ANALYSIS OF POSSIBILITIES FOR USE OF WARM MIX ASPHALT IN LATVIA

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ABSTRACT

Warm Mix Asphalt (WMA) production technologies allow lowering the production and paving temperature of the conventional Hot Mix Asphalt (HMA) by at least 20°C without compromising the performance of asphalt. This promises various benefits over HMA, for example, allows to reduce the energy consumption, thus lowering the greenhouse gas emissions, permits to extend the paving season, attain better compaction, provides longer haul distances etc. However, in order to reach widespread implementation of WMA, it is necessary to provide enough information to the decision makers on the benefits of this technology. The article presents an overview of different WMA products and production principles, benefits and drawbacks associated with the technologies. A total of fifteen products that were found to be used in Europe are reported in the paper. However, not all of the technologies are suitable for Latvia, because of the necessary economical investments, climate, local legal provisions and the industry traditions. Potentially most favourable technologies for Latvian circumstances are analysed with the reference to local road specifications.

Key words: Warm Mix Asphalt (WMA), greenhouse gases

INTRODUCTION

WMA is a relatively new technology that allows significant lowering of the production and pavement temperature of conventional hot mix asphalt (HMA) without compromising the performance of the pavement. The temperature reduction range varies depending on what WMA product is used, but the common classification of asphalt by the production temperature is presented in Figure 1.

WMA promises various benefits, e.g., reduced greenhouse gas emissions, lower energy consumption, improved working conditions, lower binder viscosity, better compaction, etc. These technological advantages of WMA allow using it not only as a substitute for conventional HMA by applying the same asphalt specifications, but also to use it in circumstances, where the usage of HMA would not be eligible. However, in order to reach widespread implementation of WMA, it is necessary to provide enough information to the decision makers on the benefits of this technology and ensure that the asphalt has the same or better mechanical characteristics and long-term performance as HMA.

The article is based on the Master thesis by Martins Zaumanis at the Danish Technical University, published as a monograph (Zaumanis, 2011).

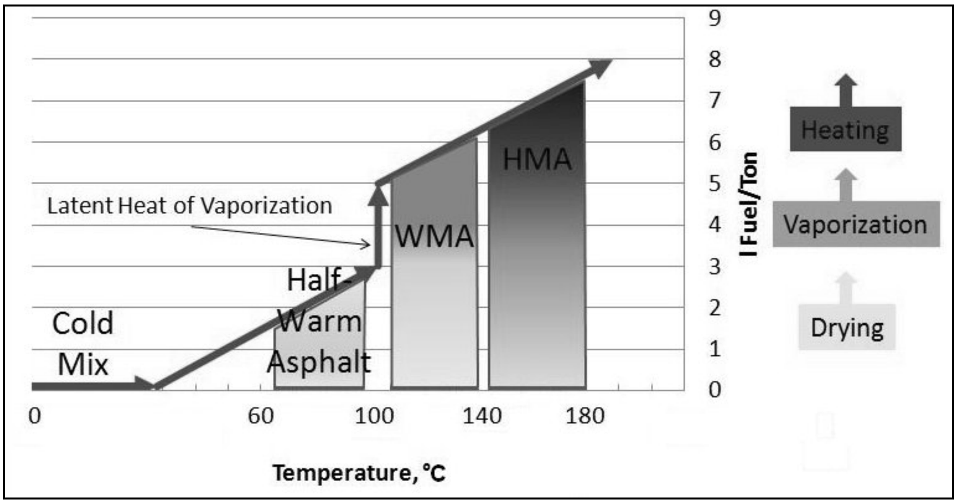

Figure 1. Asphalt classification by production temperature.

WMA PRODUCTION TECHNOLOGIES

The existing WMA production technologies can be categorised in three groups:

1. Foaming technologies;
2. Organic or wax technologies;
3. Chemical additives.

The most widely used products available in the European market and their descriptions are listed in Table 1. The reported values of the production temperatures were not the same in all the literature reports, therefore the most commonly reported data or data supported by the production company are listed first and the data from a different research - afterwards. Differences in the reports may be caused by different factors, such as the production technology, type and the amount of additives used, mix design methods, climatic conditions, material use, etc. The amount of WMA additive usually depends on the materials used, their proportion and especially the grade and type of the bitumen used.

Table 1

Common WMA Technologies in Europe

Product	Company	Description	Reports from countries	Additive	Production temperature [or reduction ranges]
		FOAMING TECHNOLOGY			
Low Energy Asphalt	LEACO	Water based Hot coarse aggregate mixed with wet sand	US; France, Spain, Italy	Yes, ±0.5% of bitumen weight of coating and adhesion additive	≤100°C* 105-124°C
WAM-Foam	Shell and Kolo-Veidekke	Foaming process using two binder grades	US, Norway	Antistripping agents could be added to soften binder	110-120°C* 100-120°C. 62°C
LEAB	BAM	Water based Mixing of aggregates below water vaporization	Netherlands	0.1% of bitumen weight of coating and adhesion additive	90°C
LT Asphalt	Nynas	Water based Binder foaming + hydrophilic filler	Italy, Netherlands	0.5-1.0% of hygroscopic filler by mixture weight	90°C
Aspha-Min	Eurovia	Water containing Zeolite	US; France, Germany	0.3% by mixture weight	[30°C]* [12°C] [20-30°C]
		ORGANIC TECHNOLOGY			
Sasobit	Sasol	Fischer-Tropsch wax	US, EU, worldwide	2.5-3.0% of bitumen weight in Germany 1-1.5% of bitumen weight in US	[10-30]* [20-30°C] [18-54°C] 130-150°C
Asphaltan A Romonta N	Romonta GmbH	Montan wax for mastic asphalt	Germany	1.5-2.0% of bitumen weight	[20°C]
Asphaltan B	Romonta GmbH	Rafined Montan wax with fatty acide amide for rolled asphalt	Germany	2-4% by mixture weight 2.5%by mixture weight	[20-30°C]
Licomont BS 100	Clariant	Fatty acid amide	Germany	3% of bitumen weight	[20-30°C]

Product	Company	Description	Reports from countries	Additive	Production temperature [or reduction ranges]
3E LT or Ecoflex	Colas	proprietary	France	Yes, not specified	[30-40^{o}C]
		CHEMICAL TECHNOLOGY			
Evotherm ET	Mead-Westvaco	Chemical bitumen emulsion	US, France, worldwide	In form of bitumen emulsion	[50-75^{o}C]* [37-54^{o}C] >93^{o}C. 85-115^{o}C
Evotherm DAT	Mead-Westvaco	Chemical package plus water	US, France, worldwide	30% by weight of binder	[45-55^{o}C]* >93^{o}C. 85-115^{o}C
CECABASE RT	CECA Arkema group	Chemical package	US, France	0.2-0.4% by mixture weight	120^{o}C* 101^{o}C
Rediset WMX	Akzo Nobel	Cationic surfactants and organic additive	US, Norway	1.5-2% of bitumen weight	[≥30^{o}C]* [16^{o}C] 126^{o}C
Warmmix L	Star Asphalt	Amide based chemical package	France, Italy, East. Europe	0,5% of bitumen weight	[30 ^{o}C]*

*Temperature range from the product supplier

Foaming technology

Foaming technologies use small amounts of cold water injected into the hot binder or directly in the asphalt mixing chamber. The water rapidly evaporates and is encapsulated in the binder, producing a large volume of foam. The foaming action in the binder temporally increases the volume of the binder and lowers the viscosity, which improves the coating and workability. In the foaming processes enough water must be added to cause the foaming action without adding too much, so that stripping problems arise. To ensure this, most of the producers advise to use antistripping (adhesion, coating) additives to ensure that moisture susceptibility of an asphalt mixture is minimized. Liquid antistripping additives are recommended for WMA production processes (D'Angelo et al, 2008; Chuwdhury et al., 2008). They are added to the binder just before mixing with aggregates, typically 0.5% by the weight of the binder.

There are several foaming technologies available that could be sub-categorised into two groups: water based and water containing (Asphalt Institute, 2007; Perkins, 2009).

The water containing technology uses finely powdered synthetic zeolite that has been hydro-thermally crystallized. It contains about 21 percent water of crystallization which is released when temperature is increased above 85^{o}C. When the additive is added to the mixture simultaneously with the binder, water is released as fine mist, which foams the binder. Controlled foaming effect of 6 to 7 hours of increased workability is reported (Chuwdhury et al., 2008; D'Angelo et al., 2008; Drüschner, 2009).

Water based technologies use a foaming process which is created by injecting cold water into hot asphalt binder using special equipment or technology. The water rapidly evaporates, producing a large volume of foam, which slowly collapses (Asphalt Institute, 2007; Perkins, 2009).

It is considered that these technologies are the most technically complex and require relatively large financial investments for plant modification. There are also some concerns on the moisture susceptibility and permanent rutting of asphalt produced by these technologies. These are pressing problems in Latvia even for HMA, therefore, it is considered that thorough research and laboratory testing is necessary before implementing these technologies in Latvia.

Organic technology

Organic or wax additives are used to achieve the temperature reduction by reducing the viscosity of the binder at the production temperature. The processes show the decrease of viscosity above the melting point of wax, making it possible to produce asphalt mixes at lower temperatures. After crystallisation, waxes tend to increase the stiffness of the binder and the resistance of asphalt to deformation. The type of wax must be selected carefully so that the melting point of the wax is higher than expected in service temperatures and to minimize embrittlement of the asphalt at low temperatures (D'Angelo et al., 2008; Perkins, 2009).

Different researches (for example (Zaumanis et al., 2010; Hurley et al., 2006)) show that WMA that is produced using waxes often has better resistance to plastic deformation than the traditional HMA. This performance can be explained by forming of the lattice structure in bitumen below the crystallisation point of wax. This process stiffens the binder and increases the resistance to permanent deformations of asphalt.

Waxes are also often used as additives to improve the resistance to deformation and to improve the workability of the mixture for the traditional HMA. Keeping in mind that there are considerable problems with the resistance to permanent deformations in Latvia it is considered that waxes may be successfully used for the production of WMA here.

Chemical additives

A variety of chemical packages are used for different products. They usually include a combination of emulsification agents, surfactants, polymers and additives to improve the coating, mixture workability, and compaction, as well as adhesion promoters (antistripping agents). The added amount and temperature reduction depends on the specific product used. The chemical additive package is used either in the form of an emulsion or added to bitumen in the mix production process. This results in relatively minor modifications needed to the asphalt plant or to the mix design process (Chuwdhury et al., 2008; Perkins, 2009)..

BENEFITS AND DRAWBACKS OF WMA

WMA technologies promise a number of benefits, when used. They can vary depending upon which specific WMA technology is used. However, generally the benefits can be categorized in four groups:

- Environmental;
- Production;
- Paving;
- Economic.

The concerns are mostly subjected to a relatively short WMA implementation period and insufficient accessibility of in-situ performance results. The test results in laboratory show some potential problem areas that should be given care to when designing and using WMA. They will be discussed later.

Environment and production

The most important benefit of WMA is the possibility to reduce the greenhouse gases in the atmosphere. This is realized through reduced temperature for production and paving of asphalt. The ranges of possible energy reduction in the production process reported in the research (Kristjansdottir, 2007) are:

- WAM Foam – 30% to 40%;
- Aspha-Min – 30%;
- Sasobit – 20%;
- Evotherm – 50% to 70%.

According to the research (D'Angelo et al., 2008), this gives a plant stack emission reduction of:

- CO_2 in the range of 15% to 40%;
- SO_2 – 20% to 35%;
- volatile organic compounds (VOC) up to 50%;
- carbon monoxide (CO) – 10% to 30%;
- nitrous oxides (NO_X) – 60% to 70%.

The reduction of aerosols, fumes and dust is also beneficial to the worker health and to the people in the surrounding territories of production and paving sites. This may mean easier permission for a plant site in urban areas. The actual reduction in each specific case depends primarily on the temperature reduction rate and according to (Brosseaud et al., 2008) greenhouse gases (CO_2, N_2O, and CH_4) are reduced in the same proportion as the energy gain, which is illustrated in Figure 1. Reduction of fuel used for asphalt production results also in reducing the demand of non-renewable fuel extraction and dropping the carbon footprint of fuel production and transportation.

Because of the different production technology for WMA, it promises several benefits that are indirectly related to the reduction of atmospheric pollution. Lower mixing temperatures and the modification of bitumen results in different visco-elastic behaviour of the binder in the WMA technology pavements. Less aging during the production and paving process tends to improve the pavement flexibility, which reduces susceptibility to fatigue and temperature cracking. This results in the improvement of the pavement longevity (life cycle), further reducing the potential costs for restoring the asphalt overlay (Perkins, 2009). Lowering of bitumen viscosity in the production process allows incorporating a higher percentage of reclaimed asphalt pavements (RAP). Even up to 90% of RAP is reported in the research (Drüschner, 2009) and WMA still results in less effort needed for compaction, which means additional energy saving realized in the paving process. The overall benefit of RAP usage is the resolving of the problem of RAP utilisation, saving of landfill space, reduction of virgin aggregates and energy used for mining.

It must be noted that some of the environmental benefits may be offset with the carbon footprint embodied for producing additives and/or any additional equipment supporting the production of WMA. The producers of two WMA additives were contacted. None of them were able to provide the necessary information of the amount and types of energy used in the production of these products or the amount of the greenhouse gases produced.

Paving

Improved workability and compaction are attained when using WMA. Lower paving temperature enhances the working conditions for the paving crew, which means enhanced productivity and improved quality. The reduced viscosity decreases the risks of ensuring the necessary compaction, especially when working in cold weather and, because the difference between the mix and ambient temperature is smaller than for HMA, a longer compaction window is provided. It may permit a longer paving season and/or paving during nights. Additionally, producing WMA at HMA temperatures will permit even longer compaction time. The Latvian road specifications (LVC, 2009) permit paving of asphalt wearing course only when the temperature is higher than 10^{o}C (for layers between 40-60mm) or higher than 15^{o}C (for layers <40mm). These temperatures are usual for Latvia only from April to September (Latvijas vides, ģeoloģijas un meteoroloģijas centrs, 2011). Use of WMA additives could allow extending the paving season by several months thus ensuring a significant economical effect for contractors. It is reported (D'Angelo et al., 2008) that field trials were conducted in Germany with Sasobit at ambient temperatures ranging from +1^{o}C to + 3^{o}C and better density was achieved if compared to HMA mixture.
Similarly to cold weather paving, because of the possibility to compact the mixture in lower temperature, longer haul distances are promised for WMA. Therefore, producing WMA technology mixtures at the temperatures traditional for HMA, more distant sites and large urban areas like Riga can be served from large distances without losing workability. This means expanded market areas and a reduced asphalt cost due to the decrease in the mobilisation expanses. Another benefit for the city or high maintenance roads that need to be opened for traffic as soon as possible is that faster putting into operation times can be achieved. Since the initial temperature is significantly lower, less time is necessary for cooling the mixture. This can also be important for expanding airports, like the International Airport of Riga, where the stretch of time for construction can be very tight.

Economical

Different techniques of producing Warm Mix Asphalt (WMA) promise various energy savings for the production - this mostly depends on how much the production temperature was lowered and what kind of fuel is used. The economical benefit from the energy savings should be discussed together with the cost and type of the energy used, as higher energy prices promise greater savings. Indirect economical effects can be realized through the reduction of the mobilization costs and longer paving season. Another indirect benefit is less wear on the asphalt plant due to the reduced temperature.
Economical benefits should be evaluated together with environmental benefits. If stricter emission standards are implemented, there may be higher economical potential for WMA. In this case the potential benefits may not be completely economically quantifiable and should be evaluated together with environmental regulations.
The savings with reduced energy consumption may be offset by the additional costs of WMA production technologies. It must be established if the reduced energy consumption reduces the overall costs of WMA production in each specific case. If no proof on production cost lowering is established, it may be possible that contractors will not choose this technology for the other benefits alone.

Table 2

Additional costs for some of WMA products

Parameter	WAM Foam	Aspha-min	Sasobit	Evotherm
Equipment modification or installation costs	\$30,000-\$70,000	\$0-\$40,000	\$0-\$40,000	Minimal
Royalties	\$15,000 first yr \$5,000 plant/yr 0.30/ton	None	None	None
Cost of material	N/A	\$1.3/kg	\$1.7/kg	7-10% more than asphalt binder
Recommended dosage rate	N/A	0.3% by weight of mix	1.5 to 3.0% by weight of binder	Use in place of bitumen
Approximate cost per ton of mix	\$0.30 (not incl. royalties)	\$3.60	\$1.30-\$2.60	\$3.50-\$4.00

Potential increases depend on production techniques as different WMA technologies require different additional costs. Increase in costs may arise from:

– the investment and the depreciation of plant modification;
– the costs of the additives;
– possible costs for technology licensing.

The research (Kristjansdottir, 2007) involves comparison of possible additional expenses for WMA production (Table 2).

The data are gathered from different research and therefore using different production plants and other specific conditions. However, it gives a good impression on the additional costs of different WMA technologies.

CONCERNS ON WMA PERFORMANCE

In order to reach widespread implementation of WMA, it is necessary to ensure that the asphalt has the same or better mechanical characteristics and long-term performance as HMA. WMA has been used in all types of bituminous mixtures, including dense graded, stone mastic, porous, and mastic asphalt. It has been used with different aggregates and all grades of binder as well as polymer modified bitumen and Reclaimed Asphalt Pavement (RAP), and a variety of layer thicknesses and traffic levels have been applied for WMA. Based on these findings, there are generally no restrictions on WMA implementation. However, there is some concern about some mechanical properties and longevity of WMA.

Permanent deformations

There is a general concern for WMA rutting performance that is connected with the decreased mixing temperature which may lead to incomplete drying of aggregates and insufficient coating with bitumen.

Another aspect that may influence decreased resistance to permanent deformations is the decreased oxidative hardening of bitumen due to the lower production and compaction temperature. These problems might be treated with adding active adhesion agents or initially choosing a harder bitumen grade.

Potential rutting problems require careful evaluation of asphalt in laboratory. Care should be given to preparation of the testing samples, because there might be a necessity for mixture aging before compaction to ensure proper correlation with the actual production process. The choice of the right compaction method might also be a problem, because some methods might not be sensitive enough to temperature changes.

The WMA that is produced by treating bitumen with wax usually shows better resistance to deformations than the reference HMA. This can be explained by forming of the lattice structure in bitumen below the crystallisation point of wax, which stiffens the asphalt at in-service temperatures.

Moisture sensitivity

Due to low mixing temperatures, the moisture contained in the aggregate may not completely evaporate during mixing and the retained water in the aggregates could lead to increased susceptibility to moisture damage. Because of residual moisture left behind by the microscopic foaming process, this is even more critical for WMA technologies that involve foaming as a binder viscosity lowering action. These problems, if they occur, may be successfully treated with active adhesion agents.

Low temperature behaviour

It is reported in several researches from the U.S (Wanger et al., 2008; Hurley et al., 2006; Chowdhury et al., 2008) that the use of waxes for tests with the Bending Beam Rheometer (BBR) increases the bitumen stiffness and reduces the relaxing abilities at low temperature regimes. Accordingly, wax modification leads to worsening of the low temperature behaviour and it has been determined that the threshold of SUPERPAVE concept PG bitumen leads to worsening of low temperature grade of 2-3^{o}C and the bitumen ability to creep is worsened by 6-9^{o}C.

Compaction

WMA is reported to have better compaction potential due to decreased viscosity and less bitumen ageing in the production process. This can allow to save the compaction energy and to reduce the time necessary for compaction which may be especially important at low temperature paving. The reduced compaction risks, if realized, carry the cost that can far exceed the additional costs for WMA production.

However, wax technologies require additional attention regarding the temperature conditions for rolling. The compaction must be finished before the wax starts to crystallize; after this temperature the wax forms a lattice structure in the asphalt that may be damaged if the compaction is continued. This means that the compaction window is shorter than for HMA and additional rollers may be required to reach the necessary density in the given time window.

WMA AND NORMATIVE

The European standards for bituminous mixtures (EN 13108-1 to -7) do not preclude the use of WMA. The standards include maximum temperatures for particular mixtures, but there are no minimum requirements. The minimum temperature of asphalt mix is declared by the manufacturer. The standards also allow usage of additives if the performance of asphalt is equivalent to the reference mixture. Thus the European standards are not a barrier for introduction of WMA.

The Latvian Road Specifications 2010 (LVC, 2009) also allow introduction of different chemical additives, if the asphalt manufacturer can ensure the required asphalt performance and a test section of 2 lanes in 50 m length to prove this has been built. The production temperature is precluded and depends on the bitumen type. For example, for 70/100 bitumen it is 140°C-180°C. At the moment only for asphalt with polymer modified bitumen it is allowed to define different temperature. However, the work group that develops the newest redaction of the Latvian Road Specifications has proposed to remove this provision, therefore, this will no longer be an obstacle when the new document is approved.

CONCLUSIONS

The most significant advantage of the use of WMA is, of course, the possibility to reduce the use of fuel and thus cut the carbon footprint of the asphalt industry. The results show, for example, the possible direct savings of CO_2 in the range from 15% to 40% and other indirect environmental benefits. The mechanical properties of WMA show that it has a potential to replace the conventional HMA and in special circumstances it even has advantages over HMA. However, despite the promising performance in comparison with HMA, this technology has not yet gained acceptance in the asphalt industry, mostly because of the lack of information on the testing results. More data and in-situ case study examples that compare WMA and HMA technologies would help to overcome the caution in the road building industry for implementation of WMA. Introduction of the EN standards for WMA and national specifications that would allow adequate evaluation of WMA would also stimulate the usage of WMA technologies.

Environmental and other benefits alone are not sufficient for widespread implementation of this technology. It must be established whether the reduced energy consumption also reduces the overall costs of WMA production. If no proof of lower production costs is established, it is most likely that contractors will not choose this technology for its other benefits alone, and WMA may not become widespread. However, the economical benefit from energy savings should be discussed together with the cost and type of the energy used, because higher energy prices promise greater savings when temperature is reduced. The prices of additives may also change when the technology becomes more widespread and finally, application of stronger environmental regulations and additional taxes for carbon footprint will also stimulate faster development of WMA technologies and usage in actual commercial projects.

The most promising specialization for WMA in Latvia at the moment is the reduced pavement compaction risks in cold weather. This could allow to extend the paving season and thus ensure decreased due dates of construction objects and additional turnover for contractors.

There are some considerations on the physically-mechanical characteristics of asphalt that have to be taken into account before switching from production of WMA to HMA. The research results show varying performance for different WMA products; therefore careful examination should be performed with the local materials and in the given climatic conditions the characteristics of a particular WMA product before implementing it into regular practice should be examined. Performance based tests are considered to be most useful for the evaluation of WMA at the desired temperature and special care should be given to the evaluation of the moisture sensitivity, permanent deformation, low temperature properties (for waxes) and stiffness.

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