The use of Warm Mix Asphalt

EAPA – Position Paper

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Summary

Since the mid 1990s a range of techniques has been developed to reduce the mixing and laying temperatures and energy of manufacture of Hot Mix Asphalt (HMA),

This paper focuses on Warm Mix Asphalt (WMA) technologies for producing asphalt at temperatures slightly above 100 °C with properties or performance equivalent to that of conventional HMA.

A typical WMA is applied at a temperature around 20 - 40 °C lower than an equivalent Hot Mix Asphalt. Less energy is involved and, during the paving operations, the temperature in the mix is lower, resulting in improved working conditions for the crew.

This document provides the potential users and - producers of WMA with information and it gives an overview of:

- Techniques available
- Performance of WMA mixes
- Benefits of WMA
- The way European asphalt standards allow the use of WMA
- Summary and recommendations
- References and literature

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1. Introduction

The first WMA techniques were developed in the late 1990's. Additives were trialled in Germany and in Norway the WAM-Foam process was developed.

Figure 1 shows how WMA fits into the full range of techniques from cold mix through to hot mix:

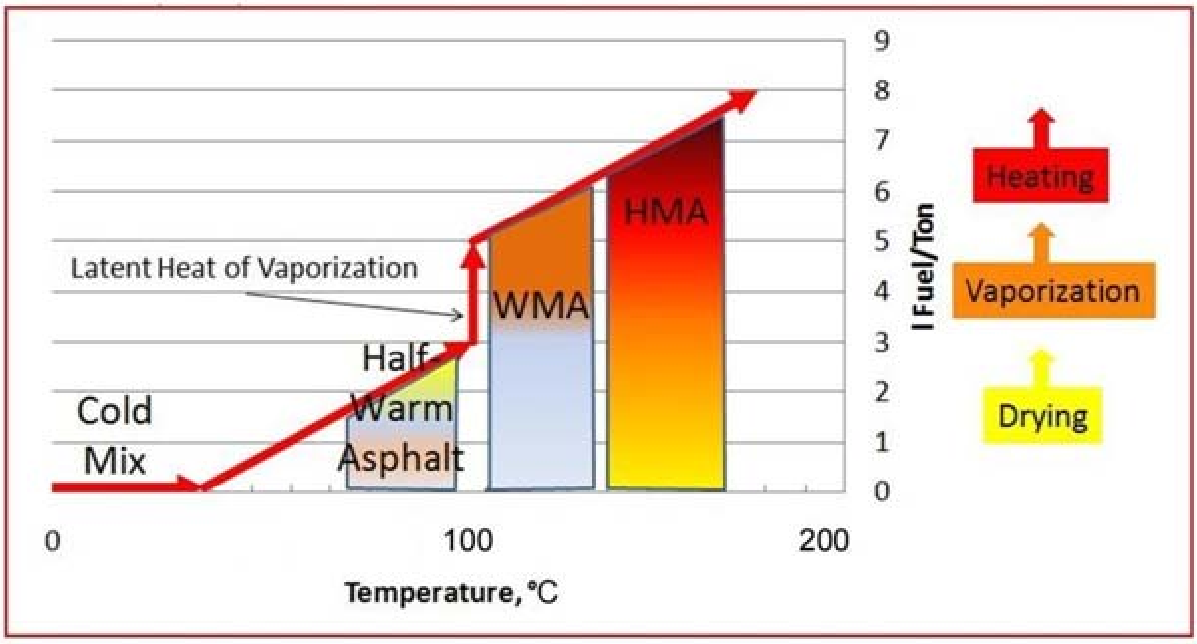


Figure 1: Classification by temperature range (Temperatures, and fuel usage are approximations) [1.]

- Cold mixes: produced with unheated aggregate and bitumen emulsion or foamed bitumen.
- Half Warm Asphalt: produced with heated aggregate at a mixing temperature (of the mix) between approximately 70 °C and roughly 100 °C.
- Warm Mix Asphalt: produced and mixed at temperatures roughly between 100 and 140 °C.
- Hot Mix Asphalt: produced and mixed at temperatures roughly between 120 and 190 °C The production temperatures of Hot Mix Asphalt depend on the bitumen used.

This paper describes the main WMA techniques that are used and which have an asphalt production temperature above 100 °C. These mixes have properties and performance which are equivalent to conventional Hot Mix Asphalt.

2. Techniques to produce WMA

Warm-Mix Asphalt (WMA) technologies operate above 100 °C, so the amount of water remaining in the mix is very small. Various techniques are used to reduce the effective viscosity of the binder enabling full coating and subsequent compactability at lower temperatures.

The most common techniques are:

- Organic additives
- Chemical additives
- Foaming techniques

Organic additives to the mix or to the bitumen

Different organic additives can be used to lower the viscosity of the binder (bitumen) at temperatures above about 90°C. The type of additive must be selected carefully so that its melting point is higher than the expected in-service temperatures (otherwise permanent deformation may occur) and to minimize embrittlement of the asphalt at low temperatures. The organic additives, usually waxes or fatty amides, can be added either to the mixture or to the bitumen.

A commonly used additive is a special paraffin wax produced by conversion of natural gas.

Organic additives typically give a temperature reduction of between 20–30 °C whilst they also improve the deformation resistance of asphalt so modified.

Chemical additives

Chemical additives do not change the bitumen viscosity. As surfactants they work at the microscopic interface of the aggregates and the bitumen. They regulate and reduce the frictional forces at that interface at a range of temperatures, typically between 140 and 85°C. It is therefore possible to mix the bitumen and aggregates and to compact the mixture at a lower temperature.
Chemical additives may reduce the mix and compaction temperatures by about 20 - 30°C.

Foaming techniques - to initiate a foaming process of the bitumen

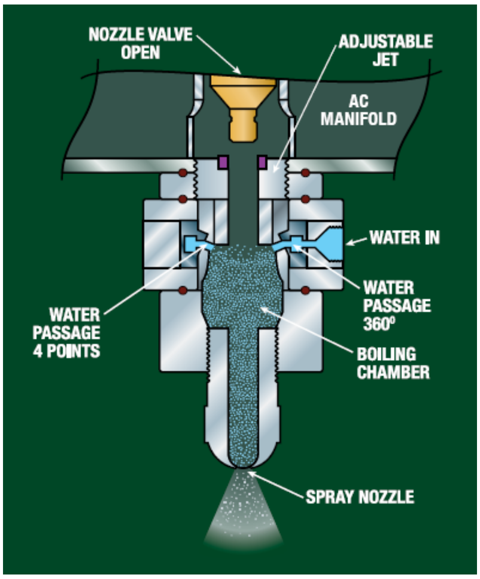
A range of foaming techniques is applied to reduce the viscosity of bitumen. Various means are employed to introduce small amounts of water into the hot bitumen. The water turns to steam, increases the volume of the bitumen and reduces its viscosity for a short period until the material has cooled. The foam then collapses and the bitumen behaves as a normal binder.
The amount of expansion depends on a number of factors, including the amount of water added and the temperature of the binder [2.].

Two techniques are commonly used for foaming:

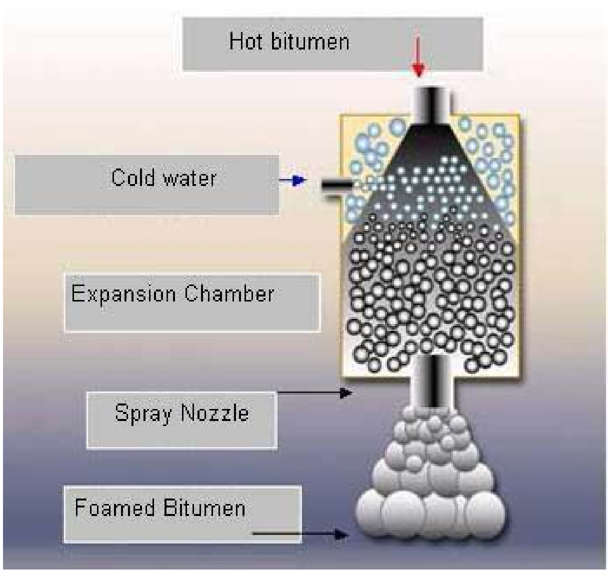
- injection foaming nozzles
- minerals

The direct method of foaming is to inject a small controlled amount of water to hot bitumen via a foaming nozzle. This results in a large but temporary increase in the effective volume of the binder which facilitates coating at lower temperatures. Some

vapour remains in the bitumen during compaction reducing effective viscosity and facilitating compaction. On cooling the binder reverts to normal, as the amount of water is insignificant.
This technique can enable a temperature reduction of the asphalt mix of about 20 to 30°C. Figures 2 and 3 show examples of foaming nozzles.



Figures 2: Foaming nozzle [3.]



Figures 3: Foaming nozzle [2.]

The "Two phase process" [4.] is a method where a soft grade of bitumen is used to initially coat the aggregate, then the filler is added. After this, foamed hard bitumen is added and mixed resulting in a warm mixture of an intermediate binder grade.

An indirect foaming technique uses a mineral as the source of foaming water. Hydrophilic minerals from the zeolite family are commonly used. Zeolite is a crystalline hydrated aluminium silicate that contains about 20 percent of crystalline water, which is released above 100 deg C. This release of water creates a controlled foaming effect, which can provide an improved workability for a 6- to 7-hour period, or until the temperature drops below 100 °C.
In this instance the foaming results in an improved workability of the mix which can subsequently allow a decrease in the mix temperature by approximately 30°C with equivalent compaction performance.

3. Equivalent performance of WMA

There is a history of use of WMA going back over more than ten years, from the early sites in Germany and Norway.

Germany

In Germany many test sections and commercial applications of WMA (and other low temperature techniques) were constructed between 1998 and 2001. The BASt has monitored seven test sections. Six of the seven projects were SMA mixes and one was a dense-graded mix. Based on laboratory and field performance data in all cases, the test sections had the same or better performance than the HMA control sections [5.].

Norway

The oldest test sections with WAM-Foam in Norway were built in 1999. Also in Norway the overall conclusion is that the WAM-Foam sections appeared to perform similarly to previous HMA overlays [1.]

It was concluded in [1.] that: based on the laboratory and short-term (3 years or less) field performance data, WMA mixes appear to provide the same performance as, or better performance, than HMA. Other studies have also showed that the performance and the in-service characteristics of WMA mixes are equivalent to those of the traditional mixes, and frequently even better [6.] [7.].

There are believed to be several reasons for this good performance. In particular, as a result of improved workability, a higher compacted density can be achieved. This higher density reduces the long-term in-service hardening of the bitumen and also prevents ingress of water. Lower production temperatures can also decrease the ageing of the bitumen during the production stage which can additionally improve the thermal and fatigue cracking resistance of the asphalt.
Workability improvements also have the potential to extend the construction season and the time available for placement of the asphalt mixture during any given day.

4. Benefits of WMA

In the Kyoto protocol, the ratifying states agreed to lower the emission of greenhouse gases, which essentially concerns CO_2 emissions, to 5% below the 1990 level between the years 2008 and 2012. The European asphalt industry strives to contribute to this and to initiate measures for emission reduction. Lower mixing and laying temperatures will result in reduced emissions. There are also positive effects on the working environment during production and paving.

In this chapter the benefits of using/producing WMA are described with regard to:

- Environmental benefits
- Paving benefits
- Asphalt workers benefits
- Economical benefits

Environmental benefits

Because of the lower production temperature of WMA less fuel is needed to heat the aggregate. This results in lower emissions. The actual reductions vary based on a number of factors and should be considered on a case by case basis.

For WMA and Half Warm Asphalt significant reductions are however reported in the literature:

Plant stack emissions from WMA and Half Warm Asphalt production are significantly reduced [1.]. CO_2 reductions are in the order of 20 to 40 %. SO_2 reductions are in the range of 20 to 35 %. The reduction of volatile organic compounds (VOC) can be up to 50 % and for carbon monoxide (CO) by 10 to 30 %. For nitrous oxides (NO_x) the reduction can be as much as 60 to 70 %.

Particulate release reductions vary from 20 to 55 % [1.].
Actual reductions vary based on a number of factors, such as the fuel used.
Technologies that result in greater temperature reductions are expected to have greater emission reductions.

Other researchers [6.] have shown similar data as in [1.]: Emissions of greenhouse gases like CO2, NO2 and SO2 are also reduced in the same proportion as the energy gain, which is about 25% to 50% according to the processes.
Tests for asphalt aerosols/fumes and polycyclic aromatic hydrocarbons (PAHs) indicated significant reductions compared to HMA, with results showing a 30 to 50 percent reduction [1.]. It should be noted that all of the exposure data for conventional HMA were below the current acceptable exposure limits.

So, in short:

- The reduction of the production temperature in the WMA and Half Warm Asphalt processes do lead to significant reductions of stack emissions;
- The reduced fuel and energy usage gives a reduction of the production of green house gases and reduces the CO_2 / Carbon footprint;
- The lower mixing and paving temperatures help to minimise fumes, emissions, and odours and a subsequent reduction of workers' potential for exposure to fugitive emissions from the plant.

NB – the embodied CO_2 “footprint” of additives may offset some of the savings gained from energy and emissions reductions.

Manufacturing and paving benefits

The use of Warm Mix Asphalt has several advantages, not only for the asphalt mix itself but also for the paving operations:

Manufacturing benefits:

- Lower asphalt temperatures results in less hardening of the bitumen/binder during manufacture
- The WMA process will lower the amount of dust extraction because the aggregate is heated to a lower temperature
- WMA is fully compatible with the use of RAP.

Paving operations benefits

The use of Warm Mix Asphalt improves the handling characteristics of asphalt and creates a more comfortable (working) environment for the asphalt workers and the public near work sites:

- WMA can be compacted at a lower temperature than conventional HMA for an equivalent degree of compaction.
- Alternatively, producing WMA at HMA temperatures will permit an extended time for haulage and compaction. Therefore more distant sites can be served from each plant with the same degree of workability, or the period of workability to achieve the same degree of compaction is extended. Or, a higher degree of compaction can be achieved at the same (HMA) temperature. This can additionally extend the laying season into colder months and/or night working.
- WMA can be used in deep patches where the site is restricted. As the lower temperature WMA starts with less heat it will therefore cool faster to ambient temperatures. Therefore, the site can be opened for traffic at an earlier stage.
- The lower mixing and paving temperatures minimises fume and odour emissions and creates cooler working conditions for the asphalt workers. As a rule of thumb, the release of fume is reduced by around 50% for each 10degC reduction in temperature.
- This reduction in emissions of fume and odour also minimises inconvenience to the public near work sites.

Economical aspects

Cost reductions may arise from:

- Because of the lower production temperature of WMA less fuel is needed to dry and heat the aggregate.
- Because of the lower production temperature there may be less wear of the asphalt plant [8.] [9.].

Cost increases may arise from:

- The investment and the depreciation of the plant modification (if needed)
- The costs of the additives (if additives are used).
- Technology licensing costs

Dependent on the interaction of these factors the costs of WMA production should be expected to be similar to or slightly higher than that of normal hot mix.

5. WMA and European standards

The European Standards for “Bituminous mixtures” (EN 13108-1 to -7) have been in force since 1st March 2008. These Standards do not preclude the use of Warm Mix Asphalt.

The European Standards include maximum temperatures for particular mixtures, but there are no minimum temperatures The minimum temperature of the asphalt mix at delivery is declared by the manufacturer. The standards also contain provisions for dealing with mixtures containing additives, subject to demonstration of equivalent performance.

Thus, European Standards should not be seen as a barrier to the introduction of WMA.

6. Procurement

Increasing focus on energy use and carbon footprint is likely to stimulate interest in the wider use of WMA and other energy reducing technologies. It may be appropriate to give some advantage to low energy/low carbon technologies in the procurement process to encourage their use. Any “Green” Procurement needs to take a Life Cycle Assessment approach to ensure that alternative products provide equivalent performance and that the appropriate maintenance scenarios are fully assessed. Various transparent and objective models are under development to assist in this process.

7. Summary and recommendations

In recent years several techniques have become available for producing Warm Mix asphalt. The most commonly used at this moment are:

- Organic additives
- Chemical additives
- Foaming techniques

These permit the production and paving of asphalt mixes at temperatures which are 20 to 40 °C lower than traditional hot-mix asphalt.
Studies have showed that the performance characteristics of WMA mixes can be at least equivalent to conventional mixes. This can be achieved because of the often better workability and hence better compaction which can be achieved.
The lower production temperature also reduces the ageing of the bitumen during the production stage, which results in an improved thermal and fatigue cracking resistance.

The use of WMA is beneficial with respect to:

- The environment: less energy needed and less emissions
- The paving operations: better workability, extending the construction season and earlier opening of the road
- Asphalt workers: reduced potential for exposure to fumes and odours and a cooler working environment
- Economical issues: Less fuel needed.

WMA techniques can be used for most types of asphalt mixtures, including mixtures traditionally produced at elevated temperatures such as EME2 and Mastic Asphalt as well as Polymer Modified Asphalts.

New techniques continue to be developed.

Because of the many advantages of WMA, its usage is growing and it is expected that the use of WMA will become standard practice.

The advantages with regard to the environment, the asphalt workers, the paving operations and the economical benefits also have to be brought to the attention of the politicians and the specifiers in road authorities and they have to be convinced of the advantages of the WMA.

In the future more data to support the good performance and the enhanced durability should be provided, based on the experience of the existing paving projects.
In the future the Carbon Footprint / environmental aspects will become more important and the use of WMA may prove to be one of the ways to achieve a lower Carbon Footprint. A good and easy to use LCA-tool to calculate environmental effects will be beneficial during the tendering process.

Last but not least, including WMA technologies in local and national specifications will stimulate the industry to provide society with state-of-the-art solutions regarding ecological issues.

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