Development of Warm Mix Asphalt Policies and Specifications in Minnesota

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ABSTRACT

Warm mix asphalt (WMA) is a general term describing the use of any additive or technology that allows for lower asphalt plant mixing temperatures. Developed in Europe, WMA was brought to the United States in 2004 and has since gained widespread use around the country. The Minnesota Department of Transportation (MnDOT) saw the promise in this technology, especially the anticipated benefit of reduced low temperature and reflective cracking because of the reduced binder aging at the plant. This paper describes the short history of WMA development in Minnesota, highlighting the policies and specifications surrounding its use.

Warm mix asphalt in Minnesota was really driven by the asphalt paving industry, with parallel work being conducted in MnDOT research. Mathy Construction built the first WMA demonstration projects in 2007 on several county roads in the southeast portion of Minnesota. Anderson Brothers shortly followed suit by building several WMA projects in Crow Wing County in the northcentral part of our state. The county’s early experience led them to quickly allow for alternate WMA bids in new construction projects. More recently, Bituminous Roadways, Knife River, and Duininck Brothers have installed foaming nozzles on a total of six asphalt plants around the Twin Cities and greater Minnesota.

MnDOT paved the first WMA project on a state highway in 2008 at the MnROAD research facility. The following year WMA was used on a mill and overlay project on TH 95 to complete a late season paving project. In 2010 warm mix was required on two district paving projects per the District Materials Engineers’ requests. One of these jobs on TH 169 also incorporated intelligent compaction and the MOBA IR temperature measurement system, which gave MnDOT additional insight into the behavior of WMA during construction.

MnDOT’s warm mix asphalt policy is captured in a 2009 Position Memo written by the Bituminous Engineer. It states in part, “MnDOT is interested in considering the use of WMA as an option to HMA and will proceed on a case-by-case basis.” The 2360 asphalt paving specification is a permissive spec, essentially saying nothing about WMA and therefore permitting its use. RAP and recycled shingles are allowed in WMA mixtures, and the Department has no pre-approved list of WMA technologies. MnDOT staff developed a list of Frequently Asked Questions in 2010 to aid in the implementation by many contractors and local agencies.

MnDOT continues to meet with WMA technology suppliers to better understand the different products on the market. MnDOT personnel have spoken at several conferences and workshops around the state and region, where they have educated agency, industry, and academic personnel about their experience with WMA in Minnesota. The use of warm mix is steadily increasing in Minnesota, and expectations are for that trend to continue.

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BACKGROUND

Introduction to Warm Mix Asphalt

Warm mix asphalt (WMA) is a general term that refers to the use of an additive or technology that allows asphalt mixtures to be produced at lower plant temperatures (1). Temperature reductions from WMA have been documented from 20°F to 100°F. Warm mix was first developed in Europe and brought to the United States in 2004, and since that time its use has grown rapidly throughout the country. Many benefits from using WMA have been postulated, including reduced fuel consumption, lower fumes and emissions, better compaction, and comfort of workers (2-4).

Driving Factors for WMA in Minnesota

The Minnesota Department of Transportation (MnDOT) is a leader in research and implementation of innovative technologies in the pavement industry including recycling, binder modification, intelligent compaction, and other issues. We had a desire as a department to get in on the ground floor of this technology and to closely monitor the growth in its use around the country. MnDOT researchers began tracking WMA in its early days in the U.S. and brought it to the attention of the Bituminous Office with the goal of constructing some demonstration projects around the state.

The biggest driving factor behind MnDOT’s desire to use WMA was its potential reduction in low temperature and reflective cracking. Because of the reduced temperatures at the mixing plant, the WMA binder would encounter less aging or oxidation from Day 1. This reduced aging would hopefully delay the onset of cracking, and the softer binder in general would lessen the extent of cracking once it did occur. Low temperature cracking has long been the primary mode of distress in asphalt pavements in Minnesota, and anything that could be done to reduce this cracking would be received very well. In fact, MnDOT produced a summary report in 2007 that documented the significant reduction in thermal cracking realized from the switch to a softer asphalt binder for new construction with the switch to implementation of the Superpave system in the early 1990s (5). Additional reductions from cracking were anticipated with the use of warm mix.

Another contributing factor for our desire to use warm mix in Minnesota was the broad category of environmental benefits. The safety and comfort of personnel working in asphalt production and paving operations is of paramount importance to MnDOT and the local contractors. Reduced greenhouse gas emissions, fumes, and burner fuel are other environmental benefits we hoped to reap from using warm mix.

In terms of operational benefits from warm mix, MnDOT hoped to see better compaction in the field by way of increased density and more uniform mix placement. The reality of being located in a northern climate means that paving is often done late in the season when weather conditions are less than ideal. Using warm mix would give us a better chance of achieving adequate compaction when late-season paving is necessary.
WARM MIX ASPHALT USE IN MINNESOTA

Asphalt Contractors

In parallel with MnDOT’s efforts to demonstrate the use of WMA, the asphalt producers and paving contractors were early champions of warm mix as well. The Minnesota Asphalt Pavement Association (MAPA) is active in the state, and they put forth early effort to educate industry professionals about warm mix through newsletters, technical briefs, and workshops.

In addition, Mathy Construction Company in Onalaska, WI (just across the border from southeast Minnesota) developed their own warm mix additive after extensive laboratory trials. Many other local contractors began exploring the possibilities of using warm mix asphalt because of the potential benefits they saw from it.

Local Agencies

The first known WMA project in Minnesota was constructed by Mathy Construction Company in Olmsted County in 2007. County Road 104 was paved with warm mix for a 5-mile stretch in one direction, while the other direction was a typical hot mix asphalt control. That same year Goodhue County placed about 537 tons of warm mix along CSAH (County State Aid Highway) 11.

In 2008 Crow Wing County paved County Road 108 with 2913 tons of WMA along with 272 tons of HMA control. This project upgraded the gravel road to a paved surface and was let as an alternate bid project of sorts, with the contractor having the option of using either PG 58-34 asphalt binder or PG 58-28 binder with a warm mix additive. The contractor chose the WMA alternative offered a bid price about $2-3 per ton less than the PG 58-34 HMA. The county performed a life cycle cost analysis on HMA vs. WMA, and they estimated an additional five years of service life were gained with the use of WMA (6). Crow Wing County now allows HMA vs. WMA alternate bids on several projects, and the use of warm mix asphalt is a somewhat regular occurrence.

Several other counties around Minnesota have constructed warm mix asphalt project in recent years including Wright, Scott, and Ramsey Counties. In addition several cities (St. Paul, Edina), local government agencies (Three Rivers Park District), and private developers (Little Six Casino) have used warm mix asphalt with great success.

Minnesota Department of Transportation (MnDOT)

MnDOT constructed our first “pseudo” warm mix asphalt project in 1995 as a demonstration project in conjunction with the TRB Low Volume Roads Conference. However, at the time it was called oil gravel and was a technology borrowed from the Scandinavian countries. Oil gravel used either asphalt emulsion or cutback technology, and it was a thin flexible driving surface over a strong stone base. Several oil gravel test sections were constructed at the MnROAD research facility as well as several county roads throughout Minnesota in the late 1990s. These projects used what could be called warm mix, lukewarm mix, and even cold mix paving practices (7).

The first true warm mix asphalt project by MnDOT was again constructed at MnROAD in 2008. Six Mainline test sections were constructed: five over various aggregate base types and a sixth as an overlay of a 15-year old full depth HMA pavement. These pavements consisted of both wear and non-wear WMA layers and were 12.5 mm Superpave mixtures meeting a traffic
level of 3-10 million Equivalent Single Axle Loads. A PG 58-34 asphalt binder was specified along with 20% RAP that was milled from the 15-year old MnROAD test sections. No requirements for the WMA technology were specified, so the contractor chose Evotherm 3G technology because of its ease of use. The warm mix totaled just over 2100 tons for the project. Both the asphalt plant and paving operations reported business as usual, and positive comments were received from the crew. Laydown temperature was about 225°F. The contractor was able to achieve adequate density with less compactive effort (one less roller). He reported a notable reduction in fumes and emissions, although these were not measured or quantified. Figure 1 shows visual comparisons of HMA vs. WMA operations on the MnROAD project, with a noticeable decrease in emissions from warm mix.

In 2009 another WMA job was constructed late in the fall. The project was let as a typical HMA pavement, but due to circumstances beyond the contractor’s control paving was slated for late October before the winter set in. A supplemental agreement was written to pave with warm mix, and the contractor was paid an additional 60¢ per ton to cover the cost of the Evotherm 3G additive. The contractor initially believed he could get by with less compactive effort, but paving on the first day failed to achieve adequate compaction. After he went back to the same rolling pattern that he used on the HMA portions of the project satisfactory density was achieved.

In 2010 two more WMA projects were let in MnDOT Districts 3 and 7. These required the use of warm mix asphalt for certain portions of the contract, so MnDOT Research and Bituminous Office staff collaborated to write special provisions for the projects. These provisions read, in part,

The contractor is responsible to use the same design used to produce the Hot Mix Asphalt, then modifying it to accommodate products or processes to meet the Warm mix criteria. This modification process will be limited to the same as described by the WMA Technical Working Group and found at http://www.warmmixasphalt.com/WmaTechnologies.aspx.

Recycled Asphalt Shingles will not be allowed in any mixes on this project. The Warm Mix Asphalt produced will not be allowed to exceed temperatures greater than 275°F.

Recycled shingles are normally allowed in MnDOT paving projects at up to 5%, but for these two projects the engineer wanted to put tighter controls on the asphalt mixture.

The District 3 project in northcentral Minnesota actually produced warm mix asphalt at two different temperatures (approximately 235°F and 275°F) along with a control hot mix asphalt section at 300°F. The WMA technology used on this project was again Evotherm 3G. The District 7 project in southwestern Minnesota used a plant foaming technology, AquaBlack, to produce the warm mix. WMA production temperatures on this project were approximately 275°F.

An additional benefit from one of the two WMA projects in 2010 was the use of intelligent compaction and an infrared temperature measuring system on the back of the paver. This innovation was initiated by the MnDOT Bituminous Office in an effort to achieve more uniform compaction as well as a more uniform temperature profile on our bituminous paving projects. This technology was not necessarily aimed at using on warm mix, but it did provide some valuable information to the Department, as shown in Figures 2 and 3. Figure 2 is a screenshot of the data analysis software that very clearly shows both a production temperature change and the paver stops. This information is helpful in providing information to MnDOT and
the contractor for creating a more uniform paving project. Figure 3 is another screenshot that shows thermal segregation from the end of each truck on an HMA paving project. This thermal segregation is not evident in the WMA projects that we have seen (8).

Figure 1. Visible Emissions from WMA (Left) vs. HMA (Right) at the Plant (Top), Loadout (Middle), and Paver (Bottom)
Figure 2. Infrared Data Showing WMA Production Temperature Change and Paver Stops

Figure 3. Infrared Data Showing HMA Thermal Segregation from Truck Loads
In addition, another WMA job is proposed in MnDOT District 8 in 2011. This project will be about 5100 tons of warm mix with the AquaBlack foaming technology. MnDOT and the asphalt contractors in Minnesota are slowly becoming more comfortable with warm mix asphalt, and we expect that trend to continue into the foreseeable future. Table 1 presents a summary of the known MnDOT warm mix asphalt projects.

Table 1. MnDOT WMA Projects

<table>
<thead>
<tr>
<th>Year</th>
<th>Roadway</th>
<th>Closest City</th>
<th>WMA Technology</th>
<th>WMA Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>MnROAD</td>
<td>Monticello</td>
<td>Evotherm 3G</td>
<td>2,118</td>
</tr>
<tr>
<td>2009</td>
<td>TH 95</td>
<td>Stillwater</td>
<td>Evotherm 3G</td>
<td>60,000</td>
</tr>
<tr>
<td>2010</td>
<td>TH 169</td>
<td>Aitkin</td>
<td>Evotherm 3G</td>
<td>39,928</td>
</tr>
<tr>
<td>2010</td>
<td>TH 60</td>
<td>Worthington</td>
<td>AquaBlack</td>
<td>7,430</td>
</tr>
<tr>
<td>2011</td>
<td>TH 12</td>
<td>Willmar</td>
<td>AquaBlack</td>
<td>5,100</td>
</tr>
</tbody>
</table>

CURRENT STATE OF AFFAIRS IN MINNESOTA

MnDOT Policies and Specifications

In 2009 the MnDOT Bituminous Engineer wrote a memo that stated our official Department position regarding the use of warm mix asphalt. The memo describes several benefits of WMA but also mentions that at that point the only MnDOT usage of WMA was at MnROAD. The position affirms,

The 2009 MnDOT Bituminous Specification does not address WMA; however, MnDOT is interested in considering the use of WMA as an option to HMA and will proceed on a case-by-case basis (9).

The following summer Research and Bituminous Office Staff teamed up to write a “Frequently Asked Questions” document regarding warm mix. This document is kept on file and distributed to MnDOT, county, city, contractor, and consultant personnel when they call with questions about WMA. Table 2 lists the questions that are answered in this FAQ document (10).
Table 2. WMA Frequently Asked Questions

<table>
<thead>
<tr>
<th>Question</th>
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<tbody>
<tr>
<td>What is Warm Mix Asphalt?</td>
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<tr>
<td>The contractor has approached us (local agencies) about substituting</td>
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<tr>
<td>WMA for HMA. Should we use WMA on our project?</td>
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<tr>
<td>Should we pay an additional cost for warm mix?</td>
<td></td>
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<tr>
<td>Are there any pavement performance issues with WMA?</td>
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<tr>
<td>With the increased use of RAP and/or shingles, are we getting complete</td>
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<tr>
<td>blending between the recycled and virgin binders?</td>
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<tr>
<td>Are there any different procedures required for QC/QA testing?</td>
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<tr>
<td>How do I perform a WMA mix design?</td>
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<tr>
<td>Can modified binders be used with WMA?</td>
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<tr>
<td>What traffic levels can WMA be used on?</td>
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<tr>
<td>Where can I get more information on WMA?</td>
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</table>

In 2011 the Bituminous Engineer wrote another guidance memo to MnDOT construction resident engineers and materials engineers that again expressed the Department position on warm mix asphalt. This memo reiterates our support of warm mix and states in part,

_To date, we have not experienced any issues with regard to WMA construction. Additionally, I am not aware of any issues relating to WMA construction on the national level._

_Since there is no language in the specification precluding its use WMA is an acceptable alternative to HMA. However, the laboratories performing the testing of WMA need to be aware of its use so that they can adjust their laboratory compaction temperatures (11)._  

MnDOT’s current bituminous specifications are essentially silent on the use of warm mix (12). By not explicitly addressing warm mix, we implicitly allow it on any project. As long as contractors are able to meet all required volumetric and performance criteria, they are free to use WMA. MnDOT specifications allow both recycled asphalt pavement (RAP) and recycled asphalt shingles (RAS) on almost all projects (all mixture types except stone matrix asphalt and porous asphalt) including warm mix asphalt. We have no pre-approved products list for warm mix.

_WMA Technology Used to Date_

To date, the authors are aware of only two WMA technologies that have been used in Minnesota: Evotherm 3G and the AquaBlack plant foaming system.

The current Evotherm technology was originally developed by Mathy Technology and Engineering in cooperation with Paragon Technical Services under the name Revix. It is now marketed by MeadWestvaco under the name Evotherm 3G. It is a waterless chemical package that is typically blended with the asphalt binder at the terminal and comes to the asphalt plant ready to use. At least one contractor in Minnesota has used this technology on enough projects that he has set up his asphalt plant to add the chemical package on site. We suspect that many contractors have chosen Evotherm 3G because of its ease of use and potentially significant temperature reductions (13).
The other WMA process used in Minnesota, AquaBlack, is a simple foaming device that is easy to install and operate on an existing asphalt plant. This device costs considerably less than many other plant foaming technologies, and the manufacturer claims that its efficient design will require minimal maintenance over time. At least three asphalt mix producers have purchased the AquaBlack foaming device and installed it on at least six plants around Minnesota. The likely reasons that contractors have used this technology include its relatively low cost and ease of use (14). In fact, several plants have the foaming nozzle turned “on” all the time when producing asphalt mixtures. One of the drawbacks from this technology is that temperature reductions have been on the order of 20°F to 50°F; contractors have not been able to achieve as significant temperature reductions as with some other WMA technologies.

In addition, MnDOT staff have had conversations with representatives of several other warm mix technologies including Akzo Nobel, Aspha-min, Astec, LEADCAP, McConnaughay Technologies, PQ Corporation, and Shell. MnDOT is very open to exploring other WMA technologies if the opportunity presents itself. Our position is that we will not specify (or rule out) a particular WMA technology. We will evaluate each product on a case-by-case basis to determine if it has a beneficial use in Minnesota.

WMA TECHNOLOGY TRANSFER AND IMPLEMENTATION

Technology Transfer
MnDOT has been engaged in multiple technology transfer activities in recent years regarding warm mix asphalt. These include presentations at local and regional conferences and workshops, publications, information and data sharing with outside groups, and advising a university undergraduate student group on a warm mix asphalt synthesis project. MnDOT Research and Bituminous Office staff have presented the use of warm mix asphalt at several conferences, workshops, and business meetings in Minnesota and surrounding states. These presentations have been in front of a wide audience including state and local agencies, contractors, university researchers, consultants, and Federal Highway Administration. These conferences include:

- Association of Asphalt Paving Technologists
- Combined State Binder Group
- Greater Iowa Asphalt Conference
- Minnesota Association of Asphalt Paving Technologists
- Minnesota Asphalt Contractors’ Workshop
- Minnesota Asphalt Pavement Association Annual Meeting
- Minnesota Local Road Research Board
- Minnesota Pavement Conference
- MnDOT Design Engineers Workshop
- MnDOT District Engineers Meeting
- MnDOT Materials Engineers Organization Meeting
- MnDOT Office of Materials & Road Research Employee Meeting
- North Dakota Asphalt Conference
- North Dakota Society of Professional Engineers
- State Pavement Technology Consortium
Transportation Research Board Annual Meeting
TRB AFD40 Committee (Accelerated Pavement Testing) Webinar
TRB International Partnership Meeting
Western Research Institute Pavement Performance Prediction Symposium

MnDOT staff have written several publications that share information about warm mix asphalt in Minnesota. These include a TERRA Fact Sheet and a MnROAD Research Brief that were both published in June 2009 (15-16) as well as a research paper that was presented at the ASCE T&D Congress in 2011 on sustainable technologies at MnROAD (17). This paper was subsequently edited and reprinted in the May 2011 issue of Civil Engineering to be distributed to a wide engineering audience (18).

MnDOT staff also receive numerous phone calls and email inquiries regarding our use of warm mix. We have shared information with graduate students at North Dakota State University, Texas A&M, University of Minnesota, and other universities. We have also provided information to the US Environmental Protection Agency and the National Cooperative Highway Research Program (NCHRP) regarding the use of WMA in Minnesota.

Finally, MnDOT Research staff advised an undergraduate student group at Michigan Technological University on a project entitled “Warm Mix Asphalt Application Synthesis for the Upper Midwest.” The goal of this project was to gather information on current WMA practices, capabilities, and experiences in northern climates. The project team produced a white paper (19) and hosted a webinar. These final products detailed current practices for using WMA in northern climates, highlighted successful WMA projects, and identified impediments to the increased use of warm mix.

**Implementation Support**

Imperative in any research program is the support of local champions to bring a technology into full implementation. MnDOT Research and Bituminous Office staff have been actively supporting state and local agencies as they implement warm mix asphalt on their projects.

Perhaps most importantly, we began by supporting our own MnDOT District material and construction personnel. We have helped to write specifications, be present during construction to observe and help solve any issues, answer questions regarding quality control and quality assurance testing, and track WMA pavement performance over time.

MnDOT staff have since branched out to talk with bituminous pavement engineering staff in North Dakota, Wisconsin, Iowa, Maryland, California, Texas, and Washington state. These have taken the form of both informal conversations and more formal face-to-face meetings where we discuss various WMA technologies, specifications, laboratory testing procedures, long term pavement performance, and a host of other issues. This information sharing allows MnDOT staff to continually improve our specifications and practices while at the same time assist neighboring states in their implementation of warm mix.

MnDOT staff have also assisted several cities and counties as they began to implement warm mix throughout Minnesota. We have helped Crow Wing, Scott, and Wright Counties (among others) with the same issues described above, most notably specification development and laboratory testing procedures. MnDOT Research receives a significant amount of funding from the Minnesota Local Road Research Board, so as part of this funding we are available to advise local agencies on a wide range of pavement-related topics including warm mix.
Lingering Questions

While MnDOT is excited about the growing use of warm mix in Minnesota and around the country, we realize that it is not a panacea and will not solve all our problems. The authors are hard pressed to recall a warm mix project anywhere in the country that went poorly. Perhaps because this is still a relatively new technology, contractors and agencies are paying attention and doing all the things they should be doing in terms of best practices. However as the use of WMA becomes more common, people may have a tendency to get complacent. This is where problems will occur.

The biggest question that MnDOT personnel have is in regards to how much RAP and RAS can realistically be added to WMA without causing problems. We have been concerned lately that increased percentages of RAP lead to incomplete blending between recycled and virgin binders. Due to the reduced plant mixing temperatures inherent in the use of WMA, the amount of heat transfer to the RAP is likely to be less. Significantly stiffer RAS materials are thought to have even more problems in this regard. With that being said, MnDOT has not explicitly limited the amount of RAP in WMA, although in some cases RAS was prohibited. The NCHRP 9-43 project has gone a long way in answering these questions, essentially saying that the RAP and virgin binders do blend adequately under normal circumstances and that RAS binders may not fully blend depending on mix temperatures (20).

Other questions that MnDOT has regarding the use of WMA involve the long term pavement performance. Rutting, moisture damage, thermal and reflective cracking, and durability are issues that have been raised by others, but we have not seen these problems in Minnesota to date. MnDOT staff continue to stay abreast of local and national research on warm mix asphalt, and we are considering carefully how the results can be implemented in Minnesota.

SUMMARY

This paper provided information on how MnDOT has progressed from our early uses of warm mix asphalt to where we are today. MnDOT recognizes WMA as a significant technological advancement that, unlike any other in recent memory, will change the way asphalt pavements are built in Minnesota. The wide range of WMA technologies has tremendous potential to benefit both specifying owner agencies and contractors in our state. MnDOT stands to benefit from improved pavement performance, increased density, and better pavement uniformity. Contractors stand to benefit from increased profits (from density and ride incentives) that come with building better, more uniform pavements. Everyone involved including MnDOT, contractors, and the general public, will benefit from reduced effects on the environment during production. As MnDOT continues to gain comfort and expertise with warm mix asphalt, we aim to share our experiences with others so that it becomes implemented on a widespread basis.
REFERENCES