



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

8 AUG 2011

FROM: HQ AFCESA/CEO
139 Barnes Drive, Suite 1
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SUBJECT: Engineering Technical Letter (ETL) 11-3: Warm Mix Asphalt (WMA)

1. Purpose. This ETL provides information regarding available technologies, applications, benefits, performance, and costs of warm mix asphalt (WMA). Recommendations on the use of WMA for road and airfield pavements are also provided.

2. Application. All Department of Defense (DOD) organizations responsible for airfield maintenance and repair.

2.1. Authority: Air Force policy directive (AFPD) 32-10, *Air Force Installations and Facilities*

2.2. Effective Date: Immediately

2.3. Intended Users:

- Major command (MAJCOM) civil engineers
- Base civil engineers (BCE)
- Base maintenance organizations/building managers

2.4. Coordination:

- MAJCOM civil engineers
- Air Force Center for Engineering and the Environment (HQ AFCEE)

3. References.

Anderson, RM., Baumgardner, G., May, R., and Reinke, G. (2008). "Engineering properties, emissions, and field performance of warm mix asphalt technologies." *NCHRP 9-47*, Transportation Research Board, Washington, D.C.

D'Angelo, J., Harm, E., Bartoszek, J., Baumgardner, G., Corrigan, M., Cowser, J., Harman, T., Jamshidi, M., Jones, W., Newcomb, D., Prowell, B., Sines, R., and Yeaton, B. (2008). "Warm-Mix Asphalt: European Practice." *Report FHWA-PL-08-007*, U.S. Department of Transportation, Washington, D.C.

4. Acronyms:

- °C - degree Celsius
- °F - degree Fahrenheit

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AC	- asphalt cement
AFCESA	- Air Force Civil Engineer Support Agency
BACT	- best available control technology
DOD	- Department of Defense
DOT	- Department of Transportation
ETL	- engineering technical letter
HMA	- hot mix asphalt
lb	- pound
MAJCOM	- major command
NCHRP	- National Cooperative Highway Research Program
RAP	- reclaimed asphalt pavement
WMA	- warm mix asphalt
yr	- year

5. Background.

5.1. The normal production temperatures for HMA range from over 300 °F (149 °C) to approximately 350 °F (177 °C). This high temperature ensures the workability of HMA, especially when polymer is used. In addition, hauling time is usually considered when determining the production temperature. However, higher temperatures lead to excessive oxidation of HMA during production, excessive emissions, and higher energy costs. As a result, the Federal Highway Administration (FHWA) and the HMA industry have worked together to evaluate warm mix asphalt (WMA) as a production and paving process that potentially reduces emissions and energy costs while it improves safety during construction. There are several WMA technologies that allow the mixture temperature to be reduced approximately 50 °F to 100 °F (10 °C to 38 °C). This reduces emissions and energy costs.

5.2. The first trial section of WMA in the U.S. was placed in February 2004. Since then, millions of tons of WMA have been paved. Several states, including Texas, Alabama, and Indiana, have approved the use of WMA on state roads and use it as a standard process. Furthermore, some states allow the use of WMA on any project that was bid for hot mix asphalt (HMA). However, the use of WMA for airfield paving has been limited. In 2008, Boston's Logan International Airport was the first airport in the nation to use WMA on runway rehabilitation when 26,000 tons of WMA were paved on runway 4R/22L. The required performance and energy savings were accomplished with this project. Therefore, in 2009 a larger project (55,000 tons) was constructed at Logan International Airport for rehabilitation of runway 9-27, where the ease of WMA compaction was demonstrated along with reduced emissions and energy savings. Other paving trials were conducted at Ted Stevens Anchorage International Airport and Elmendorf AFB, Alaska.

5.3. State Departments of Transportation (DOT) may begin using WMA as a standard mixture type in the future, given its acceptable long-term performance. If that occurs, then WMA is likely to become the norm and HMA the exception. Consequently, other state and federal agencies may be required to use WMA, given

its energy and cost savings, reduced negative environmental impact, and improved safety during construction.

5.4. This ETL presents an overview of different WMA technologies available in the U.S., along with current practice on placement and compaction, performance observations, potential benefits, and costs of using each of these technologies. Recommendations for using WMA along with ongoing research are presented in paragraphs 9 and 10.

6. Technologies for Mix Production.

6.1. Introduction. This ETL presents different technologies available in the U.S. to produce WMA. Each technology acts to reduce the necessary mixing and compaction temperature, thus reducing the required plant production temperature. WMA technologies can be classified into three main groups: those using water for foaming, those using chemical additives or surfactants, and those using organic additives or wax. More than 20 WMA technologies are available in the U.S., but this number will change with time as more technologies are developed.

6.2. Water for Foaming. These technologies consist of adding a small amount of water to the asphalt binder, either through a plant foaming system or by adding a material containing internal water, such as zeolite. Once the water is added to the hot asphalt binder it expands from the conversion of liquid to gas/steam. The small bubbles generated act to reduce the viscosity of the asphalt binder coating on the rock, thereby allowing the mix to be handled and worked at lower temperatures.

6.2.1. Mechanical Spray Foaming. This foaming process requires the installation of a foaming manifold over the existing asphalt injection system on the mixing drum of the plant and installation of corresponding asphalt binder and water feed lines into the manifold. A foaming device in the manifold is used to foam the asphalt binder with water. In the process, a small amount of water is introduced through the nozzles, causing the asphalt binder to expand by about 18 times its original volume. The resultant production temperatures are typically 50 °F to 90 °F (10 °C to 32 °C) less than conventional HMA for the same binder.

6.2.2. Two-Stage Process. This process consists of a two-stage addition of the asphalt binder. In the first stage, the aggregate is coated with a very soft binder (flux) that controls the minimum mixing and compaction temperatures for the mixture. In the second stage, a harder binder is added with the addition of a very small amount of water. The water foams the hard asphalt, allowing the expanded binder to coat the aggregate and improve workability during compaction. This technology requires storage for the two different binder grades as well as two heated asphalt lines into the mixing chamber.

6.2.3. Zeolite. Zeolite is a crystalline hydrated aluminum silicate that can be natural or manufactured. It is typically sold in granular form with approximately a

No. 50 mesh size and contains approximately 20% water by weight. The water is released from the zeolite when heated to 212 °F (100 °C). When water is released in an HMA, it foams the asphalt. The foamed asphalt, which is more workable than asphalt cement before foaming, allows coating of the aggregates at lower temperatures and improves compactability. The zeolite can be introduced into the asphalt plant by various methods. On a batch plant, it can be manually added directly into the pug mill or automatically using a weight bucket. On a drum plant, the zeolite could be added through the reclaimed asphalt pavement (RAP) collar or by using a specially built calibrated vane feeder to control the quantity of material pneumatically blown into the drum.

6.3. Chemical Additives. Chemical additives are used to produce WMA by reducing the binder's apparent viscosity or increase its wettability. These additives can be injected at the mixing plant or asphalt terminal and can achieve lower production temperatures than foaming processes. In addition, it is thought that some of the additives can reduce mixture stripping.

6.4. Organic Additives or Wax. Organic additives such as wax cause a decrease in the asphalt binder's viscosity when heated above the melting point, allowing mixing and coating. The increased workability at mixing and compaction temperatures acts to improve compactability. These additives can be incorporated at the asphalt terminal or in the contractor's tank by circulation without requiring high-shear blending. Other organic additives are referred to as "intelligent fillers," as they provide improved flow at mixing and compaction temperatures, and added stiffness at temperatures below the congealing (solidifying) point of 212 °F (100 °C).

7. Placement and Compaction.

7.1. Overview. Procedures for placing and compacting WMA do not differ from placing and compacting HMA, other than the temperature at which these operations occur. With most WMA technologies, the temperature of the bituminous material at the end of compaction is lower than with HMA, and also closer to service temperature. Therefore, the usage of WMA allows the mix to more quickly cool to operating temperature.

7.2. Placement. The reduced temperature of WMA makes its placement much more comfortable for construction personnel because it is typically 50 °F to 100 °F (10 °C to 38 °C) cooler than HMA. WMA also allows placing multiple lifts within a short time window and placing bituminous materials on crack-sealed substrates without the occurrence of bumps. Bumps are created when the HMA heats the sealer, resulting in movement during rolling. The reduced temperature of WMA limits this movement as the sealer remains stiff at this temperature; thus, bumps may not occur.

7.3. Compaction. The reduced mixing and compacting temperatures of WMA allow more time to roll the mixture and obtain adequate density. The window for compacting WMA mixes is extended for a longer period of time and the mix remains

more workable to a lower temperature than HMA. The operating temperature of WMA helps to achieve a more uniform compaction because it allows the rollers to have better spacing and ensures proper mat coverage. A more consistent mat density is achieved and the surface mat texture is less open than conventional HMA. This allows achieving desired density with fewer compaction passes.

8. Observations.

8.1. Performance.

8.1.1. Laboratory test results appear to show that WMA will likely provide good performance. The performance areas of primary interest when considering using WMA are moisture damage and rutting. Some laboratory studies have shown that WMA has higher moisture sensitivity than typical HMA. The lower mixing and compacting temperatures of WMA can result in incompletely drying the aggregate. The resulting water trapped in the coated aggregate may cause moisture damage.

8.1.2. Usually, mixes experience higher rutting potential as mixing and compacting temperatures decrease. However, several studies have shown comparable rutting results from laboratory wheel-track tests for HMA and WMA. In general, long-term performance of WMA is still being evaluated and could be technology-dependent.

8.2. Lower Emissions.

8.2.1. Reported measurements have shown that pollutant emissions during WMA production are lower than those during HMA production. WMA emission measurements have been reported ranging between 30% and 98% of that for HMA. Table 1 lists the typical reductions in plant emissions expected with the use of WMA technologies for mix production. Actual reductions may vary based on a number of factors. Technologies that result in greater temperature reductions are expected to have greater emissions reductions.

Table 1. Expected Reductions in Plant Emissions with use of WMA

Plant Emissions	Expected Reductions
Carbon dioxide (CO ₂)	30% to 40%
Sulfur dioxide (SO ₂)	30% to 40%
Volatile organic compounds (VOC)	50%
Carbon monoxide (CO)	10% to 30%
Nitrous oxides (NO _x)	60% to 70%
Dust	20% to 25%

Adapted from D'Angelo et al. (2008).

8.2.2. The importance of WMA benefits will depend on the local environmental situation. Reduced emissions will help meet new, stringent regulations in areas where emission regulations are becoming stricter. The use of WMA may be encouraged in densely populated areas where air quality is substantially lower and the introduction of new emission sources is tightly controlled.

8.2.3. The Federal Clean Air Act limits 194 atmospheric pollutants and requires emission sources like HMA plants to use the best available control technology (BACT) to limit their emissions. Overall, HMA plants located in nonattainment areas (localities where air pollution levels persistently exceed national ambient air quality standards, or that contribute to ambient air quality in a nearby area that fails to meet standards) may see some economic incentive in selling their reduced emissions or increasing mix production through WMA use. However, for other HMA producers there is little incentive because HMA plants generally are already in compliance with the Clean Air Act. Either stricter air quality standards or a formal inclusion of WMA as a BACT are needed if lower emissions are to be a viable incentive for HMA plants. However, its use will also be determined per the overall benefits of producing WMA.

8.3. Lower Energy Consumption. Reductions in energy consumption of 20% to 75% compared to regular HMA production have been measured for WMA technologies. This depends on how much the production temperature was lowered. The importance of this benefit depends on the type and cost of energy. Reductions in energy consumption can be a significant incentive in areas where energy cost is relatively high. Overall, in places where fuel is relatively expensive, energy savings could offset the increased cost for WMA if energy savings are near 50%. Otherwise, energy savings alone are less than the expense of WMA for most processes. If the WMA costs decrease in the future as expected, and if fuel costs continue to outpace inflation, most WMA processes could become a net economic benefit on the basis of reduced energy consumption alone.

8.4. Reclaimed Asphalt Pavement (RAP). A high RAP content in HMA represents a challenge for design and construction due to the RAP's aged and stiffened binder, which often causes problems with workability and compactability. Another challenge is to select the appropriate temperature during mixing and compacting that is high enough to drive off moisture from aggregates and low enough to avoid further stiffening of the already aged binder in the RAP. WMA technologies may be beneficial with mixes containing high proportions of RAP in two ways: 1) the increase in workability will aid in mixing and compacting; and 2) the decreased aging of the new binder as a result of the lower production temperatures may offset the aged RAP binder, similar to using a softer binder grade. Laboratory studies have confirmed that the use of WMA technologies with RAP enables the production of HMA at 260 °F (127 °C), with properties comparable to those of HMA produced at 300 °F (149 °C). Successful use of RAP in WMA has also been reported in the field.

8.5. Cold Weather Construction. Some contractors and agencies have been exploring the use of WMA to extend the paving season in cold weather. Depending on the location and weather, paving projects are typically prohibited after a certain calendar date because colder temperatures allow less time for compaction, resulting in lower in-place density. WMA technologies allow mixes to remain workable at cooler temperatures, increasing the time available for compaction.

8.6. Cost. The use of WMA technologies generally involves an increase in mix production costs, which is associated with equipment modifications and cost of materials. These costs fluctuate and are expected to decrease as the use of WMA technologies increases over time. Table 2 presents general costs of WMA technologies per ton of mix. However, savings in energy cost and compaction effort should be considered.

Table 2. WMA Technologies Costs

WMA Process	Installation Costs	Royalties	Cost of Material	Recommended Dosage Rate	Approximate Increased Cost per Ton of Mix
Mechanical spray foam	\$100,000–\$120,000	None	None	1% water to binder	None
Two-stage foam process	\$60,000–\$85,000	\$15,000 first yr \$5,000/plant/yr \$0.30/ton	\$75 premium on soft binder	3% weight of binder	\$0.27 + \$0.35 Royalty
Zeolite	\$5,000–\$40,000	None	\$0.60/lb	0.3% by weight of mix	\$3.60–\$4.00
Chemical additives	\$1,000–\$5,000	None	\$35–\$50 premium on binder	30% water / 70% AC	\$3.50–\$4.00
Organic additives or waxes	\$5,000–\$40,000	None	\$0.80/lb	1.5%–3% by weight of binder	\$2.00–\$3.00

Adapted from Anderson et al. (2008).

9. Recommendations.

9.1. At least ten WMA technologies are available in the U.S. So far, the implementation of these technologies for production and placement of asphalt pavement material at lower temperatures has proceeded with virtually no complications. The benefit of lower fuel consumption and emissions, coupled with a higher use of RAP, seems to favor the implementation of WMA. At least ten states have adopted permissive specifications for contractors to produce and place asphalt mix at low temperature as long as it meets all other criteria and costs do not increase.

9.2. Guide specifications have been developed for the use of WMA technologies for highway construction. However, research is still underway to support these specifications with observed laboratory and field performance. The design specifications or use of WMA on airfields is prohibited without prior approval of the MAJCOM pavement engineer. All WMA mix technologies and mix designs and/or specifications shall be reviewed by AFCESA or the U.S. Army Corps of Engineers Transportation Systems Center (TSC) before advertising any WMA contract or placing WMA on the airfield.

9.3. Based on research to produce this ETL, it has been determined that the adoption of WMA has progressed rapidly and become a standard for road construction across the U.S. WMA technologies have good potential for use in airfield pavements and work is underway to develop guide specifications. Once the guide specifications are produced, it is anticipated that airfield work within the DOD will increase significantly. The Air Force allows WMA to be used for all work performed on roads and parking lots subject to non-airfield state DOT specifications if the DOT specification allows WMA.

10. Current Research Efforts.

10.1. User agencies and producers in various states are working together to evaluate WMA technologies. Individual state trial projects and two national research projects (National Cooperative Highway Research Program [NCHRP] 9-43 and 9-47) have addressed WMA mix design, performance testing, production, construction, and field performance. The National Asphalt Pavement Association (NAPA), FHWA, the American Association of State Highway and Transportation Officials (AASHTO), and researchers formed a national technical working group to evaluate the performance of WMA technologies, quantify environmental benefits, develop performance specifications, provide technical guidance, and disseminate information. The working group meets several times each year to coordinate technical guidance, such as material properties and emissions-testing protocols to evaluate WMA compared to HMA.

10.2. The U.S. Army Corps of Engineers was funded by HQ AFCESA to conduct an evaluation of WMA technologies at the Engineer Research and Development Center (ERDC) and develop guide specifications for airfield pavements. The study evaluated the performance of different WMA technologies to determine which have the best potential for use in airfields. The objectives of the study were to monitor projects being constructed with WMA to document materials used, observe construction processes, and identify any issues related to the production of the mix; monitor these projects during their early life to identify premature performance problems; and develop a guide specification for the use of WMA technologies for airfield pavements. Based on lab work and field observations, a good indication of the rutting potential and a better understanding of the mix design procedures were obtained. Results from this study will be summarized in a forthcoming ERDC technical report and an ETL.

11. Point of Contact. Recommendations for improvements to this ETL are encouraged and should be furnished to the Pavements Engineer, HQ AFCESA/CEOA, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32408-5319, DSN 523-6439, commercial (850) 283-6439, e-mail AFCESAR@tyndall.af.mil.

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