The use of Warm Mix Asphalt

EAPA – Position Paper

EUROPEAN ASPHALT PAVEMENT ASSOCIATION

©European Asphalt Pavement Association
Rue du Commerce 77
1040 Brussels,
Belgium
www.eapa.org
info@eapa.org
October 2014

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 lower emissions, lower exposure and improved working conditions for the crew.
This lower exposure supports the goal of the European asphalt industry to reduce bitumen fumes during paving operations.

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
- Consequences for the asphalt plants when producing WMA
- Experience in various countries
- Summary and recommendations
- References and literature

List of content **Page**

Summary		3
1.	Introduction	5
2.	Techniques to produce WMA • Organic additives • Chemical additives • Foaming techniques	6
3.	Equivalent performance of WMA	8
4.	Benefits of WMA • Asphalt workers benefits • Environmental benefits • Manufacturing and paving benefits • Paving operations benefits	9
5.	WMA and European standards	12
6.	Consequences for the asphalt plant when producing WHA	12
7.	Procurement	17
8.	Experience • Experience in EAPA member countries • Experience in other countries	17
9.	Summary and recommendations	21
10.	References / literature	22

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:

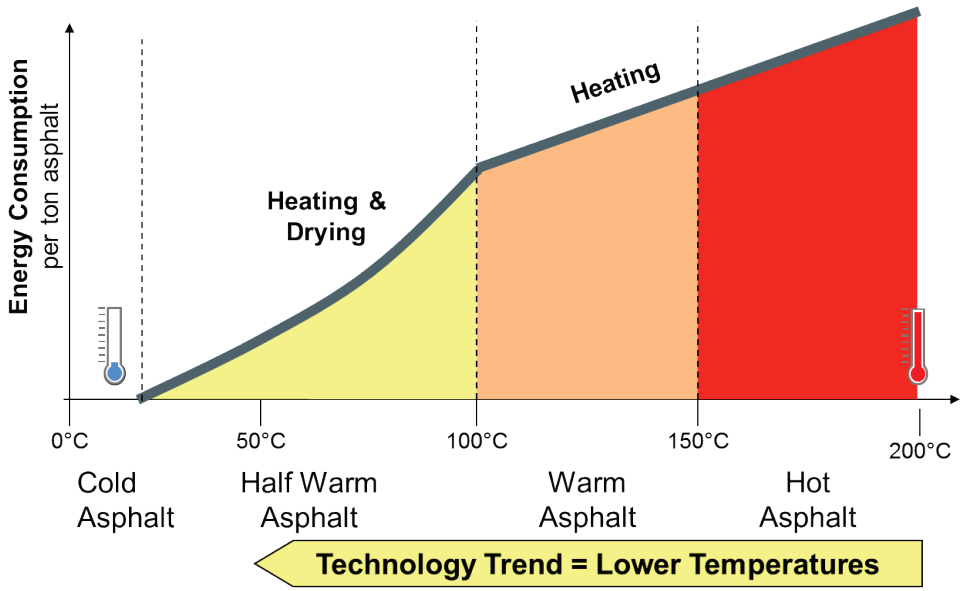


Figure 1: Classification by temperature range

- Cold mixes: produced with unheated aggregate and bitumen emulsion or foamed bitumen.
- Half Warm Asphalt: produced between approximately 70 °C and roughly 100 °C.
- Warm Mix Asphalt: produced and mixed at temperatures roughly between 100 and 150 °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.

The lower mixing and paving temperatures obtained by the use of Warm Mix Asphalt minimise 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 12 °C reduction in temperature [1.].

This reduction of emissions is the most important reason for the European asphalt industry stimulating the use of Warm 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 20–40 °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 85 and 140°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 - 40°C.

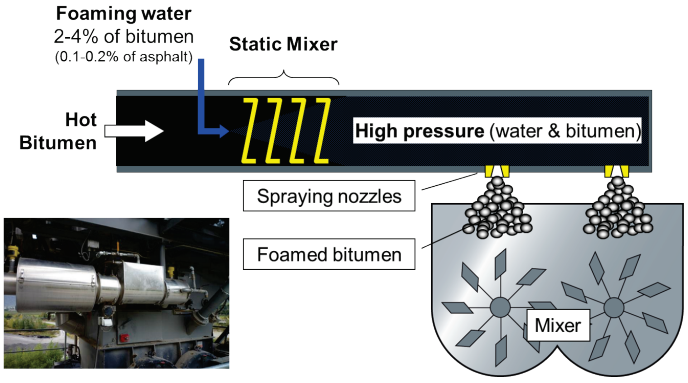
Foaming techniques - to initiate a foaming process of the bitumen

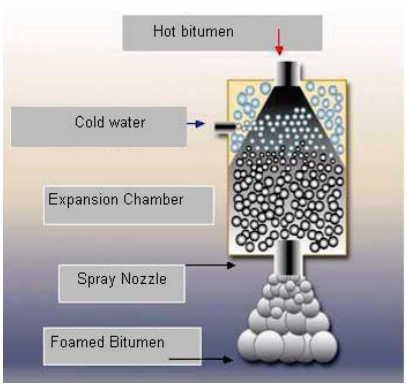
A range of foaming techniques is applied to reduce the viscosity of bitumen. Various means are employed to introduce small amounts of water into the hot bitumen. The water turns to steam, increases the volume of the bitumen and reduces its viscosity for a short period. The expansion of the bitumen allows the coating of the aggregates at lower temperatures and the residual moisture supports the compaction of the asphalt on the construction site. Production and paving temperatures can be reduced in parallel.
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 40°C.
Figures 2 and 3 show examples of foaming nozzles.





Figures 2: Foaming nozzle www.foamasphalt.info] *Figures 3: Foaming nozzle [2.]*

On batch mixing plants, bitumen foaming can be combined with a multi-phase mixing process. Another "Two phase foaming process" [3.] 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 °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.

A second indirect foaming technique uses the moisture on the sand (or RAP) to generate naturally created foam. It is a sequential technique. The coarse aggregate which represents about 80% of the mix design is dried/heated to 130-160°C, it is then coated by the bitumen and thereby creating a thick binder film on the coarse particles. The next stage involves the addition of the cold/wet fraction. The moisture

in contact with the hot bitumen causes foaming which facilitates easy coating of the cold and wet RAP or fine aggregate.

This technique enables the same temperature reduction as the direct foaming through nozzles, about 20 to 40°C.

Next to the above mentioned techniques there are also combined products that can be used to produce Warm Mix Asphalt, like pallets with fibres and zeolite or fibres with organic additives.

As one can see the gain in temperature reduction is between 20 to 40°C (more or less) independent from the technique used. One has to keep in mind that this gain also depends on the paving grade of the bitumen used.

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 [4.].

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 [5.]

It was concluded in [5.] 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.

Recent studies

In [8.] a review of field trials of WMA technologies conducted in various countries in the world is presented, with the emphasis on performance differences between WMA and conventional HMA.

At the National Center for Asphalt Technology (NCAT) in Auburn, Alabama, USA and at the University of California Pavement Research Center (UCPRC), USA they conducted accelerated loading studies of the comparative performance of WMA and HMA technologies under accelerated heavy loading using the Heavy Vehicle Simulator (HVS). These trials have involved the production of the mixes, the construction of test pavements, and the monitoring of field performance, including detailed (within-pavement) response-to-load data. Extensive laboratory studies of both field and laboratory samples were also carried out in order that the relative performance of WMA with HMA could be compared with recommendations made regarding the implementation of WMA into current HMA mix design procedures.

The work being conducted at NCAT and UCPRC has suggested that the performance of WMA pavements is at least equivalent to that of HMA [10.].

Numerous studies have been carried out in Europe and show that the same mechanical performance / the same mechanical properties can be obtained compared with the traditional hot mixes whatever the process used is.

4. Benefits of WMA

The most important benefit of using Warm Mix Asphalt is the significant lower bitumen fume exposure level during paving operations compared to Hot Mix Asphalt. This lower exposure level supports the goal of the European asphalt industry in reducing bitumen fumes during paving operations to improve the working environment of the asphalt workers.

The second reason is the Kyoto protocol. Here 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 greenhouse gas emissions.

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

- Asphalt workers benefits
- Environmental benefits
- Manufacturing and paving benefits
- Paving operations benefits

Asphalt workers benefits

The lower mixing and paving temperatures minimise fume and odour emissions and create cooler working conditions for the asphalt workers. As a rule of thumb, the release of fume is reduced by around 50% for each 12 °C reduction in temperature. So a temperature reduction of 25 °C can lead to fume emission reduction of about 75%.

This reduction of emissions is the most important reason for the European asphalt industry stimulating the use of Warm Mix Asphalt and is in line with the IARC recommendation given in 2009.

The IARC study "A Case-Control Study of Lung Cancer Nested in a Cohort of European Asphalt Workers" [9.] that was published in July 2009, found no evidence of an association between lung cancer risk and exposure to bitumen fume. The conclusion of this study did however mention that "The findings of our study underline the importance of the current trend in reducing inhalation and dermal exposure to bitumen in the workplace".

Reducing the exposure during paving operations will also reduce possible irritation due to bitumen fumes.

It is for these reasons that the European asphalt industry is stimulation the use of Warm Mix Asphalt in order to reduce the exposure during paving operations.

> NB – The use of an additive or a modified bitumen needs to be assessed, as the emissions of such additives can offset the jobsite emission benefits of lower paving temperatures.

Figure 4 shows the time trends in assigned exposure for main exposure variables [9.] that should be continued.

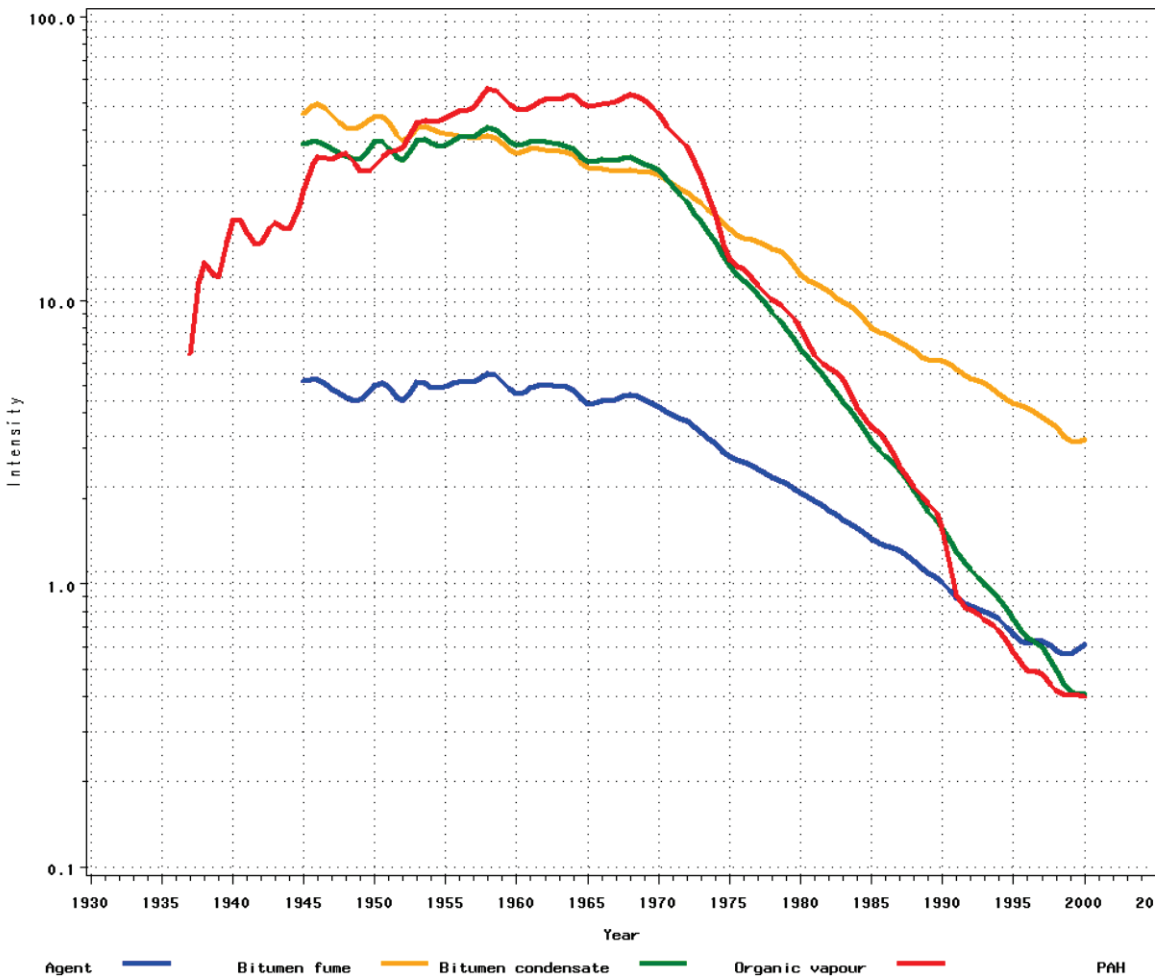


Figure 4: Time trends in assigned exposure for main exposure variables [9.]

A study in Norway in 2011 showed that the exposure of asphalt fumes / vapour was significantly lower when paving WMA compared to HMA. In Norway [10.] the working environment was assessed at 11 trial sections during road paving works with both HMA and WMA at the same day. The results of the study showed an average (arithmetic mean) statistically significant reduction in asphalt fumes of 58-67% depending on the measurement method at a mean reduction in asphalt temperature of 29° C.

This reduction in emissions of fume and odour also minimises inconvenience to the public near work sites.

Environmental benefits

Because of the lower production temperature of WMA less fuel is needed to heat the aggregate. This results in lower emissions of the asphalt plant. 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 [5.]. 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 % [5.].
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 [5.]: 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 [5.]. 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
- Lower production temperatures reduce the thermal stress on the plant components.
- WMA is fully compatible with the use of Reclaimed Asphalt.

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:

- For some technologies like foam, 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.

5. WMA and European standards

The European Standards for “Bituminous mixtures” (EN 13108-1 to -7) 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. Consequences for the asphalt plant when producing WMA

Mixing asphalt at lower temperatures affects the whole production process. There are the changes of the process directly related to the WMA-technology applied (e.g. foam generator) and the other consequences or additional requirements that an asphalt plant needs to fulfil (e.g. operational range of burner).

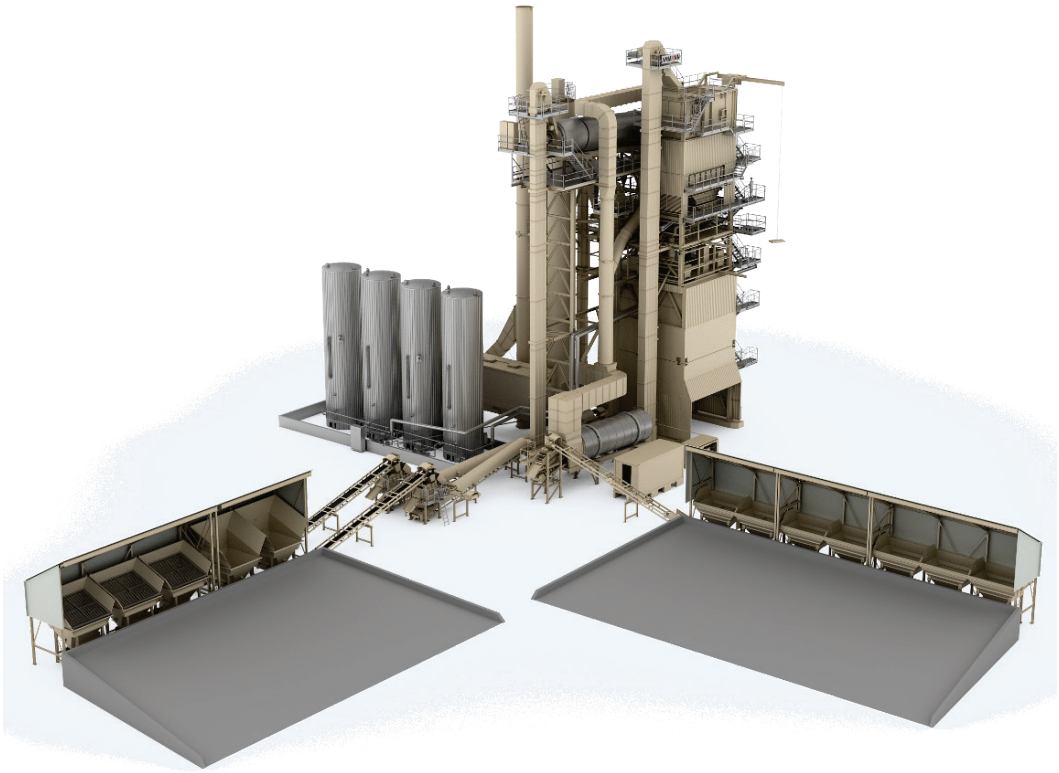


Figure 5: Modern batch mixing asphalt plant

Maintaining Required Baghouse Temperatures.

Condensation of the exhaust gas in the filter system needs to be prevented. Condensation would lead to clogging of the filter bags and also to corrosion of the metallic components. Therefore, the exhaust gas temperature in the baghouse needs to be above the dew point any time. Lowering the aggregate temperature changes the thermal balance in the drying drum. In order to ensure the required exhaust gas temperatures, variable frequency drives can be installed on the drying drum. This gives the possibility to maintain high exhaust gas temperatures while heating the aggregates to lower temperatures. In general, a variable rotational speed of the drying drum creates high flexibility to the heating process.

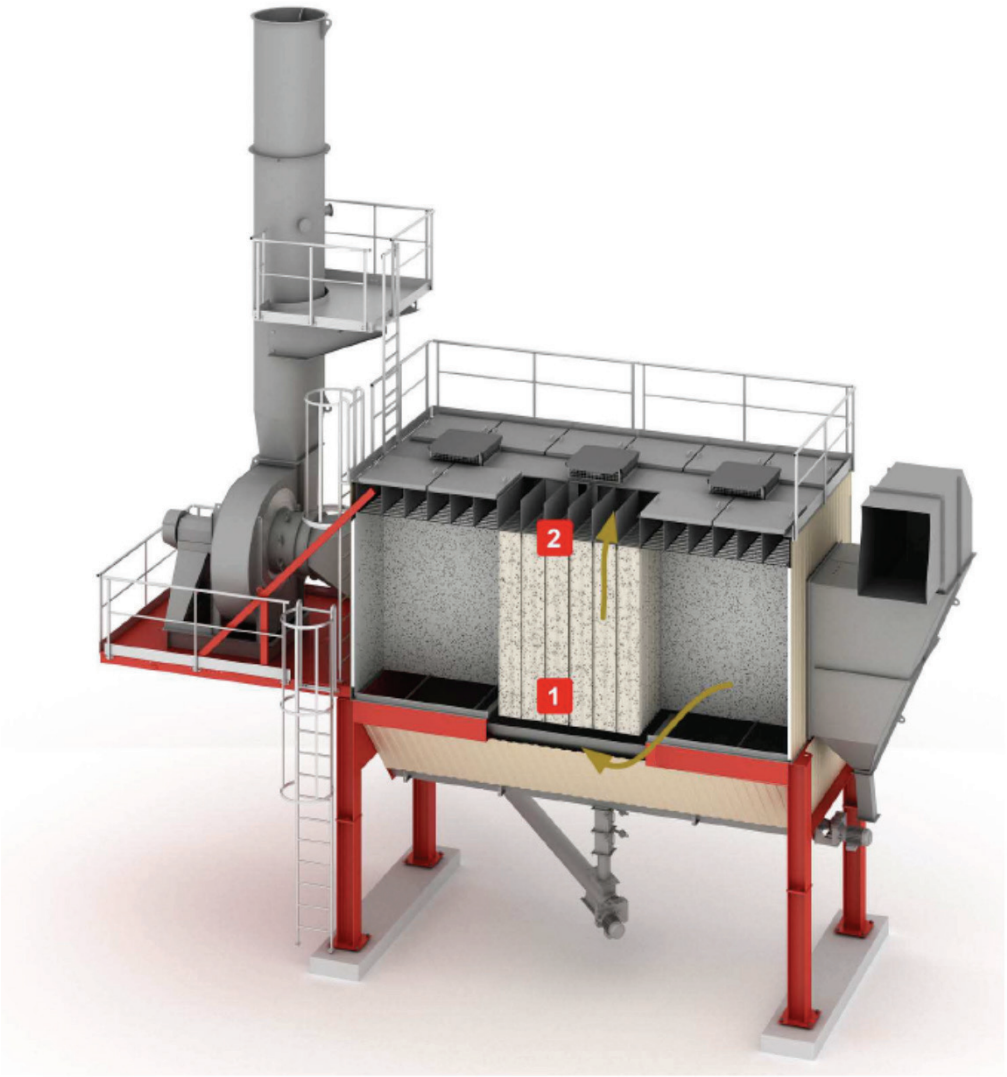


Figure 6: Baghouse Filter

Drying aggregates at lower temperatures

Conventional drying drums are designed to dry and heat the aggregates at Hot Mix temperature. Depending on the available drying drum, changes in the type and position of the flights inside the drum might be necessary. As mentioned above, variable rotation speed of the drying drum supports this as well.

Operational range of the burner

One of the benefits of low temperature asphalt is the reduced fuel or gas consumption. The burner therefore needs to be able to produce a stable flame at partial load. Electronic burner control systems ensure the correct air to fuel and fuel to auxiliary air ratios. If the burner is not able to work at accurate performance levels, the plant would need to start and stop the drying process too often leading to a drop of efficiency.

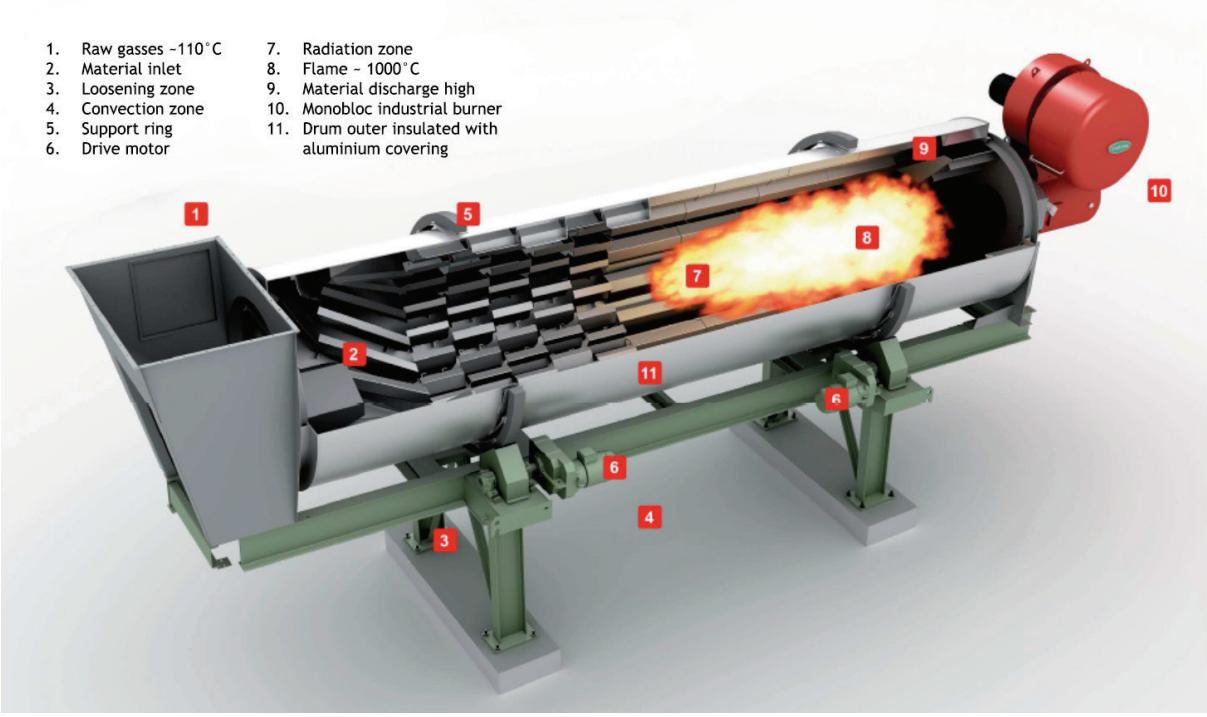


Figure 7: Drying and heating drum

Process and quality control

The complexity of asphalt production increases when applying low temperature technologies. Quality control of the production process needs to be focussed on. A high level of automation (e.g. additive additions), process controls (e.g. pressure levels in bitumen foam generators, temperature measurements) and documentation is required. Modern asphalt production systems deliver this functionality to ensure compliance.

Foam Generator

A foam bitumen installation expands the product portfolio of a mixing plant and enables the foaming of different of road construction bitumen and also polymer modified bitumen. It can also be used to manufacture cold base courses with 100 % recycled materials for example. First hot bitumen is pumped into the foam generator. Cold water with no chemical additive is injected in under high pressure and mixed with the hot bitumen. This water / bitumen mix is then forced through the outlet.

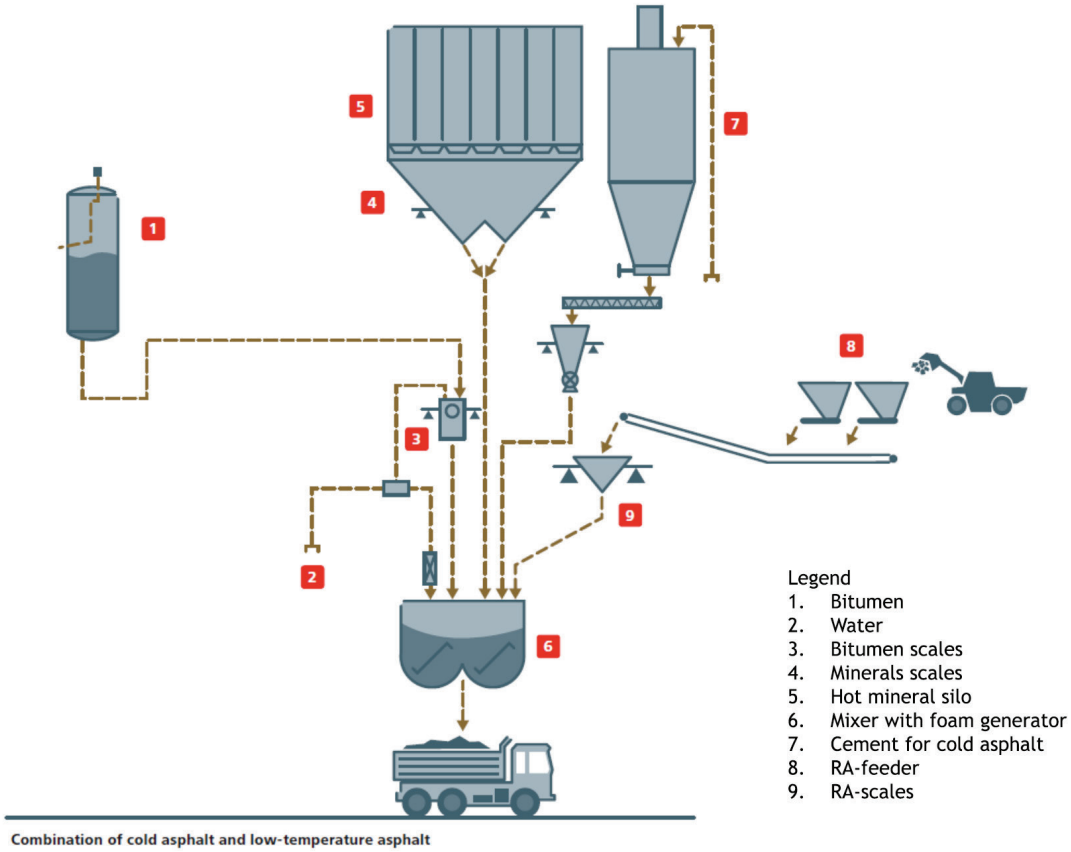


Figure 8: Flow chart of asphalt production with foam bitumen

Storage capacity for modified bitumen

Some low temperature asphalts are based on modified bitumen. Depending on the storage and segregation characteristics of these types of bitumen, bitumen tanks need to be equipped with components (e.g. agitators, pumping) that prevent segregation.



Figure 9: Stirring device on a bitumen tank

Flexibility in mixing sequence

In parallel of applying additives or foaming techniques, the mixing time and the sequence of component addition into the mixer needs to be adapted. The plant control system needs the corresponding flexibility to define mixing sequences for each asphalt production recipe.

7. 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 available to assist in this process.

8. Experience

8.1 Experience from EAPA member countries

Czech Republic:

Recent progress in WMA technology in the Czech Republic

Research on Warm Mix Asphalt (WMA) at the Czech Technical University in Prague (CTU) and Technical University of Brno (VUT) have led to the Preliminary national specifications for WMA (TP 238) published by the Czech Ministry of Transport in 2012. This specification is also valid for mastic asphalt placed at lower temperatures than in the past. A few job sites were realised with this type of mastic asphalt (MA) by the company Eurovia. Some experiments with this MA were also carried out by other Czech contractors. The WMA for compacted asphalt layers is used more frequently. Czech divisions of some multinational companies as Skanska and Porr can use this technology if it is demanded.

The implementation of WMA in the Czech Republic has been described in a paper on the HAPA Conference on WMA in 2013 [11.].

In 2013 all asphalt layers of the pavement in an important road tunnel in Prague were paved with WMA. The use of WMA in the tunnel was a requirement the Administration. During the paving of the WMA, in October 2013, the emissions in this tunnel were measured by the Transport Research Centre CDV (http://www.cdv.cz/en/). The final report of the emission measurements on a couple of job sites will be published by CDV in 2014.

There is also a 3 years research project called "The most effective use of reclaimed asphalt pavement layers for production of new asphalt mixes" (TA02030549) funded by the Technology Agency of the Czech Republic. The final report of this project will be published in 2014. Here the first experimental section was laid on a secondary road in autumn 2013 by the company Froněk. This company has a parallel drum in its mixing plant which permits the addition of 50 % of RAP. The use of WMA (foam technology) enabled them to keep the production temperature at about 130 °C. The mix design was realised in co-operation with CTU.

A research project called CESTI started in 2013. One part of it will focus on the further development of WMA and low temperature Mastic Asphalt. Some leading contractors and the CTU Prague and the VUT Brno participate on this project.

Denmark

In Denmark the company NCC is producing WMA using the foamed bitumen technique where the foamed bitumen is created in a patented foam generator. In September 2012, they conducted a study in cooperation with the Danish Road Directorate on motorway 321 at Ulladulla, where they paved a WMA under exactly the same conditions (in the middle of a day-production) as the traditionally produced asphalt.

The product was a polymer modified SMA 11 and the temperature was lowered to WMA with approx. 20 °C compared to the traditionally produced asphalt. The materials were examined and the compaction rate was determined. They obtained identical volumetric data and the same adhesion for the WMA and the traditional asphalt.

The installation was almost identical and WMA can be easily applied by the paver. The hardening of WMA was slightly lower than the traditional asphalt produced. Based on these studies the remainder of the job was done as WMA and they obtained very satisfactory volumetric data and installation. Since this job NCC has paved WMA for several other jobs, including "GAB II" on the sections Tuse - Vig and Aaby - Middelfart. (GAB II is a base course mixture. It is a mix with a 32 mm grade and a high sand content (~ 65%) in which a 16/32 fraction of alluvial aggregates is added).



WMA sections (Denmark)



WMA surface (Denmark)

France

In France today, the use of WMA is now more and more developed. In order to increase the use of WMA, the French association (USIRF) has written a recommendation to promote the WMA use: (extract)

> "The given USIRF recommends the systematic use of warm mix asphalt, except in special cases; such cases with specific technical constraints or in case of a motivated refusal of the road authority.
> The USIRF reminds that the stimulation of the use of warm mix asphalt is one of the objectives of the voluntary agreement of actors in design, construction and maintenance of road infrastructure, road and urban public space signed in March 25, 2009.
> Jean Louis Marchand,
> USIRF President"

Since this date, the use of WMA has increased to achieve 7.5 % of the total asphalt production in 2012. Furthermore, French documents are in progress to explain and facilitate the WMA use and one conclusion is the following:

> "In the present state of knowledge, the first environmental assessments and realised follow-ups, we can only strongly recommend the use of warm asphalt mixes to meet environmental expectations"

All techniques to decrease the mixing temperature are used in France and the different studies performed show that the technical specifications (mechanical performances of the asphalt concrete) are achieved whatever the process used.

Finally, more and more often, WMA are produced and used with Reclaimed Asphalt, this giving a better environmental assessment.

Norway

WMA stimulation in Norway by giving a bonus

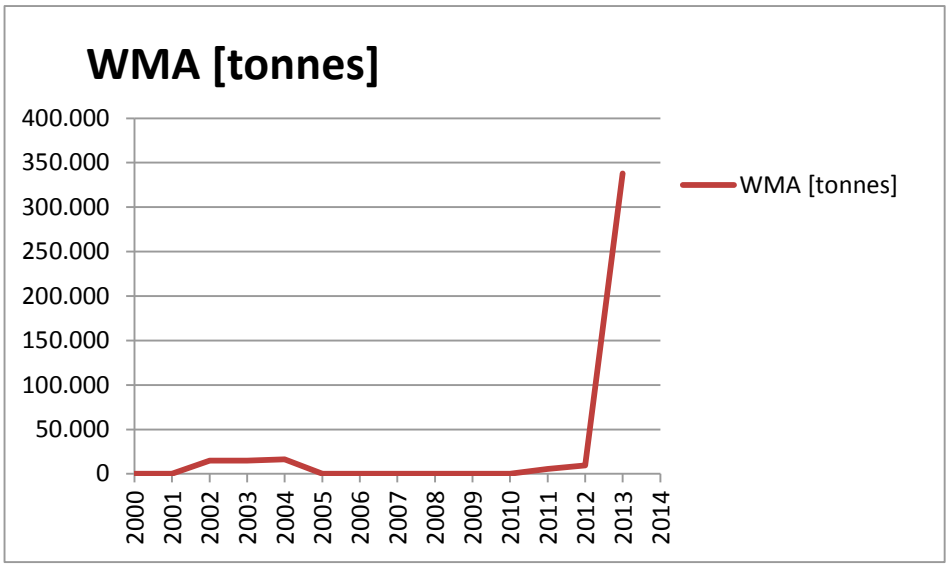
In 2010 the Asphalt Producer Association in Norway (FAV) initiated a new project called Low Temperature Asphalt "LTA-2011" to study the consequence for the asphalt workers' health and the asphalt quality, by doing 11 trial sections with 6 different technics. The production temperature was decreased by 30 °C. On each site also a reference section with ordinary HMA was established.

The conclusions of that study were:

- No significantly differences in the work load for the workers
- A reduction of 50 % of the fumes
- No differences in quality for WMA versus HMA pavement regarding air voids, evenness and rutting.

In 2012 the Norwegian Labor Inspection Authority wanted to accelerate the use of Warm Mix asphalt. To achieve this, the Road Administration in Norway has rewarded the contractors with a bonus of €4/ton, when produced by at least 25 °C less than conventional production, assuming the same quality requirements. This was the case in 2013 and is the case in 2014.

By the end of 2013, 3 contractors (on 16 different plants) have produced 210.000 tons of Warm Mix Asphalt.



The use of Warm Mix Asphalt / Low Temperature Asphalt (LTA) in Norway

In Norway the asphalt industry takes it responsibility for improving the working environment and responds to the IARC recommendations to lower the production temperature, by promoting WMA in collaboration with the Norwegian Road Administration.

Sweden

In 2013 they produced about 145 000 tonnes of Warm Mix Asphalt in Sweden. This was produced by using the KGO-method; a kind of WMA developed by Karl-Gunnar Olsson. They were not using foaming or additives in 2013 in Sweden (With the KGO (Karl-Gunnar Ohlson) method, the coarse fractions of the aggregate mix are initially coated with the bitumen. The fine aggregates, filler and sand, are added afterwards. This is supposed to result in an asphalt mix with better compacting properties so that the asphalt mix can be produced, laid and compacted at a lower temperature level).

Turkey

In Turkey the Technical Specifications for Highways contain provisions for dealing with mixtures with WMA additives, subjected to demonstration of equivalent performance. Until now there is no field experience on highways. There is a research project to develop Warm Mix Asphalt production technology conducted by the General Directorate of Highways and the Scientific and Technological Research Council. The study will be finalised by the end of 2015. The main purpose is to produce domestic additives for WMA.

Additionally, transportation boards of some universities have research studies on additives and also foam asphalt. In Istanbul there are trial sections constructed on urban roads by using with zeolite and wax in 2012. The performance of these sections is quite good as well as conventional asphalt production techniques.

In Europe, more and more countries are now equipped for producing WMA with different processes.

8.2 Experience from other countries

USA:

In the USA the use of Warm Mix Asphalt is increasing faster than in Europe. The following table shows the data of 2009 – 2012.

Year	Million tonnes of WMA	Total asphalt production [Million tonnes]	% WMA
2009	15,2	325	5 %
2010	37,3	326	11 %
2011	62,3	332	19 %
2012	77,1	323,5	24 %

The techniques used in USA in 2012 are:

- Plant Foaming 88.1%
- Chemical Additive 9.6%
- Additive Foaming 2.1%
- Organic Additive 0.2%

Switzerland

In Switzerland a research project is underway to include war mix technologies in the standards (VSS Planet). Individual asphalt producers and contractors are propagating warm mix technologies.

Swiss websites to promote the use of WMA:

http://www.lowtemperatureasphalt.info/en/: site created to propagate the use of foam bitumen for low temperature asphalt.

http://www.ecoroad.ch/ECOR/: site created by the Swiss asphalt association (SMI) to propagate the use of warm mix technologies in Switzerland.

9. 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:

- Asphalt workers: reduced potential for exposure to fumes and odours and a cooler working environment
- Environment: less energy needed and less emissions
- Paving operations: better workability, extending the construction season and earlier opening of the road
- 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 asphalt mixtures with polymer modified bitumen.

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.

10. References / literature

[1.] Brandt HCA, de Groot PC, A Laboratory Rig for Studying Aspects of Worker Exposure to Bitumen Fumes, American Industrial Hygiene Association Journal 60:182–190 (1999)

[2.] Jenkins, K. Mix Design Considerations for Cold and Half-Warm Bituminous Mixes with Emphasis on Foamed Bitumen. Doctoral Dissertation, Stellenbosch University, 2000.

[3.] Larsen, O.R., O. Moen, C. Robertus, B.G. Koenders; WAM Foam Asphalt Production at Lower Operating Temperatures as an Environmental Friendly Alternative to HMA - Proceedings 3rd Eurasphalt & Eurobitume Congress, Vienna 2004.

[4.] Erfahrungssammlung über die Verwendung von Fertigprodukten und Zusätzen zur Temperaturabsenkung von Asphalt, published by Bundesanstalt für Straßenwesen

(BASt), Bergisch Gladbach (www.bast.de - > Fachthemen -> Straßenbautechnik -> temperaturreduzierte Asphaltbauweisen -> Erfahrungssammlung.pdf
Valid version when printing these guidelines: November 2010

[5.] Warm-Mix Asphalt: European Practice; International Technology Scanning Program, FHWA-PL-08-007, February 2008, FHWA-HPIP, U.S. (Department of Transportation, Washington, DC, USA. (www.international.fhwa.dot.gov)

[6.] Y. Brosseaud, M. Saint Jacques, Warm asphalt mixes: overview of this new technology in France, Paper 0309, Transport Research Arena Europe 2008, Ljubljana.

[7.] X. Carbonneau, J.P Henrat, F. Létaudin, Environmentally friendly energy saving mixes, Proceedings of the 4th Eurasphalt & Eurobitume Congress, Copenhagen 2008; paper 500-010.

[8.] Review of Overseas Trials of Warm Mix Asphalt Pavements and Current Usage by Austroads Members; AUSTROADS TECHNICAL REPORT; AP-T215-12; November 2012; ISBN 978-1-921991-57-8; Australia.

[9.] Boffetta, P. et al. A Case-Control Study of Lung Cancer Nested in a Cohort of European Asphalt Workers, Final Report, 1 July 2009, IARC, Lyon, France.

[10.] Norwegian WMA project – Low Temperature Asphalt 2011; Main report (in Norwegian with English Summary), FAV, 2012, Norway.

[11.] Fiedler J., Kašpar J., Valentin J. WMA specifications and experience with this mix type in the Czech Republic, HAPA conference, Hungary, 2013.

[12.] R. Rühl, Lower temperatures – The best for asphalt, bitumen, environment and health and safety; Proceedings of the 4th Eurasphalt & Eurobitume Congress, Copenhagen 2008; paper 500-013.

[13.] Y. Edwards; Influence of waxes on polymer modified mastic asphalt performance; Proceedings of the 4th Eurasphalt & Eurobitume Congress, Copenhagen 2008; paper 401-014.

[14.] Prowell, B., Hurley, G., Frank, B. [2011] Warm-Mix Asphalt: Best Practices. Report No. QIP-125. National Asphalt Pavement Association (USA). Lanham, Maryland, USA (3rd edition published January 2012)

[15.] Low Temperature Asphalt (LTA) for a sustainable pavement (in Dutch); CROW Publication 319, ISBN- 978 90 6628 613 9, CROW, the Netherlands

[16.] Warm mix asphalts; Tips and tricks developed by professionals for professionals: DAV, July 2009, Germany