Session 5.0

Crumb Rubber Modifier (CRM) Technologies

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Wet and dry processes have been used to incorporate rubber in hot mix asphalt (HMA). Two technologies which use wet processes are: the McDonald (batch) technology and the continuous blending technology. Two technologies which use dry processes are: the PlusRide technology and the generic dry technology.

In the wet process the Crumb Rubber Modifier (CRM) is blended with asphalt cement before mixing the CRM modified binder with the aggregate. In McDonald technology the CRM is mixed in a blending tank and reacted in a holding tank before introduction into the mix. In continuous blending technology the CRM and the asphalt cement can be mixed just before the binder is introduced into the mix or it can be mixed and placed in a storage tank for use later. Fifteen to twenty-two percent (by weight of binder) of a 10–30 mesh CRM is generally used in McDonald technology. The continuous blending technology uses a finer grind of CRM in amounts ranging from five to twenty percent (by weight of binder).

In the dry process the crumb rubber materials are blended with the aggregate before adding the asphalt cement to the blended mixture. The mix production practices for the dry process are similar to those practices used for the construction of conventional HMA. The CRM is added directly to the mixture. In a drum plant it is added at the RAP opening. In a batch plant it is added to the dry aggregate at the pugmill.

A detailed discussion of the four different technologies (two wet processes and two dry processes) follows.

5.1 McDonald Technology

5.1.1 Description

The wet process is any process that blends CRM with asphalt cement before mixing the blended binder with the aggregate. The result is a modified binder having significantly different properties than the original asphalt cement. The process is the result of early work done by Charles McDonald. Per telephone conversation with Carl Jacobson, CRAFCO, there are no current patents covering the wet process.

In McDonald technology, typically 15 to 22 percent ground rubber (No. 16 sieve to a No. 30 sieve) is mixed with an asphalt (usually an AC-10 or AC-20) and reacted for one-half hour to one hour. The result is a thick elastic material called asphalt rubber (AR) binder.
5.1.2 Details

A primary purpose for adding CRM to an asphalt cement is to provide an improved binder. The following paragraphs will discuss the uses of AR binders using the McDonald technology and the claimed benefits from the use of AR binders.

Uses of AR Binders (McDonald Technology)

The AR binders have been used for many applications to include the following:

1. **Crack and joint sealant**

2. **Seal Coats.** This is a Stress Absorbing Membrane (SAM) and generally consists of a spray application of AR binder at the rate of approximately 0.50 gsy with approximately 35 psy of chips.

3. **Stress Absorbing Membrane Interlayer (SAMI).** This is a SAM placed between layers of HMA generally during an overlay project. The purpose is to retard the development of reflection cracks and to reduce water penetration into the underlying layers.

4. **Hot Mix Asphalt.** This is a HMA that uses the AR binder in lieu of a conventional asphalt cement. It can be either an open-graded, gap-graded or dense-graded HMA.

5. **Subgrade seals.** This is a spray application of AR binder similar to a SAM. It could be used to keep moisture out of a subgrade or to provide an impermeable liner for a water retention basin.

Claimed Advantages for McDonald Technology

The following advantages are claimed for AR binders:

1. **Reduces aging.** Asphalt cement that contains CRM shows the effects of reduced oxidation or aging. This is because of the antioxidants and carbon black from the tire that are in the AR binder.

2. **Increases flexibility of the mix.** Mixtures containing AR binders are more flexible than standard conventional asphalt mixes.

3. **Softening point.** The use of CRM in a binder will increase the softening point of the resultant binder by 20 to 50°F.
4. **Improved temperature susceptibility.** The use of an AR binder results in improved cold weather performance characteristics and improved hot weather performance characteristics than its base conventional asphalt.

**Gradations**

When using the McDonald technology the rubber content should be a minimum of 15 percent by weight of the binder and should meet the gradations from Table 5-1. The aggregate gradation of dense-graded HMA mixtures should be maintained on the coarse side of the gradation band to accommodate AR binder.

| Table 5-1. Suggested rubber gradations for a dense-graded HMA (Ref 3) |
|---------------------------|--------------------------|
| **Sieve size** | **Percent passing** |
| No. 10 | 100 |
| No. 16 | 98–100 |
| No. 30 | 70–200 |
| No. 50 | 10–40 |
| No. 200 | 0–5 |

A recommended aggregate gradation for an open-graded HMA containing AR binder is shown in Table 5-2. An open graded mix made with AR binder will have a higher binder content than the same mix with a conventional binder.

When using McDonald technology the CRM should meet the gradation requirements shown in Table 5-3.
Table 5-2. Suggested aggregate gradations for open-graded CRM HMA (percent passing) (Ref 3)

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>3/8 ince</th>
<th>1/2 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot; (19.0 mm)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1/2&quot; (12.5 mm)</td>
<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td>3/8&quot; (9.5 mm)</td>
<td>85-100</td>
<td>75-95</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>25-55</td>
<td>20-45</td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>5-15</td>
<td>5-15</td>
</tr>
<tr>
<td>No. 30 (600 μm)</td>
<td>0-10</td>
<td>0-10</td>
</tr>
<tr>
<td>No. 200 (75 μm)</td>
<td>0-5</td>
<td>0-5</td>
</tr>
</tbody>
</table>

Table 5-3. Suggested CRM gradations for an open-graded HMA (Ref 3)

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Percent passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 10</td>
<td>100</td>
</tr>
<tr>
<td>No. 16</td>
<td>75-100</td>
</tr>
<tr>
<td>No. 30</td>
<td>25-60</td>
</tr>
<tr>
<td>No. 50</td>
<td>0-20</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-5</td>
</tr>
</tbody>
</table>

5.1.3 Mix Design

Dense-graded HMA

Marshall and Hveem mix design methods can be used to design dense-graded HMA with McDonald asphalt rubber. Modifications are made to the procedures to account for the AR binder. As previously noted, the aggregate gradation needs to be on the coarse side of the band. If the gradation is too fine, or the rubber particles too large, compaction problems may result. Because of the replacement of a portion of the asphalt cement by rubber, the binder content for a mix with AR will be higher than the binder content would be for a conventional HMA. The asphalt cement and CRM used to make the McDonald AR binder for the mix design needs to be mixed in a very controlled manner. The lab specimens should be mixed and compacted at elevated temperatures.
After the specimens have been made both the standard Marshall and Hveem test procedures can be used. However, because of the increased viscosity, elasticity and softening point of the asphalt rubber binder, the target level for the design parameters are adjusted. The target level for the VTM (voids in total mix) should be set at 3 to 4 percent rather than 3 to 5 percent. Also the flow requirements should be raised. For the Hveem procedure, the VTM should be similar to the Marshall procedure. The Hveem stability should be 20 to 30 when using aggregate that normally produces 35 to 40 stabilities with conventional asphalt cement binder.

*Open-Graded Friction Courses (OGFC)*

In open-graded mixes with McDonald AR binder, the higher viscosity of the binder will allow the use of binder contents higher than those used in standard open-graded mixes. Binder contents of 10 to 11 percent have been used without experiencing excessive drain down. The procedures outline in the FHWA report FHWA-RD 74-2 “Design of Open Graded Asphalt Friction Courses” should be used as a general guideline for the design of these mixes.

The major difference between production of a McDonald HMA and a conventional hot mix asphalt is the pre-blending and reaction of the CRM with asphalt cement to produce an AR binder for the resultant HMA mixture. The reaction is accomplished in insulated trucks and/or tanks. When the CRM is added to the asphalt, the temperature of the asphalt cement is between 176°C to 204°C (350°F to 400°F). The asphalt cement and CRM are combined and mixed in a blender unit and then pumped into the agitated storage tank for reaction. The reaction tank has a mechanical agitating system that will keep the mixture dispersed. The temperature is maintained between 162°C and 190°C (325°F and 375°F) during the minimum 45 minutes reaction time. The required amount of AR binder is added at the mixing chamber of the HMA production plant.

The construction of HMA with McDonald AR binder is very similar to constructing conventional mix. The temperature of the AR binder is between 162°C and 190°C (325°F and 375°F). The mixing temperature is generally 143°C and 162°C (290°F to 325°F), laydown temperature is generally higher, and compaction should be accomplished while the material is “hot” because the viscosity of AR binder increases rapidly.
5.2 Continuous Blending Technology

5.2.1 Description

The wet process is any process that blends CRM with asphalt cement before mixing the blended binder with the aggregate. The result is a modified binder. The differences between the McDonald technology and the continuous blending technology is the manner in which the CRM and the asphalt cement are blended and reacted. Also, the McDonald technology uses a coarser CRM than the continuous process. Typically in the continuous blending technology, 5 to 20 percent ground rubber is blended with an AC-5 or AC-10 asphalt. The idea is that the use of the fine rubber gradation will shorten the reaction time between CRM and asphalt cement.

5.2.2 Details

The continuous blending technology differs from the McDonald technology in that the CRM material used for the binder is a finer grind material. Table 5-4 presents a typical gradation of the CRM used. The Florida DOT recommended CRM contents by weight of binder are: 12 to 16 percent for open-graded mixes, 5 to 12 percent for dense graded mixes and 15 to 20 percent for surface treatments.

<table>
<thead>
<tr>
<th>Screen</th>
<th>Percent passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 60</td>
<td>98 to 100%</td>
</tr>
<tr>
<td>No. 80</td>
<td>88 to 100%</td>
</tr>
<tr>
<td>No. 100</td>
<td>75 to 100%</td>
</tr>
</tbody>
</table>

5.2.3 Mix Design

The mix design procedures for the continuous blending technology will be similar to those for the McDonald technology.

5.2.4 Modification to Equipment

The mixing of the CRM and the asphalt cement is accomplished in a self-contained portable blending/metering unit as show in Figure 5-1. The system can be set up at the HMA plant site and interlocked into the existing asphalt binder feed system. Some asphalt terminals and refineries are examining this technology for large quantity production.
The construction practices for the continuous blending technology are similar to those described for the McDonald technology.

Figure 5-1. Continuous blending technology portable blending/metering unit

This process primarily uses CRM as a rubber aggregate which is incorporated into a gap-graded aggregate prior to mixing with asphalt cement, producing a rubber modified hot mix asphalt concrete (RU-MAC). The coarse rubber particles act as elastic aggregates which flex on the pavement surface under traffic and break ice. The mix design was refined in the mid 1980's establishing the gap-graded mix now commonly called PlusRide. EnvirOtire, Inc.* markets this technology at the present time as PlusRide II.

The CRM used in PlusRide is predominantly a granulated crumb rubber passing the 6.4 mm (1/4") sieve with the fraction passing the 2 mm (No. 10) sieve supplemented with granulated buffings or ground CRM. Like
the mineral aggregate, the gradation of the CRM follows a specific band as follows:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼&quot;</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>76–100</td>
</tr>
<tr>
<td>No. 10</td>
<td>28–42</td>
</tr>
<tr>
<td>No. 20</td>
<td>18–24</td>
</tr>
</tbody>
</table>

By specifying a granulated CRM, the smooth sheared surfaces of a particle are less reactive (lower surface area than ground CRM) and its cubical shape can be factored into the combined gradation of CRM and aggregate. The CRM is ambient granulated from ground whole passenger or truck tires (heavy equipment tires are not permitted). It is free of wire and free-flowing. Calcium carbonate or talc can be added to maintain its free-flowing condition. CRM in a PlusRide mixture can range from 1 percent to 6 percent by weight of the total mix. However, 3 percent has most commonly been used.

The mineral aggregates used in the PlusRide system should conform to the physical requirements for those aggregates used in the conventional HMA surface courses. The aggregate should have a minimum fracture requirement of 75 percent with at least one mechanically fractured face for all material retained on the No. 10 sieve and above.

Three aggregate gradations which reflect different maximum aggregate sizes, are specified in the PlusRide II system as shown in Table 5-5. The PlusRide II mixtures must be gap-graded to allow space for the CRM. For the PlusRide II 12 and PlusRide II 16 mixtures, this gap grade restricts the amount of aggregate passing the 6.4 mm (¼") sieve and retained on the No. 10 sieve to be 12 percent maximum. Failure to provide a sufficient gap grading would cause the coarse rubber to resist compaction and result in a low-density pavement with high air voids. The mix also contains a higher minus-200 content compared to conventional HMA mixtures to fill air voids.

*EnvirOtire, Inc. 1904 Third Avenue, Seattle, Washington 98101
(Phone 206-587-6018)
Table 5-5. Mix composition of PlusRide II (after Ref. 3)

<table>
<thead>
<tr>
<th>Property</th>
<th>PlusRide 8</th>
<th>PlusRide 12</th>
<th>PlusRide 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>% passing 3/4&quot;</td>
<td>100</td>
<td>60-80</td>
<td>50-62</td>
</tr>
<tr>
<td>% passing ½&quot;</td>
<td>--</td>
<td>100</td>
<td>--</td>
</tr>
<tr>
<td>% passing ⅛&quot;</td>
<td>60-80</td>
<td>30-44</td>
<td>30-44</td>
</tr>
<tr>
<td>% passing No. 10</td>
<td>23-38</td>
<td>20-32</td>
<td>20-32</td>
</tr>
<tr>
<td>% passing No. 30</td>
<td>15-27</td>
<td>13-25</td>
<td>12-23</td>
</tr>
<tr>
<td>% passing No. 200</td>
<td>8-12</td>
<td>8-12</td>
<td>7-11</td>
</tr>
<tr>
<td>Asphalt content, % by weight of mix</td>
<td>8.0-9.5</td>
<td>7.5-9.0</td>
<td>7.5-9.0</td>
</tr>
</tbody>
</table>

The asphalt cement binder chosen for the PlusRide mix is usually the same grade as used for conventional HMA in the project area. The asphalt content generally varies from 7.5 to 9.0 percent which is substantially higher than conventional HMA. The target air void content is 2 to 4 percent.

The CRM is handled like an aggregate, and is dry mixed with the hot mineral aggregate prior to mixing with the asphalt cement. Generally, a mix design using this concept will include a percentage of ground CRM passing No. 20 sieve which produces a partially reacted modified binder. Evidence of this reaction has been noted by the "swelling" which occurs in the laboratory mix.

The limited reaction time allows the surface of the coarse rubber particle to react with the asphalt cement, but does not permit sufficient time for the reaction to penetrate the entire rubber mass. This creates an asphalt/rubber interface which bonds the two materials together.

The following advantages have been claimed when PlusRide RUMAC is used.

**Increased fatigue life.** This is attributed to the modified asphalt binder and elastomeric aggregate. Laboratory fatigue tests conducted by Takallou et al. indicate such improvements are possible.

**Resistance to reflective, shrinkage and thermal cracking.** When the stress at the tip of a crack reaches a rubber particle, the particle is likely to absorb the stress, delaying the advance of the crack. Laboratory studies have indicated increased resistance to low temperature cracking.
5.3.3 Mix Design

**Ice disbonding.** Rubber granules exposed at the RUMAC surface compress slightly when subjected to traffic wheel loads. This creates a small area of flexibility that will not retain ice when it begins to crystallize. Obviously this will only happen when the surface is loaded continuously and when the ice is relatively thin.

**Greater resistance to rutting.** This is attributed to greater resiliency of the RUMAC course, which results in reduced permanent deformation. Repeated load permanent deformation tests conducted by Takallou et al.\(^7\) indicate this trend. However, Stuart and Mogawer\(^6\) have reported decreased resistance to rutting in their laboratory evaluation, which was directly related to the rubber and the associated 1.5 percent increase in asphalt content.

Since PlusRide II is a resilient/elastic RUMAC mixture, the conventional properties of stability and flow do not apply for the mix design. The objective of the design is to determine the gradation of aggregates, asphalt content and rubber content that yield a mix having:

1. A high-coarse aggregate content, gap-graded to provide space for the rubber granules to form a dense, durable and stable mixture upon compaction.

2. A rich asphalt/filler ratio. Asphalt cement and filler are used to fill voids. The mix must have a high asphalt content to ensure a workable mixture and durable pavement.

3. A low void content in the compacted mix. The voids should be in the range of 2 percent to 4 percent, with 3 percent being the normal.

One of the three specified, gap-graded aggregate gradation bands (as shown in Table 5-5) are used depending on the desired maximum aggregate size. The gapping within the specified aggregate gradation band is critical. The 12 percent (maximum) aggregate fraction passing the 6.4 mm (\(\frac{1}{4}\)"") sieve and retained on the No. 10 sieve must be maintained within specified tolerance during production. A mineral filler is usually required to meet the high minus 200 requirements. When a mineral filler is needed, the type and quantity to be used in production must be used in the mix design. The asphalt cement content should range from 7.5 percent to 9.0 percent by weight of total mix. A guide for selecting the trial contents is the rule of thumb that PlusRide II requires approxi-
mately 2 percent more asphalt than a conventional mixture of similar size and type aggregates.

A sieve analysis must be performed on a representative sample of CRM to ensure that it meets the specified gradation (reported earlier).

A mixing temperature of 160°C (320°F) is used to prepare various mixtures of different asphalt contents. To prevent expansion of the compacted specimen, the base plate must be removed immediately and the specimen set over a 98 mm (3 7/8") diameter x 25 mm (1") thick wood plug. Another wood plug should be placed on top of the specimen, weighted and allowed to cool.

The theoretical maximum specific gravity may be determined by several methods, the Rice method being the most common. If the theoretical maximum specific gravity is calculated, a value of 1.19 should be used for the specific gravity of the rubber, or the specific gravity should be measured.

After the specimens have cooled to room temperature, the bulk specific gravity is determined and percent air voids calculated. If the percent air voids are not within the design tolerance (2-4%), the amount of asphalt and filler is adjusted and/or the aggregate gradation is adjusted, and another set of trial mixtures prepared. The primary criterion for an acceptable mix design is the percentage of air voids.

If the aggregate does not contain enough minus 200 material, then it will necessary to add mineral filler to the RUMAC mix. This might require a separate silo for mineral filler.

For batch mix facilities CRM is delivered to the site in 22 to 27 kilogram (50 to 60 pound) plastic bags. The bags are made of a low melting point material which allows the operator to charge the mixing chamber with the entire bag of CRM. The process and equipment required for introducing RAP (reclaimed asphalt pavement) into a drum mix facility can also be used to introduce CRM into the drum.

EnvirOtire, Inc. has now developed a CRM proportioning and feed system conveniently mounted on a trailer, which automatically proportions the correct amount of ground and granulated rubber and introduces it into both batch and drum HMA facilities.

No modifications are needed to conventional hauling, placing, and compaction equipment.
5.3.5 Modification to Procedures

Only a few modifications to the construction practices are needed for PlusRide RUMAC. The CRM is added directly to the HMA facility. This will require a separate CRM feed system tied into the aggregate feed system. On a batch facility, this is presently accomplished by manually feeding the pugmill with a predetermined number of sacks of CRM. On drum mix facilities, the CRM feed system introduces the CRM at the RAP hopper and must be tied to the cold-feed aggregate weigh system. A sensitive weigh system is necessary to monitor the small amount (3 percent by weight of mix) of CRM being introduced into the drum. As mentioned earlier, EnvirOtire, Inc. has a portable mix and feed system which can introduce the required amounts of CRM into the HMA mix produced by both batch and drum mix facilities. Except for an extended dry mix cycle during batch plant production, the only other modification to mix production is mix temperature. The temperature of PlusRide RUMAC mixture should be 150 to 175°C (300 to 350°F) after mixing.

The PlusRide RUMAC mixture occupies about 10 percent greater volume in the pugmill than a conventional mix for the same weight. Since PlusRide mix uses approximately 2 percent more asphalt cement, the limiting factor on batch size may be the capacity of the asphalt cement bucket.

Quality control is very important for PlusRide RUMAC. The mix is very sensitive to variations in the materials’ gradations and proportions. Poor production, placement, or compaction control have resulted in premature failure of the pavement. Extraction methods will not provide accurate means of monitoring CRM content nor binder content. Similarly, asphalt content gauges will measure all the CRM in the sample as a part of the binder content. Therefore, proper calibration of the equipment which measures the materials fed into the HMA facility is critical.

Compaction control is also very important for PlusRide RUMAC. The materials should be compacted while hot to achieve density before the binder stiffens as the mat cools. Hand work should be held to a minimum. The use of rubber-surfaced equipment, particularly pneumatic rollers, should be avoided. Only detergent-based release agents should be used on the haul trucks and rollers. In addition to these modifications, the finish roller must continue to compact the PlusRide mat until it cools below 60°C (140°F). Because the CRM is only partially “reacted,” the material in the compacted lift continues to react at elevated temperatures. The reaction causes the crumb rubber to swell and expand the mixture. The additional rolling retains the mat density until the increasing binder viscosity can counteract the reaction’s decreasing potential to expand.
The first generic dry technology system, generic RUMAC (also known as the “TAK” system), uses an equivalent or slightly lower percentage of CRM compared to PlusRide. The CRM is also finer than that used in PlusRide. A conventional dense-graded aggregate is used with only slight modification. The gradation of CRM is adjusted to suit the aggregate gradation. It is a two component system in which the fine crumb rubber interacts with asphalt cement, and the coarse crumb rubber performs as an elastic aggregate in the HMA mixture. The combination of modifying the asphalt binder and increasing the elasticity of the HMA mixture has been claimed to increase the fatigue life, reduce thermal and reflective cracking, and increase the adhesion of the modified binder to the aggregate. However, this system has been described somewhat generally in the literature. No significant information is available as to how the amount and the gradation of CRM is determined for a specific mineral aggregate.

Another type of generic dry technology system uses lower amounts of CRM and smaller size (No. 80 mesh) CRM as compared to generic RUMAC. It is believed that the fine CRM modifies the asphalt binder during the mixing process and subsequent storage and transportation of the HMA to the job site.

These systems are in the public domain and, therefore, no royalty payments are involved. Experimental field applications of the generic dry process have been made in New York, Illinois, Florida, Kansas, Iowa, Oregon, California and Ontario, Canada. Construction reports are available from the Department of Transportation of some States.

**Generic RUMAC System**

As mentioned earlier, generic RUMAC is a two component system. The CRM passing No. 20 sieve reacts with the asphalt cement producing a modified binder. A pre-reaction may be needed to achieve the optimum modification. The coarse CRM replaces a portion of the aggregate in the HMA mixture, and acts as an elastic aggregate.

One to three percent crumb rubber by weight of the HMA mixture is generally added. The crumb rubber is ambient granulated or ground from whole passenger and/or light truck tires. Heavy equipment tires are not permitted. The crumb rubber greater than 10 mesh in size must
be produced from ambient granulation. The crumb rubber passing the
10 mesh sieve may be produced from either ambient granulation or am-
bient grinding. Uncured or devulcanized rubber is not acceptable.
Rubber tire buffings, from either recapper or tire manufacturers must
not be used as supplement to the granulated rubber mixture unless they
are further processed by granulation or grinding. The rubber granulate
must be processed by ambient granulation to maintain the structural in-
tegrity, particle shape and minimum surface area. The first stage of the
whole tire processing can use other methods to remove steel and fabric.

Aggregate gradation is examined to see the sieve sizes wherein the
CRM can be incorporated. Consideration is given to the fact that CRM
swells after it comes in contact with asphalt cement during mixing, haul-
ing, placement, and compaction. The size of the CRM should be
smaller (by one sieve size) than the gap existing in the mineral aggreg-
ate.

Since conventional aggregate gradations are used, it is necessary to de-
terminelhe appropriate CRM gradation. However, the grading
flexibility in most CRM plants is rather limited at the present time. The
cost of CRM will increase if unusual CRM grading requirements are
specified.7

Generic RUMAC has been successfully constructed in New York, Ore-
gon and Ontario; mix composition and construction details for New
York and Ontario are given in References 11 and 12, respectively.

**Asphalt Rubber System**

In Florida, an experimental project constructed in June 1989 used CRM
in one section utilizing generic dry process technology different from
generic RUMAC system. Number 80 mesh CRM was used in an open-
graded friction course (nominal maximum aggregate size of 9.5 mm or
\( \frac{3}{8} \) inch) at 10 percent by weight of binder. Little information is avail-
able regarding the details of this new generic technology system.

**Generic RUMAC System**

Preliminary tests are performed to establish the CRM content. The
maximum CRM content which meets the agency’s minimum stability
requirement is selected. Generally, up to 2 percent CRM is used in sur-
face courses and up to 4 percent in base courses. The cubical shape of
granulated CRM is factored into the combined gradation of CRM and
aggregate. The specific gravity differences between CRM particles and aggregate require a weight adjustment factor of 2.3 for the CRM to determine the composite gradation.

After the amount and the gradation of CRM are selected, trial specimens are made with 75 blows of Marshall hammer. Optimum asphalt content is selected based on the air voids. The voids should be in the range of 2 to 4 percent, with 3 percent being the normal. The selected mix must meet the minimum stability requirement like the control mix without CRM. Marshall flow should not exceed 20. Very limited data is available on the complete mix design procedure.

Some mix design information from the initial New York projects is given below.

New York Projects: Three generic dry technology designs ("TAK" systems) were constructed using 1, 2 and 3 percent CRM by weight of total mix. A control section (no rubber) and a PlusRide section were also constructed for comparison. The CRM supplied on the project is given in Table 5-6. The gradation specified for aggregate plus CRM for the New York Type 6F surface course mix is given in Table 5-7.

**Table 5-6. CRM gradation—New York projects**

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Percent passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specified</td>
</tr>
<tr>
<td>⅛&quot;</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>—</td>
</tr>
<tr>
<td>⅝&quot;</td>
<td>75-85</td>
</tr>
<tr>
<td>No. 10</td>
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<tr>
<td>No. 20</td>
<td>30-40</td>
</tr>
<tr>
<td>No. 40</td>
<td>0-10</td>
</tr>
</tbody>
</table>
Table 5-7. Mix gradation—New York projects

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Percent passing</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>100</td>
<td>—</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>95-100</td>
<td>—</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>65-85</td>
<td>±7</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>38-65</td>
<td>±7</td>
</tr>
<tr>
<td>No. 20</td>
<td>15-39</td>
<td>±7</td>
</tr>
<tr>
<td>No. 40</td>
<td>8-14</td>
<td>±4</td>
</tr>
<tr>
<td>No. 80</td>
<td>4-16</td>
<td>±4</td>
</tr>
<tr>
<td>No. 200</td>
<td>2-6</td>
<td>±2</td>
</tr>
</tbody>
</table>

The design asphalt contents and air void contents obtained for the two projects in New York are given in Table 5-8. These are based on 75-blow Marshall hammer compaction.

Table 5-8. Design asphalt contents and air voids—New York projects

<table>
<thead>
<tr>
<th>Mix type</th>
<th>Percent rubber</th>
<th>Region 1</th>
<th>Region 9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>% AC</td>
<td>% voids</td>
</tr>
<tr>
<td>6 F (control)</td>
<td>0</td>
<td>6.0</td>
<td>3.0</td>
</tr>
<tr>
<td>6 F rubber</td>
<td>1</td>
<td>6.4</td>
<td>3.1</td>
</tr>
<tr>
<td>6 F rubber</td>
<td>2</td>
<td>6.8</td>
<td>3.2</td>
</tr>
<tr>
<td>6 F rubber</td>
<td>3</td>
<td>7.2</td>
<td>3.0</td>
</tr>
<tr>
<td>PlusRide</td>
<td>3</td>
<td>7.2</td>
<td>2.2</td>
</tr>
</tbody>
</table>

An AC-20 asphalt cement was used in all test sections. Asphalt contents for the control and RUMAC mixes were selected to obtain a target air void content of 3 percent. PlusRide mixes were designed for 2 percent air void content.

The temperature of the RUMAC mixtures was specified between 149°C (300°F) and 177°C (350°F) at the point of discharge. The target mat density was specified between 95–9 percent of the maximum theoretical specific gravity.
**Asphalt Rubber System**

Dense-graded HMA using this dry process technology is usually designed by the same Marshall design criteria as used for conventional HMA.

Similar to PlusRide RUMAC, arrangements have to be made to introduce CRM in the batch and drum mix HMA facilities. Generic dry technology has used bulk feeding systems for the CRM on projects in Illinois, Oregon and Kansas.

No modifications are needed to conventional hauling, placing, and compaction equipment.

Same as PlusRide RUMAC except that pneumatic tired rollers have been used without any problems.


2. Schnormeier, R. H. “Recycled Tire Rubber in Asphalt.” Presented at the 71st Annual Meeting of the Transportation Research Board, 1992


**5.4.4 Modification to Equipment**

**5.4.5 Modification to Procedures**

**5.5 References**


