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CONSTRUCTION GUIDELINES FOR CRUMB RUBBER MODIFIED HOT MIX ASPHALT

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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 tries 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 mixture - 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 system, 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, handwork 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

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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 land filled 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.

Landfilling 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).

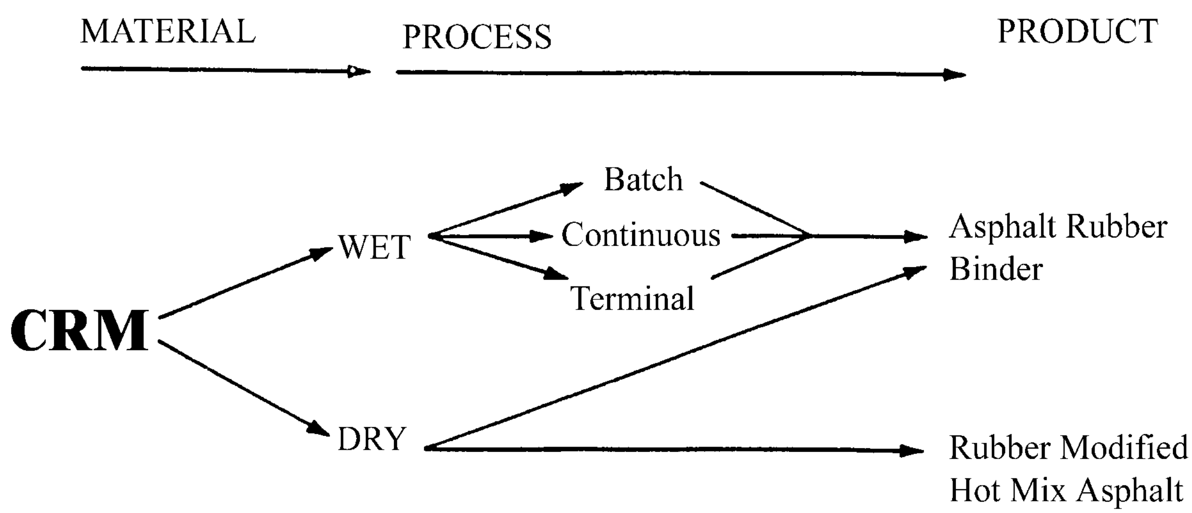
BACKGROUND

The concept of adding tire rubber (referred here as crumb rubber modifier or CRM) to asphalt started in the 1950s. In 1959, Mankowich had a patent for rubber-modified asphalt in Canada. Flinsteal Corporation dissolved CRM in asphalt in the early 1960s. The New York DOT specified a rubber modified hot mix asphalt (RMHMA) in 1962. In the early 1960s, 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 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 landfilling 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 1.1 shows the relationship between CRM terminology and the technology.



Objective

The objective of this report is to provide detailed information about the construction of crumb rubber modified hot mix asphalt pavements.

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.

CHAPTER 2: MATERIALS

This chapter provides a background on the materials used in crumb rubber modified hot mix asphalt pavements and 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

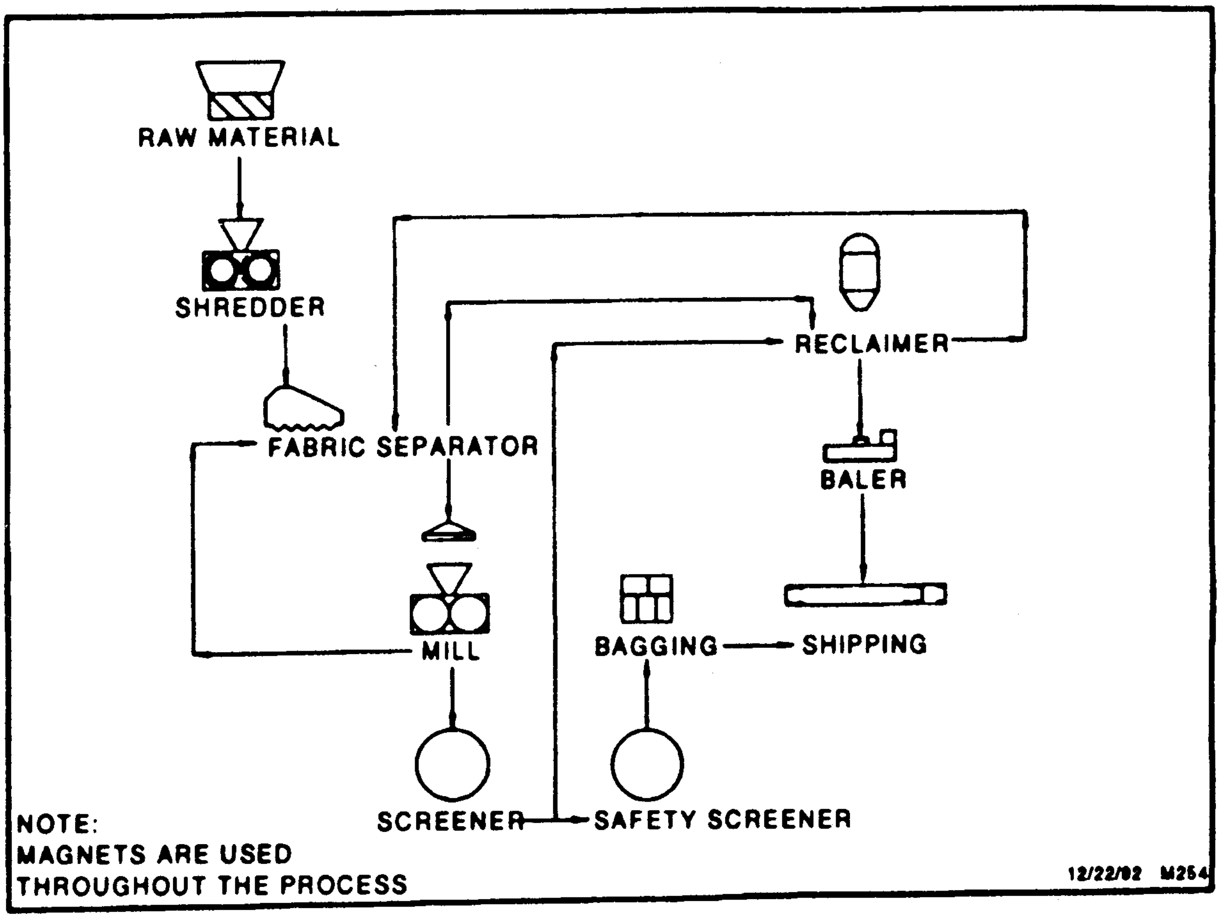
The major component of crumb rubber modifier (CRM) is scrap tire rubber, which is primarily natural and synthetic rubbers and carbon black. Automobile tires have more synthetic rubber than truck tires. Truck tires contain a higher percentage of natural rubber than automobile tires. Advances in tire manufacturing 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):

Passenger Tires	Radial	35% natural	65% synthetic
	Bias	15% natural	85% synthetic
Truck Tires	Radial	65% natural	35% synthetic
	Bias	30% natural	70% synthetic

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 2.1). The scrap tires are pre-processed by shredding to remove as much steel cord and bead wire as possible. 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).

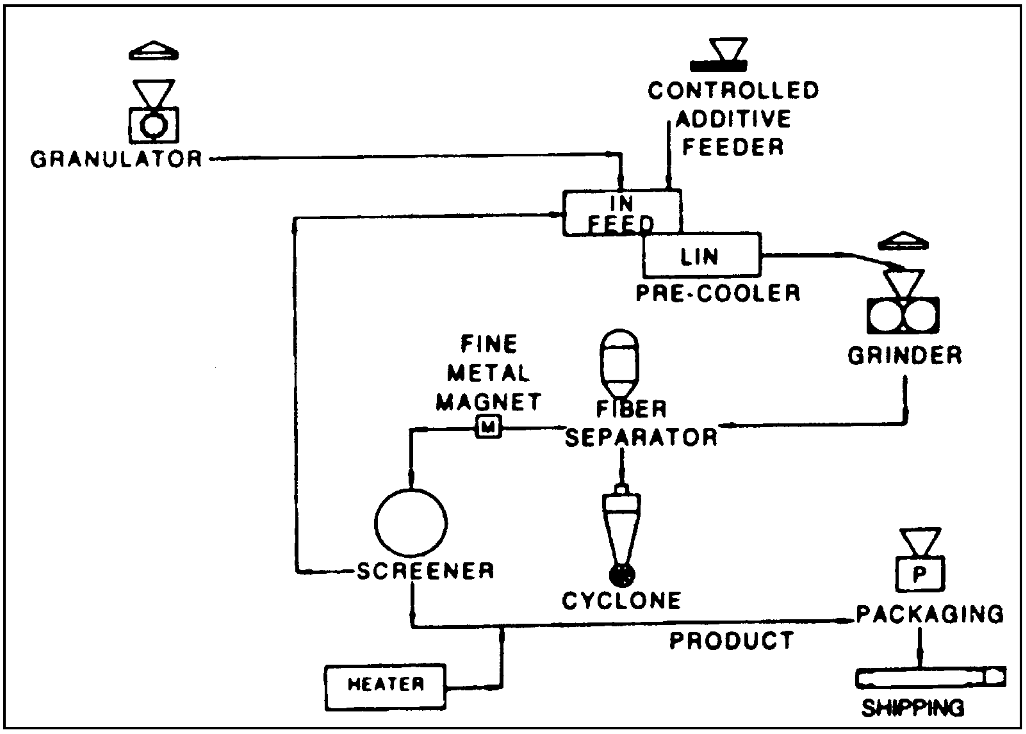


In the granulator process, steel cord and bead wire are removed and close tolerance-revolving steel plates are used to cut the scrap tires into granulated CRM. The granulated CRM is cubical, uniformly shaped with a low surface area with sizes ranging from 9.5 mm to 2.0 mm (3/8 inch to No. 10 sieve).

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 2.2 presents a schematic of the wet grinding system.

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 2.3). 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 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.


GRANULATOR
CONTROLLED ADDITIVE FEEDER
IN FEED
LIN
PRE-COOLER
GRINDER
FINE METAL MAGNET
M
FIBER SEPARATOR
SCREENER
CYCLONE
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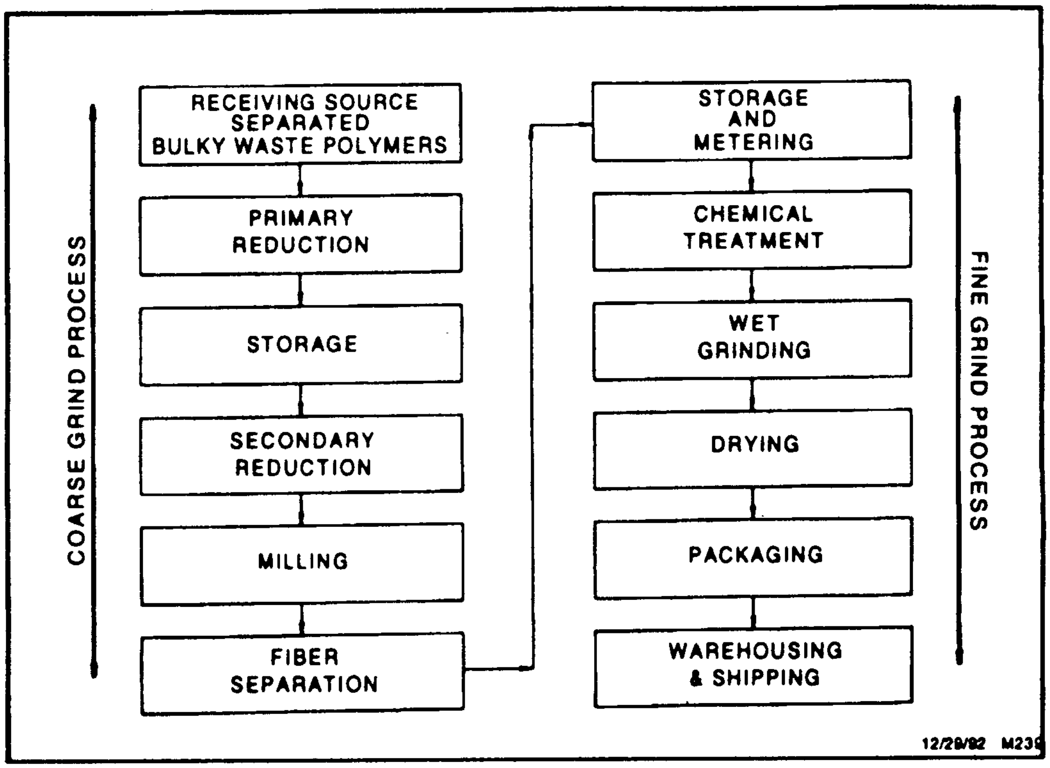
PACKAGING
PRODUCT
HEATER
SHIPPING


COARSE GRIND PROCESS
RECEIVING SOURCE SEPARATED BULKY WASTE POLYMERS
PRIMARY REDUCTION
STORAGE
SECONDARY REDUCTION
MILLING
FIBER SEPARATION
STORAGE AND METERING
CHEMICAL TREATMENT
WET GRINDING
DRYING
PACKAGING
WAREHOUSING & SHIPPING
FINE GRIND PROCESS
12/29/92 M239

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 2.1.

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 2.4 shows a typical viscosity versus time curve. The data shown in this figure is for an AC-10 with 18% ambient ground CRM.

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 2.2).

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 truckload quantities, usually 18,140 kg to 20,400 kg (40,000 to 45,000 lb). Figure 2.5 shows a supersack 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 2.1: Crumb Rubber Gradations Being Used by Selected Agencies

Sieve Size	International Surfacing Incorporated		APWA So. California Chapter				City of Phoenix	Florida		Arizona DOT	California DOT	
	Type 1	Type 2	Type D-I	Type D-II	Type D-III	Type B & C[1]		Type A	Type B		Type 1	Type 2
2.36 mm (No.8)	100	-	100	100	100	100	-	-	-	-	100	100
2.00 mm (No.10)	95-100	100	95-100	100	-	98-100	100	-	-	100	95-100	95-100
1.18 mm (No.16)	40-60	70-100	40-60	70-100	45-85	50-85	75-100			75-100	40-80	40-80
0.85 mm (No.20)	-	-	-	-	-	-	-	-	100	-	-	-
0.60 mm (No.30)	0-20	25-60	0-20	25-60	5-35	5-30	25-60	-	-	25-100	5-30	5-30
0.425 mm (No.40)	-	-	-	-	-	-	-	100	85-100	-	-	-
0.30 mm (No.50)	0-10	0-20	0-10	0-20	0-15	0-15	0-20	-	-	0-45	0-15	0-15
0.18 mm (No.80)	-	-	-	-	-	-	-	90-100	10-50	-	-	-
0.15 mm (No.100)	-	-	-	-	-	0-10	-	70-90	5-30	0-10	-	-
0.075 mm (No.200)	-	0-5	0-5	0-5	0-1	0-1	0-5	35-60	-	0	0-3	0-3
Max Particle Size	4.69mm (3/16")	4.69mm (3/16")	6.25mm (1/4")	6.25mm (1/4")	6.25mm (1/4")	6.25mm (1/4")	-	-	-	-	4.69mm (3/16")	6.25mm (1/4")

[1] Shall contain 25% natural rubber.

Table 2.2: Physical & Chemical Requirements of Crumb Rubber Modifier

Property	Florida	APWA (So. California Chapter)			
		Type D		Type B & C	
		Whole Tire	Natural Rubber	Whole Tire	Natural Rubber
Physical					
Specific Gravity	1.10 ± 0.06	1.1-1.2	1.1-1.2	1.1-1.2	1.1-1.2
Moisture	≤ 0.75%	-	-	-	-
Metal Contaminants	≤ 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
Chemical					
Acetone Content	< 25%	11-19%	4-10%	9.5-14%	5-10%
Hydrocarbon Content	40-55%	45-52%	-	30-55%	-
Ash Content	≤ 8%	≤ 8%	≥35%	≤ 18.5%	≤ 10%
Carbon Black	20-40%	28-38.8%	≤ 15%	20-38%	25-33%
Natural Rubber	16-45%[1]	16-34%	40% Min.	21-42%	45-65%

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

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.

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 will 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 2.3 and that 2 to 6 percent extender oil by weight of asphalt cement is added to their Type 2 asphalt rubber binder.

Table 2.3: Flux Oil Requirements (CalTrans)

Test	ASTM Designation	Requirement
Viscosity, SSU at 37.7°C (100°F)	D 88	2,500 min.
Flash Point, COC, °F	D 92	198.8°C (390°F)
Asphlatenes, by Weight	D 2007	0.1% max.
Aromatics, by Weight	D 2007	55% min.

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.

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 2.4 (wet process) and Table 2.5 (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 2.4: Aggregate Gradations Being Used by Selected Agencies (Wet Process)

Sieve Size	APWA So. California Chapter			Arizona		Florida		California		
	ARHM-GG-B	ARHM-GG-C	ARHM-GG-D	Gap Graded	Open Graded	Dense FC-3	Open FC-2	½” Max Gap Graded	½” Max Open Graded	_” Max Open Graded
25 mm (1")	100	-	-	-	-	-	-	-	-	-
19 mm (¾”)	90-100	100	-	100	-	-	-	100	100	100
12.5 mm (½”)	-	98-100	100	80-100	-	100	100	90-100	95-100	100
9.5 mm (_”)	60-75	78-92	78-92	65-80	100	88-98	85-100	79-87	78-89	100
4.75 mm (No.4)	28-42	28-42	28-42	28-42	30-45	60-90	10-40	32-40	32-40	90-100
2.36 mm (No.8)	15-25	15-25	15-25	14-22	6-10	-	-	18-24	18-24	29-36
2 mm (No.10)	-	-	-	-	-	40-70	4-12	-	-	7-18
0.6 mm (No.30)	5-15	5-15	5-15	-	-	-	-	9-12	-	-
0.425 mm (No.40)	-	-	-	-	-	20-45	-	-	-	-
0.075 mm (No.200)	0-5	2-7	2-7	0-2.5	0-2.5	2-6	2-5	2-7	-	-
Typical CRM Gradation	10 Mesh	10 Mesh	10 Mesh	10 Mesh	10 Mesh	40 or 80 Mesh	40 or 80 Mesh	10 Mesh	10 Mesh	10 Mesh
Typical CRM Percentage by Weight of AC	17-22	17-22	17-22	Min 20%	Min 20%	5%	12%	17-22	17-22	17-22

Table 2.5: Aggregate Gradations Being Used by Selected Agencies (Dry Process)

Sieve Size	Oklahoma		Kansas	
	ARM	BRM	ARS	ARB
25 mm (1")	90-100	-	-	-
19 mm (¾”)	75-90	100	-	90-100
12.5 mm (½”)	57-72	85-95	100	65-85
9.5 mm (_”)	-	70-85	78-92	47-72
4.75 mm (No.4)	25-40	25-40	17-38	27-47
2.35 mm (No.8)	-	-	6-22	14-30
2 mm (No.10)	15-25	15-25	-	-
1.18 mm (No.16)	-	-	2-18	-
0.6 mm (No.30)	-	-	2-15	4-17
0.425 mm (No.40)	7-17	7-17	-	-
0.3 mm (No.50)	-	-	2-13	2-13
0.15 mm (No.100)	-	-	2-11	-
0.075 mm (No.200)	3-7	3-7	2-8	2-8
Typical CRM Gradation	40 Mesh	40 Mesh	80 Mesh	80 Mesh
Typical CRM Percentage by Weight of AC	1%	1%	1 to 1.5%(1)	1 to 1.5%(1)

(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 Superpave technology is implemented, it will be expanded to include CRM hot mix asphalt.

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° above the desired temperature (176° (350°)) 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 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.

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 stabliometer 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 the 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:

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

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

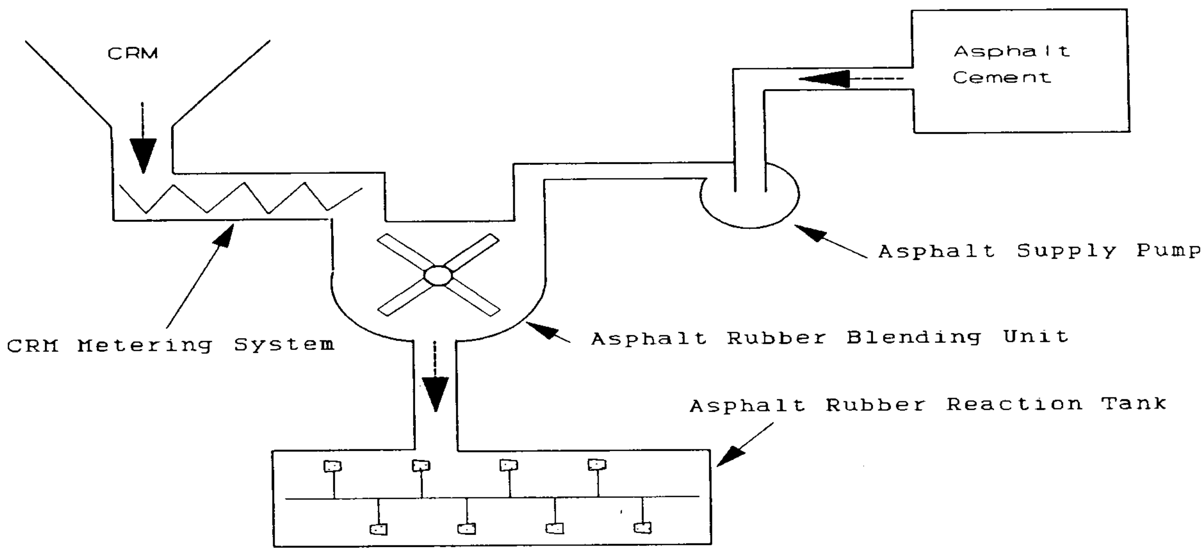
Charles H. McDonald (12) pioneered the U.S. development of the wet process. His work began in the mid 1960s, when he applied asphalt-rubber patching materials. McDonald's experimental work with Altos Rubber, Arizona DOT, and Sahuaro Petroleum and Asphalt Company resulted in the development of commercial 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. These companies and others evaluated different types and sizes of rubber, polymers, diluents, aromatic oils, and base asphalt cements.

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^{o}C (400^{o}F) will cause the combined temperature to drop to about 177^{o}C (350^{o}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 2.1 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.

Field Blending Systems

Features of the various field blending systems and the typical formulations are summarized in Tables 4.1 and 4.2. A detailed discussion of the various systems is provided below.

Table 4.1: Field Blending Techniques - Equipment

Product/Company	Asphalt Preheater	Rubber Storage	Reaction Vessel	Storage Tank	Comments
CEI	Yes	Bags, supersacks	Yes	Yes	Combined reaction & storage tank
ISI	Yes	Bags, supersacks	Yes	Yes	Combined reaction & storage tank
Manhole Adjusting	Yes	Bags	Yes	Yes	Combined reaction & storage tank
Heatec	Yes	Bags, supersacks	No	No	-
Rouse Rubber	Yes	Bags	No	No	-

Table 4.2: Field Blending Techniques - Formulations

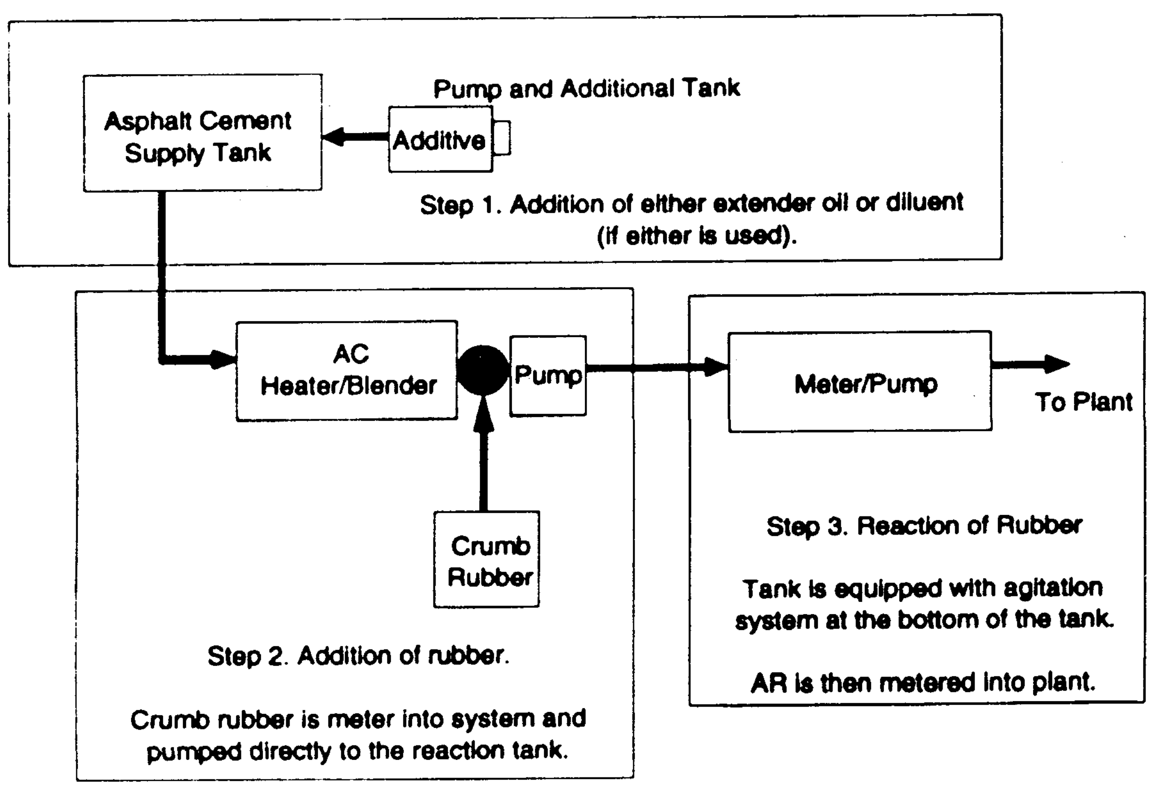
Product/Company	CRM, % by total wt of Binder[1]	Flux	Chemical Stabilizer	Other Polymers	Typical Size of CRM, Mesh[1]	Past Use
CEI	15+	When Required	No	No	Minus 8 to 10	Arizona California Nevada New Mexico
ISI	15+	When Required	No	No	Minus 8 to 10	Arizona California Florida Nevada New Mexico
Manhole Adjusting	15+	When Required	No	No	Minus 8 to 10	Arizona California Nevada New Mexico
Heatec	5 & 12	No	No	No	40 & 80	Florida
Rouse Rubber	5 & 12	No	No	No	40 & 80	Florida Alabama Mississippi Kansas

1 - The percent CRM and the typical size represents what is currently being produced. This does not imply that other percentages or sizes cannot be used with the system being described.

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 provides 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 (400ºF). 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

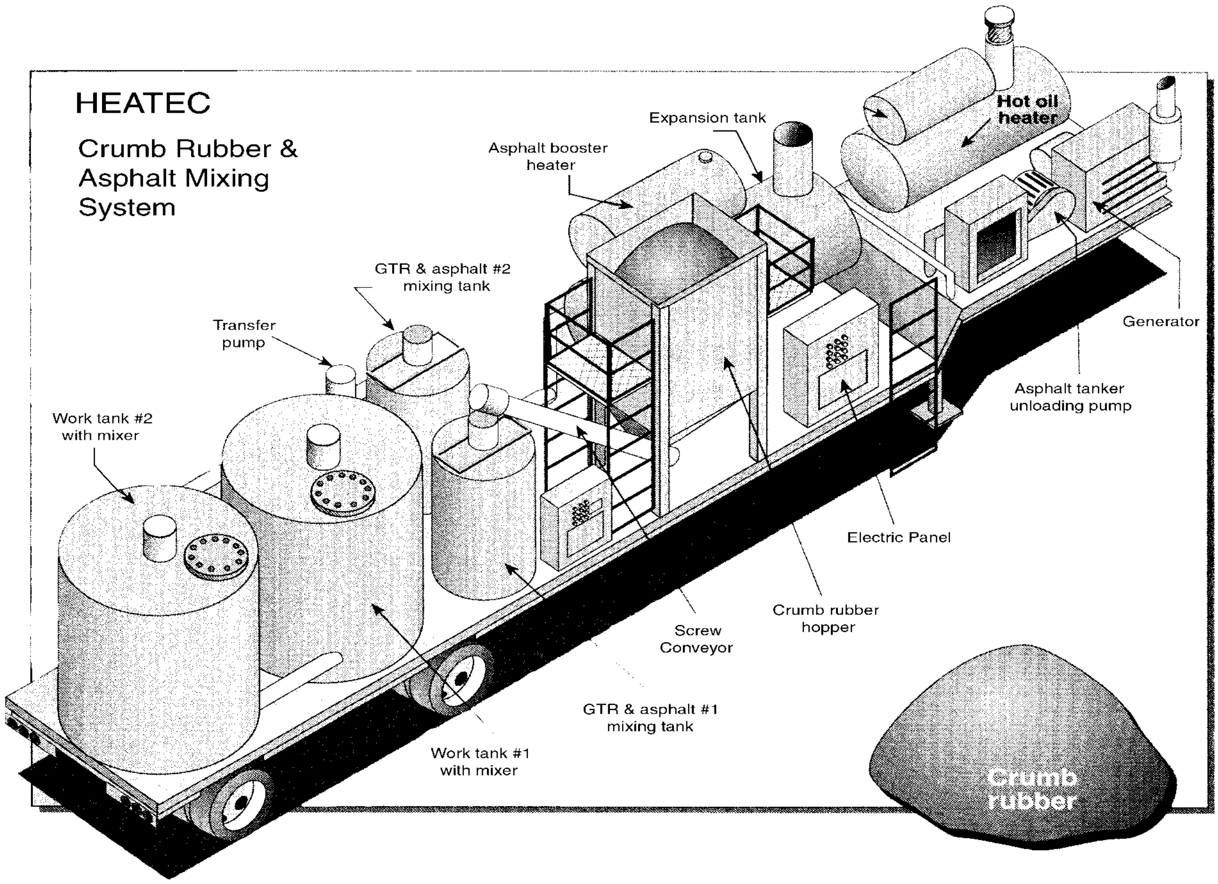
113,562 liter (30,000 gal.) capacity and each compartment is 56,780 liters (15000 gallons). A turbine mixer (operated at 56 rpm) is located in each compartment to keep the crumb rubber in suspension. It is held in the agitation tank for 45 to 60 minutes prior to use. This system can produce approximately 45 metric tons (50 tons) of asphalt rubber binder per hour.

International Surfacing Incorporated (ISI). ISI located in Chandler, AZ., uses a blending system that they developed based on the original McDonald process (see Figure 4.2). 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 amounts of CRM and asphalt cement are 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.



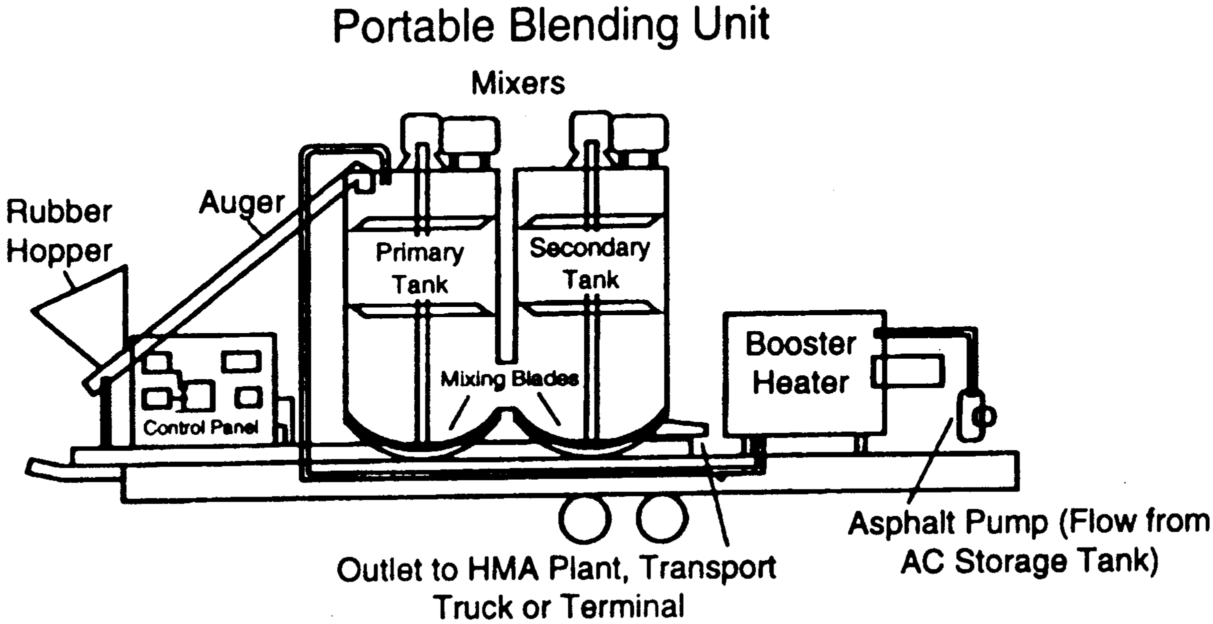
Manhole Adjusting Contractors, Inc. Manhole Adjusting Contractors, Inc. uses a blending system that they have developed and refined based on the original Arizona Refining Co. system (Figure 4.3) and work primarily in the Los Angeles area. They use a combination of natural rubber (from ground tennis balls) 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 190ºC (375ºF) and 232ºC (450ºF). 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 4.4 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 that 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 the HMA contractor needs it. 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.

<u>Rouse Rubber Industries, Inc.</u> Rouse Rubber Industries, located in Vicksburg, MS, has developed a portable blending and metering unit on a trailer (see Figure 4.4 for schematic and Figure 4.5 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 162ºC (325ºF). 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). Adjusting the rate of the auger that feeds the rubber controls the percent 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.

Central Blending Systems

Features of the various terminal blending systems and the typical formulations are summarized in Tables 4.3 and 4.4. A detailed discussion of the various systems in provided below.

<u>Anderson-Columbia Construction Co</u>. 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 4.6. 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

Table 4.3: Central Blending Techniques - Basic Equipment

Product/Company	Asphalt Preheater	Rubber Storage	Blending Equipment	Reaction Vessel	Storage Tank	Comments
Dura-Tirephalt	-	Yes	Yes	Yes	-	Combined Reaction/ Storage Tank
Neste	-	Yes	Yes	-	-	-
Blacklidge Emulsions	No	Storage Silos	Vertical Tank	No	Yes	Combined Reaction & Storage Tank
Anderson-Columbia	No	Bags	Vertical Tank	No	Yes	Combined Reaction & Storage Tank
Cortland	No	Silos	Mixing Chamber	No	Yes	Combined Reaction & Storage Tank

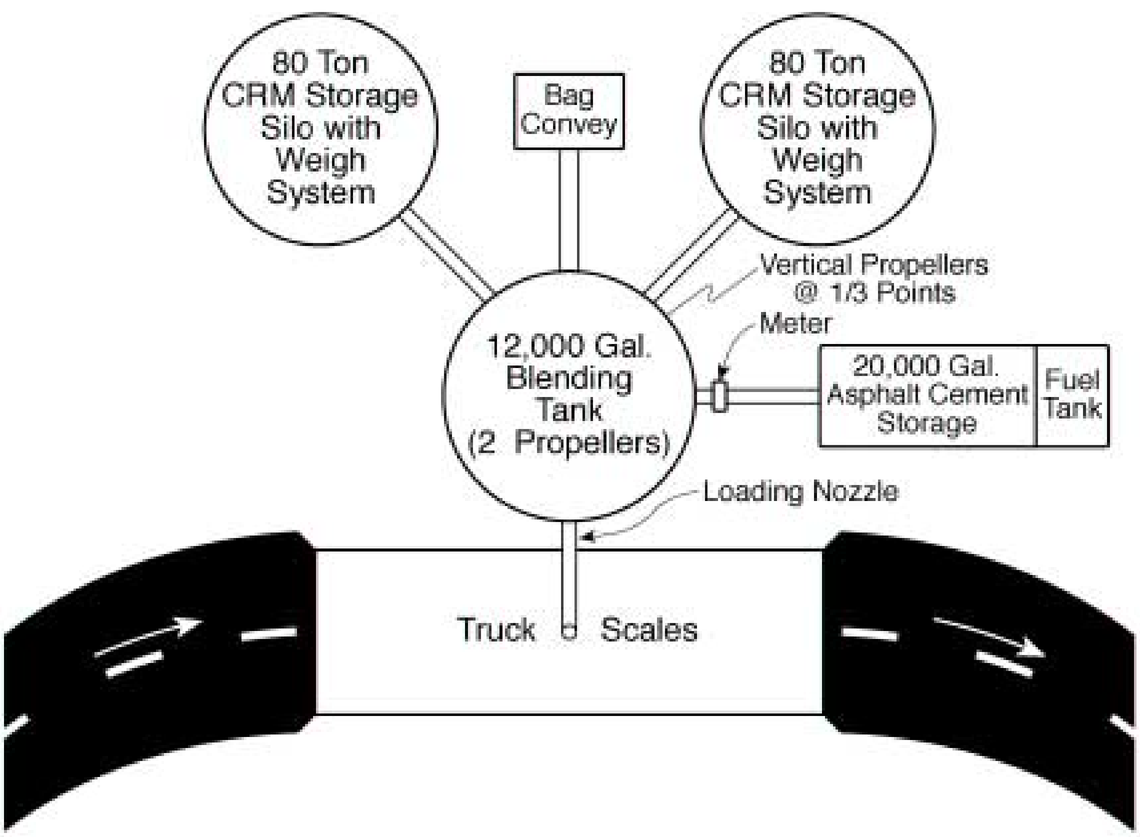
Table 4.4: Central Blending Techniques - Formulations

Product/ Company	CRM, % by Total Wt of Binder[1]	Flux	Chemical Stabilizer	Other Polymers	Typical Size of CRM, Mesh[1]	Past Use
Ecoflex Bitumar Group	10	-	-	-	10-20	Maryland, New Hampshire, New York, N. Carolina, Vermont, Ontario, Quebec
Dura-Tirephalt McAsphalt	7-15	-	-	-	30-40	Ontario
Neste	-	-	-	Yes	-	Arizona, Louisiana, Nevada, Texas, Utah
Blacklidge Emulsions	5 & 12	No	No	No	80 & 40	Florida
Anderson-Columbia	5 & 12	No	No	No	80 & 40	Florida
Cortland	10-15	No	No	No	80 & 40	New York, New Hampshire

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.

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 22,712 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 is 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 rubbers 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 (7,000 gallon) units located at the Tampa terminal. The crumb rubber is loaded into a hopper out of fifty-pound bags and augured into the unit.

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-Tirephalt. 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 of 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 63-34).

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 United 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 150°C (300°F). It can be reheated slowly prior to its use to a temperature of between 150°C (350°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 gap-graded aggregate mixtures and coarse rubber particles (¼ inch top size) that comprise about three percent by weight of mixture. The claim for this material was increased durability, increased rut distance 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 is 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 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 were fed into a mixing device where the asphalt cement was added (Figure 5.1). 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 tone 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.

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 temperatures 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 2.2 and 2.3 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 2.5 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.

<u>Wet Process</u>

1. The aggregate gradation desired (see Table 2.5 for 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.

<u>Dry Process</u>

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 9.1). 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 has developed 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 ignition method can be utilized to accurately determine the asphalt rubber content in the HMA mixture. The Tennessee DOT successfully used the oven for quality control on two projects.

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 the 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 of 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.

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15. Colley, J.O., *A Study of Flexible Pavement with Ramflex Rubber Additives*, Report No.1, Mississippi State Highway Department, December 1, 1970.

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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 noontide 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 SAMI 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 Bernandino, 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

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 Cuamonga, 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 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

The Special Provisions revise, amend, and where in conflict, supersede applicable Sections of the Standard Specifications for Highway Construction, Edition of 1988.

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:

	% Passing (by weight)	
Sieve Size	Type ARM	Type BRM
1-1/2"	100	
1"	90-100	
3/4"	75-90	100
1/2"	57-72	85-95
3/8"	---	70-85
No. 4	25-40	25-40
No. 10	15-25	15-25
No. 40	7-17	7-17
No. 200	3-7	3-7
%AC-20	4.0-7.5*	4.9-8.0*

* Lower Limit may be adjusted if the effective specific gravity of the combined aggregates is greater than 2.65.

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 VMA 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:

Sieve Size	Percent Passing (by weight)
No. 40	98-100

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:

Natural Rubber	15%-30%
Carbon Black	25%-38%
Ash	8% maximum
Acetone Extract	10%-18%
Rubber Hydrocarbon	40%-50%

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 140º 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 the following):

(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):

(ARM)	ASPHALT CONCRETE, TYPE ARM	TON
(BRM)	ASPHALT CONCRETE, TYPE BRM	TON

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
TO THE
STANDARD SPECIFICATIONS
EDITION OF 1990

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:

Apparent Viscosity, 350ºF., Spindle 3, 20 RPM cps (Modified ASTM 2669) (See Note 1)	Min 1,000 Max 4,000
Penetration, 77ºF., 100 g, 5 sec.: 1/10 mm. (ASTM D5)	Min 25 Max 75
Penetration, 39.2ºF., 200 g, 60 sec.:1/10 mm. (ASTM D5)	Min 15

Softening Point: ºF., (ASTM D36)	Min	130
Resilience, 77ºF.,: % (ASTM D3407)	Min	20
TFOT Residue, (ASTM D1754) Penetration Retention, 39.2ºF.:%	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 100ºF. (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

Rubber Gradation	Master Grading Limits				
	#10	#16	#30	#50	#2

MINIMUM	0	0	40	80	95
MAXIMUM	0	30	75	100	10

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 t 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 350ºF 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 he 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 300ºF and 350ºF 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)

**KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
TO THE
STANDARD SPECIFICATIONS
EDITION OF 1990**

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 RAP in this mix.

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

Mix Designation = ARB			Percent Retained - Square Mesh Sieves						
	1/2"	3/8"	4	8	16	30	50	100	200
ARS	0	8-22	62-83	78-94	82-98	85-98	87-98	89-98	92-98

Maximum Moisture = 0.5

JOB MIX TOLERANCES:

± 6	± 5	±5	±4	±3	±3	±2

KANSAS DEPARTMENT OF TRANSPORTATION
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STANDARD SPECIFICATIONS
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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)
-A maximum of 15% natural and from an alluvial deposit.

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

Mix Designation = ARB — Percent Retained - Square Mesh Sieves

1"	3/4"	1/2"	3/8"	4	8	16	30	50	100	200
0	0-10	15-35	28-53	53-73	70-86	----	83-96	87-98	----	92-98

Maximum Moisture = 0.5

JOB MIX TOLERANCES:

3/8"	4	8	16	30	50	100	200
± 6	± 6	± 5	± 5	± 4	± 3	± 3	± 2

5-20-92

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
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NOTE: **Whenever this Special Provision conflicts with the Plans or Standard Specifications, this Special Provisions shall govern.**

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:

Crumb Rubber Modifier (CRM-VI)
Percent Retained-Square Mesh Sieves

Rubber	Master Grading Limits		
Gradation	#60	#80	#100
MINIMUM	0	0	0
MAXIMUM	2	12	25

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 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.

Transportation, June 16, 1989