Using Warm Mix Technology to Improve Applications of Asphalt Rubber in California

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ABSTRACT

Warm mix asphalt (WMA) is the name given to certain technologies that reduce the production and placement temperatures of asphalt mixes. Asphalt Rubber (AR) has been used in the United States since 1960s. This field blended asphalt rubber normally requires higher production and compaction temperatures to produce quality pavements. This paper evaluates whether there are any benefits of using warm mix technologies with AR hot mixes as well as spray applications. The potential savings in energy and reduction in green house gas emissions could be great. In addition, California has high standards on emissions and air quality requirements for asphalt spray applications. The warm mix technology could reduce the temperature of asphalt rubber placement and thus reduce the emissions to meet the California air quality requirement.

The paper includes a brief literature review and a survey of users of WMA in the United States. Then it concentrates the research on the use of warm mix technologies with AR in California. The warm mix rubberized hot mix asphalt applications includes Route 152 near Santa Clara, Interstate 5 near Santa Nella, Interstate 5 near Orland, CA-94 in San Diego, SR-101 in Fortuna, SR-70 in Marysville, and SR 99 in Sutter County. The warm mix technologies with asphalt rubber chip seal applications include Interstate 5 near Fresno, and City of Roseville.

Field evaluations of these projects demonstrate that there are a wide range of benefits which can be attained by using warm mix technology in AR mixes. These include reduced fuel usage and emissions, improved compaction, longer paving seasons, night paving, long hauling distances, and improved working conditions. The placement temperatures of AR hot mixes were reduced from 350 °F to less than 300 °F. Spray temperatures for AR Chip Seals were lowered from 400 °F to 340 °, which reduced the emissions significantly.

Keywords: asphalt rubber, warm mix asphalt, rubberized hot mix asphalt, AR chip seal
INTRODUCTION

A two year study has been completed to determine the feasibility of using warm mix technologies for asphalt rubber (AR) hot mixes. Because the production and paving temperatures with warm mix technology can be significantly lower than conventional AR mixes, the potential savings in energy and reduction in emissions could be great.

Warm mix asphalt (WMA) is the name given to certain technologies that reduce the production and placement temperatures of asphalt mixes (1). Generally, the production and placement temperatures should be between 185 °F (85 °C) and 275 °F (135 °C) for an asphalt to be considered warm mix asphalt (2). In the United States, WMA is a relatively new technology; however, Europe has been at the forefront of WMA technologies since the mid 1990’s. The first project in Europe was completed in 1995 (3), but it wasn’t until 2002 when the National Asphalt Pavement Association (NAPA) scheduled a European tour to study the use of WMA that the United States got involved with these technologies. In 2004, the first field trials were completed in both Florida and North Carolina (4). Since then, WMA has been used extensively in the USA (3). California had its first field testing project using WMA in 2006. The University of California Pavement Research Center (UCPRC) completed the “first phase of a comprehensive study into the use of warm-mix asphalt” for Caltrans in July of 2008. The results confirmed that using the warm mix additives lowered the production temperatures by 35 °C (60 °F) as well as many other benefits (5). The UCPRC is conducting the second phase of HVS study on WMA with AR techniques in 2010. During the summer of 2011, nearly 1 million tons of WMA will be placed.

There are a wide range of benefits that are reported by using WMA. Reduced fuel usage and emissions are the two major benefits. Other benefits that have been reported include compaction aides, longer paving season/hauling distances, and improved working conditions (4). While there isn’t a range of established values for fuel reduction, of the WMA projects monitored, fuel savings of 20% to 35% are possible (3). The level of emission reduction varies upon several factors including the degree of temperature reduction, aggregate moisture content, and reclaimed asphalt pavement (RAP) usage (4). In California, we also note the emissions drop dramatically when used with asphalt rubber (AR) binders.

The benefits associated with warm mix asphalt rubber (AR) chip seals are similar to those reported for WMA. A hot application of warm mix asphalt rubber binder can be applied at a lower temperature which produces lower emissions at the plant and at the job site. The lower emissions equates to a healthier work environment for both the equipment operators and the laborers. The ability to apply the chips to the binder at a lower temperature with the warm mix alternative increases the time window for a successful chip application. The lower application temperature of a warm mix AR chip seal can also extend the total construction season compared to a non-warm mix alternative. The warm mix AR chip seals offer a less expensive maintenance treatment than a thin blanket HMA overlay, plus a much short construction time.

The objectives of this study were to evaluate the feasibility of using warm mix technologies for AR hot mixes to determine whether these technologies will allow operations at lower temperatures without harming the performance of the mix, as well as to determine the effect on mix performance.
TYPES OF WARM MIX TECHNOLOGIES

There are multiple warm mix technologies being marketed in the United States at this time (6). The technologies can be grouped into technologies that use one of the following:

- Some type of organic additive or wax
- A chemical additive or surfactant
- Water for foaming

Some of the processes used in the United States to date are summarized in Table 1. Most of the current information on warm mixes can be found at the web site located at www.warmmixasphalt.com . Table 2 lists typical production and paving temperatures for some warm mix technologies.

TABLE1 WMA Technologies Used in the United States

<table>
<thead>
<tr>
<th>No</th>
<th>Supplier-Product</th>
<th>Type of Additive</th>
<th>Web Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Advanced Concepts Engineering co. LEA-CO</td>
<td>Foaming</td>
<td><a href="http://www.lea-co.com">www.lea-co.com</a></td>
</tr>
<tr>
<td>2</td>
<td>AESCO Madsen Eco-Foam II</td>
<td>Foaming</td>
<td><a href="http://www.aescomadsen.com/literature.htm">www.aescomadsen.com/literature.htm</a></td>
</tr>
<tr>
<td>3</td>
<td>Akzo Nobel Rediset WMX</td>
<td>Chemical</td>
<td><a href="http://www.surfactants.akzonobel.com">www.surfactants.akzonobel.com</a></td>
</tr>
<tr>
<td>4</td>
<td>Arkema Group CECABASE RT</td>
<td>Chemical</td>
<td><a href="http://www.cecachemicals.com">www.cecachemicals.com</a></td>
</tr>
<tr>
<td>5</td>
<td>Aspha-min GmbH</td>
<td>Foaming</td>
<td><a href="http://www.aspha-min.com">www.aspha-min.com</a></td>
</tr>
<tr>
<td>6</td>
<td>Astec Industries Double Barrel Green</td>
<td>Foaming</td>
<td><a href="http://www.astecindustries.com">www.astecindustries.com</a></td>
</tr>
<tr>
<td>7</td>
<td>BP Bitumen (WAM Foam)</td>
<td>Foaming</td>
<td><a href="http://www.shell.com/bitumen">www.shell.com/bitumen</a></td>
</tr>
<tr>
<td>8</td>
<td>Gencor Industries Green Machine</td>
<td>Foaming</td>
<td><a href="http://www.gencorgreenmachine.com">www.gencorgreenmachine.com</a></td>
</tr>
<tr>
<td>9</td>
<td>Mathy Technology and Engineering Services, Inc. (Revix)</td>
<td>Chemical</td>
<td><a href="http://www.mathy.com">www.mathy.com</a></td>
</tr>
<tr>
<td>10</td>
<td>Herman Grant Company HGrant Warm Mix System</td>
<td>Foaming</td>
<td><a href="http://www.hermangrant.com">www.hermangrant.com</a></td>
</tr>
<tr>
<td>11</td>
<td>Iterchimica Qualitherm</td>
<td>Chemical</td>
<td><a href="http://www.qprshopworx.com">www.qprshopworx.com</a></td>
</tr>
<tr>
<td>12</td>
<td>Maxam Equipment Inc. AQUABlack Solutions</td>
<td>Foaming</td>
<td><a href="http://www.maxamequipment.com">www.maxamequipment.com</a></td>
</tr>
<tr>
<td>13</td>
<td>McConnaughay Technologies</td>
<td>Foaming</td>
<td><a href="http://www.mcconnaughay.com">www.mcconnaughay.com</a></td>
</tr>
<tr>
<td>14</td>
<td>MeadWestvaco Asphalt Innovations Evotherm™</td>
<td>Chemical</td>
<td><a href="http://www.meadwestvaco.com">www.meadwestvaco.com</a></td>
</tr>
<tr>
<td>15</td>
<td>Meeker Equipment Inc. Aquaback Warm Mix Asphalt</td>
<td>Foaming</td>
<td><a href="http://www.meekequipment.com">www.meekequipment.com</a></td>
</tr>
<tr>
<td>17</td>
<td>PQ Corporation Advera WMA</td>
<td>Foaming</td>
<td><a href="http://www.pqcorp.com">www.pqcorp.com</a></td>
</tr>
<tr>
<td>18</td>
<td>Saso Wax Americas, Inc. Sasobit</td>
<td>Organic</td>
<td><a href="http://www.sasolwax.com">www.sasolwax.com</a></td>
</tr>
<tr>
<td>19</td>
<td>Shell</td>
<td>Chemical</td>
<td><a href="http://www.shell.com">www.shell.com</a></td>
</tr>
<tr>
<td>21</td>
<td>Terex Roadbuilding Warm Mix Asphalt System</td>
<td>Foaming</td>
<td><a href="http://www.terexrb.com">www.terexrb.com</a></td>
</tr>
</tbody>
</table>
### TABLE 2 Typical WMA Production and Paving Temperatures

<table>
<thead>
<tr>
<th>WMA ADDITIVES</th>
<th>Production Temp(°F/°C)</th>
<th>Paving Temp (°F/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Barrel Green</td>
<td>250-275 / 121-135</td>
<td>~235 / 113</td>
</tr>
<tr>
<td>Evotherm™</td>
<td>180-250 / 82-121</td>
<td>160-240 / 71-116</td>
</tr>
<tr>
<td>Rediset WMX</td>
<td>~265 / ~129</td>
<td>~225 / 107</td>
</tr>
<tr>
<td>REVIX</td>
<td>245-265 / 118-129</td>
<td>205-225 / 96-107</td>
</tr>
<tr>
<td>Sasobit</td>
<td>200-280 / 93-138</td>
<td>150-250 / 66-121</td>
</tr>
<tr>
<td>WAM Foam</td>
<td>212-248 / 100-120</td>
<td>176-230 / 80-110</td>
</tr>
<tr>
<td>Zeolite</td>
<td>~275 / ~135</td>
<td>&gt;212 / &gt;100</td>
</tr>
<tr>
<td>RHMA</td>
<td>325-375 / 163-191</td>
<td>285-350 / 141 - 177</td>
</tr>
</tbody>
</table>

Note: Temperatures were found from the following sources: (4), (7), (8), and (9).

The processes which use organic additives or waxes exhibit a decrease in the viscosity when heated above the melting point of the wax, allowing for mixing and coating. The processes using surfactants work via a variety of different chemical mechanisms. The processes that consume water utilize the volume expansion due to the conversion of liquid to gas/steam which causes an expansion of the asphalt binder resulting in a decrease in mix viscosity. The water can be introduced through a foaming operation or by using a material containing internal moisture, such as clay zeolite, or from moist aggregate.

The choice of which WMA process to use depends on several factors. One consideration is how many tons of mix will be produced. Some of the processes have higher initial costs. Others using additives have higher costs per ton of mix produced. Another consideration is how much temperature reduction is required since some processes offer more temperature reduction than others. Some additives can affect the final PG binder grades. Typically, both the high and low temperature grades are affected.

### ASPHALT RUBBER WITH WARM MIX

Asphalt Rubber(AR) has been used in asphalt mixes since as early as the mid 1960’s when it was pioneered by the city of Phoenix, Arizona, to be used in their chip seal program for the city’s streets. Since Arizona DOT fully implemented their rubber asphalt program in 1988, they have used more than 4.2 million tons of asphalt rubber which results in the recycling of 15 million old tires (10).
California has also been a major user of AR since the 1980’s and currently places about 30% of all its HMA that includes AR. The use of asphalt rubber has proven to reduce the traffic noise level and pavement cracking. This benefit is evident in colder environments where normal asphalt pavements experience cracking at a higher rate. By introducing rubber into the asphalt, the increased flexibility of the RHMA has reduced reflection cracking by 20% (11).

Given the benefits of using rubber asphalt, there are qualities that make it less attractive to utilize. Including rubber into the asphalt reduces the workability of the mixture. This, in turn, results in higher mixing and compaction temperatures to achieve the desired workability (12). Asphalt Rubber production can also only be limited to 1,000 tons per day in some areas because of the restriction for maximum allowable emissions (13).

However, with the implementation of WMA, these problems should no longer be an issue. Both the production and compaction temperatures of asphalt rubber can be reduced considerably (12). While the temperatures of rubberized warm mix asphalt mixture (RWMA) are outside of the definition of WMA, 185°F (85°C) and 275°F (135°C), the warm mix technology helps reduce the odor and smoke coming from the asphalt mixture (2). This temperature reduction also reduces hot plant fuel usage and emissions, allowing more asphalt rubber to be produced without exceeding the maximum allowable emissions (13).

Fatigue cracking is due to the recurring traffic load on a roadway. This type of cracking is one of the best indications that the pavement is under distress. A study completed at Clemson University in 2008 (14) investigated whether or not if the addition of rubber to WMA would affect the fatigue behavior of the asphalt mixture by comparing it to Rubberized Hot Mix Asphalt (RHMA). The study concluded that combining rubber with the WMA was beneficial because it improved “the rheological properties of both the unaged and the aged binders.” It was determined also that the warm mix additives offset the increase of production and compaction temperatures induced by the addition of rubber. The fatigue life is greater for warm mix mixtures that include crumb rubber than the control RHMA mixture. The study also found that much of the fatigue life, stiffness, and cumulative dissipated energy values in asphalt mixtures depends on the type of aggregates used (14).

A few other agencies are beginning to look at the use of warm mix technologies with asphalt rubber or with terminal blends containing crumb rubber. A Rubberized Warm Mix Asphalt demonstration project occurred in August of 2008 on I-295, between the Rhode Island border and the I-95 interchange (2). The Orlando Paving Division of Hubbard Construction also installed a RWMA-OGFC along U.S. 27 near the city of Clermont, FL. On U.S. 98, in between Dade City and Lakeland, Florida, an 8 mile stretch of RWMA was placed at 1.5” thick by APAC Southeast Inc. (15). Another trial project which incorporated crumb rubber and the WMA additive Sasobit® occurred in Newcastle, England, in late November of 2006 (16). However, no agency has studied it as much as Caltrans. Their experiences are discussed in the next section.

**SUMMARY OF PROJECTS USING WARM MIX TECHNOLOGIES WITH ASPHALT RUBBER IN CALIFORNIA**

California has begun to see an increase in the use of RWMA projects. This is perhaps, partially due to the fact that by 2013, Caltrans has been mandated to use rubberized asphalt concrete (RAC) in 35% of its total statewide production (17). The projects completed to date are listed in
order of the year completed in Table 3 and their locations can be seen in Figure 1. Additional projects are underway in 2011.

**TABLE 3 Selected AR with Warm Mix Technologies Constructed in California**

<table>
<thead>
<tr>
<th>Road Name</th>
<th>Location (PM: n/n)</th>
<th>Date Constructed</th>
<th>Warm Mix Additive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santa Clara Rte. 152</td>
<td>Santa Clara</td>
<td>Mar 2006</td>
<td>Sasobit</td>
</tr>
<tr>
<td>Interstate 5</td>
<td>Santa Nella (105.9/106.4)</td>
<td>Sep 2008</td>
<td>Astec DBG &amp;Evotherm</td>
</tr>
<tr>
<td>Interstate 5</td>
<td>Orland</td>
<td>May 2009</td>
<td>Evotherm</td>
</tr>
<tr>
<td>Interstate 5</td>
<td>Near Firebaugh, Fresno Co. (PM 37.2 to PM 45.0)</td>
<td>Sep 2010</td>
<td>Astech PER &amp; Engineered Additives WMA</td>
</tr>
<tr>
<td>CA-94</td>
<td>San Diego</td>
<td>Jun 2009</td>
<td>Advera, Evotherm, Sasobit</td>
</tr>
<tr>
<td>SH 70</td>
<td>Marysville</td>
<td>July 2009</td>
<td>Evotherm</td>
</tr>
<tr>
<td>SR-101</td>
<td>Fortuna (54.2/56.3)</td>
<td>Sep 2009</td>
<td>Evotherm</td>
</tr>
<tr>
<td>SH 99</td>
<td>Sutter County</td>
<td>Nov 2009</td>
<td>Evotherm</td>
</tr>
<tr>
<td>Various</td>
<td>City of Roseville</td>
<td>Sep-Oct 2010</td>
<td>Engineered Additives WMA</td>
</tr>
</tbody>
</table>

**FIGURE 1** Locations of California RWMA projects.
**Example of Rubberized Hot Mix Asphalt Applications**

**Santa Clara Project**

In 2006 Santa Clara Rte. 152 received a 1.75 inch overlay on the shoulder using 200 tons of RHMA-G with Sasobit. The Sasobit was added to the rubber binder and mixed for 45 minutes. There was a recorded drop in the production temperature of 40 °F (23 °C) (from 320°F/160 °C to 280°F/138 °C). The paving took place at night with a 30 minute haul time. After two years, the shoulder still “looked good” (1). Figure 2 shows the completed shoulder immediately after construction in 2006 and the shoulder condition in 2008, and also in 2010. There were no signs of distress after four years shown in Figure 2c (18).

![Figure 2a: Santa Clara shoulder in 2006](image1)

![Figure 2b: Santa Clara shoulder in 2008](image2)

![Figure 2c: Santa Clara shoulder in 2010](image3)

**c) 2010**

**FIGURE 2** Finished shoulder for Santa Clara Rte. 152.

**I-5 District 3 (2009)**

The project in District 3 occurred along a 9 mile (36 lane miles) strip of Interstate 5, near Orland. The project called for a removal of the existing OGFC asphalt and replacing it with 1.2 inches of RHMA-O. Approximately 18,000 tons was used for the project along with the WMA additive of Evotherm™. The production temperature started with WMA additive at 320°F (160°C) for the
first 200 tons paved. The temperature was then dropped to 300°F (149°C) where it remained for the rest of the day with 2,200 tons of mix produced at that temperature. For the next three days, the plant’s starting production temperature was 300°F (149°C) and then dropped the temperature to 290°F (143°C) for the rest of the day. On day five, the production temperature started at the usual 300°F (149°C), and then dropped to 290°F (143°C). At 1:30pm, the temperature was again reduced to 285°F (141°C) for approximately 200 tons, then back to 290°F (143°C) for the remainder of the day. At all temperatures, the product was able to be easily placed, with the breakdown temperatures ranging from the specified 285°F (141°C) all the way down to 250°F (121°C), and final rolling temperatures from 235-260°F (113-127°C). There was little to no chunking on the mat or in the windrow, and there was very little smoke.

The binder design was 81.5% PG 64-16 asphalt and 18.5% crumb rubber. Of the percentage of crumb rubber, 75% of that was from recycled tires while the remainder was high natural rubber. With 7.2% rubberized asphalt by dry weight of aggregate, it was estimated that 168 tons of scrap tires were used in the resurfacing of the roadway instead of them ending up in the landfill (19). Figure 3a shows the breakdown rolling of the passing lane in the southbound direction. Figure 3b gives an indication as to the thickness of the overlay and the size of aggregates used. Figure 3c shows that the pavement was in good condition in April 2010.
Example of Asphalt Rubber Spray Applications

I-5, District 6 (2010)
This project took place in September, 2010 and includes chip seals for all shoulder areas and a rubberized asphalt concrete RHMA-G overlay for both the NB and SB No. 1 and No. 2 lanes. It was agreed between the contractor and Caltrans to place a trial section of warm mix asphalt rubber seal coat in place of the contracted polymer modified seal coat. The trial section for the warm mix asphalt rubber seal coat is on the NB median shoulder from PM 37.2 to PM 45.0.

The seal coat consisted of an asphalt rubber binder followed with an application of hot pre-coated chips. The warm mix asphalt rubber consisted of PG 64-16 base asphalt with crumb rubber. The additives included Engineered Additives WMA at 1.5%, and Astech PER at 0.5% by weight of total asphalt binder. The binder was applied at a rate of 0.6 gal/yd². The chip rock consisted of a 3/8 inch pre-coated hot applied screenings and was applied at a temperature of over 300°F. It was pre-coated with 0.5% of PG64-16 and applied at a rate of 30 lbs/yd². The binder design shows the asphalt rubber binder characteristics for 375°F, and for 340°F with 1.5%
WMA additive (20). The asphalt rubber binder for the trial section was applied from the
distribution truck at approximately 340°F and cooled to a temperature of approximately 301°F
by the time it reached the pavement surface. Figure 4 shows the pictures from the Caltrans D6
project.

Figure 4. Photos of Asphalt Rubber Chip Seal Project on I-5 Should in D6

The equipment train ran at approximately 3 miles per hour with 2-sweepers to clean the surface,
followed by 2-oil trucks applying asphalt rubber binder. Shortly after the binder application, a
Bear Cat chip spreader applied the 3/8 inch pre-coated hot chips. The rubber tired roller then
rolled the chips into the hot binder. There was about one or two-minutes time lapse between the binder application and the chip application, but it can have a time window of up to 15 minutes due to the warm mix additives.

Some emissions were visible, but were substantially less than when the binder is applied at the typical 400°F. Energy savings were those resulting from lowering the temperature of asphalt rubber for the warm mix binder from 400°F to 340°F. This 60°F drop in the asphalt rubber binder application temperature reduced energy use and emissions. The warm mix technology also provides a long time period for chip placement and rolling.

**Future plans**
Caltrans has planned more RWMA projects in 2011, primarily in Districts 1 and 3. The total tonnage in these Districts is approaching 1 million tones. These projects will generate more experience on using warm mix technology in rubberized asphalt concrete.

**SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS**

**Summary**
Warm Mix Asphalt is a relatively new, innovative technology that is being used to reduce paving and production temperatures of HMA. There are three different categories of the WMA additives: Chemical, Organic, and Foaming (with and without the use of water). Benefits that have been documented when using WMA are: increased worker safety, improved working conditions, reduction in burner costs, reduction in the amount of burner fuel used, reduction in the blue smoke, and an increase in the haul time and paving season.

Depending on which type of additive used, the plant will need to undergo little to no modifications or many modifications. It is up to contractors or engineers to decide which additive they wish to use and modify that plant to accommodate that additive. Some additives require similar or the same modifications. This will enable the plant to produce the asphalt with both additives and possibly obtain more business due to the fact that it can produce both.

Rubber has been used in the asphalt industry since the mid 1960’s. Over the years, the industry has recycled millions of old tires by using them in the asphalt, saving them from taking up valuable space in our landfills. Rubber has been more expensive to incorporate in the mix design of asphalt because it requires a higher temperature to obtain the desired workability. However, it has been discovered that by adding a WMA additive to the mix design, the production and paving temperatures are reduced. While they aren’t reduced as much as a WMA devoid of rubber, the temperatures can be reduced to a range that makes the use of rubber more cost effective. This can be seen by the increase in the usage of RWMA in recent years, and if these projects yield high-quality results that are equal to or better than HMA, then RWMA will likely be a standard mix for most, if not all, States.

**Conclusions**
The results from this study suggest the following conclusions are warranted:

- Warm mix technologies can be used with asphalt rubber mixes. They allow the mixes to be placed at night and in cooler climates.
• Warm mix technologies can increase the workability of asphalt rubber mixes. They extend the paving season and allow their use where asphalt rubber could not be used before.
• Warm mix technologies can improve workers’ working conditions. They reduce undesired asphalt rubber odor and blue smoke coming with regular asphalt rubber job.
• Warm mix technologies can reduce fuel usage because it reduces the production temperatures by 30 to 80°F (19-45°C). They have energy saving benefits for asphalt rubber mixes.
• Warm mix technologies can reduce emission at both production and paving procedures. The carbon footprint and green house gas conditions can be improved.
• To date, the initial performance of warm mixes asphalt rubber placed in California is good.
• The warm mix AR chip seals offer agencies a maintenance treatment for cracked and aged pavements that has a lower construction cost than a one inch thin blank HMA overlay and faster construction.
• The construction time for a warm mix AR chip seal is much shorter than for a one inch thin blanket HMA overlay, and is less disruptive to the motorists and adjacent residents.
• Depending on the actual temperature reduction of the product, the warm mix alternatives may offer as much as an 80% emission savings, plus a sizable energy savings. This emission reduction may equate to huge cost savings in permit fees paid to air quality control agencies.

Recommendations

Based on the findings to date, the following recommendations are appropriate:

• More agencies should consider the use of warm mixes with asphalt rubber for night time construction and for cool climates.
• More trials should be constructed for using warm mix technologies for spray applications with asphalt rubber and terminal blends.

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