TSPWG M 3-250-03.11-3
25 September 2019

TRI-SERVICE PAVEMENTS WORKING GROUP (TSPWG) MANUAL

WARM MIX ASPHALT (WMA)

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

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Indicate the preparing activity beside the service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

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Change No.	Date	Location

This TSPWG manual supersedes Air Force Engineering Technical Letter (ETL) 11-3, *Warm Mix Asphalt (WMA)*, 8 August 2011.

FOREWORD

This Tri-Service Pavements Working Group Manual provides guidance regarding available technologies, application, benefits, performance, and cost of warm mix asphalt (WMA). It supplements guidance found in other Unified Facilities Criteria, Unified Facility Guide Specifications, Defense Logistics Agency Specifications, and service-specific publications. The information in this TSPWG Manual is referenced in technical publications found on the Whole Building Design Guide. It is not intended to take the place of service-specific doctrine, technical orders (TOs), field manuals, technical manuals, handbooks, Tactics, Techniques, and Procedures (TTPs), or contract specifications, but should be used along with these to help ensure pavements meet mission requirements.

All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the TSPWG Manual, the SOFA, the HNFA, and the BIA, as applicable.

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TRI-SERVICE PAVEMENTS WORKING GROUP MANUAL (TSPWG M)
NEW SUMMARY SHEET

Document: TSPWG Manual 3-250-03.11-3, *Warm Mix Asphalt (WMA)*

Superseding: ETL 11-3, *Warm Mix Asphalt (WMA),* 8 August 2011

Description: This TSPWG Manual provides specifications for construction of contingency airfields. It applies to Department of Defense (DoD) agencies and their contractors.

Reasons for Document:

- Provides designers and maintenance personnel the latest materials and methods for use of Warm Mix Asphalt (WMA).

Impact: There is no cost impact. The following benefits should be realized:

- Supplemental information on the operation, maintenance, and repair of pavements, as well as airfield damage repair, will be available to all services.
- Maintenance and/or upgrading of this supplemental information will include inputs from all services.

Unification Issues:

None

Note: Use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this manual does not imply endorsement by the DoD.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Normal production temperatures for hot mix asphalt (HMA) range from over 300 °F (149 °C) to approximately 350 °F (177 °C). High temperatures ensure the workability of HMA, especially when polymer is used. Hauling time is usually taken in account 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 WMA as a production and paving process that potentially reduces emissions and energy costs while it improves safety during construction. Several technologies allow the WMA mixture temperature to be reduced approximately 50 °F to 100 °F (10 °C to 38 °C) from that of HMA.

1-1.1 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 use of WMA on state roads as a standard process. Some states allow the use of WMA on any project that was bid for HMA.

1-1.2 However, 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. Required performance and energy savings were achieved with this project. 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, together with reduced emissions and energy savings. Other paving trials were conducted at Ted Stevens Anchorage International Airport and Elmendorf AFB, Alaska.

1-1.3 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, other state and federal agencies may be required to use WMA

1-2 PURPOSE AND APPLICABILITY.

This manual provides an overview of different warm mix asphalt (WMA) technologies available in the U.S., along with current practice for placement and compaction, performance observations, and potential benefits and costs of using each of these technologies. Chapter 5 discusses current research into WMA technologies and Chapter 7 provides recommendations for use of WMA.

This manual applies to DoD agencies and their contractors.

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CHAPTER 2 TECHNOLOGIES FOR MIX PRODUCTION

2-1 INTRODUCTION.

Each technology to produce WMA acts to reduce required mixing and compaction temperatures, thus reducing the required plant production temperature. WMA technologies are classified into three main groups based upon use of:

- water for foaming
- chemical additives or surfactants
- organic additives or wax

More than twenty WMA technologies are available in the U.S., but this number will change with time as more technologies are developed.

2-2 WATER FOR FOAMING.

These technologies involve 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 due to 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.

2-2.1 Mechanical Spray Foaming.

This process requires 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 coats 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. Production temperatures are typically 50 °F to 90 °F (10 °C to 32 °C) lower than conventional HMA for the same binder.

2-2.2 Two-Stage Process.

This process involves 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 along with 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. Storage is required for the two different binder grades, as well as two heated asphalt lines into the mixing chamber.

2-2.3 Zeolite.

Zeolite is a crystalline hydrated aluminum silicate that occurs naturally or can be 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.

Zeolite is introduced into the asphalt plant in various ways. On a batch plant, it is manually added directly into the pug mill, or automatically using a weight bucket. On a drum plant, the zeolite is 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.

2-2.4 Sasobit®.

Sasobit® is a synthetic hard wax which has been used successfully worldwide in asphalt road construction since 1997. Mixing and paving temperatures can be reduced by as much as 405 °F (243 °C), because at temperatures above 239 °F (115 °C), Sasobit® is completely soluble in bitumen, reducing viscosity significantly. Reduced viscosity at standard temperatures enhances the workability of the asphalt mix. During the cooling phase, Sasobit® starts to crystallize at 194 °F (90 °C) and forms a lattice structure in the bitumen, which has a stiffening effect. Deformation resistance increases significantly when adding the appropriate quantity of Sasobit® without impairing low-temperature performance. Sasobit® is added to asphalt similar to zeolite.

2-3 CHEMICAL ADDITIVES.

Chemical additives are used to produce WMA by reducing the binder’s apparent viscosity or increasing its wettability. Additives are injected at the mixing plant or asphalt terminal and achieve lower production temperatures than foaming processes. In addition, some of the additives may reduce mixture stripping.

2-4 ORGANIC ADDITIVES OR WAX.

Organic additives such as wax cause a decrease in the asphalt binder’s viscosity when heated above the additive’s melting point, allowing mixing and coating. The increased workability at mixing and compaction temperatures acts to improve compactability. These additives are incorporated at the asphalt terminal or in the contractor’s tank via 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).

CHAPTER 3 PLACEMENT AND COMPACTION

3-1 INTRODUCTION.

Procedures for placing and compacting WMA and HMA are the same, except for their working temperatures. With most WMA technologies, the temperature of the bituminous material after compaction is lower than with HMA, and also closer to service temperature. Therefore, using WMA allows the mix to cool more quickly to operating temperature.

3-2 PLACEMENT.

WMA’s reduced temperatures make placement much more comfortable for construction personnel (50 °F to 100 °F (10 °C to 38 °C) cooler than HMA). Multiple lifts are placed within a short time window, and bituminous materials are placed on crack-sealed substrates without resulting bumps. When HMA heats the sealer, bumps are created from movement during rolling. WMA limits this movement because the sealer remains stiff.

3-3 COMPACTION.

The reduced mixing and compacting temperatures of WMA allow more time to roll the mixture and obtain adequate density; the mix remains more workable at a lower temperature than HMA. The operating temperature of WMA also helps to achieve a more uniform compaction because it allows the rollers to achieve better spacing and ensures proper mat coverage. A more consistent mat density is achieved and the surface mat texture is less open. Desired density is achieved with fewer passes.

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CHAPTER 4 PERFORMANCE

4-1 INTRODUCTION.

Laboratory test results currently show that WMA performs well. Performance areas of primary interest 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 may result in incompletely dried aggregate; water trapped in the coated aggregate may cause moisture damage.

Mixes typically experience increased rutting as mixing and compacting temperatures decrease. However, several studies have shown comparable rutting results from laboratory wheel-track tests of both HMA and WMA. In general, long-term performance of WMA is still being evaluated and could be technology-dependent.

4-2 LOWER EMISSIONS.

4.2.1 Pollutant emissions measure lower during WMA production than during HMA production. WMA emissions have been reported ranging between 30 percent and 98 percent of HMA emissions. Table 1 lists the typical reductions in plant emissions expected when using WMA technologies for mix production. Actual reductions may vary based on a number of factors. Technologies that yield 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 FHWA-PL-08-007.

4.2.2 Benefits of WMA will vary with the local environment. Reducing emissions is beneficial where emission regulations are stricter. Use of WMA is encouraged in densely populated areas where air quality is substantially lower and introduction of new emission sources is tightly controlled.

4.2.3 The Federal Clean Air Act limits 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 formal inclusion of WMA as a BACT are needed for HMA plants to adopt WMA.

4-3 LOWER ENERGY CONSUMPTION.

Significant reduced energy consumption has been measured for WMA technologies compared to regular HMA production. Energy saved depends on how much production temperature is lowered; the 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 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.

4-4 RECLAIMED ASPHALT PAVEMENT (RAP).

The high RAP content in HMA presents a challenge due to its aged and stiffened binder, often causing problems with workability and compactability. Another challenge is to select the appropriate temperature during mixing and compacting -- high enough to drive off moisture from aggregates, and low enough to avoid further stiffening of the already aged binder. WMA technologies are beneficial with mixes containing high proportions of RAP in two ways: (1) the increase in workability will aid mixing and compacting; and (2) decreased aging of the new binder due to lower production temperatures may offset the aged RAP binder, similar to using a softer binder grade. Laboratory studies have confirmed that using WMA technologies with RAP enables the production of WMA at 260 °F (127 °C), with properties comparable to those of HMA produced at 300 °F (149 °C).

4-5 COLD WEATHER CONSTRUCTION.

Some contractors and agencies have been exploring using 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.

4-6 COST.

Use of WMA technologies typically 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 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 Costs*

WMA Technology	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 NCHRP 9-47. Costs have changed significantly since publication in January 2009 and are provided here for reference only.*

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CHAPTER 5 CURRENT RESEARCH

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.

The U.S. Army Corps of Engineers was funded by HQ AFCESA (now AFCEC) 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 have been incorporated into UFGS 32 12 15.13, *Asphalt Paving for Airfields*. UFGS 32 12 16, *Asphalt Paving for Roads*, scheduled for publication in 2019, will include WMA.

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CHAPTER 6 OBSERVATIONS

Adoption of WMA has progressed rapidly and become a standard for road construction across the U.S. Multiple states have adopted permissive specifications for contractors to produce and place asphalt mix at low temperatures as long as other criteria are satisfied and costs do not increase. The benefit of lower fuel consumption and emissions, coupled with a higher use of RAP, favors implementation of WMA.

WMA technologies have good potential for use in airfield pavements and guide specifications have been developed (reference Chapter 5). Now that guide specifications have been produced, airfield application of WMA within DoD should increase significantly.

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CHAPTER 7 RECOMMENDATIONS

WMA is permitted for use in all work performed on roads and parking lots subject to non-airfield state DOT specifications if the DOT specification allows WMA. WMA on airfields is allowed subject to UFGS 32 12 15.13.

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APPENDIX A BEST PRACTICES
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APPENDIX B GLOSSARY

ºC	degree Celsius
ºF	degree Fahrenheit
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt cement
AFCEC	Air Force Civil Engineer Center
BACT	best available control technology
BIA	Bilateral Infrastructure Agreement
CO	carbon monoxide
CO_2	carbon dioxide
DoD	Department of Defense
DOT	Department of Transportation
ERDC	Engineering Research and Development Center
ETL	Engineering Technical Letter
FHWA	Federal Highway Administration
HMA	hot mix asphalt
HNFA	Host Nation Funded Agreement
HQ AFCESA	Headquarters Air Force Civil Engineer Support Agency
HQ USACE	Headquarters United States Army Corps of Engineers
lb	pound
MAJCOM	major command
NAPA	National Asphalt Pavement Association
NAVFAC	Naval Facilities Command
NCHRP	National Cooperative Highway Research Program
NOx	nitrous oxide

RAP	reclaimed asphalt pavement
SME	subject matter expert
SO_2	sulfur dioxide
SOFA	Status of Forces Agreement
TO	Technical Order
TSPWG M	Tri-service Pavements Working Group Manual
TTP	Tactics, Techniques, and Procedures
UFGS	Unified Facilities Guide Specification
U.S.	United States
VOC	volatile organic compounds
WMA	warm mix asphalt
yr	year

APPENDIX C REFERENCES

DEPARTMENT OF DEFENSE

http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-32-12-15-13

UFGS 32 12 15.13	*Asphalt Paving for Airfields*

FEDERAL HIGHWAY ADMINISTRATION

https://international.fhwa.dot.gov/pubs/pl08007/pl08007.pdf

PL-08-007	*Warm-Mix Asphalt: European Practice*

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

www.trb.org/NotesDocs/NCHRP09-47_IR.pdf

9-47	*Engineering Properties, Emissions, and Field Performance of Warm Mix Asphalt Technologies*