components of the FC-3 mixture shall be either crushed gravel, crushed granite, crushed slag, or crushed limestone from the Colitis formation as specified for use in FC-2. In addition, use of aggregates other than these listed above may be permitted if approved by the State Materials Office.

The fine aggregate components shall consist of crushed screenings or a combination of crushed screenings and local materials. The crushed screenings shall be composed of hard, durable particles resulting from the crushing or processing of coarse aggregate as specified above. In addition, screenings from other approved sources may be used provided that the total
of these screenings along with silica sand or local materials does not exceed 40 percent. The gradation requirements of the screenings shall be as specified in 902-5.1.

Not more than 20 percent by weight of the total aggregate used shall be silica sand or local materials as defined in Section 902.

Continuing approval of all sources of material for use in FC-2 and FC-3 will be based on field performance.

337-3.3 Grading Requirements: The job mix formula, as established by the Contractor and approved by the Department, shall be within the design range specified in Table 331-1 for all friction courses.

337-3.4 Stability for FC-3: The constituents for FC-3 shall be combined in such proportions as to produce a mix having Marshall properties within the limits shown in Table 331-2.

337-4 Marc Design.

The mix design shall conform to the requirements of 331-4.3 of these specifications except that Item No. 7 in 331-4.3.1 shall not apply to FC-2. For FC-3, data shall be submitted showing that the Max design meets the requirements of Table 331-2 using conventional AC-30. The asphalt rubber will then be substituted at the optimum conventional binder content for production and shall be shown as the optimum binder content on the approved mix design.

337-5 Contractor’s Quality Control.

The Contractor shall provide the necessary quality control of the friction course mix and construction in accordance with the applicable provisions of 6-8.4 and 331-4.4. After the mix design has been approved, the Contractor shall furnish the material to meet the approved mix design in accordance with the provisions of 331-4.4.2 and Table 331-3. Plant calibration shall comply with the provisions of 331-4.4.3 and Table 331-3.

337-6 Acceptance of Mix.

337-6.1 Acceptance at the Plant: The bituminous mix shall be accepted at the plant with respect to gradation in accordance with the applicable requirements of 331-5. Acceptance determinations for asphalt rubber binder content for mixtures produced by batch, drum, or continuous mix plants are as follows:
337-6.1.1 Batch Plants: All batch plants producing friction course mixtures containing asphalt rubber shall be equipped with an automatic printer system which is capable of printing either the individual bin weights or total aggregate weight, as well as the amount of asphalt rubber binder, that is delivered to the pugmill. Each batch of asphaltic concrete mixture produced shall have an individual printout.

The asphalt rubber binder content for acceptance purposes shall be based on the calculated binder content from the printout of the batch that is selected based upon the random number. Payment shall be based on the provisions of Table 331-6, using the Asphalt Cement Content (printout) characteristic.

The batch scales and the accuracy of the automatic printer system shall be certified at least once every six months. Such certification shall be furnished by an approved certified scale technician and the Contractor shall be responsible for obtaining this certification. The automatic printer system shall maintain an accuracy of one percent for the asphalt rubber binder and aggregate.

337-6.1.2 Drum-Mix Plants: All drum-mix plants producing friction course mixtures containing asphalt rubber shall be equipped with a metering/printer system that is capable of one of the following:

1) Printing an instantaneous reading, upon demand, of dry aggregate and asphalt rubber binder being delivered to the drum (in TPH). The asphalt rubber binder content for acceptance purposes will then be based on the calculated binder content from the printout that is obtained based upon the random number.

2) Printing an instantaneous reading at a regular frequency of no longer than 5 minutes, of dry aggregate and asphalt rubber binder that is delivered to the drum (in TPH). The asphalt rubber binder content for acceptance purposes will then be based upon the calculated binder content from the printout obtained that is nearest to the random number.

The instantaneous readings of asphalt rubber binder and dry aggregate shall be synchronized such that the readings are representative of the proportions of asphalt rubber binder and dry aggregate at the instant that they are combined.

Payment shall be based on the provisions of Table 331-6, using the Asphalt Cement Content (printout) characteristic.

The metering/printer system shall be certified at least once every six months. Such certification shall be furnished by an approved certified scale technician and the Contractor shall be responsible for obtaining this certification. The metering/printer system shall
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maintain an accuracy of one-half percent for the asphalt rubber binder and one percent for the aggregate.

337-6.1.3 Continuous-Mix Plants: All continuous-mix plants producing friction course mixtures containing asphalt rubber binder shall be equipped with a metering/printer system as approved by the District Bituminous Engineer. The asphalt rubber binder content for acceptance purposes will then be based on the calculated binder content from the metering/printer system that is obtained based upon the random number.

Payment shall be based on the provisions of Table 331-6, using the Asphalt Cement Content (printout) characteristic.

The metering/printer system shall be certified at least once every six months. Such certification shall be furnished by an approved certified scale technician and the Contractor shall be responsible for obtaining this certification. The metering/printer system shall maintain an accuracy of 1/2% for both the asphalt rubber binder and aggregate.

337-6.2 Acceptance on the Roadway: The bituminous mix will be accepted on the roadway with respect to density and surface tolerance in accordance with the applicable provisions of 330-10 and 330-12. There will be no density requirements for FC-2.

337-6.3 Additional Tests: The provisions of 331-5.5 shall apply to the friction courses - FC-2 and FC-3.

337-7 Special Construction Requirements.

337-7.1 Temperature Requirements for FC-2:

337-7.1.1 Air Temperature at Laydown: The mixture shall be spread only when the air temperature (the temperature in the shade away from artificial heat) is at or above 60°F.

337-7.1.2 Temperature of the Mix: The asphalt rubber binder and aggregates shall be heated and combined in such a manner as to produce a mix having a temperature, when discharged from the pugmill, of 290°F. The tolerance from this established temperature shall be as specified in Table 330-1. All other requirements of 3304.3 shall apply to FC-2.

337-7.2 Temperature Requirements for FC-3:

337-7.2.1 Air Temperature at Laydown: The mixture shall be spread only when the air temperature (the temperature in the shade away from artificial heat) is at or above 45°F.
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337-7.2.2 Temperature of the Mix: The asphalt rubber binder and aggregates shall be heated and combined in such a manner as to produce a mix having a temperature, when discharged from the pugmill, of 310°F. The tolerance from this established temperature shall be as specified in Table 33S1. All other requirements of 330 6.3 shall apply to FC-3.

337-7.3 Compaction of FC-2: Only seal rolling will be required; this rolling will be accomplished using a tandem steel wheel roller. The weight of the steel-wheel roller shall not exceed 135 pounds per linear inch (PLI) of drum width.

\[
PLI = \frac{\text{Total Weight of Roller (pounds)}}{\text{Total Width of Drums (inches)}}
\]

Rolling shall be accomplished with a single coverage and with a nominal amount of overlap. Where the lane being placed is adjacent to a previously laid mat, the longitudinal joint will not be pinched in a manner with the roller on the cold mat. The longitudinal joint will be pinched with the roller on the mat being rolled, overlapping onto the cold mat by no more than three inches.

In no case shall a roller be allowed on the mat after the seal rolling has been completed.

337-7.4 Prevention of Adhesion: In order to minimize adhesion to the drum during the rolling operations, a small amount of liquid detergent may be added to the water in the roller.

At intersections and in other areas where the pavement may be subjected to cross-traffic before it has cooled, the approaches shall be sprayed with water in order to wet the tires of the approaching vehicles before they cross the pavement.

337-7.5 Thickness of Friction Courses: The thickness of the friction course shall be designated in the plans. This is the minimum desirable thickness for FC-3, and the maximum desirable thickness for FC-2. The minimum spread rate for FC-2 shall be 25 pounds per square yard when lightweight aggregates are used and 40 pounds per square yard when conventional aggregates are used.

337-7.5.1 Thickness Requirements-Tonnage Payment: For FC-2 mixes where payment is on a tonnage basis, the rate of application shown on the plans shall be considered approximate. The intent is to achieve the maximum thickness of the friction course shown in the plans. Particular care must be exercised to avoid exceeding the established rate of
application for FC-2 mixes.

337-7.5.2 Thickness Requirements - Square Yard Payment: The thickness shall be determined in accordance with 330-15.1 except that the average thickness will not be calculated. Cores will not be taken in areas where the friction course is being transitioned in thickness to tie into an existing surface. The maximum allowable deficiency from the thickness specified in the plans shall be 1/4 inch. If any area is deficient in thickness by more than the allowable tolerance, the Contractor shall correct the deficiency by removing and replacing the friction course at the proper thickness. Thickness deficiencies may be corrected by overlaying if approved by the Engineer. The overlay shall extend 50 feet either side of the deficient area and shall extend across the full width of the roadway.

As an exception to the foregoing, if the Engineer determines that the friction course will satisfactorily perform its intended function without corrective work, the friction course may be left in place without compensation. The area for which no payment will be made shall be the product of the total distance between cores indicating thickness within tolerances and the width of the lane which was laid in the particular pass in which the deficient thickness occurred. Additional cores will be taken as necessary to define the limits of a deficiency. Open-graded friction courses will not be cored for thickness determinations.

337-7.6 Hot Storage of FC-2 Mixes: When surge or storage bins are used in the normal production of FC-2, as with the drum mixer plants, the maximum time the mix is allowed to remain in the surge or storage bin shall not exceed one hour.

337-7.7 Longitudinal Grade Controls for Open-Graded Friction Courses: on open-graded friction courses, the use of the longitudinal grade control (skid, ski, or traveling stringline) is prohibited. The use of the joint matcher is required.

337-7.8 Transportation Requirements of Friction Course Mixtures: All loads of friction course mixtures shall be covered with a tarpaulin as specified in 320-6.4.

337-8 Method of Measurement.

337-8.1 Payment Based on Area: When the plans indicate that the friction course is to be paid for on an area basis, the area to be paid for shall be plan quantity subject to 9-3.2. The pay area shall include entire areas of transitions to tie into existing pavement but excluding areas for which no payment is to be made due to deficient thickness as defined in 337-7.5. No adjustment to the area to be paid for will be made for extra thickness.

337-8.2 Payment Based on Weight: When the plans indicate that the friction course is to be paid for by weight, the weight shall be determined as provided in 320-2 (including provisions for the automatic recordation system).
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For FC-2 mixes, in the event the actual rate of application exceeds the rate established by the DOT Lab (as provided in 337-7.5.1) by in excess of ten pounds per square yard, the weight to be paid for shall be reduced to a theoretical quantity computed as the product of the actual area covered by the friction course and the established rate of application plus ten pounds per square yard.

337-8.3 Bituminous Material: The provisions of 331-6.4 apply to bituminous materials used in friction course mixes.

337-9 Basis of Payment.

337-9.1 Asphalt Rubber Binder: The bid price for the friction course mix shall include the cost of the asphalt cement, ground tire rubber, anti-stripping agent and blending and handling of the asphalt rubber binder in the friction course mix. The bid price for the friction course shall be based on the following asphalt rubber binder contents:

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>Asphalt Rubber Binder Content (%) by weight of total mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC-2</td>
<td>7.1</td>
</tr>
<tr>
<td>FC-3</td>
<td>6.5</td>
</tr>
</tbody>
</table>

13.8 for FC-2 with lightweight aggregate.

If the asphalt rubber binder content in the approved mix design increases or decreases from the foregoing percentages, the bid price of the mix will be adjusted based on the invoice price of the asphalt rubber binder material plus ten percent of the invoice price. When the asphalt rubber binder is blended at the asphalt plant, the invoice price will be a combination of the invoice price for the asphalt cement, the ground tire rubber and the blending of the asphalt rubber binder.

\[
\text{Adjustment} (\$/sy) = t \frac{ARBC_{\text{design}} - ARBC_{\text{table}}}{8.6 \text{ lb/gal}} \times 100 \text{ lb/sq yr} \times (\text{IP})1.10
\]

where

- \( ARBC_{\text{Table}} \): Asphalt Rubber Binder Content (%) from above table,
- \( ARBC_{\text{Design}} \): Asphalt Rubber Binder Content (%) in the mix design, as issued by the Materials Office,
- \( t \): Design Thickness (inches),
- \( \text{IP} \): Invoice Price.
As an example, when the asphalt rubber binder content for a FC-3 mix is determined to be 7.0 percent the adjustment shall be calculated as follows:

\[
\text{\$ Per square yard} = t \times (0.005 \text{ arc 100 lb/sy-in} / 8.6 \text{ lb/gal}) \times \text{Invoice Price} \times 1.10
\]

where \( \text{ARBC}_{\text{Design}} - \text{ARBC}_{\text{Table}} = 0.070 - 0.065 = 0.005 \), and other variables are defined above.

*For FC-2 the lb/sy-inch will be based on the average spread rate for the project, and the thickness will not be needed.

The contract unit price per square yard for Asphaltic Concrete Friction Course shall be full compensation for all the work specified under this Section.

Payment shall be made under:

- Item No. 337-5 - Asphalitic Concrete Friction Course per square yard.

I. ASPHALT RUBBER BINDER. (FA 9-12-94) (REV 8-25-94)

SECTION 336 (Pages 42-46) of the Supplemental Specifications is deleted and the following substituted:

SECTION 336
ASPHALT RUBBER BINDER

336-1 Description.

This specification governs the production of asphalt rubber binder for use in Asphaltic Concrete Friction Courses and Asphalt Rubber Membrane Interlayers.

336-2 Materials.

336-2.1 Asphalt Cement: The particular grade of asphalt cement as specified in Table 336-1 for the respective uses shall meet the requirements of Section 916.

336-2.2 Ground Tire Rubber: The type of ground tire rubber shall meet the requirements of Section 919.

336-3 Asphalt Rubber Binder.
The asphalt cement and ground tire rubber shall be thoroughly mixed and reacted in accordance with the requirements of Table 33S1. The rubber type shall be in accordance with the approved design mix. Blending of the asphalt cement and ground tire rubber will be accomplished at the asphalt supplier’s terminal or at the project site.

336-4 Equipment.

The blending equipment for asphalt rubber binder shall be designed for that purpose and shall be capable of producing a homogeneous mixture of ground tire rubber and asphalt cement meeting the requirements of Table 336-1. The blending unit may be a batch type or continuous type and shall provide for sampling of the blended and reacted asphalt rubber binder material during normal production. The accuracy of the meter used to determine the asphalt rubber binder content of bituminous mixtures shall be certified once every six months. Such certification shall be furnished by an approved scale technician, and the Contractor shall be responsible for obtaining this certification.

In order to meet specification requirements specialized equipment will be necessary to handle and keep the asphalt rubber uniformly blended while in storage. Storage tanks shall be equipped with a sampling device.

336-5 Testing and Certification Requirements.

336-5.1 Blending at Project Site: The ground tire rubber content in the asphalt rubber binder will be monitored by the Department on a daily basis based on the following: (1) the weight of the ground tire rubber used, and the gallons of asphalt rubber binder used the weight per gallon for the various types of asphalt rubber binder shown in Table 336-1 are to be used for these calculations) or (2) the weight of the ground tire rubber used and the number of gallons of asphalt cement used.

336-5.2 Blending at Asphalt Supplier’s Terminal: Where the asphalt rubber binder is blended at the asphalt suppliers terminal, each load delivered to the project site shall be certified that the asphalt rubber binder has been produced in accordance with and meets the requirements of 336-3. In addition, the certification shall include the certification requirements for the asphalt cement, and ground tire rubber, as specified in 916-1.2 and 919-6, respectively.

336-5.3 Testing of Asphalt Rubber Binder:

336-5.3.1 Quality Control Requirements: The asphalt rubber binder shall be tested for the viscosity requirement of Table 336-1 by the Contractor at the following frequencies and situations:
Florida Department of Transportation

(1) One per batch (for batch blending) or two per day (for continuous blending) during blending at the project site.

(2) Each load delivered to the project site when blended at the asphalt supplier’s terminal.

(3) Beginning of each day from the storage tank when the asphalt rubber binder is stored at the project site.

The viscosity testing equipment specified in FM 5-548 shall be obtained by the Contractor and made available to the Department for acceptance purposes.

In the event that the Quality Control and Acceptance samples are being tested simultaneously, the Acceptance Test results can be used for quality control.

336.5.3.2 Acceptance Requirements: The Department will test the asphalt rubber in accordance with FM 5-548 to assure conformance with the minimum viscosity requirement as specified in Table 33S1. Specific frequencies and situations are as follows:

(1) One per batch (for batch blending) or two per day (for continuous blending) during blending at the project site.

(2) Beginning of each day from the storage tank when the asphalt rubber binder is stored at the project site.

If the asphalt rubber binder does not meet the minimum viscosity requirement, the Contractor shall make the appropriate adjustments in order to (1) correct the viscosity of the blended material, and (2) correct the blending operation. These corrective actions may include increasing the GTR content, lowering the blended temperature, or increasing the reaction time. In the event that the corrective actions taken by the Contractor fail to correct the problem, or the material consistently fails to meet the minimum viscosity requirement, all asphalt rubber production operations shall be stopped until the problem has been solved. Production operations shall not resume until approval is granted by the District Bituminous Engineer. Any mix placed with low viscosity asphalt rubber binder shall be subject to an engineering evaluation to determine if it should be removed and replaced. In the event that the viscosity of the asphalt rubber binder increases to the extent that paving operations of the mixture are adversely affected (i.e. density or texture problems occur), plant operations shall be stopped until the problem has been resolved.
<table>
<thead>
<tr>
<th>Binder Type</th>
<th>ARB-5</th>
<th>ARB-12</th>
<th>ARB-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber Type</td>
<td>Type A</td>
<td>Type B (or A)¹</td>
<td>Type C (or B or A)¹</td>
</tr>
<tr>
<td>Min. % Ground Tire Rubber (by weight of asphalt cement)</td>
<td>5</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>AC Grade</td>
<td>AC-30</td>
<td>AC-30</td>
<td>AC-20</td>
</tr>
<tr>
<td>Min. Temperature, °F</td>
<td>300</td>
<td>300</td>
<td>335</td>
</tr>
<tr>
<td>Max. Temperature, °F</td>
<td>335</td>
<td>350</td>
<td>375</td>
</tr>
<tr>
<td>Min. Reaction Time (minutes)</td>
<td>10</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Unit Weight at 60°F² (lb/gal)</td>
<td>8.6</td>
<td>8.7</td>
<td>8.8</td>
</tr>
<tr>
<td>Min. Viscosity³ (Poises)</td>
<td>4.0 @ 300°F</td>
<td>10.0 @ 300°F</td>
<td>15.0 @ 350°F</td>
</tr>
</tbody>
</table>

¹Use of finer rubber could result in the reduction of the minimum reaction time.
²Conversions to standard 60°F are as specified in 300-8.3.

NOTE: The minimum reaction time may be adjusted if approved by the State Materials Office 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. The asphalt rubber binder for use in membrane interlayers shall be applied within a period of six hours unless some form of corrective action such as cooling and reheating is approved by the State Materials Office.

336.6 Use of Excess Asphalt Rubber.

Excess asphalt rubber may be utilized in other asphaltic concrete mixtures requiring the use of an AC-30 by blending with straight AC-30 so that the total amount of GTR in the binder is less than 2.0 percent. Asphalt rubber blended with any asphalt material that is used as a recycling agent in a recycled mixture must be blended in such proportions that the total amount of GTR in the recycling agent is less than 1.0 percent.
1. GROUND TIRE RUBBER FOR USE IN ASPHALT RUBBER BINDER
   (FA 9-12-94) (REV 5-25-94)

SECTION 919 (Pages 253-255) of the Supplemental Specifications is deleted and the following substituted:

SECTION 919
GROUND TIRE RUBBER
FOR USE IN ASPHALT RUBBER BINDER

919-1 Description.

This specification governs ground tire rubber for use in asphalt rubber binders for use in a variety of paving applications.

919-2 General Requirements.

The ground tire rubber shall be produced from tires such that the final processing is an ambient grinding method. The rubber shall be sufficiently dry so as to be free flowing and to prevent foaming when mixed with asphalt cement. The rubber shall be substantially free from contaminants including fabric, metal, mineral, and other non-rubber substances. Up to four percent (by weight of rubber) of talc or other inert dusting agent, may be added to prevent sticking and caking of the particles.

919-3 Physical Requirements.

The physical properties of the ground tire rubber shall be determined in accordance with FM 5-559, and shall meet the following requirements:

Specific Gravity - 1.10 + 0.06

Moisture Content - Maximum 0.75 %

Metal Contaminants - Maximum 0.01%

Gradation - The gradation shall meet the limits shown in Table 919-1 for the type of rubber specified.
Table 919-1
Gradations of Ground Tire Rubber

<table>
<thead>
<tr>
<th>Sieve Size % Passing</th>
<th>Type A</th>
<th>Type B</th>
<th>Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>---</td>
<td>---</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>---</td>
<td>100</td>
<td>85-100</td>
</tr>
<tr>
<td>40</td>
<td>100</td>
<td>85-100</td>
<td>20-60</td>
</tr>
<tr>
<td>80</td>
<td>90-100</td>
<td>10-50</td>
<td>5-20</td>
</tr>
<tr>
<td>100</td>
<td>70-90</td>
<td>5-30</td>
<td>---</td>
</tr>
<tr>
<td>200</td>
<td>35-60</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

919-4 Chemical Requirements.

The chemical composition of the ground tire rubber shall be determined in accordance with ASTM D 297 and shall meet the following requirements:

- Acetone Extract - Maximum 25 percent.
- Rubber Hydrocarbon Content - 40 to 55 percent.
- Ash Content - Maximum 8 percent.
- Carbon Black Content - 20 to 40 percent.
- Natural Rubber - 16 to 45 percent.
  10 percent for Type A rubber.

919-5 Packaging and Identification Requirements.

The ground tire rubber shall be supplied in moisture resistant packaging such as either disposable bags or other appropriate bulk containers. Each container or bag of ground tire rubber shall be labeled with the manufacturer’s designation for the rubber and the specific type, maximum nominal size, weight and manufacturer’s batch or lot designation.

919-6 Certification Requirements.

The manufacturer of the ground rubber shall furnish the Engineer certified test results.
covering each shipment of material to each project. These reports shall indicate the results of tests required by this specification. They shall also include a certification that the material conforms with all requirements of this specification, and shall be identified by manufacturer's batch or lot number.
PART 6

SECTION 600 - MODIFIED ASPHALTS, PAVEMENTS AND PROCESSES

600-1 REQUIREMENTS.

600-1.1 General. Section 600 covers various processes for both wet and dry crumb rubber materials and methods. Other products may be added as they are developed. The types of methods all utilize whole scrap tire crumb rubber. These specifications were developed to provide quality products that should produce reasonable results. While the specifications have been developed, the engineering properties are still being evaluated. The Engineer should evaluate the various methods and specify those to be considered for bidding in the project Specifications.

600-1.2 Mix Designs and Certifications. The Contractor shall furnish to the Engineer a mix design and samples of all materials to be used at least 15 working days before construction is scheduled to begin. The mix design and certifications shall include, but are not limited to, the following information:

1) Mix Design:
   a) Combined aggregate gradation.
   b) Individual bin gradations (hot for batch, cold for drum plant)
   c) Percentage of each component (asphalt-CRM, and bins).
   d) Source and paving grade of asphalt.
   e) Density.
   f) Air voids.
   g) Voids and Mineral Aggregate (VMA).
   h) Stability.

2) CRM:
Southern California Chapter of APWA

a) Source of CRM.

b) Identification of Grade of CRM.

600 1.3 Definitions.

Asphalt - A dark brown to black cementious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing.

Asphalt Modifier (extender oil) - An aromatic oil used to supplement the asphalt/crumb rubber modifier reaction.

Asphalt-Rubber (AR) - Asphalt cement modified with crumb rubber modifier.

Buffings - High quality scrap tire rubber which is a byproduct from the conditioning of tire carcasses in preparation for retreading.

Crackermill - A process at ambient temperature that tears apart scrap tire rubber by passing the material between rotating corrugated steel drums, reducing the size of the rubber to a crumb particle.

Crumb Rubber Modifier (CRM) - A general term for scrap tire rubber that is reduced in size and is used as a modifier in asphalt paving materials.

Cryogenic Separation - An initial process that freezes the scrap tire rubber for the separation of steel and fabric from used tire rubber.

Diluent - A lighter petroleum product (typically kerosene) added to asphalt rubber binder just before the binder is spray applied to the pavement surface.

Dry Process - Any method that minces the crumb rubber modifier with the aggregate before the mixture is charged with asphalt binder. This process only applies to hot-mix asphalt production.

Granulated CRM - Cubical, uniformly shaped, cut crumb rubber particles with a low surface area which are generally produced by a granulator.

Granulator - Process that shears apart the scrap tire rubber, cutting the rubber with revolving steel plates that pass at close tolerance, reducing the size of the rubber to a crumb particle.
Ground CRM - Irregularly shaped, torn crumb rubber particles with a large surface area which are generally produced by a crackermill.

Hot-Mix Asphalt (HMA) - HMA is used generically to include many different types of mixes produced at elevated temperatures in an asphalt plant. Three types of HMA are dense-graded, open-graded, and gap-graded.

Reaction - The interaction between asphalt cement and crumb rubber modifier when blended together. The reaction, more appropriately defined as polymer swell, is not a Chemical reaction. "It is the absorption of aromatic oils from the asphalt cement into the polymer chains of the crumb rubber.

Rubber Aggregate - That portion of the crumb rubber modifier added to a hot-mix asphalt mixture using the dry process which retains its physical shape and rigidity.

Rubber Modified Hot-Mix Asphalt (RUMAC) - A dry process of hot-mix asphalt mixtures which incorporate crumb rubber modifier primarily as rubber aggregate.

Shredding - The initial process that reduces the whole scrap tires into pieces.

Asphalt-Rubber and Aggregate Membrane [ARAM (SAM)] - A surface treatment using an asphalt-rubber spray application and cover aggregate.

Asphalt-Rubber and Aggregate Membrane Interlayer [ARAMI (SAMI)] - A membrane beneath an overlay designed to resist the stress/strain of reflective cracks and delay the propagation of the cracks through the new overlay. The membrane is a spray application of asphalt-rubber binder and cover aggregate.

Wet Process - Any method that blends crumb rubber modifier with the asphalt cement prior to incorporating the binder in the asphalt paving project.

600-2 CRUMB RUBBER MODIFIED (CRM) BINDERS AND PAVEMENTS - WET PROCESS.

600 2.1 Asphalt-Rubber.

600 2.1.1 General. Asphalt-rubber shall consist of a mature of paving asphalt and crumb rubber modifier (CRM) and shall conform to Type A, B, C, or D or as specified or contained in the Contract Documents.
600 2.1.2 Type A. Asphalt-rubber shall be a combination of whole scrap tire CRM, paving asphalt, and diluent (when required for spray applications) conforming to 600 2.

600 2.1.3 Type B. Asphalt-rubber shall be a combination of whole scrap tire CRM, natural CRM, paving asphalt, and asphalt modifier conforming to 600 2.

600 2.1.4 Type C. Asphalt-rubber shall conform to at least the requirements for Type A asphalt-rubber, but may substitute a maximum of 3 percent total binder weight of natural rubber in lieu of any whole scrap tire CRM quantities.

600 2.1.5 Type D. Asphalt-rubber shall be a combination of whole scrap tire CRM, natural CRM (slightly less than Type B), paving asphalt, and asphalt modifier conforming to 600 2.

600 2.2 Materials. The Contractor shall submit test reports and certificates of compliance for the asphalt, CRM's, diluent, or modifier to be used. In addition, when requested by the Engineer, the Contractor shall submit samples of the tested material along with the certificates of compliance.

600 2.2.1 Paving Asphalt. The asphalt used for asphalt-rubber shall be AR 2000 or AR 4000 conforming to 203-1. Any proposed change to the viscosity grade, as specified, shall be submitted to the Engineer by the Contractor 48 hours prior to beginning work. The asphalt for Type B or Type D asphalt-rubber shall be modified with an asphalt modifier meeting the requirements of Table 600 2.2 (B).

600 2.2.2 Crumb Rubber Modifier (CRM). The material shall be whole scrap tire crumb rubber or other crumb rubber products meeting the requirements of this subsection. Steel and fiber separation may employ any method. Cryogenic separation shall be performed separately from and prior to grinding or granulating. Any CRM shall be ground or granulated at ambient temperature. CRM may contain a maximum of 0.01 percent of wires and an other contaminants, except fabric which shall not exceed 0.5 percent by weight of CRM. CRM used in spray applications shall have less than 0.1 percent, by weight of CRM, of wires and fabric. CRM for use in spray applications may be produced an or In part from tire tread buffings in order to meet the maximum fabric requirements of this subsection. CRM shall be dry and free flowing. Calcium carbonate or talc may be added up to a maximum of 4 percent by weight of CRM to prevent CRM particles from sticking together. The CRM shall have a specific gravity range from 1.1 minimum to 1.2 maximum as determined by ASTM D 297. Whole scrap tire CRM shall be derived from whole scrap tires generated within the State boundaries of the user agencies. Whole scrap tire CRM material shall conform to the following chemical analysis in Table 600 2.2.2 (A):
The natural CRM used in Type B and Type C asphalt-rubber shall meet the following chemical analysis in Table 600-2.2.2 (B):

The combined whole scrap tire CRM and natural rubber CRM material used in Type D asphalt-rubber shall conform to the combined chemical analysis in Table 60S2 2.2 (C). Whole scrap tire CRM shall meet the chemical analysis in Table 600-2.2.2 (A). The natural CRM shall conform to the chemical analysis in Table 600-2.2.2 (B) or Table 600-2.2.2 (D).

### TABLE 600-2.2.2 (A)

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Test Method</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone Extract</td>
<td>D 297</td>
<td>11.0%</td>
<td>19.0%</td>
</tr>
<tr>
<td>Ash Content</td>
<td>D 297</td>
<td>--</td>
<td>8.0%</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>D 297</td>
<td>28.0%</td>
<td>38.8%</td>
</tr>
<tr>
<td>Rubber Hydrocarbon</td>
<td>D 297</td>
<td>42.0%</td>
<td>52.0%</td>
</tr>
<tr>
<td>Natural Rubber Content</td>
<td>D 297</td>
<td>16.0%</td>
<td>34.0%</td>
</tr>
</tbody>
</table>

### TABLE 600-2.2.2 (B)

<table>
<thead>
<tr>
<th>TEST</th>
<th>ASTM Test Method</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone Extract</td>
<td>D 297</td>
<td>4%</td>
<td>10%</td>
</tr>
<tr>
<td>Ash Content</td>
<td>D 297</td>
<td>35%</td>
<td>----</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>D 297</td>
<td>----</td>
<td>15%</td>
</tr>
<tr>
<td>Natural Rubber Content</td>
<td>D 297</td>
<td>40%</td>
<td>----</td>
</tr>
</tbody>
</table>
TABLE 600-2.2.2 (C)

<table>
<thead>
<tr>
<th>TEST</th>
<th>ASTM Test Method</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone Extract</td>
<td>D 297</td>
<td>9.5%</td>
<td>17.5%</td>
</tr>
<tr>
<td>Ash Content</td>
<td>D 297</td>
<td>---</td>
<td>18.5%</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>D 297</td>
<td>20.0%</td>
<td>38.0%</td>
</tr>
<tr>
<td>Rubber Hydrocarbon</td>
<td>D 297</td>
<td>30.0%</td>
<td>55.0%</td>
</tr>
<tr>
<td>Natural Rubber Content</td>
<td>D 297</td>
<td>21.0%</td>
<td>42.0%</td>
</tr>
</tbody>
</table>

TABLE 600-2.2.2 (D)

<table>
<thead>
<tr>
<th>TEST</th>
<th>ASTM Test Method</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone Extract</td>
<td>D 297</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>Ash Content</td>
<td>D 297</td>
<td>---</td>
<td>10%</td>
</tr>
<tr>
<td>Rubber Hydrocarbon</td>
<td>D 297</td>
<td>25%</td>
<td>33%</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>D 297</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td>Natural Rubber Content</td>
<td>D 297</td>
<td>45%</td>
<td>65%</td>
</tr>
</tbody>
</table>

Type D CRM shall conform to the requirements of 600-2.2.2. Type D CRM shall conform to the combined gradation, Table 600 2.2.4 (A). The asphalt modifier shall meet the requirements of Table 600 2.2.5 (B).

600 2.2.3 Formulations and Certifications. The Contractor shall supply to the Engineer for approval a binder formulation and samples of all materials to be used, at least 15 working days before construction is scheduled to begin. The binder formulation shall consist of the following information:

Paving Asphalt.

1) Source of paving asphalt and grade of asphalt cement.

2) Source and grade of additives used.
3) Percentage of asphalt cement and additives by total weight of the asphalt-rubber blend.

CRM.

1) Source of CRM.

2) Identification or grade of CRM.

3) Percentage of CRY by total weight of the asphalt-rubber blend.

If CRM from more than one source is used, the above information will be required for each CRM used.

Minimum Brookfield viscosity using a Number 3 rotor.

Laboratory test results of the proposed blend per the test parameters for the type of asphalt-rubber selected including the minimum mixing reaction time.

When permitted by the Engineer, asphalt-rubber material, not used on another agency’s project, may be used by another agency if the initial using agency certifies the following:

1) The total gallons and type of material being held over.

2) The amount of CRM contained within the holdover load on a percentage basis.

3) The grade of paving asphalt used and its source.

4) Date of original mixing.

5) Number or reheat cycles.

The Contractor shall notify the Agency at least 4 hours in advance of the need for a holdover load certificate. If, through no fault of the Contractor, the Agency is not able to provide the Contractor with a holdover certificate before the end of the shift which resulted in the holdover material, the Contractor and the asphalt-rubber supplier shall under the penalty of perjury, certify to the above criteria. The maximum percentage of material held over shall not exceed 33 percent of the total amount of finished blended material contained in any vessel. In
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no case, will more than 20 tons of holdover asphalt-rubber material be allowed to be transferred from one project to another. In all cases, the holdover asphalt-rubber material blended with new asphalt-rubber binder shall meet the viscosity requirements of the type being used.

Holdover material shall meet all of the following:

1) It shall be certified.

2) It shall not exceed the 33 percent blending requirements set forth above.

3) It shall be a maximum of 20 tons.

4) When blended with new asphalt-rubber material it shall meet the requirements of the type being used.

600-2.2.4 Type A. Type A CRM shall conform to the requirements of 600 2.2.2 and conform to the combined gradations for either Type I or Type II in Table 600 2.2.4 (A). The asphalt-rubber diluent (Ceresine) shall be compatible with all other materials and meet the requirements in Table 6XPOL2.2.4 (B).

600-2.2.5 Type B. Type B CRM shall conform to the requirements of 600-2.2.2 and shall conform to the combined gradations in Table 600-2.2.4 (A) asphalt-rubber modifier shall meet the requirements in Table 600 2.2.5 @ ).

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
</tr>
</thead>
<tbody>
<tr>
<td>N o. 8</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>N o. 10</td>
<td>95-100</td>
<td>100</td>
<td>---</td>
</tr>
<tr>
<td>N o. 16</td>
<td>40-60</td>
<td>70-100</td>
<td>45-85</td>
</tr>
<tr>
<td>N o. 30</td>
<td>0-20</td>
<td>25-60</td>
<td>5-35</td>
</tr>
<tr>
<td>N o. 50</td>
<td>0-10</td>
<td>0-20</td>
<td>0-15</td>
</tr>
<tr>
<td>N o. 100</td>
<td>---</td>
<td>---</td>
<td>0-10</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-5</td>
<td>0-5</td>
<td>0-1</td>
</tr>
</tbody>
</table>

1. CRM from more than one source may be used provided the combined CRM gradation meets the specified limits. No particles shall exceed a length of 1/4 inch as _d on any axis.

2. CRM gradations shall be determined per ASTM C 136 with the following modifications: To a 100 gram sample of CRM add 5.0 grains of talc. Mix the CRM and talc for a _ of 1 minute in a seeded pint size jar and shake or stir for all particle agglomerates/chips are broken and the talc is uniformly mixed. After sieving the combined materials for 10 minutes, sum the total weight of the contents of each sieve, including the pan, and subtract 100. The rongunder is to be subtracted from the bottom pan cans.

This is the adjusted bottom pan rongunder, accounting for the talc used. If the sum of the weights is less than 103.5 grains or greater than 103.5 grains, the test shall be repeated with a new sample. The procedure is not applicable to CRM's with greater than 30% passing the No. 50 sieve.
TABLE 600-2.2.5 (A)

<table>
<thead>
<tr>
<th>Property</th>
<th>ASTM Test Method</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Point, COC, °F</td>
<td>D 92</td>
<td>130</td>
<td>---</td>
</tr>
<tr>
<td>Initial Boiling Point, °F</td>
<td>D 86</td>
<td>340</td>
<td>415</td>
</tr>
<tr>
<td>Dry Point, °F</td>
<td>D 86</td>
<td>390</td>
<td>---</td>
</tr>
</tbody>
</table>

1. Type B CRM shall contain 25±2 percent (by total weight of CRM) natural rubber. No particles shall exceed a length of 1/4 inch as measured on any axis.

2. ASTM C 136 modified per Table 600-2.2.4 (A).

TABLE 600-2.2.5 (B)

<table>
<thead>
<tr>
<th>Sieve Size²</th>
<th>Percentage Passing Sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum - Maximum</td>
</tr>
<tr>
<td>No. 8</td>
<td>100</td>
</tr>
<tr>
<td>No. 10</td>
<td>98-100</td>
</tr>
<tr>
<td>No. 16</td>
<td>50-85</td>
</tr>
<tr>
<td>No. 30</td>
<td>5-30</td>
</tr>
<tr>
<td>No. 50</td>
<td>0-15</td>
</tr>
<tr>
<td>No. 100</td>
<td>0-10</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-1</td>
</tr>
</tbody>
</table>

1. Type B CRM -11 cousin 2512 pomp (by total weight of CRUD naval rubber. No particles shall exceed a length of 1/4 inch as measured on any axis.

2. ASTM C 136 modified per Table 600-2.2.4 (A).

TABLE 600-2.2.5 (B.)

<table>
<thead>
<tr>
<th>Property</th>
<th>ASTM Test Method</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, SUS @ 100°F</td>
<td>D 88</td>
<td>2,500 Minimum</td>
</tr>
<tr>
<td>Flash Point, COC, °F</td>
<td>D 92</td>
<td>390 Minimum</td>
</tr>
<tr>
<td>Molecular Asphaltenes, % by wt.</td>
<td>D 2007</td>
<td>0.1 Minimum</td>
</tr>
<tr>
<td>Aromatics, % by wt.</td>
<td>D 2007</td>
<td>55 Minimum</td>
</tr>
</tbody>
</table>

600-2.3 Mixing. Mixing of the asphalt and CRM shall be accomplished as specified herein for the type being furnished.
600-2.3.1 Type A Asphalt-Rubber. The proportions of these two materials, by weight, shall be 80 + 3 percent asphalt and 20 + 3 percent Type A CRM. For spray application, the minimum CRM content shall be 20 percent. The asphalt-rubber binder shall meet the physical parameters in Table 600-2.3.1 (A) for the climate specified when reacted at 350°F + 25°F for 30 to 60 minutes in the laboratory and at the time of use on the project. If diluent is used, the sample shall be obtained prior to the addition of diluent when testing for conformance with the physical parameters in Table 600-2.3.1 (A).

### TABLE 600-2.3.1 (A)

<table>
<thead>
<tr>
<th>Climate Type</th>
<th>Hot</th>
<th>Moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. monthly max. temp. (a) (Hottest Month)</td>
<td>≥ 110°F</td>
<td>≤</td>
</tr>
<tr>
<td>Avg. monthly min. temp. (b) (Coldest Month)</td>
<td>≥ 30°F</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Hot</th>
<th>Moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brookfield Viscosity, 350°F, No. 3 Rotor, 20 RPM, Centipoise (ASTM D 2669)</td>
<td>Min. 1,500</td>
<td>1,500</td>
</tr>
<tr>
<td></td>
<td>Max. 6,500</td>
<td>6,000</td>
</tr>
<tr>
<td>Needle Penetration, 77°F, 100g, 5 sec.; 1/10mm (ASTM D 5)</td>
<td>Min. 25</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Max. 75</td>
<td>75</td>
</tr>
<tr>
<td>Penetration, 39.2°F, 200g, 60 sec.; 1/10mm (ASTM D 5)</td>
<td>Min. 10</td>
<td>15</td>
</tr>
<tr>
<td>Softening Point: °F (ASTM D 36)</td>
<td>Min. 135</td>
<td>130</td>
</tr>
<tr>
<td>Resilience, 77°F: % (ASTM D 3407)</td>
<td>Min. 25</td>
<td>20</td>
</tr>
</tbody>
</table>

Properties specified are to be measured before the addition of diluent. The amount of allowable diluent shall be determined by prior testing in advance of use.

The temperature of the asphalt shall be between 375°F minimum and 450°F maximum at the addition of the CRM. The temperature shall not exceed 10°F below the actual flash point of the mixture. The CRM shall be combined and mixed together in an asphalt-rubber mechanical blender meeting the requirements of 600 2.4. The combined asphalt and CRM shall be pumped into a storage/reaction tank or distributor truck meeting the requirements of 600 2.4 and allowed to react for a period of time as required by the Engineer, which shall be based on laboratory testing by the asphalt-rubber supplier. The required mixing/reaction time shall be 30 minutes minimum to 60 minutes maximum. The temperature of the asphalt-rubber mixture shall be between 325°F minimum to 375°F maximum during the reaction period.
For spray applications, after the full reaction has occurred, the mixture may be diluted with a diluent per 600 2.2.4. The amount of diluent used shall be 0 percent minimum to 5 percent maximum, by volume, of the asphalt-rubber mixture as required for adjusting viscosity for spraying or better wetting of the screenings. The temperature of the mixture shall not exceed 350°F at the time the diluent is added. The asphalt-rubber material may be utilized immediately following reaction. The application temperature shall be between 325°F minimum and 400°F maximum. The application temperature shall not be higher than 10°F below the actual flash point of the mixture.

If the material is not to be used within 6 hours of mixing, the heat shall be discontinued. The material shall be uniformly reheated to a temperature between 325°F minimum and 400°F maximum at time of use. Additional diluent, asphalt, and/or CRM, meeting the requirements of this subsection, may be added as needed. The cumulative amount of additional diluent shall not exceed 3 percent of total binder weight. The cumulative amount of additional CRM shall not exceed 10 percent of total binder weight. The cumulative amount of additional asphalt shall be such that the resulting asphalt-rubber binder conforms to the minimum CRM content as required in 600-2.3.1. The maximum number of reheating cycles shall not exceed three. Any time the material cools to below 300°F or is held above 375°F for more than 6 hours after mixing shall constitute a reheat cycle. Reheated asphalt-rubber binders had conform to the requirements of the approved blend formulation as required in Table 600-2.3.1(A).

600-2.3.2 Type B Asphalt-Rubber. Shall consist of the following:

1) Paving asphalt conforming to AR 4000 grade in 600-2, crumb rubber modifier (CRM) conforming to 600-2.2.2 and Table 600-2.2.5 (A), and asphalt modifier conforming to Table 600-2.2.5 (13).

2) The percent of asphalt modifier shall be 1 percent minimum to 6 percent maximum by volume of paving asphalt. The exact amount to be added shall be the amount in the binder formulation submitted and approved by the Engineer.

3) The proportions of the two materials, by weight, shall be 80 ± 2 percent paving asphalt with modifier, and 20 + 2 percent CRM. The CRM shall contain a minimum of 75 percent + 2 percent crumb rubber derived from whole scrap tire rubber with the balance of the crumb rubber obtained from natural rubber sources conforming to Table 600-2.2.2 (B.).

The temperature of the blended asphalt and modifier shall be between 375°F minimum and 450°F maximum when the CRM is added. The temperature shall not exceed 10°F below the actual flash point of the mixture. The CRM shall be added and mixed with the...
asphalt-modifier blend in an asphalt-rubber blender conforming to 6052.4 The combined materials shad be pumped into a storage/reaction tank or distributor truck meeting the requirements of 600.2.4. The combined materials shad be allowed to react for a period of 30 minutes minimum after incorporation of all the CRM. The temperature of the combined materials shall be maintained between 375°F minimum and 425°F maximum during the mixing period. Agitation or recirculation shad be adequate to provide good mincing and dispersion of the combined materials. The asphalt-rubber material may be utilized immediately following reaction. The application temperature at the time of use on the project shad be between 375°F minimum and 425°F maximum.

After reaction, the AR 4000, asphalt modifier, and CRM, the asphalt-rubber binder shall conform to the requirements in Table 600-2.3.2 (A).

If the material is not to be used within 6 hours of mixing, the heat shad be discontinued. The material shall be uniformly reheated to a temperature between 375°F minimum and 425°F maximum at time of use. Additional CRM meeting the requirements of 600.2.2.2 may be added as needed. The cumulative amount of additional CRM shall not exceed 10 percent of total binder weight. The maximum number of reheating cycles shall not exceed three. Anytime the material cools to below 300°F or is held above 375°F for more than 6 hours after mixing, it shall constitute a reheat cycle. Reheated asphalt-rubber binder shall conform to the requirements in Table 600-2.3.2 (A).

TABLE 600-2.3.2 (A)

<table>
<thead>
<tr>
<th>TEST PARAMETER</th>
<th>TEST METHOD</th>
<th>SPECIFICATION LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>Brookfield Field viscosity @ 375°F, No. 3 Rotor, 20 RPM, Centipoise</td>
<td>ASTM D 2669</td>
<td>1,150</td>
</tr>
<tr>
<td>Cone Penetration @ 77°F, 1/10mm</td>
<td>ASTM D 217</td>
<td>25</td>
</tr>
<tr>
<td>Resilient @ 77°F, % Rebound</td>
<td>ASTM D 3407</td>
<td>15</td>
</tr>
<tr>
<td>Field Softening Point, °F</td>
<td>ASTM D 36</td>
<td>125</td>
</tr>
</tbody>
</table>

**600.2.3.3 Type D Asphalt-Rubber.** Asphalt modifier conforming to Table 600 2 2 5 (B.) shall be 2 percent minimum to 6 percent maximum, by volume of the paving asphalt. The exact amount to be added shall be the amount submitted in the binder formulation and
approved by the Engineer.

The proportions of the two materials, by weight, shall be $80 + 2$ percent paving asphalt and modifier, and $20 + 2$ percent CRM. The CRM shall contain a minimum of 77 percent crumb rubber derived from whole scrap tire (CRM) with the balance of the crumb rubber obtained from natural rubber sources. The combined CRM shall meet the chemical analysis in Table 600 2.2.2 (C).

The temperature of the blended asphalt and modifier shall be between $350^\circ F$ minimum and $450^\circ F$ maximum when CRM is added. The temperature shall not exceed $10^\circ F$ below the actual flash point of the mixture. The CRM shall be added rapidly and be mixed and reacted with the asphalt-modifier blend for a period of 30 minutes minimum after incorporation of all the CRM. The temperature of the combined materials shall be maintained between $350^\circ F$ minimum and $425^\circ F$ maximum during this period. Agitation or recirculation shall be adequate to provide thorough mixing and dispersion of the combined materials.

Following reaction, the paving asphalt, asphalt modifier, and CRM; the asphalt-rubber binder shall conform to the requirements in Table 600 2.3.3 (A) at the time of use on the project.

The asphalt-rubber binder material may be utilized immediately following reaction. The application temperature shall be $350^\circ F$ minimum and $425^\circ F$ maximum. However, if the material is not to be used within 6 hours of mixing, the heating shall be discontinued.

The material shall be uniformly reheated to a temperature between $350^\circ F$ minimum and $425^\circ F$ maximum at the time of use. Additional CRM meeting the requirements of 600-2.2.2 may be added as needed. The cumulative amount of additional CRM shall not exceed 10 percent of total binder weight. The maximum number of reheating cycles shall not exceed three. Anytime the material cools below $300^\circ F$ or is held above $375^\circ F$ for more than 6 hours after mixing, it shall constitute a reheat cycle. Reheated asphalt-rubber binder shall conform to the requirements in Table 600 2.3.3 (A).
TABLE 600 2.3.3 (A)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brookfield Field Viscosity @ 400°F, No. 3 Rotor, 20 RPM</td>
<td>ASTM D 2669 Modified #1</td>
<td>600</td>
<td>2000</td>
</tr>
<tr>
<td>Cone Penetration @ 77°F, 10 mm</td>
<td>ASTM D 217</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>Resilient @ 77°F, % Rebound</td>
<td>ASTM D 3407</td>
<td>15</td>
<td>---</td>
</tr>
<tr>
<td>Softening Point, °F</td>
<td>ASTM D 36</td>
<td>125</td>
<td>165</td>
</tr>
</tbody>
</table>

600 2.4 Equipment. Equipment utilized in preparing, distributing, and storing asphalt-rubber shall include the following:

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

2) Blender Equipment Types. All blending materials shall be measured using devices approved by the Engineer:

(a) Blender I: The blender shall consist of a mixing chamber within a 400-gallon tank. A mixer head assembly consisting of a shear plate and double suction cones shall be used for mixing, and shall be located on a shaft within the mixing chamber. The RPM's of this shaft shall be maintained between 2,500 and 3,500 during the mixing process. Auger-style mixing shall not be used. The internal mixing chamber shall have a 3/4-inch mesh screen at the bottom that all asphalt-rubber material shall exit through after being subjected to the mixing process. The mix process shall be continuous and shall produce a homogeneous mixture of asphalt and CRM that conforms to the specified ratios of the approved blend formulation. An asphalt-totaling meter, CRM feed-system meter, and a blend-ratio meter shall be used to maintain component percentages during the mixing process. The blending unit shall have a separate asphalt-feed pump and finished-product pump.

(b) Blender II: The blender shall have a two-stage continuous mixing process capable of producing a homogeneous mixture of asphalt cement and CRM at the mix design specified ratios of the approved blend formulation. This unit shall be equipped with separate feed systems for CRM and asphalt cement, and be
(5) **Viscometers.** The Contractor shall supply a Brookfield viscometer for use by the Engineer to verify the viscosity of the asphalt-rubber on all projects where a field laboratory is used. All asphalt concrete batch plants are required to have a field laboratory for use by the Engineer per 8-3.

**600 2.5 Crumb Rubber Modified Rot-Mu~ Asphalt (CRM-HMA) Wet Process.**

**600 2.5.1 General.** CRM-HMA shall be the product of mixing mineral aggregate, asphalt binder, and CRM at a central-mixing plant and shall conform to 4-1-4, 203-6, and 600-1.2, Asphalt Concrete, except as modified herein.

**600 2.5.2 Wet Process.** A wet-process mix is defined as any process which incorporates CRM into the hot paving asphalt by mixing and blending (asphalt-rubber) prior to incorporating the binder with the aggregate at the central-mixing plant.

**600 2.5.3 Materials.** The asphalt-rubber binder shall conform to 600-2.1. Subsection 203-6.2 1 shall not apply.

**600 2.5.4 Composition and Grading.** Asphalt-rubber hot-mix - gap-graded (ARHM-GG) will be designated by class, i.e., ARHM-GGC, and shall conform to the requirements of this subsection and Table 600-2.5.4 (A).
## TABLE 600 2.5.4 (A)

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>ARHM-GG-B Min. - Max.</th>
<th>ARHM-GG-C Min. - Max.</th>
<th>ARHM-GG-D Min. - Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>100</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>90-100</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>---</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>31/8&quot;</td>
<td>60-75</td>
<td>78-92</td>
<td>78-92</td>
</tr>
<tr>
<td>No. 4</td>
<td>28-42</td>
<td>28-42</td>
<td>28-42</td>
</tr>
<tr>
<td>No. 8</td>
<td>15-25</td>
<td>15-25</td>
<td>15-25</td>
</tr>
<tr>
<td>No. 30</td>
<td>5-15</td>
<td>5-15</td>
<td>5-15</td>
</tr>
<tr>
<td>No. 200</td>
<td>2-7</td>
<td>2-7</td>
<td>2-7</td>
</tr>
</tbody>
</table>

| % Asphalt-rubber Binder by Weight of Dry Aggregate | 7.8-8.4 | 7.5-8.7 | 7.5-8.7 |
| Air Voids % Calif. Test 367                        | 2-5     | 2-5     | 2-5     |
| Stabilimeter Value Min. Calif. Test 304 and 366    | 25      | 25      | 25      |
| Voids in Mineral Agg. Percent Min.                 | 18      | 18      | 18      |

### 600-2.5.5 Mix Designs and Certifications

The optimum binder content for ARHM-GG mixes shall be determined by California Test Method 367 except that Step 2 regarding surface flushing shall not be used. Voids shall be substituted in selecting the optimum binder content between 2 percent minimum to 5 percent maximum as approved by the Engineer. Compaction shall be in accordance with California Test Method 304 except for the following:

**Mincing Temperatures:**

- Asphalt-rubber = 340°F - 360°F
- Aggregate = 290°F - 310°F
- Compaction Temperature = 290°F - 300°F

In addition to the formulations and certifications required in 600 2.2.3 for asphalt-rubber, the Contractor shall furnish to the Engineer a mix design and samples of all
materials to be used at least 15 working days before construction is scheduled to begin. The mix design and certifications shall include, but are not limited to, the following:

1) Combined aggregate gradation.

2) Individual bin gradations (hot for batch, cold for drum plant).

3) Percentage of each bin.

4) Asphalt-rubber formulation per 600-2.2.3.

5) Density.

6) Air Voids.

7) Voids in Mineral Aggregates (VMA).

8) Stability.

600-2.5.6 Miscellaneous Requirements. Miscellaneous requirements shall conform to 203-6.8 except that the temperature of the asphalt-rubber binder shall be 300°F minimum to 400°F maximum for Type A, C, and D asphalt-rubber; and 375°F minimum to 425°F maximum for Type B asphalt-rubber when added to the aggregate. The temperature of the aggregate at the time of adding the asphalt-rubber binder shall be 300°F minimum to 350°F maximum.

600-2.6 Asphalt-Rubber Hot-Mix - Gap-Graded (ARSM-GG).

600 2.6.1 General. ARHM-GG shall conform to the specifications for 302-5 except ARHM-GG shall consist of one or more courses of an asphalt-rubber binder and graded aggregate conforming to 600 2.5 placed upon a prepared roadbed or base, or over existing pavement. The courses shall conform to the requirements as shown on the Plans or in the Specifications.

600 2.6.2 Distribution and Spreading. Distribution and spreading shall conform to 302-5.5 except that at the time of delivery to the work site, the temperature of the ARHM-GG shall be 285°F minimum to 325°F maximum. At the direction of the Engineer, this maximum temperature may be raised to 350°F during cold climatic conditions. Atmospheric temperature shall be 50°F and raising.
600 2.6.3 Rolling. Rolling shall conform to 302-5.6 except that a vibratory roller using the vibratory mode shall be used for initial breakdown rolling unless otherwise directed by the Engineer. The initial breakdown rolling shall be completed before the ARHM-GG temperature falls below 275°F measured immediately in front of the roller. Pneumatic rollers shall not be used.

600 2.6.4 Rock Dust Blotter. At the option of the Engineer, when traffic conditions warrant, a rock dust blotter may be required to avoid tracking. Rock dust blotter shall conform to 200-1.2 and be uniformly applied using a mechanical spreader at a rate of 2 pounds minimum to 4 pounds maximum per square yard. When the ARHM-GG pavement has cooled to below 150°F, the rock dust blotter may not be required. Rock dust blotter placement and sweeping shall be included in the price bid for other items of work and no additional compensation will be allowed therefore.

600 2.7 Asphalt-Rubber and Aggregate Membrane (ARAM) Surfacing or Interlayer.

600 2.7.1 Screenings. Screenings when used as a cover aggregate for ARAM shall be crushed rock conforming to the following gradations in Table 600-2.7.1 (A):

Screenings shall be medium 3/8 inch unless otherwise specified. Screenings shall be preheated between 260°F to 300°F and adequately coated with 0.70 percent to 1 percent viscosity Grade AR 4000 asphalt at the central mixing plant to prevent free dust. The exact amount of asphalt shall be recommended by the Contractor and approved by the Engineer. Screenings shall conform to the requirements of Table 200-1.2 (13).

600 2.7.2 General. ARAM surfacing or interlayer shall involve cleaning and preparing the existing surface, spreading asphalt-rubber and cover aggregate, rolling, and sweeping.

The construction sequence of an ARAM shall be as follows:

1) The surface, when specified or as directed by the Engineer, shall be cold planed and repaired.

2) The surface shall be cleaned.

3) Asphalt-rubber shall be applied.

4) Cover aggregate shall be placed, rolled, and loose material removed. Only then will the ARAM surface be opened to traffic. A minimum of 48 hours shall
elapse after placement of the screenings before a slurry seal conforming to 3024 may be applied, unless otherwise directed by the Engineer.

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

600-2.7.3 Pavement Preparation. Unless otherwise specified, all cracks 1/4 inch or greater in width shall be cleaned and sealed with an approved hot-applied crack sealant. Holes, spills, and cracks greater than 1 inch in width shall be filled and compacted with an F-AR-4000 asphalt concrete mix. The pavement shall then be cleaned with a power broom.
APPENDIX D - SPECIFICATIONS BEING USED BY VARIOUS AGENCIES - DRY PROCESS

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR
PLANT MIX ASPHALT CONCRETE PAVEMENT - TYPES ARM AND BRM
PROJECT NO. NH-215(54), KIWOA COUNTY


411.01. DESCRIPTION. (Add the following):

This work shall include furnishing and placing rubber modified hot mix asphalt concrete which contains twenty pounds of crumb rubber modifier (CRM) per ton of bituminous mixture. The rubber shall be uniformly added and blended throughout the bituminous mixture.

411.02. MATERIALS. (Add the following):

All materials used in asphalt concrete Type ARM shall meet the requirements of Section 708 for asphalt concrete Type A and all materials used in asphalt concrete Type BRM shall meet the requirements of Section 708 for asphalt concrete Type B, except the job-mix formula shall be within the following broad range:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Type ARM % Passing (by weight)</th>
<th>Type BRM % Passing (by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2&quot;</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1&quot;</td>
<td>90-100</td>
<td></td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>75-90</td>
<td>100</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>57-72</td>
<td>85-95</td>
</tr>
</tbody>
</table>
The gradation ranges above establish the limits of the job-mix formula. The job-mix formula shall be established as close as possible to the middle of the range, especially the No. 10 sieve.

The requirements for properties of laboratory molded specimens for asphalt concrete Type ARM shall be the same as those for asphalt concrete Type A and asphalt concrete Type BRM shall be the same as those for asphalt concrete Type B except the density, percent of maximum theoretical specific gravity, for lab-molded specimens shall be 96.5 plus/minus 0.5 for mix design and 96.5 plus/minus 1.0 for plant-produced mixtures and the minimum V.M.A. for ARM and Type BRM shall be 15 and ___ respectively.

The gradation shall be determined by AASHTO T27 and T11 on aggregate belt samples. The asphalt content shall be determined by use of the nuclear asphalt content gauge in accordance with OHD L-26.

Crumb rubber modifier shall be scrap tire rubber which has been processed by ambient grinding, ambient granulating, and/or wet grinding methods. The CRM may be obtained from any combination of passenger and truck tires which meet this specification. The gradation of the CRM shall be tested in accordance with AASHTO T27 using a 50 gram sample and shall meet the following requirements:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing (by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 40</td>
<td>98-100</td>
</tr>
</tbody>
</table>

* Lower Limit may be adjusted if the effective specific gravity of the combined aggregates is greater than 2.65.
A mineral powder (such as calcium carbonate) meeting AASHTO M17 may be added, up to a maximum of 4 percent by weight, to reduce sticking and caking of the crumb rubber particles.

The chemical composition of the CRM shall be determined by ASTM D297 and shall meet the following requirements:

<table>
<thead>
<tr>
<th>Natural Rubber</th>
<th>15%-30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Black</td>
<td>25%-38%</td>
</tr>
<tr>
<td>Ash</td>
<td>8% maximum</td>
</tr>
<tr>
<td>Acetone Extract</td>
<td>10%-18%</td>
</tr>
<tr>
<td>Rubber Hydrocarbon</td>
<td>40%-50%</td>
</tr>
</tbody>
</table>

The specific gravity of the CRM shall be 1.15 plus/minus 0.05. The fiber content shall be less than 0.1 percent by weight for spray applications and less than 0.5 percent for all other applications. The CRM shall contain no metal particles. The moisture content shall be less than 0.75 percent by weight. Mineral contaminants (prior to addition of mineral powder) shall not be greater than 0.25 percent by weight.

Fiber content shall be determined by weighing fiber balls which are formed during the gradation test procedure. Rubber particles shall be removed from the fiber balls before weighing. The metal content shall be determined by thoroughly passing a magnet through a 50 gram sample.

The moisture content shall be determined in accordance with AASHTO T255 using a controlled temperature oven at 140° F and a 50 gram sample.

The mineral contamination content shall be determined before the mineral powder is added using saline float separation. Stir a 50 gram sample into a 1 liter glass beaker filled with saline solution (1 part table salt into 3 parts distilled water) and allow the sample to stand for 30 minutes. The mineral contaminant is that material which does not float to the top of the beaker.

The CRM will be accepted based on a Type A certification supplied by the manufacturer for the lot or lots of material in the shipment.
411.03 EQUIPMENT.

(a) Mixing Plants. (Add the following):

The contractor will supply equipment and a method, that is acceptable to the Engineer, for calibrating and controlling the flow of CRM with plus/minus 1 percent of the desired rate and for continually monitoring the CRM flow rate. If the proposed production method specifies adding whole units of CRM into the pugmill of the batch plant, the containers shall be a low density polyethylene material having a melting point less than 240°F. If the CRM is shipped and handled using bulk methods, the flow rate of the CRM will be controlled through a metering system which is interlocked with the production rate of the bituminous mix so that proper proportioning will be obtained at all times. A device shall be provided to indicate that CRM is being delivered uniformly and shall activate a visible or audible signal to the plant operator when the flow of CRM is reduced or interrupted.

411.04. CONSTRUCTION METHODS. (Add the following):

Asphalt concrete Type ARM shall be produced and placed in accordance with Section 411 for asphalt concrete Type A. Asphalt concrete Type BRM shall be produced and placed in accordance with Section 411 for asphalt concrete Type B.

c) Mixing. (Add the following):

CRM shall be uniformly added and mixed at the rate specified using one of the following methods or other methods approved by the Materials Engineer:

1. The CRM and asphalt cement shall be uniformly preblended before being added to the aggregate in the hot mix plant.

2. The CRM shall be introduced and uniformly dispersed into the drum mixer at the point of introduction of the asphalt without loss to the dust collector system.

3. The CRM shall be added to and uniformly blended with hot aggregate and asphalt cement in the outside drum of a double drum hot mix plant.

4. The CRM shall be added to and uniformly blended with hot aggregate and asphalt cement in the pugmill of a batch or continuous mix plant.

(i) Compaction. (Add the following):

Pneumatic Rollers shall not be used.

411.05 METHOD OF MEASUREMENT. (Delete subsection (a) and replace with
(a) Plant mix asphalt concrete pavement including the aggregate, crumb rubber modifier, liquid asphalt, and other ingredients as specified in the job-mix formula shall be measured by the ton of combined mixture.

411.06. BASIS OF PAYMENT. (Add the following):

<table>
<thead>
<tr>
<th>(ARM)</th>
<th>ASPHALT CONCRETE, TYPE ARM</th>
<th>TON</th>
</tr>
</thead>
<tbody>
<tr>
<td>(BRM)</td>
<td>ASPHALT CONCRETE, TYPE BRM</td>
<td>TON</td>
</tr>
</tbody>
</table>
NOTE: Whenever this Special Provision conflicts with the Plans or Standard Specifications, this Special Provision shall govern.

ASPHALT RUBBER (REACTED)

1.0 DESCRIPTION.

The reacted asphalt rubber binder - bituminous mixture will include the incorporation of reacted asphalt rubber into the bituminous mixture, using the bituminous mixture shown in the contract. The percent of asphalt rubber in the mixture shall be in accordance with the recommendation of the supplier of the asphalt rubber.

BID ITEM
   Asphalt Rubber (Reacted)

2.0 MATERIALS.

(a) The aggregate for bituminous mixture shall conform to the requirements listed elsewhere in the plans or proposal.

(b) Asphalt Rubber.

   The asphalt-rubber binder shall be a uniform reacted blend of compatible paving grade asphalt cement, granulated reclaimed crumb rubber modifier (CRM), extender oil, if required, and liquid anti-stripping agent when indicated by standard moisture susceptibility tests. The asphalt-rubber binder shall meet the physical parameters listed below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent Viscosity, 350°F., Spindle 3, 20 RPM</td>
<td>1,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Penetration, 77°F., 100 g, 5 sec.: 1/10 mm. (ASTM D5)</td>
<td>25</td>
<td>75</td>
</tr>
</tbody>
</table>
Kansas Department of Transportation

Penetration, 39.2°F., 200 g, 60 sec.: 1/10 mm. (ASTM D5)  
Min 15

Softening Point: °F., (ASTM D36)  
Min 130

Resilience, 77°F.: % (ASTM D3407)  
Min 20

TFOT Residue, (ASTM D1754) Penetration Retention, 
39.2°F.: %  
Min 75

Note 1: A calibrated Haake viscosimeter may be used for field control.

Asphalt Extender Oil: An asphalt-extender oil may be added, if necessary, to meet the requirements of asphalt rubber binder. Extender oil shall be a resinous, high flash point, aromatic hydrocarbon meeting the following test requirements:

Viscosity, SSU, at 100°F. (ASTM D88)  
2500 min.

Flash Point, COC, degrees F. (ASTM D92)  
390 min.

Molecular Analysis (ASTM D 2007):
Asphaltenes, Wt. %  
0.1 max.
Aromatics, Wt. %  
55.0 min.

All equipment shall conform to the standard specifications unless noted otherwise in this Special Provision.

(c) Granulated Reclaimed Vulcanized Rubber.
(1) General.
The crumb rubber modifier (CRM) shall be vulcanized rubber produced primarily from processing automobile and/or truck tires by ambient grinding methods. The CRM shall be substantially free from contaminants including fabric, metal, mineral, and other non-rubber substances. The CRM shall be sufficiently dry to be free flowing and not produce a foaming problem when added to hot asphalt cement. Up to 4% by weight of talc or other appropriate blocking agent can be added to reduce agglomeration of the CRM.

(2) Physical Requirements.
Gradation and Particle Length: When tested in accordance with ASTM C-136 (Modified) using a 50 gram sample, the resulting CRM gradation shall meet the following gradation limits:

Crumb Rubber Modifier (CRM-III)  
Percent Retained - Square Mesh Sieves  
140
Kansas Department of Transportation

<table>
<thead>
<tr>
<th>Rubber Gradation</th>
<th>Master Grading Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#10</td>
</tr>
<tr>
<td>MINIMUM</td>
<td>0</td>
</tr>
<tr>
<td>MAXIMUM</td>
<td>0</td>
</tr>
</tbody>
</table>

Maximum Particle Length 3/16"

(3) Fiber Content.
The CRM shall be designated Grade A or Grade B. For Grade A CRM, the fiber content shall be less than 0.1% by weight. For Grade B CRM, the fiber content shall be less than 0.5% by weight. Fiber content shall be determined by weighing fiber agglomerations which are formed during the gradation test procedure. Rubber particles shall be removed from the fiber agglomerations before weighing.

(4) Moisture Content.
The moisture content of the ground rubber shall be less than 0.75% by weight.

(5) Mineral Contaminants.
The mineral contaminant amount of the CRM shall be less than 0.25% by weight as determined after water separating a 50 gm. CRM sample in a 1 liter glass beaker filled with water.

(6) Metal Contaminants.
The CRM shall contain no visible metal particles as indicated by thorough stirring of a 50 gm. sample with a magnet.

(7) Packaging.
The CRM shall be supplied in moisture resistant packaging such as either disposable bags or other appropriate containers. Bags shall be palletized into units for shipment and glue shall be placed between layers of bags to increase unit stability during shipment. Palletized units containing bags shall be wrapped with ultra-violet resistant stretch wrap. The maximum allowable tolerance per bag will be 2 lbs. for bags weighing 100 lbs. or less.

(8) Labeling.
Each container or bag of CRM shall be labeled with the manufacturer designation for the CRM and the specific grade in accordance with this specification, the nominal CRM weight designation with tolerance, and the manufacturer lot designation. Palletized units shall contain a label which indicates the manufacturer and production lot number designations, CRM type, and net pallet weight.
(9) Certification.
The manufacturer shall ship along with he CRM, a Type “B” certification as listed in Section 2600 of the Standard Specifications.

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

(d) Asphalt Rubber Blend Design.

The asphalt cement shall be grade AC-5 unless otherwise recommended by the asphalt rubber supplier and approved by the Engineer. The mixture design shall be performed by the asphalt-rubber supplier. The proportion of ground rubber shall be between 12 and 23 percent by weight of the total mixture of the asphalt-rubber binder.

The Contractor shall supply to the Engineer a mix formation at least 10 days before pavement construction is scheduled to begin. The mix formula shall consist of the following information:

(1) Design Job Mix
   Shall meet the requirements of Section 1103.

(2) Asphalt Cement
   Source of Asphalt Cement
   Grade of Asphalt Cement
   Source and Grade of Extender Oil
   Percentage of Asphalt Cement and Extender Oil by
   Total Weight of the Asphalt-Rubber Binder

(3) Crumb Rubber Modifier (CRM)
   Source of CRM
   Grade of CRM
   Percentage of CRM by Total Weight of the
   Asphalt-Rubber Mixture

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

(4) Anti-Strip Agent
   Source of Anti-Strip
Percentage of Anti-Strip by Weight of Asphalt

(5) Physical properties of the blend in accordance with 2.0 (b). Also the weight per
gallon of the blend at 350°F and minimum asphalt-rubber viscosity for addition to
the aggregate.

(6) Design Asphalt-Rubber Content based on the dry weight of the aggregate.

(7) Mix Temperature range for the aggregate and asphalt rubber binder.

(8) Density Requirement - The mixture design will be based on either the 50 blow or
75 blow Marshall. The 50 blow Marshall will be used unless the 75 blow Marshall
is designated elsewhere in the plans or proposal.

3.0 CONSTRUCTION REQUIREMENTS

(a) The Contractor shall have a representative of the asphalt rubber supplier available
on the project during production of the asphalt rubber bituminous mixture.

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

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

(2) Blender.
The asphalt-rubber mechanical blender with a two stage continuous mixing process
capable of producing a homogeneous mixture of asphalt cement and CRM, at the mix design
specified ratios, as directed by the engineer. This unit shall be equipped with a CRM feed
system capable of supplying the asphalt cement feed system, as not to interrupt the continuity
of the blending process. A separate asphalt cement feed pump and finished product pump are
required. This unit shall have both an asphalt cement totalizing meter in gallons and a flow rate
meter in gallons per minute.

(3) Storage Tank.
The asphalt-rubber mechanical blender with a two stage continuous mixing process
capable of producing a homogeneous mixture of asphalt cement and CRM, at the mix design
specified ratios, as directed by the engineer. This unit shall be equipped with a CRM feed
system capable of supplying the asphalt cement feed system, as not to interrupt the continuity of the blending process. A separate asphalt cement feed pump and finished product pump are required. This unit shall have both an asphalt cement totalizing meter in gallons and a flow rate meter in gallons per minute.

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

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

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

(6) Other Equipment.
Equipment other than listed above may be used on a performance basis if approved by the Chief of Materials and Research. The equipment shall be specifically designed for blending the asphalt cement and rubber. The asphalt-rubber produced shall meet the requirements listed in 2.0(b) of this specification.

(c) Asphalt-Rubber Mixing, Reaction and Transfer Procedure.
(1) Asphalt Cement Temperature: The temperature of the asphalt cement shall be between 375 and 425 degrees F. when the CRM is added.

(2) Blending and Reacting: The asphalt and CRM shall be combined and mixed together in a blender unit, pumped into the agitated storage tank, and then reacted for 30 to 60 minutes from the time the CRM is added to the asphalt cement.

Temperature of the asphalt-rubber mixture shall be maintained between 350 degrees F. and 400 degrees F. during the reaction period. The asphalt-rubber may be cooled to between 300°F and 350°F after it has reacted for the specified period.

(3) Transfer: After the material has reacted for 30 to 60 minutes, the asphalt-rubber shall be metered into the mixing chamber of the hot mix plant at the percentage required by the job-mix formula.

(4) Delays: When an extended (greater than 6 hours) delay occurs in binder use after
its full reaction, the asphalt-rubber shall be allowed to cool. The asphalt-rubber shall be reheated slowly just prior to use to a temperature between 300 degrees and 375 degrees F., and shall also be thoroughly mixed before pumping and metering into the hot mix plant for combination with the aggregate. The viscosity of the asphalt-rubber shall be checked by the asphalt-rubber supplier. If the viscosity is out of the range specified in Section 2.0 (B) of this specification, the asphalt-rubber shall be discarded or adjusted by the addition of either the asphalt cement or CRM to produce a material with the appropriate viscosity.

(d) Compaction requirements.

The Reacted Asphalt Rubber Binder - Bituminous Mixture shall be compacted in accordance with Subsection 603.

A minimum of two rollers meeting the requirements of Subsection 151.03 shall be furnished. At least one of the rollers will be a vibratory roller. Pneumatic tired rollers will not be allowed.

4.0 METHOD OF MEASUREMENT

The Reacted Asphalt Rubber Binder - Bituminous Mixture will be measured and paid as per the Standard Specifications.

Asphalt rubber (reacted) for use in the Reacted Asphalt Rubber Binder - Bituminous Mixture will be measured as per the Standard Specifications and be paid for in tons.

5.0 BASIS OF PAYMENT.

The amount of asphalt rubber (reacted) used and accepted, measured as provided above, shall be paid for at the Contract unit price per ton for “Asphalt Rubber (Reacted)”, which price shall be full compensation for furnishing all materials, equipment, labor, tools and incidentals necessary to complete the work.

04-19-93 M&R (RGM)
NOTE: Whenever this Special Provision conflicts with plans or standard specifications, this Special Provision shall govern.

SUBSECTION 1103
AGGREGATES FOR BITUMINOUS MIXTURES

Add the following to Subsection 1103.

1103.02 Requirements.
(b) (1.4.5) For Mix Designation ARS. Mix designation ARS may be composed of any combination of aggregate and mineral filler supplements meeting the applicable requirements of Table 5, providing the mix meets the general composition requirements of 1103.02 (b) (1.3) and the following composition limits.

The mix shall contain:
- A minimum of 40% primary aggregate. The primary aggregate shall be chat, crushed porphyry, crushed sandstone, or crushed gravel (CG-1).
- A minimum of 40% crushed limestone.
- A maximum of 10% natural sand from an alluvial deposit. The actual amount of sand in the mixture may be adjusted by the District Materials Engineer to improve the properties of the mix.

(d) The Contractor will not use R.A.P. in this mix.

Add the following to Table 6 - REQUIREMENTS OF COMBINED AGGREGATES FOR BITUMINOUS MIXTURES.

<table>
<thead>
<tr>
<th>Mix Designation</th>
<th>Percent Retained - Square Mesh Sieves</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot; 3/8&quot;</td>
<td>4 8 16 30 50 100 200</td>
</tr>
<tr>
<td>ARS 0 8-22</td>
<td>62-83 78-94 82-98 85-98 87-98 89-98 92-98</td>
</tr>
</tbody>
</table>

Maximum Moisture = 0.5

JOB MIX TOLERANCES:

± 6 ± 5 ± 5 ± 4 ± 3 ± 3 ± 2
NOTE: Whenever this Special Provision conflicts with plans or standard specifications, this Special Provision shall govern.

Add the following to Subsection 1103.

1103.02 Requirements.
(b) (1.4.5) For Mix Designation ARB. Mix Designation ARB may be composed of any combination of aggregate and mineral filler supplements meeting the applicable requirements of Table 5, providing the mix meets the general composition requirements of 1103.02 (b) (1.3) and the following composition limits.
The mix shall contain:
- A minimum of 75% crushed aggregate.
- A minimum of 40% crushed limestone.
- No MFS-6 (Fly Ash)
0A maximum of 15% natural and from an alluvial deposit.

Add the following to Table 6 - REQUIREMENTS OF COMBINED AGGREGATES FOR BITUMINOUS MIXTURES.

<table>
<thead>
<tr>
<th>Mix Designation</th>
<th>Percent Retained - Square Mesh Sieves</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARB</td>
<td>1&quot; 3/4&quot; 1/2&quot; 3/8&quot; 4 8 16 30 50 100 200</td>
</tr>
<tr>
<td></td>
<td>0 0-10 15-35 28-53 53-73 70-86 ---- 83-96 87-98 ---- 92-98</td>
</tr>
<tr>
<td></td>
<td>Maximum Moisture = 0.5</td>
</tr>
</tbody>
</table>

JOB MIX TOLERANCES:

± 6  ± 6  ± 5  ± 5  ± 4  ± 3  ± 3  ± 2

5-20-92
SECTION 603

RUBBER MODIFIED PLANT MIX BITUMINOUS CONSTRUCTION

Page 301, subsection 603.01. Add the following to the first paragraph:

This work shall include furnishing and placing rubber modified hot mix asphaltic concrete (RUMAC). The rubber shall be uniformly added throughout the bituminous mixture.

Page 301, subsection 603.01. Add the following bid item:

Crumb Rubber Modifier

Page 301, subsection 603.02. Add the following to this subsection:

Crumb rubber modifier (CRM) shall be scrap tire rubber which has been processed by ambient grinding or granulating methods. The CRM may be obtained from any combination of passenger and truck tires which meet this specification. The rubber particles shall be reduced to the gradation limits and have the chemical compost listed below.

The gradation of the CRM shall meet the following limits:

<table>
<thead>
<tr>
<th>Rubber Gradation</th>
<th>Master Grading Limits</th>
<th>Percent Retained-Square Mesh Sieves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#60</td>
<td>#80</td>
</tr>
<tr>
<td>MINIMUM</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MAXIMUM</td>
<td>2</td>
<td>12</td>
</tr>
</tbody>
</table>
A mineral powder (such as calcium carbonate) meeting AASHTO M17 may be added, up to a maximum of 4% by weight of the rubber, to reduce sticking and caking of the crumb rubber particles.

The chemical compost of the CRM shall meet the following:

- Natural Rubber (ASTM D297) 18% Minimum
- Carbon Black (ASTM D297B) 35% Maximum
- Ash (ASTM D297B) 7% Maximum
- Acetone Extract (ASTM D297) 18% Maximum
- Rubber Hydrocarbon by difference 42% Minimum

The specific gravity of the CRM shall be 1.15 ±0.05.

Deleterious Substances:
- The fiber content shall be less than 0.1% by weight for spray applications and less than 0.5% for all other applications. The CRM shall contain no metal particles. The combined volatile and moisture content shall be less than the 1% by weight. Mineral contaminants (prior to addition of mineral powder) shall not be greater than 0.25% by weight.

  Fiber content shall be determined by weighing fiber balls which are formed during the gradation test procedure. Rubber particles shall be removed from the fiber balls before weighing. The metal content shall be determined by thoroughly passing a magnet through a 50 gram sample.

  The combined volatile and moisture content shall be determined in accordance with AASHTO T255 using a controlled temperature oven at 60ºC (140ºF) and 50 gram sample.

  The mineral contamination content shall be determined before the mineral powder is added using saline float separation. Stir a 50 gram sample into a 1 liter glass beaker filled with a saline solution (1 part table salt into 3 parts distilled water) and allow the sample to stand for 30 minutes. The mineral contaminant is that material which does not float to the top of the beaker.

Page 312, subsection 603.03. Add the following to this subsection:

(I) Rubber Modified Plant Mix.

During the initial production of the RUMAC, the contractor shall have a representative of the rubber supplier available on the project to assist in the plant calibration and training of the contractors personnel.

CRM shall be uniformly added to the hot aggregates for bituminous construction using one of the following methods or other methods approved by the Engineer:
(1) The CRM and asphalt cement shall be uniformly preblended before being added to the aggregate in the hot mix plant.

(2) The CRM shall be added to and uniformly mixed with hot aggregate and asphalt in the outside drum of a double drum hot mix plant or in the pugmill of a batch or continuous flow plant.

(3) The CRM shall be added to and uniformly mixed in a single or twin shaft pugmill with the hot mixed bituminous concrete after it has been discharged from the hot mix plant. The single or twin shaft pugmill shall be specifically designed for the mixing of bituminous concrete.

The contractor will supply a method, that is acceptable to the Engineer, for calibrating the flow of CRM and for continually monitoring the CRM flow rate. If the CRM is shipped and handled using bulk methods, instead of bags, the CRM will be feed through a system meeting the requirements of Subsection 151.21 © (2.5) Mineral Filler Feed System of the Standard Specifications. The flow rate of the CRM will be controlled through a weigh pot which is so interlocked with the production rate of the bituminous mix that proper proportioning will be obtained at all times.

Page 316, subsection 603.04 (b) (6). Add the following to this subsection:

The CRM shall be accepted under the following conditions:

(a) Receipt of a Type B certification as specified in Section 2600.

(b) Visual inspection for condition and conformance with other requirements.

Page 319, subsection 603.08. Add the following to this subsection:

(g) The CRM will be measured by the pound. Deduction will be made for the number of pounds not placed on the road.

Page 320, subsection 603.09. Add the following to this subsection:

(g) The amount of CRM added to the plant mix, measured as provided above, shall be paid for at the Contract unit price per pound for “Crumb Rubber Modifier”, which price shall be full compensation for furnishing the CRM, and for all equipment, tools, labor and incidentals necessary to incorporate the CRM into the plant mix.