Warm Mix Status quo of Warm Mix Asphalt in Europe in 2015

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Abstract

Since the mid-1990s, a range of techniques has been developed to reduce the mixing and laying temperatures of asphalt mixtures with around 20 - 40 °C compared to the traditional Hot Mix Asphalt (HMA). These techniques lead to a so-called Warm Mix Asphalt (WMA).

The use of WMA is beneficial with respect to

- *Asphalt workers: reduced 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, reduced ageing of the bitumen during the production stage*
- *Economic issues: Less fuel needed.*

In the future, the Carbon Footprint / environmental aspects will become more important and the use of WMA with a high percentage of Reclaimed Asphalt is one of the ways to achieve a lower Carbon Footprint.
Therefore, the European asphalt industry shall extend its use and it is up to the industry to be active in that perspective. The asphalt industry has to protect its workers (health) and to deliver the benefits (environmental and economic).
The main chapter of this paper shows, that the use of WMA is growing in many European countries and industry becomes more and more experienced. The overall experiences with the material show equivalent performance and durability compared with Hot Mix Asphalt. Several initiatives of the European asphalt industry indicate that there will be an increased use of this material, e.g. industry in France, Norway and Sweden have declared goals for market shares in the near future.
Additionally, several measures that can be taken from industry and third parties to increase the use of WMA are presented.
Because of the many advantages of WMA, its usage is growing and it is expected that the use of WMA will become standard practice in the future.

12. Introduction

Many techniques have been developed to reduce the production and laying temperature of asphalt as the so-called Warm Mix Asphalt (WMA) since the late 1990's. These techniques, the history and the derived benefits of this WMA have been described and presented in detail in many papers [1] [4] [5]. Therefore, this paper only describes briefly the main WMA techniques that are currently used and provides a comprehensive summary of the benefits using WMA. The main chapter of this paper describes the status quo of the use of WMA in several European countries with their regulations, obligations, incentives, as well as techniques used and provides data of the WMA production in these countries, followed by conclusions and the viewpoint the European asphalt industry.

13. What is WMA?

WMA is a procedure and not a product

In recent years, several techniques have become available for producing Warm Mix

Asphalt. The most commonly used techniques at this moment are organic additives, chemical additives, foaming techniques and combinations of these techniques. At this moment up to 45 different WMA techniques are currently known. Since different techniques can be applied, WMA is a specific procedure and not a product.

These procedures permit the production and paving of asphalt mixes at temperatures, which are 20 to 40 °C lower (or even more) than traditional hot-mix asphalt. In some states, WMA is called Low Temperature Asphalt (LTA) or Temperature Reduced Asphalt.

Standardisation of WMA

Because it is a procedure and not a product there are no explicit product standards for WMA and the European Standards for "Bituminous mixtures" (EN 13108-1 to -7) can be used for Warm Mix Asphalt. The European Standards include maximum production temperatures for asphalt mixtures and there are no minimum temperatures. The manufacturer declares the minimum temperature of the asphalt mix at delivery. The standards also contain provisions for dealing with mixtures containing additives. Therefore the European Standards should not be seen as a barrier to the introduction of WMA.

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

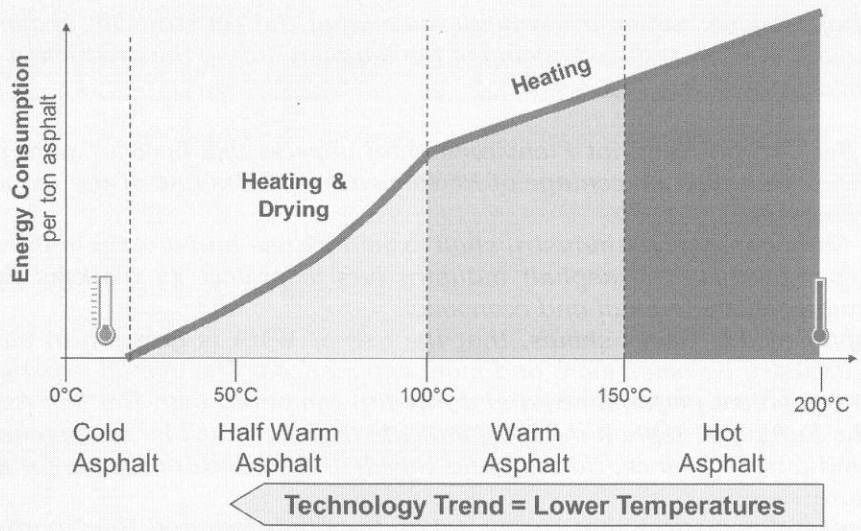

Figure 1: Classification of asphalt by temperature range [1]

The mixture types shown in table 1 are defined as:

- 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.

Techniques to produce WMA

The Warm Mix Asphalt (WMA) technologies described in this paper 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 WMA techniques are:

- Organic additives
- Chemical additives
- Foaming techniques

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.

Organic additives added to the mixture 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 mixing 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 into vapour, 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.

More explanations of two commonly used techniques for foaming, the injection foaming nozzles and minerals as well as consequences for the asphalt plant when producing WMA are given in [1].

14. Why using 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 CO2 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.

Following 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. Thus, 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 recommendations given in 2009.
The IARC study "A Case-Control Study of Lung Cancer Nested in a Cohort of European Asphalt Workers" that was published in July 2009 [7], 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".
A study in Norway in 2011 showed that the exposure of asphalt fumes / vapour was significantly lower when paving WMA compared to HMA. 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 [2].
Reducing the exposure during paving operations will consequently reduce possible irritation due to bitumen fumes.
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 [3]. CO2 reductions are in the order of 20 to 40 %. SO2 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 (NOx) the reduction can be as much as 60 to 70 %. Particulate release reductions vary from 20 to 55 % [3].
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 data shows that emissions of greenhouse gases like CO_2, NO_2 and SO_2 are also reduced in the same proportion as the energy gain, which is about 25% to 50% according to the processes.

Thus, the reduction of the production temperature in the WMA and Half Warm Asphalt processes lead to significant reductions of stack emissions and the reduced fuel and energy usage gives a reduction of the production of greenhouse gases and reduces the CO2 / Carbon footprint.

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

Manufacturing benefits:
- Lower asphalt temperatures results in less hardening of the bitumen/binder during the manufacturing process
- 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. Alternatively, 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.

15. Practice and production figures of WMA in Europe

In no European country, legal requirements concerning WMA have been established, but in some countries, the regulations have been adopted or the government gives incentives to use WMA. This chapter gives an overview of the status quo of WMA in several European countries concerning potential regulations/ obligations, incentives, and techniques. In addition, data regarding the amount of WMA used are provided as the percentage of the total asphalt production.

Examples, experiences and best practices with WMA in many European countries, the USA and Australia are given in [1] and [4].

Situation in Europe compared to the USA and Japan

In Europe, the market share of WMA of the total production of Hot Mix Asphalt and Warm Mix Asphalt is below 3% at this moment. Indeed, there has been an increase since 2009, but not worth mentioning compared to the USA with a market share of more than 32% in 2014 coming from less than 5% in 2009 and even better than the 0.3% market share in Japan (figure 2).

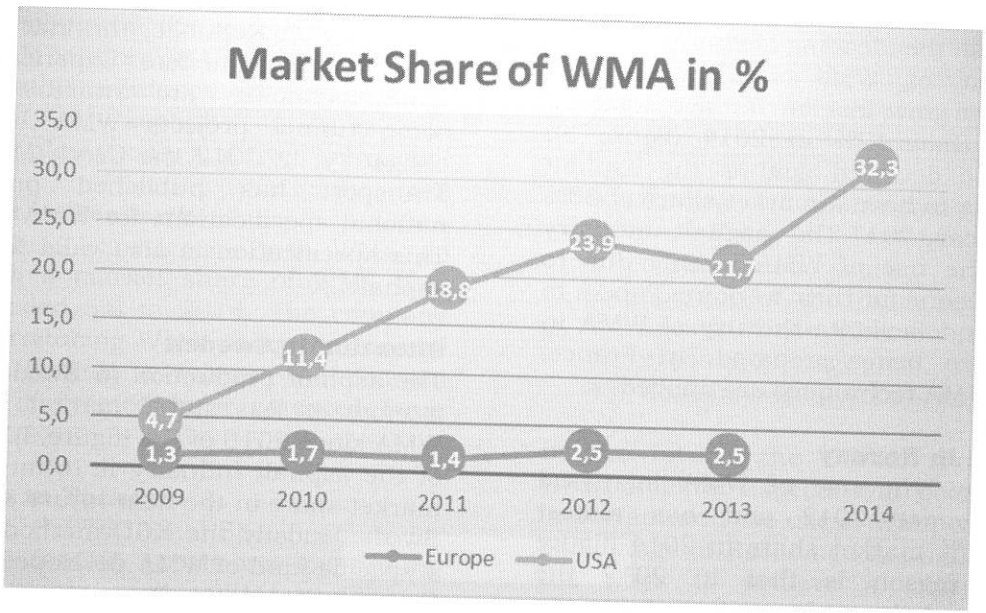

Figure 2: Percentage of WMA of total asphalt production in Europe and the USA from 2009-2014 [6]

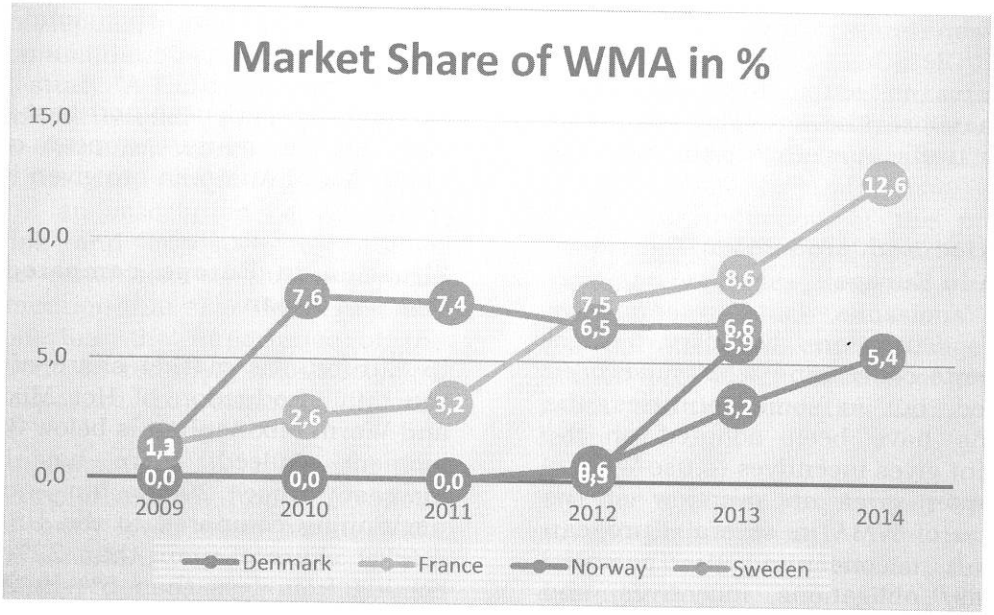

Figure 3: Percentage of WMA of total asphalt production in selected European countries from 2009-2014 [6]

Situation in France

France is the leading country in the production of WMA in Europe. The production grew fast in the last years up to more than 12% in 2014 (figure 3). There, the declared goal of the asphalt industry is to have a market share of 30% in the year 2017.The asphalt industry pushed the use of WMA mainly due to health reasons for their workers. Papers to explain and facilitate the use of WMA in France are being prepared. In France, various WMA techniques are applied.

Situation in Norway

In Norway, the use of WMA increased strongly since 2012 and has almost reached 8% market share in 2014 (figure 3). The reason is that in 2012 the Norwegian Labour Inspection Authority wanted to accelerate the use of Warm Mix asphalt to reduce the fumes for the workers. 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 by using foaming techniques, assuming the same quality requirements. This was the case in 2013, 2014 and 2015 but will be no longer valid for 2016. The Norwegian asphalt industry is pushing the use of WMA and has set a target of 30% for the year 2015. The regularly applied technology in Norway is the foaming technique.

Situation in Czech Republic

In the Czech Republic, the market share of WMA is close to zero. Experiences with WMA technology are available and in some tunnel projects WMA had been obligatory. In 2012 the Czech Ministry of Transport has published preliminary national specifications for WMA (TP 238). This specification is also valid for mastic asphalt.

Situation in Sweden

The asphalt production in Sweden shows a more or less stable market share for WMA since 2010 of 7% (figure 3). The goal of the asphalt industry is to improve the market share in the near future to 15%. In Sweden mostly the KGO-method is used; a specific kind of WMA developed by Karl-Gunnar Olsson [1]. They are rarely using foaming or additives.

Situation in Hungary

In Hungary, the market share of WMA was below 1% in 2013, whereas the foaming technology is becoming more and more popular. In 2013, the Hungarian Asphalt Concrete regulations were modified to introduce WMA, but other asphalt mixtures have so far not been taken into account. The definition of Warm Mix Asphalt was then added to the standards: "Warm Mix Asphalt is an asphalt mixture produced at lower temperature by an asphalt mixing plant's foaming system or

with additives which help to decrease the production temperature. The temperature limits decrease by 10 to 30 °C. The technology does not change the properties of the bitumen used for the asphalt production in the temperature range were the asphalt is used, so the requirements for the asphalts produced by this technology are the same than those for the hot mix asphalts. With this technology the energy consumption and the CO2 emission are reduced."

Situation in Germany

In Germany, no figures of the total production of WMA (called Temperature Reduced Asphalts in Germany) exist. It is assumed, that the market share for WMA is be lower than 1%. For the production of Mastic Asphalt, it is obliged to reduce the application temperature to a maximum of 230 °C for the reduction of the bitumen fumes, which is fulfilled by the use of additives. It is also obliged to use temperature reduced asphalt mixes during paving in tunnels. The Federal research laboratory (BASt) provides a list with suitable additives for temperature reduction of asphalt mixtures. In Germany, almost only additives are used.

Situation in Denmark

In Denmark, experiences with WMA do exist with a market share of WMA that has exceeded 5% in 2014. The company NCC is producing WMA using the foamed bitumen technique where the foamed bitumen is created in a patented foam generator.

Situation in 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 only very little field experience on highways exists.

16. Conclusions and Outlook

Many techniques for Warm Mix Asphalt are available, the best ones will in future remain on the market, and there are no limitations for the use in the European asphalt standards.

The use of WMA is growing in many European countries and industry becomes more and more experienced. The overall experiences with the material show equivalent performance and durability compared with Hot Mix Asphalt. 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.

Several initiatives of the European asphalt industry indicate that there will be an increased use of this material, e.g. industry in France, Norway and Sweden have declared goals for market shares in the near future. The development in the USA with a market for WMA of one third should pull the European market in this direction too.
Because of the many advantages of WMA, its usage is growing and it is expected that the use of WMA will become standard practice in the future.

The use of WMA gives many benefits to the asphalt industry:

- Asphalt workers: reduced potential for exposure to fumes and odours and a cooler working environment
- Environment: less energy needed and less emissions for surroundings
- Paving operations: better workability, extending the construction season and earlier opening of the road, reduced the ageing of the bitumen during the production stage
- Economic issues: Less fuel needed.

In the future, the Carbon Footprint / environmental aspects will become more important and the use of WMA with a high percentage of Reclaimed Asphalt is one of the ways to achieve a lower Carbon Footprint.

Thus, the use of WMA is important for the European asphalt industry:

- Health arguments, IARC, Exposure reduction
- Lower CO2-Emissions, better Carbon Footprint
- Important for (future) Green Public Procurement

Therefore, it shall extend its use and it is up to the industry to be active in that perspective. The asphalt industry has to protect its workers (health) and to deliver

the benefits (environmental and economic).
Because of the many advantages of WMA, its usage is growing and it is expected that the use of WMA will become standard practice in the future.

What measures can be taken to stimulate the use of WMA?

a. Information exchange

The updated EAPA Position Paper on WMA [1] was recently released and 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
- Recommendations

Some national bodies and associations are preparing or have already prepared information material on WMA.

b. Pointing out the benefits of WMA

The advantages with regard to the environment, the asphalt workers, the paving operations and the economic 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.

c. Enhanced regulations including WMA

Including WMA technologies in local and national regulations will stimulate the industry to provide the society with state-of-the-art solutions regarding ecological issues.

d. Procurement

An increasing focus on energy use and carbon footprint is likely to stimulate the interest in a 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 [1].

The tools for producing and using WMA are available. Now the willingness and plans to implement the use of WMA are needed. To achieve this a broad stakeholder involvement is required. Economic incentives, e.g. in Norway [5] have shown to be very effective to stimulate the use of WMA as a start-up. The introduction of new technologies sometimes need a push to make it interesting to invest in it.

17. Literature

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