WARM MIX ASPHALT

THE INTERNATIONAL TECHNOLOGY SCANNING PROGRAM

SUMMARY REPORT

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July 11, 2007

Submitted to:

American Trade Initiatives

For distribution to:

U.S. Department of Transportation, Federal Highway Administration
American Association of State Highway and Transportation Officials,
National Cooperative Highway Research Program

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ACKNOWLEDGMENTS

This summary report was completed in cooperation with the members of the scan team and all of the transportation professionals, materials scientists and engineers, and organizational representatives who hosted the scan team and gave their time and energy to organize presentations and site visits in the various countries on the scan itinerary. Without their gracious hospitality and willingness to share their knowledge and experiences with the U.S. delegation, this report would not have been possible.

Numerous contributions were made to this report by the Warm Mix Asphalt Scan Team. The team members were: John Bartoszek (Payne and Dolan Inc.), Gaylon Baumgardner (Ergon, Inc.), Matthew Corrigan (FHWA), Jack Cowsert (North Carolina Department of Transportation (DOT)), John D'Angelo (FHWA Co-Chair), Eric Harm (Illinois DOT Co-Chair representing AASHTO), Thomas Harmon (FHWA), Mostafa "Moe" Jamshidi (Nebraska Department of Roads), H. Wayne Jones (Asphalt Institute), David Newcomb (National Asphalt Pavement Association), Ron Sines (P.J. Keating Company), and Bruce Yeaton (Maine DOT).   The author is also grateful for all of the effort put into the review of this document by the team members, particularly the co-chairs, Eric Harm and John D'Angelo, Matt Corrigan and Dave Newcomb. This truly was a team effort.

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SUMMARY REPORT

A number of new technologies have been developed to lower the production and placement temperatures of hot mix asphalt (HMA). Generically, these technologies to reduce production temperatures are referred to as warm mix asphalt (WMA). These technologies originated in Europe in response to a variety of concerns. Beginning in 2002, interest in these technologies has grown in the United States (U.S.). The American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) organized a scanning tour to Europe, allowing U.S. experts to meet first hand with the agencies who first used these technologies, the suppliers and contractors who developed them, and the contractors who build WMA pavements. The tour also allowed the team to view the performance of some of the oldest WMA projects in Europe.

A team of thirteen materials experts from the U.S. visited four European countries, Norway, Germany, Belgium, and France, in May 2007 to assess and evaluate various technologies for reducing the temperatures at which hot mix asphalt (HMA) is mixed and compacted. The scan team represented a wide variety of HMA interests in the U.S. including state agency AASHTO representatives, FHWA representatives, asphalt supplier and HMA contractor industry representatives, and a consultant. The team learned about a wide range of technologies, discussed with various agencies how and why they were implementing these technologies, visited construction sites, and viewed in-service pavements. In addition, the team tried to understand how conventional HMA practice differs between the U.S. and the various European countries and how these differences might affect potential implementation in the U.S.

The information obtained during the trip identified several implementation items to further the use of WMA in the U.S. This document provides preliminary descriptions of the findings and recommendations of the team. A separate report is currently being prepared that will provide a full description of the findings and recommendations from this trip.

Background Information

The FHWA's Office of International Programs identifies and evaluates innovative foreign technologies and practices that could significantly benefit highway transportation systems in the U.S. This approach allows advanced technology to be adapted and put into practice much more efficiently without unnecessarily spending scarce research funds to recreate advances already achieved in other countries (*1*). The main channel for accessing foreign innovations is the International Technology Scanning Program. This program is undertaken jointly with the American Association of State Highway and Transportation Officials (AASHTO) and its Special Committee on International Activity Coordination, the Transportation Research Board's National Cooperative Highway Research Program (NCHRP), private industry, and academia.

Issues of Interest

The purpose of the scan was to gather information on technologies used to produce WMA, with particular emphasis on long-term field performance. The scan team identified the following specific topics of interest pertaining to the use of WMA in Europe:

- *WMA Processes* - What processes, materials and construction practices are being used in the production and placement of Warm Mix Asphalt (WMA)?
- *Mix Design and Construction Practices* - How do these processes, materials, and production practices differ from standard mix designs and production?
- *WMA Performance* - What are the performance characteristics of WMA in terms of rutting, fatigue cracking, thermal cracking, moisture damage, etc.?
- *Limitations of WMA* - What class of roadway or pavement, traffic volumes, and truck volumes are best suited for WMA use?
- *WMA Benefits* - What are the benefits and future plans for using WMA?

Summary of Findings

A number of factors were consistently identified which are driving the development of WMA in Europe including:

- Environmental aspects and sustainable development concerns, "Green Construction," particularly reduction of energy consumption and resulting reduction in CO_2 emissions.
- Improvement in field compaction. Improvements in the compactability of WMA mixes facilitate an extension of the paving season and allow the possibility for longer haul distances.
- Welfare of workers, particularly with Gussaphalt or mastic asphalt which is produced at much higher temperatures than HMA.

One of the pillars of sustainable development is environmental protection. Reduction in the usage of natural resources (fuel) and the production of CO_2 are key elements of sustainable development. Reduction of CO_2 emissions are mandated as part of the European Union's ratification of the Kyoto Agreement. It does not appear that the Kyoto Agreement directly impacts the HMA industry in Europe. However, the HMA industry has taken a proactive approach in investigating means of reducing CO_2 emissions. This was apparent in all of the countries visited.

Although not a prime factor, some contractors acknowledged that improvement in field compaction was realized when using WMA technology. They saw this as an added benefit in insuring adequate in-place density for long term performance. More widely recognized were potential benefits of extending the paving season and potential for longer haul distances. As in the US, there are locations in Europe having climatic conditions which restrict HMA placement to warmer months. Extending the paving season and or providing for longer haul distances can make the use of HMA more economical.

Contractors noted that reduced temperatures improved workers' comfort and productivity. In addition, enforcement of a new European Union regulation called REACH, Registration, Evaluation, Authorization of Chemical substances, will begin in 2007. It requires chemical suppliers to provide information to workers on potential exposure and to set derived non-effect levels (DNEL). Asphalt binders are included under these regulations. Research has shown a strong correlation between production temperatures and asphalt fume production. It is anticipated the DNEL levels will set asphalt application temperatures less than 200 °C (392 °F). While this is well above the temperature at which HMA is placed, particularly in the U.S., it is less than temperatures used for the production of Gussasphalt. Gussasphalt (mastic asphalt) currently makes up 1.6 percent of the total HMA usage in Germany. Mastic asphalt is also used in France, mainly in Paris. Although mastic asphalt usage is relatively small, it is a technology which agencies want to continue to specify. This seems to be a driving force towards WMA in areas where mastic asphalt is routinely used. Mastic asphalt is not used in the U.S.

WMA Technologies

There are a number of ways to classify the WMA technologies viewed during the scan. One way of classifying the technologies is by the degree of temperature reduction. Figure 1 shows a classification of various application temperatures for asphaltic concrete from cold mix to hot mix. Warm asphalt mixes are separated from half-warm asphalt mixtures by the resulting mix temperature. If the resulting temperature of the mix at the plant is less than 100 °C (212 °F), the mix is considered a half-warm mix. If the temperature of the mix at the plant is above, 100 °C (212 °F), the mixture is considered a warm mix. There is still a wide range of production temperatures within warm mix asphalt, from mixes that are 20 to 30 C° below HMA to temperatures slightly above 100 °C (212 °F).

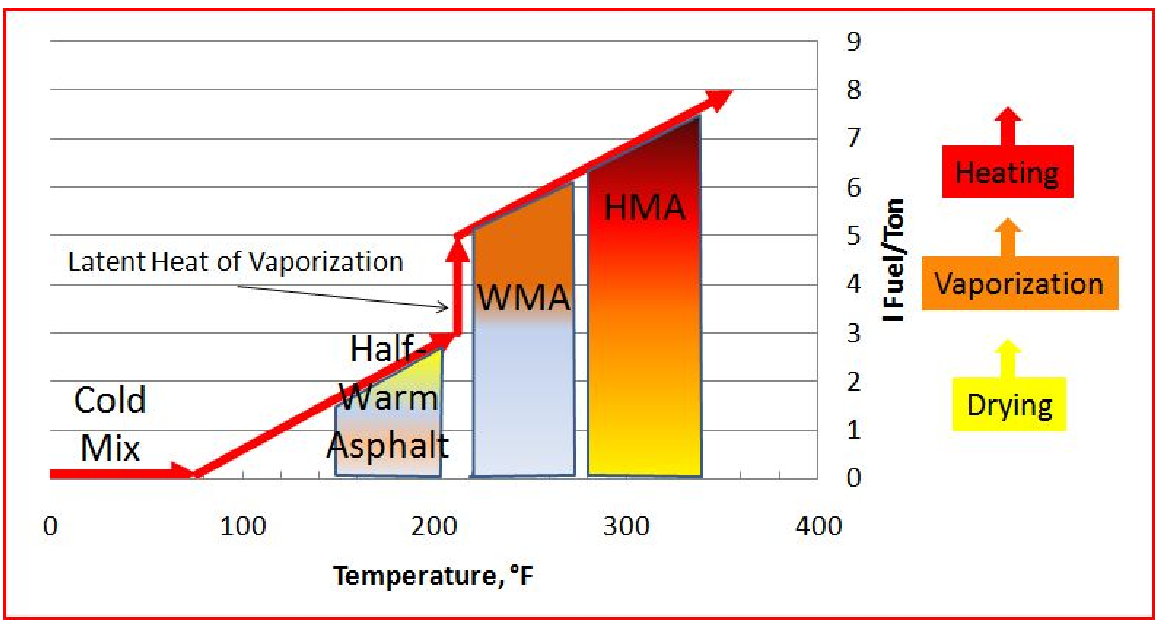

Figure 1. Classification by Temperature Range (approximate values).

Two other major classes of WMA technologies are those that use water and those that use some form of organic additive or wax to affect the temperature reduction. Processes that introduce small amounts of water to hot asphalt, either via a foaming nozzle or a hydrophilic material such as zeolite, or damp aggregate, rely on the fact that when a given volume of water turns to steam at atmospheric pressure, it expands by a factor of 1,673 (*2*). When the water is dispersed in hot asphalt and turns to steam (from contact with the hot asphalt), it results in an expansion of the binder phase and corresponding reduction in the mix viscosity. The amount of expansion varies depending on a number of factors including the amount of water added and the temperature of the binder (*3*).

The processes that use organic additives, e.g. Fischer-Tropsch wax, Montan wax, or fatty amides, show a decrease in viscosity above the melting point of the wax. The type of wax must be selected carefully, such that the melting point of the wax is higher than expected in-service temperatures (otherwise permanent deformation may occur) and to minimize embrittlement of the asphalt at low temperatures.

Additional processes include sequential coating of aggregates. Table 1 briefly summarizes the processes observed in Europe. A brief discussion of each process follows.

TABLE 1 WMA Technologies

WMA Process	Company	Additive	Production Temperature (at plant), °C	Use Reported in	Approximate Total Tonnage Produced to Date
Organic (wax) Additives – added to binder or mix					
Sasobit (Fischer-Tropsch Wax)	Sasol	Yes, in Germany added on average at 2.5% by weight of binder, lower doses, 1.0-1.5%, used in U.S.	Varies, 20-30 C° (36-54 F°) drop from HMA. German guideline recommend 130 to 170 °C (266 to 338 °F), depending on binder stiffness	Germany and 20 other countries worldwide	> 10 million tons worldwide
Asphaltan-B (Montan Wax)	Romonta	Yes, in Germany added on average at 2.5% by weight of binder	Varies, 20-30 C° (36-54 F°) drop from HMA. German guideline recommend 130 to 170 °C (266 to 338 °F), depending on binder stiffness	Germany	Unknown
Licomont BS 100 (additive) or Sübit (binder) (Fatty Acid Amides)	Clariant	Yes, approximately 3% by weight of binder	Varies, 20-30 C° (36-54 F°) drop from HMA. German guideline recommend 130 to 170 °C (266 to 338 °F), depending on binder stiffness	Germany	> 322,500 square meters since 1994
3E LT or Ecoflex (Proprietary)	Colas	Yes	Varies, 30 - 40 C° (54-72 F°) drop from HMA	France	Unknown
Foaming Processes					

WMA Process	Company	Additive	Production Temperature (at plant), °C	Use Reported in	Approximate Total Tonnage Produced to Date
Aspha-min (zeolite)	Eurovia and MHI	Yes, approximately 0.3% by total weight of mix	Varies, 20-30 C° (36-54 F°) drop from HMA. German guideline recommend 130 to 170 °C (266 to 338 °F), depending on binder stiffness	France and Germany US	Approximately 300,000 tons
ECOMAC (cold mix warmed before laying)	Screg	Yes (unknown type/quantity)	Placed at ˜45 °C (113 °F)	France	Some trials
LEA, also EBE and EBT (foaming from portion of aggregate fraction)	LEACO, Fairco, and EiffageTP	Yes, 0.2 to 0.5% by weight of binder of a coating and adhesion agent	< 100 °C (212 °F)	France, Spain, and U.S.	70,000 tons
LEAB® (direct foam with binder additive)	BAM	Yes, added at 0.1% by weight of binder to stabilize foam, aid in coating, and promote adhesion.	90 °C (194 °F)	Netherlands	Seven commercial projects
LT Asphalt (foamed asphalt with addition of hygroscopic filler to maintain workability	Nynas	Yes, added 0.5 to 1.0% of a hygroscopic filler	90 °C (194 °F)	Netherlands and Italy	Unknown
WAM-Foam (soft binder coating followed by foamed hard binder)	Kolo Veidekke, Shell, and BP	Not necessary. A surfactant may be added to aid in the foaming of certain binders and an anti-stripping agent may be added to the soft binder.	110 - 120 °C (230 – 248 °F)	France and Norway, also Canada, Italy, Luxembourg, Netherlands, Sweden, Switzerland, and United Kingdom	> 60,000 tons
Emerging U.S. Technologies					
Evotherm™ (hot aggregate coated with emulsion)	Mead-Westvaco	Yes	85 – 115 °C (185 – 239 °F)	France, also Canada, China, South Africa, and U.S.	> 17,000 tons

WMA Process	Company	Additive	Production Temperature (at plant), °C	Use Reported in	Approximate Total Tonnage Produced to Date
Double-Barrel Green	Astec	Not necessary. An anti-stripping agent may be added similar to normal HMA	116 – 135 °C (240 – 275 °F)	U.S.	>4,000 tons
Mathy Construction		Dilute surfactant	110 °C (230 °F)	U.S.	Trial sections only

Organic Additives

Fischer-Tropsch paraffin waxes are produced by treating hot coal with steam in the presence of a catalyst. They are long-chain aliphatic hydrocarbon waxes with a melting point of more than 98°C (208°F), high viscosity at lower temperatures and low viscosity at higher temperatures. They solidify in asphalt from between 65 - 115°C (149 - 239°F) into regularly distributed microscopic small stick shaped particles. It may be used to modify binder or added directly to the mixture (*4, 5*).

Montan Wax is a combination of non-glyceride long-chain carboxylic acid esters, free long-chain organic acids, long-chain alcohols, ketones and hydrocarbons and resins; it is a fossilized plant wax. The melting point is 82-95°C (180-200°F). Also known as lignite wax or OP wax, Montan wax is obtained by solvent extraction of certain types of lignite or brown coal. Montan wax is used for making car and shoe polishes, paints, as lubricant for molding process, paper, and plastics. About a third of total world production is used in car-polishing polishes. Unrefined Montan wax contains asphalt and resins, which can be removed by refining (*5*).

Fatty Acid Amides are produced by reacting amines with fatty acids. Typically, the melting point is between 141–146°C (286 -295 °F). Similar products have been used as viscosity modifiers in asphalt for a number of years and are available in various forms from a number of suppliers. Fatty Acid Amides have been used in roofing asphalt since the late 1970s to early '80s (*5, 6*).

Foaming Processes

Aspha-Min is a synthetic zeolite composed of aluminosilicates of alkalimetals. It contains approximately 20 percent water of crystallization which is released by increasing temperature. Typically 0.3 percent zeolite by weight of mixture is added to the mixture shortly before or at the same time as binder. The zeolite releases a very small amount of water, creating a controlled foaming effect, leading to a slight increase in binder volume, and therefore reducing viscosity of the binder. Gradual release of water reportedly provides a 6 to 7 hour period of improved workability, which lasts until the temperature drops below approximately 100°C (212°F) (*5, 7*).

Little is known about the Ecomac process at this time. It appears that a traditional cold mix is prepared using an emulsion. The cold mix is stored until it is ready to be laid at which time it is warmed to improve compaction and the overall mechanical properties (*10*).

LEA, EBE, and EBT all use moisture contained in the aggregates to foam the asphalt. In the LEA process, the coarse aggregate is heated to approximately 150 °C (302 °F) and is then mixed with the total binder required for the mixture at the normal binder temperature (appropriate for the particular grade). Approximately 0.5 percent by weight of binder of a coating and adhesion additive is added to the binder just prior to mixing. After the coarse aggregate is coated, it is mixed with the cold, wet fine aggregate. Ideally, the fine aggregate should contain approximately 3 percent moisture. This moisture turns to steam and causes the asphalt on the coarse aggregate to foam, which in turn encapsulates the fine aggregate. The resulting (equilibrium) mix temperature is less than 100 °C (212 °F). In a drum plant, the fine aggregate would typically be added through the reclaimed asphalt pavement (RAP) collar. If the fine aggregate is too wet, a portion of the fine aggregate can be dried with the coarse aggregate (*8*).

The LEAB process is a commercialization of the half-warm foamed asphalt work completed by Jenkins (*3*). This process has only been used in batch plants to date. This is the only process, other than ECOMAC, which does not heat at least a portion of the aggregate to temperatures above the boiling point of water. The virgin aggregate is heated to approximately 95 °C (203 °F). RAP is heated in a separate dryer drum to 110 – 115 °C (230 – 239 °F). Typically, 50 percent RAP is used in the Netherlands. During the trials to assess moisture content of the aggregate, it was noted that the moisture content of the fines/filler going to the baghouse was high, approximately 2.2 percent. Therefore, the contractor who developed the mix, BAM, added an extra burner (after the pugmill) to heat the air going into the baghouse. An additive is added to the binder immediately before mixing to promote coating and adhesion. This additive also tends to extend the life of the foam, increasing workability (*9*).

The Nynas low temperature asphalt (LT Asphalt) uses a special foaming process in combination with about 0.5 to 1.0 percent of hydrophilic filler which helps to hold and control latent moisture from foaming. The aggregates are heated to 90°C (194°F), a special penetration graded binder is foamed with special nozzles and mixed with the aggregates along with the hygroscopic filler (*10*).

WAM-Foam is a process, not an additive or material. It is reportedly a common practice in Norway that the contractor maintains two asphalt binder grades, one nominally soft, and one nominally hard. The soft and hard binder are blended in-line to produce the desired binder grade. The soft binder typically has a viscosity grade of 1500 centistokes at 60^{o}C (V1500); the hard binder is typically a 70/100 Pen, or approximately a PG 58/64-22. The aggregate, minus any filler, is heated to approximately 130 °C (266 °F) and then coated with the soft binder which is typically 20 to 30 percent of the total binder. The hard binder is then foamed into the mixture by adding cold water at a rate of 2 to 5 percent by mass of the hard binder at approximately 180 °C (356 °F). This would result in approximately 1.6 lbs of water per ton of mix for a 5 percent total asphalt content mixture. The resulting binder grade for 20 percent of a V1500 and 80 percent of a 70/100 Pen binder would be a 70/100 Pen binder, <u>unaged</u>. Coating the coarse aggregate with the soft binder acts to satisfy the asphalt absorption of the coarse aggregate that may not otherwise occur with a stiffer binder at low temperature (*11, 12*).

Emerging U.S. Technologies
In addition to the technologies discussed in Europe, the Scan Team is aware of a number of technologies under development in the U.S.

Evotherm™ was developed in the U.S. In the original process, an emulsion is mixed with hot aggregates to produce a resulting mix temperature between 85 to 115 °C (185 to 240 °F). The emulsion is produced using a chemical package which is designed to enhance coating, adhesion, and workability. The majority of the water in the emulsion flashes off as steam when the emulsion is mixed with the aggregates. A new process has been developed called DAT, for which the same chemical package diluted with a small amount of water is injected in-line just before the mixing chamber.

Astec Industries is developing a foaming system that can be retrofitted to an existing HMA plant to produce WMA. The system uses a manifold with ten nozzles to produce the foam. Approximately 1 lb (454 g) of cold water is introduced through the nozzles per ton of mix; causing the binder to expand approximately 18 times. Typical production temperatures are 135 °C (275 °F) with the mixture being placed as low as 115 °C (240 °F).

Mathy Construction Company developed a WMA process where a diluted surfactant is injected in-line in conjunction with an expansion chamber to cause foaming and help lubricate the mix. The surfactant reduces the volatility of the foaming process and increases the half-life or working time of the resulting foam. WMA using this process is typically produced at 110 °C (230 °F). Trial sections are planned in Minnesota and Wisconsin in 2007.

WMA Mix Design and Specification Process

In Norway, the Norwegian Public Roads Administration will allow WAM-Foam to be used as long as it meets all of the same specifications as HMA. There are no variances. A special laboratory foaming unit is required to produce WAM-Foam in the laboratory. The Norwegian Public Roads Administration does require a 5-year materials and workmanship warranty. Some of the items monitored under the warranty include: potholes, longitudinal joints, delamination, voids, and ride. Pavements are rehabilitated when 10 percent of the rut depth measurements exceed 25 mm.

Although much of the research at BASt in Germany has concentrated on warm mastic asphalt mixtures which are not used in the U.S., the approach to performance testing and monitoring is of interest. Initially, laboratory screening tests including indentation (a standard test for mastic asphalt), wheel-tracking, bond value, and flexural tensile strength tests were performed. Based on the positive outcome of these tests, field trials were initiated. Field trial sections were subjected to heavy traffic on expressways. Samples were taken along with temperature and emissions data during paving. Field trials are monitored for permanent deformation, layer thickness, and surface condition for a minimum of five years. These sections have been monitored since 2002. Other data were gathered from test sections constructed by contractors on commercial projects. Based on the experience to August 2006, a “Merkblatt”, or guidelines on the use of WMA, was issued. The guidelines include information on five additives/modifiers for HMA including, Fischer-Tropsch wax, Montan wax, fatty acid amides, a blend of Montan wax and fatty acid amides, and zeolite. Zeolite is only to be used in HMA, not mastic asphalt. Germany also requires a materials and workmanship warranty, typically for four years after construction.

In France, new innovations for road authorities are evaluated by a partnership between the developer (often a contractor) and the road directorate. SETRA, Service of Technical Studies of the Roads and Expressways, represents the road directorate. Both partners have to fund the evaluation. The evaluation process starts with a laboratory evaluation; if successful, field trials are undertaken, and then guidance papers are prepared for use of the product. The final step is to incorporate the product into existing standards or develop new ones if no applicable standard exists. Trial sections are constructed along with a control section, each a minimum of 500 meters long. Trial sections are monitored for a minimum of three years. Typically, at least three trial sections are used to evaluate a single product, and a certificate is awarded at the end of a successful evaluation. The certificate technically validates the product and provides guidelines for the product's use. Certificates are often used by contractors for marketing. In 2007, Aspha-min zeolite was awarded a certificate by SETRA (Figure 2). SETRA can recommend, but not mandate, that contractors use certified products. However, a representative from a private toll road company, Cofiroute, said that they would not use an uncertified product unless they had conducted their own experiments. SETRA is not involved with urban roads. Therefore, municipalities, such as Paris, conduct their own experiments.


Sétra

CHARTE DE L'INNOVATION AUTOROUTIERE

CERTIFICAT

Figure 2. Aspha-min SETRA Certificate.

In 1988, the European Union (EU) issued the Construction Product Directive (CPD), aimed at eliminating trade barriers for construction materials produced by the various nations within the EU. The CPD requested the harmonization of standards for a variety of construction materials, including HMA. The harmonization of standards and test methods was overseen by CEN Technical Committee 227 which has developed definitions, test methods, product standards, and quality standards for the production of HMA. Product standards have been prepared for dense-graded mixtures, stone matrix asphalt, porous mixtures, and recycled asphalt, as well as other products. For dense-graded mixtures, there is both an empirical and a fundamental design procedure. The fundamental design procedure is based primarily on the French methodology. However, even the empirical design methodology includes performance-related parameters such as wheel-tracking and moisture resistance tests. The goal is to have HMA, WMA, and half-warm mixes designed the same way to the same standards.

WMA Production and Placement

As the team travelled throughout Europe, we were repeatedly told that the aggregates used to produce WMA must be dry, unless a specific moisture content was called for in the aggregate. Residual moisture in the aggregates has been a concern in the U.S. Several factors were observed which may help the Europeans achieve dry aggregates at lower production temperatures, including: use of aggregates with lower water absorption, prevalence of batch plants, and in some cases higher "warm" temperatures than have been used in the U.S. to date.

In Norway, the composite moisture content of the aggregates going into Kolo Veidekke's plant near Ås ranged from 2 to 3 percent. Further, they practiced good material management practices like covering their RAP pile (Figure 3) and their conveyors. In Germany, aggregates with low water absorptions, such as gneisses, granites, and quartzite are generally used. The aggregates used in HMA in every region of France have less than 1 percent water absorption. Lower water absorptions and composite moisture contents make it easier to dry the aggregates.

Figure 3. Kolo Veidekke's Covered RAP Storage.

The U.S. WMA Scan Team visited three asphalt plants producing WMA, one each in Norway, Germany, and France. All three plants were batch plants. The plants used to produce LEAB in the Netherlands were also batch plants. Kolo Veidekke in Norway operated drum plants too, and had modified an Amman drum plant to produce WAM-Foam. The drum plant was rated for 250 tons per hour, but typically operated in the 125 to 150 ton per hour range. Drum plants of varying sizes are also used in France.

It is hypothesized that dryer aggregate results from a batch plant operated at lower temperatures due to the increased storage time at an elevated temperature prior to coating. The smaller drum plants used in some cases have correspondingly smaller burners, making it easier to adjust the burner to run at lower temperatures. Problems with unburned fuel were not reported. Finally, in Germany, HMA is normally produced at higher temperatures than the U.S. The Merkblatt on WMA recommends that WMA be produced between 130 and 150 °C (266 and 302 °F), a 20 to 30 C° (36 to 54 °F) reduction from HMA produced in Germany (*13*).

The actual plant modifications required to produce WMA vary widely based on the technology. These will be described in more detail in the final report, although some description is included along with the description of the technologies. There are many considerations for a contractor considering WMA. Some technologies require an additive which will have a perpetual cost for every ton produced. Other technologies require significant plant modifications, but may have reduced or no long-term additive costs. From a contractor's standpoint, agencies should specify WMA on a functional basis, e.g. temperature reduction and performance, not necessarily a specific technology and allow the contractor to decide what the best way to achieve the functional requirements is.

From a placement standpoint, no differences were noticed between the equipment used to place HMA and WMA. Heavy, tamping bar, vibratory screed pavers are commonly used in Europe. In fact, they were used at all four paving sites visited by the U.S. WMA Scan Team. Kolo Veidekke has used a conventional paver when "track paving" a rutted pavement with WAM-Foam. It was generally noted that the paving equipment was cleaner when using WMA. Workability seemed to vary somewhat depending on the process, however in most cases it seemed to be good. Steel-wheel rollers were used on all of the projects visited. Rubber tire rollers are used sparingly, on HMA or WMA, in the countries visited. A Sasol representative stated that there was no observed difference in pick-up with a rubber tire roller when compacting WMA produced with Sasobit. Compaction was reportedly achieved in the same or fewer passes. Paving crews seemed to prefer WMA, particularly in the hottest part of the summer. Workers placing mastic asphalt in Germany definitely preferred the lower temperatures.

Performance of WMA

The general consensus in the countries visited on the scan tour was that WMA should provide equal or better performance than HMA. The U.S. WMA Scan Tour viewed six WAM-Foam pavement sections in Norway representing a range of traffic volumes (Figure 4). The Norwegian Public Roads Administration provided pavement management data on 28 WAM-Foam sections representing 17,800 tonnes of WMA ranging in age from two to eight years. Performance of the sections has been mixed. Where poor performance occurred, it was not attributed to the use of WAM-Foam, but rather other factors. The WAM-Foam sections appeared to perform similarly to previous HMA overlays (*14*). Good performance was achieved for the section with 15 percent RAP.

Figure 4. U.S. Scan Team Inspecting WAM-Foam Pavement in Norway

In Germany, laboratory and field performance data was presented on seven WMA test sections being monitored by BASt. In all cases, the test sections had the same or better performance than the HMA control sections (*7, 15*). In addition, several of the WMA additive suppliers presented performance data on a variety of trial sections, some of them on commercial projects. Again, the performance of the WMA was as good as or better than the HMA (or in some cases HMA that had previously been used at the site). Three of the WMA additives used in Germany, Fischer-Tropsch wax (Sasobit), Montan wax (Asphaltan-B), and fatty acid amides (Licomont BS 100 or Sübit) have the advantage of increasing the stiffness of the binders at high temperatures. The low temperatures in Germany are generally somewhat milder than the northern U.S. (PG xx-22 or warmer). Therefore there is less concern about low temperature cracking.

In France, both laboratory studies and field trials have been conducted on various WMA processes. Laboratory studies have included: gyratory tests for workability/estimation of field compaction, wheel-tracking tests for rutting resistance, Duirez test for moisture resistance, and fatigue tests. There tended to be improvement in workability for the WMA. The rutting resistance of the WMA was the same as for HMA. In some cases, the ratio of the conditioned to unconditioned Duirez test results was slightly lower for the WMA. The fatigue tests indicated similar results. Field trials have been conducted by SETRA as part of the certification process for new products (described previously), by various departments responsible for regional roads, and by private toll road operators.

In the Department of L'eure et Loir (a Department is a road authority district), southwest of Paris, they have experimented with Aspha-min zeolite and ECOMAC. Based on their experiences to date, they plan on paving 40 km (24 miles) with WMA in 2007. L'eure et Loir is using WMA because of the environmental benefits, reduction in worker exposure, and safety aspects from reduced steam if it rains while paving. They also believe it helps with long haul distances, and helps to extend the paving season. Finally, they expect the WMA may last longer (*16*).

The city of Paris has experimented with several WMA processes in the urban environment, including a dedicated bus lane. Each week, the city receives calls from concerned Parisians concerned about fumes and odors from paving projects. The first projects used WMA in conjunction with mastic asphalt. The city of Paris has also tested six WMA processes in HMA mixes, beginning in 2004. Some of the projects were constructed at night. Projects are monitored for a minimum of three years before products are approved.

The private toll road operator Cofiroute, which operates a series of toll roads southwest of Paris, constructed a trial section with Aspha-min zeolite on the A81. Although they see the same advantages to WMA as described above and are pleased with the performance of the A81 section, they have not done additional projects with Aspha-min to date due to the increased cost. Two experiments with other WMA processes are planned for 2007 (*18*).

Applications of WMA

WMA has been used in all types of asphalt concrete, including dense-graded, stone matrix asphalt, porous asphalt, and mastic asphalt. It has also been used in a range of layer thicknesses. WMA sections have been constructed on roadways with a wide variety of traffic levels, from low to high. In Norway, the highest trafficked WAM-Foam section carried 25,000 Average daily traffic (ADT) (two directions) with approximately 2,500 heavy vehicles per day (one direction). ADT values were not reported in Germany, but sections were placed with truck traffic levels of 1,600 heavy vehicles per day. The A81 toll road in France received 21,000 ADT (two directions), with 1,500 heavy vehicles per day (one direction). Legal axle loads vary in the countries visited from 10 tonnes in Norway to 13 tonnes in France. The ECOMAC process, a warmed cold-mix, is only recommended for low traffic.

Benefits of WMA

A number of potential benefits were presented from the use of WMA including: reduced emissions, reduced fuel usage, better field compaction or with less effort, extension of the paving season, longer haul distances, potential for higher RAP utilization, facilitation of deep patching, and reduced worker exposure.

Reduced Emissions
A number of suppliers presentations in Norway (Norwegian and Italian data), Belgium (Netherlands data), and France included data that indicated reduced plant emissions. Typical expected reductions are:

- CO_2 reduced 30-40%
- SO_2 reduced 35%
- VOC reduced 50%
- CO reduced 10-30%
- NO_x reduced 60-70%
- Dust reduced 20-25%

Reduced Fuel Usage
Fuel savings reported indicated burner fuel savings with WMA typically range from 20 to 35 percent. These levels could be higher if burner tuning was completed to allow the burner to run

at lower settings. Fuel savings could be higher (possibly 50 percent of more) with processes such as LEAB and LEA where the aggregates or a portion of the aggregates are not heated above the boiling point of water. It does not appear that any consideration to increased electrical usage has been considered in the analysis of potential fuel savings. No specific study that has been reported was referenced for the suggested fuel savings.

Paving Benefits
Several paving related benefits were discussed including: ability to pave in cooler temperatures and still obtain density, ability to haul the mix longer distances and still have workability to place and compact, ability to compact mixture with less effort (assuming typical conditions, not cold weather or long haul), and the ability to run high percentages of RAP. Case studies were presented in Germany where paving has been completed with various technologies when ambient temperatures were between -3 and 4 °C (27 and 40 °F). HMA containing Sasobit was reportedly hauled up to nine hours in Australia, and the material could still be unloaded.

In Germany, a case study was presented where 45 percent RAP was used in the base course. In the Netherlands, both LEAB and HMA are routinely produced with 50 percent RAP. Trials have been conducted in Germany with 90 to 100 percent RAP using Aspha-min zeolite and Sasobit.

Several technologies provided data to show that the WMA technologies acted as compaction aids and therefore reduced the required compactive effort. Finally, WMA technologies can be used to facilitate deep patches, such as those placed when repaving the Frankfurt Airport. Sasobit was used in the repaving of Frankfurt airport. Twenty-four inches of HMA were placed in a 7.5 hour window. The runway was then reopened to jet aircraft at a temperature of 85°C (185 °F).

Reduced Worker Exposure
French, German, and Italian data was presented that indicated reduced worker exposure. Direct comparisons of measurements of fumes and aerosols are difficult since different testing protocols and sampling periods are used in different countries. It should be noted that all of the exposure data for HMA was below the acceptable exposure limits. Tests for asphalt aerosols/fumes and polycyclic aromatic hydrocarbons (PAHs) indicated significant reductions compared to HMA. Data presented by the Bitumen forum (*19*) appears to result in a 30 to 50 percent reduction. Data from a forthcoming Italian study indicates even larger reductions.

Challenges

Based on the summary presented above and the team’s experience, the following represent challenges that need to be addressed as the U.S. moves forward with WMA.

- Adapt WMA products/technologies from low production batch/drum plants frequently used in Europe to higher production plants used in the U.S.
- Coarse aggregate must be dry. Aggregates with low water absorption, less than 2 percent, are used to produce WMA in Europe. Aggregates with much higher water absorptions are used in parts of the U.S. WMA processes must be adapted to produce dry aggregates in the mix. Best practices for drying and minimizing moisture in

aggregates, including paving under stockpiles and, in certain conditions, covering stockpiles, should be encouraged.

- Initial product approval. How do we sort out good innovative products from poor products? There is a need for accepted performance tests to sort out the good from the bad. The traditional practice of products/technologies being approved on a state-by-state basis needs to be changed. Products/technologies should be approved on a national, or at least a regional, basis.
- Individual contractors are going to have to determine what products/technologies will work over the widest range of applications. In the past changes have been mandated by agencies. In Europe, contractors have staffs who routinely conduct research to develop new products/processes. Whereas in the U.S., contractors generally do not have these resources available to them within their own organizations. Such resources in the U.S. are generally found in research institutions and consultants.
- Need to make sure that the overall performance is truly as good as HMA. On a life-cycle basis, if WMA does not perform as well, there will not be long term environmental benefits or energy savings.

Preliminary Implementation Goals

The U.S. has already made great strides in evaluating WMA. A WMA Technical Working Group (TWG) has been established to oversee the implementation of WMA. A large number of trial sections and demonstration projects have been completed. In some cases, WMA has been used in "production" paving. During the WMA Scanning Tour, the team learned that there is a wide variety of techniques being used to produce WMA, wider than the team was previously aware. One key element that was observed was that production temperatures were generally higher than expected. In part, this was done to ensure that the coarse aggregate particles were dry. Based on the team's experience, there are no long-term barriers to the use of WMA. However, there are many elements of WMA that still need to be investigated. There is a consensus among the WMA Scan Team that WMA is a viable technology and that U.S. Agencies and the HMA industry need to cooperatively pursue this path. Some goals toward implementation include:

- WMA should be an acceptable alternative to HMA at the contractor's discretion, provided the WMA meets applicable HMA specifications.
- An approval system needs to be developed for new WMA technologies. The approval system should be based on performance testing and supplemented by field trials. WMA TWG should lead the development of a performance based evaluation plan for new WMA products. Realistically, such a system is needed for a broader range of modifiers/technologies used in HMA.
- The WMA Scan Team should provide technology transfer of the information gained through presentations, articles, and reports. An international workshop will be organized to promote WMA in 2008.

- Best practices need to be developed for handling and storing aggregates to minimize moisture content, burner adjustment, and WMA in general or specific technologies.
- There needs to be more WMA field trials with higher traffic. The field trials need to be large enough to allow a representative sample of the mixture to be produced. The trials should be built in conjunction with a control. The WMA Technical Working Group has developed guidelines that describe minimum test section requirements and data collection guidelines. The guidelines are available on-line at: http://www.hotmix.org/view_article.php?ID=537. There needs to be a commitment by the agency to monitor the project for a minimum of three years. More information on WMA, upcoming trials, and the WMA Technical Working Group is available at: http://www.fhwa.dot.gov/pavement/asphalt/wma.cfm
- The factors affecting the economic viability of WMA need to be identified and tracked. Potential factors include: additive costs, plant modifications, asphalt costs, fuel costs, costs of emissions compliance equipment such as low NO_X burners and fugitive emissions containment systems, and costs related to worker exposure.

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