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Review paper

Warm mix asphalt use in Slovenia and in Europe: A review

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ABSTRACT

Recently, we have witnessed an extreme increase in the prices of energy and raw materials, on the one hand, and economic expansion, due to the business growth in construction sector, part of which is also the asphalt industry, on the other hand. The asphalt industry in particular is facing increasing challenges of economic acceptability and reducing greenhouse gas emissions, as well as improving working conditions. One of the possible solutions proved to be warm mix asphalts (WMA), which can be produced and compacted at reduced temperatures in comparison to hot mix asphalt (HMA). The beginnings of WMA technology in Europe date back to 1999, while in Slovenia the first field test was conducted in 2005. In the last two decades a numerous research and studies on the properties and technologies of WMA production have been conducted. According to EAPA (European Asphalt Pavement Association), the use of WMA cumulatively in Europe in period from 2013 to 2020 is slowly increasing, but the differences in WMA production in individual European countries are significant. The article presents an overview of WMA production techniques, their advantages and disadvantages and their usage in individual European countries in comparison to Slovenia.

1 Introduction

In recent decades, the growing global awareness of the negative impact of greenhouse gas emissions on the environment has led to sustainable development in all areas of human activity, including the road construction industry [1-3], to which the asphalt industry is an important contributor. Primarily because of the high temperatures (above 140 ºC) required to produce and spreading of asphalt mixtures, the asphalt industry is one of the most energy-intensive segments of the construction sector, contributing significantly to greenhouse gas and harmful vapour emissions. [3-5] Research into ways to reduce energy consumption and negative environmental impacts, as well as reduce hazardous fumes and thus improve working conditions, has led to the development of new technologies that require lower temperatures for asphalt production, paving, and compaction while maintaining its workability. [4-7] Depending on the production temperature, asphalt mixtures are broadly classified as cold mix asphalt (CMA) (0 - 30 ºC), half-warm mix asphalt (HWMA) (60 - 100 ºC), warm mix asphalt (WMA) (100 - 140 ºC), and hot mix asphalt (HMA) (> 150 ºC), [4] with minor differences in the reported temperature ranges noted by various authors [2,5,7-12]. While various studies have expressed reservations about the use of CMA and HWMA, mainly due to improper coating of the aggregate, WMA is proving to be an adequate alternative to HMA [11], and its use has gradually increased in recent years [13].

2 Warm mix asphalt

Warm mix asphalt (WMA) is produced and placed at temperatures approximately 20 to 55 °C lower than HMA. [7] The reduction in mixing and paving temperatures can be achieved by using various techniques and/or additives to lower the viscosity of the binder, while maintaining properties and workability comparable to HMA without compromising mix performance. [4,10,14] The technologies used to produce WMA can be divided into three groups: Foaming techniques, use of organic additives, and use of chemical additives. [1,4,5,8]

2.1 Foaming techniques

The basis of foaming techniques is the addition of small amounts of water, either injected into the hot binder or added directly to the mixing tank, which evaporates the water and produces a large volume of foam. The temporary expansion of the binder reduces the viscosity of the mix, which improves the coating and workability of the mix, even at lover temperatures required for the production of HMA. Some of the added water evaporates, while some remains dispersed

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in the mix for a short period of time, assisting in the compaction of the asphalt on the job site. In addition to the direct addition of water (water-based technology), indirect methods (water-containing technology) can also be used for the foaming process. In the indirect method, synthetic or natural zeolite is used to create a foaming process. A zeolite is a crystalline hydrated aluminium silicate with about 20% chemically bound water. When in contact with the asphalt binder, zeolite releases the bound water, causing a controlled foaming effect. [4,5,8,14] The second indirect foaming method uses the moisture of the sand or reclaimed asphalt pavement (RAP) used in the production process to generate foam. [5,8,14] For all foaming techniques, the amount of water should be carefully selected to facilitate adequate expansion of the binder without making the mix susceptible to moisture-induced damage (stripping). [4,5]

2.2 Organic additives

Technologies that use organic additives to reduce the viscosity of asphalt binders commonly include the use of fatty acid amides (e.g., Licomont BS), Montan wax (e.g., Asphaltan B), and Fisher-Tropsch wax (e.g., Sasobit) [1,4,5], but the use of some other additives such as carnauba wax (plant wax), [15] recycled pyrolytic polyethylene wax (RPPW) and a polyethylene wax-based asphalt binder additive made from cross-linked polyethylene (Rh-WMA Modifier), has also been investigated [16]. In these technologies, organic additives are usually mixed with the asphalt binder or directly with the asphalt mixture during asphalt mix production. The waxes used usually have a melting point of 80-120 ºC and are capable of chemically altering the interaction between viscosity and temperature of the asphalt binder. When the binder cools, the additives crystallise and form a lattice structure with microscopic and uniformly dispersed particles. Such a structure increases stiffness and improves resistance to permanent deformation of the asphalt layer, but there is some evidence of increased susceptibility to low temperature cracking. [4,5]

2.3 Chemical additives

Chemical additives are not used in the production of WMA to facilitate foaming or reduce viscosity. They primarily improve aggregate coating, mix workability, and compaction rather than reducing viscosity. Surfactants, emulsifiers, polymers, anti-stripping chemical additives, or hybrid combinations of additives are most commonly used. Some commonly available additives are Cecabase® RT, RedisetTM WMX, Rediset® LQ, Evotherm®, Revix, Interlow, ZycothermTM, Hypertherm and others. Chemical additives can be incorporated directly into the asphalt binder or into the asphalt mix during the production process. [4,5,7,15,16]

2.4 Advantages and disadvantages of using WMA

The use of WMA offers numerous advantages compared to HMA. The main advantage reported in the literature relates to the environment. At lower production temperatures, gas and dust emissions are significantly reduced. Typically by 30 to 40% for CO_2 and SO_2, 50% for volatile organic compounds (VOC), 10 to 30% for CO, 60 to 70% for NO_x, and 25 to 55% for dust. [6,10] The large reduction in emissions of asphalt fumes and polycyclic aromatic hydrocarbons (PAH), typically between 30% and 50%, has a significant impact on worker exposure and thus improves working conditions. [6] In general, for every 12 ºC reduction in asphalt production temperature, the release of vapours is reduced by about 50%. [8] In addition to the environmental and health benefits, large energy savings of up to 35% have been reported in the production of WMA compared to HMA. [3,6] Recent studies have shown that WMA has similar or even better performance than HMA, including better compaction and workability, improved resistance to permanent deformations and fatigue, longer allowable haul time and faster admission to traffic. [3,9] Improved resistance to deformation is mainly associated with the use of organic additives, while the use of other additives and technologies has less impact. [4] There are also some disadvantages to using WMA compared to HMA. The major concern is moisture-related damage, as lower production temperatures can lead to incomplete drying of aggregates and entrapment of residual moisture in the mix, causing striping and rutting and thus reducing pavement service life. [2,4,5,7,9-11,15,17] Various studies also indicated that moist aggregates and lower production temperature can significantly reduce the resistance of asphalt mixtures to permanent deformation. [4,15,17] Consequently, increased susceptibility to moisture and reduced ageing may result in intensified maintenance also due to premature rutting. Some studies have also observed that under low-temperature conditions, the use of organic additives can lead to increased binder stiffness and waxes crystallization inducing low temperature cracking. Therefore, the low temperature behaviour of WMA should be carefully evaluated. [4,15]

3 WMA background and USE

The development of WMA technology was made possible by the research and patent of August Jacob in Germany in 1928 on "foamed asphalt". [4,18] The first field trials took place in Europe between 1997 and 1999, followed by the USA in 2002 to 2004, [10] while the first trial in Slovenia took place in 2005 [1] . The initial research and field trials were followed by a series of studies around the world on the quality of WMA and the possibilities of using various additives and technologies to improve the properties of WMA, as well as studies on the increased use of RAP and other secondary raw materials in WMA. [19-22]

From 2005 to 2015, several field trials were conducted in Slovenia (Figure 1, Table 1) to promote and encourage wider use of WMA in Slovenia. [1,14]

A 2005 trial showed that lowering production temperature by about 20 ºC resulted in 16% less fuel consumption, 56% less CO_2, 61% less NO_x, and 44% less SO_x emissions, and 25 to 40% lower smoke and dust exposure for workers at the work site. [1]

At all test sites, the quality and performance of the asphalt mix and asphalt layers met the technical requirements and were comparable to HMA. [14] Although no specific monitoring of these test sections has been established, regular surveys of network performance using FWD (Falling Weight Deflectometer) and IRI (International Roughness Index), as well as visual assessment of pavement condition on Slovenian freeways and state roads, have so far not identified any quality deviations associated with WMA sections, which could lead to the conclusion that WMA in Slovenia performs similarly to HMA.

The production and use of warm mix asphalt in Slovenia has stalled somewhat since the trial sites were established, probably due to a lack of technical regulations. Nevertheless, production of smaller quantities of WMA was reported from 2017 to 2020 [13], but production was mainly related to the need to improve workability or resistance to permanent deformation. WMA production in European countries that have reported WMA production data has gradually increased, [13] but in general it is still quite low (Figure 2), especially compared to data from the United States of America (USA), where WMA production reaches 72-84 million tonnes in 2018-2020, while production in Europe combined is only 7,1-9,2 million tonnes in the same period. Figure 2 shows WMA production in the European countries included in the EAPA report for the period 2013-2020. The European champion in WMA production was France, followed by Norway with a huge increase from 2017. [13]

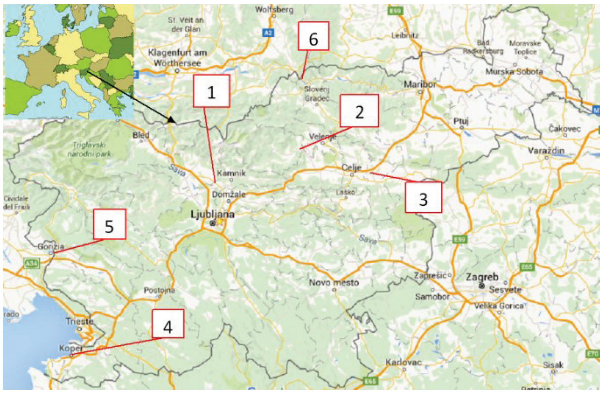

Figure 1: WMA field trial sites in Slovenia between 2005 and 2015

Table 1: Basic information on WMA field trials between 2005 and 2015 in Slovenia [1,14]

Ref. No.	Location	Year	Asphalt Mix	WMA Technology
1	Spodnji Brnik – Moste	2005	AC 22 base B 50/70 AC 16 base B 50/70 AC 11 surf B 50/70	Organic additive 3% SASOBIT
2	Ljubija near Mozirje	2006	AC 22 base B 50/70 AC 8 surf B 50/70	Organic additive 2% LICOMONT
3	Motorway section Ljubečna – Celje East	2006	SMA 8 PmB 45/80-65	Organic additive LICOMONT
4	Parking garage Port of Koper	2009	protective layer surface course	Organic additive SASOBIT
5	Roundabout Nova Gorica – Kromberk and Roundabout Nova Gorica – Rožna Dolina	2009	surface course	Organic additive SASOBIT
6	Vič - Dravograd	2015	AC 22 base B 50/70 AC 11 surf PmB 45/80-65	Organic additive SASOBIT

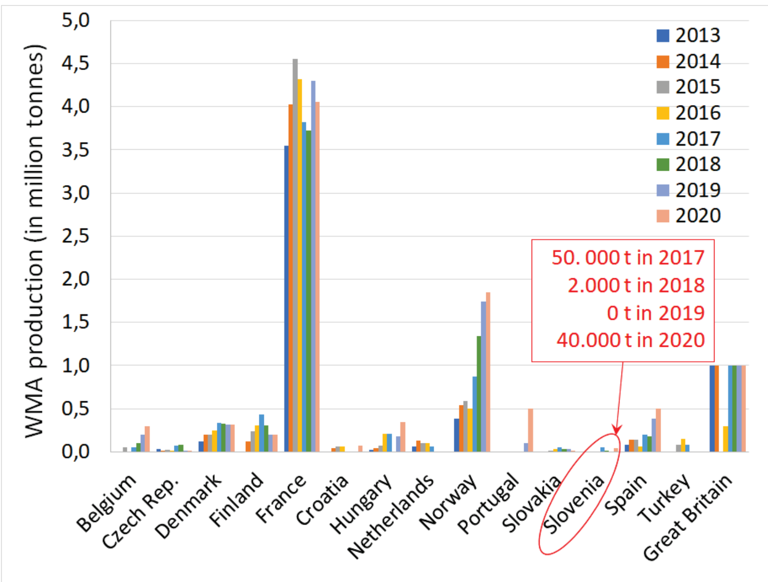

Figure 2: WMA production in Europe in the period 2013 – 2020 [13]

A better insight into WMA production can be obtained by comparing WMA production with total asphalt mix production in individual countries and in Europe combined, compared with production in the USA (Figure 3). The highest share of WMA in total asphalt production is in Norway, where it is almost 27% in 2020, which is even higher than in the USA, where the share of WMA in total asphalt production is 23%. More than 10% of WMA production was also reached in France (12,7%) and, after an extremely high increase in 2020, in Portugal (14,7%). WMA production in other European countries was below 5%, and only 2,1% was reached in Slovenia in 2020. The combined share of WMA production in Europe also does not reach 5% (3,3% in 2020), but the positive trend of WMA production is evident. [13]

For further WMA production increase in Europe it is very important, that the use of WMA is not hindered by the European standards for bituminous mixtures (EN 13108-1 to 7), [23-25] as they allow deviations from the specified temperature ranges for individual types of bituminous binders when using additives, but the manufacturer must specify the maximum production temperature and the minimum temperature of the asphalt mixture upon delivery. [8] In 2021, the technical specification TSPI - PGV.06.460 Upper structure of roads - Warm Asphalt Mixture [12] came into force in Slovenia, which defines the technical conditions for the use of warm asphalt mixtures on public roads in the Republic of Slovenia, which will hopefully encourage investors, designers and producers for wider WMA use in Slovenia.

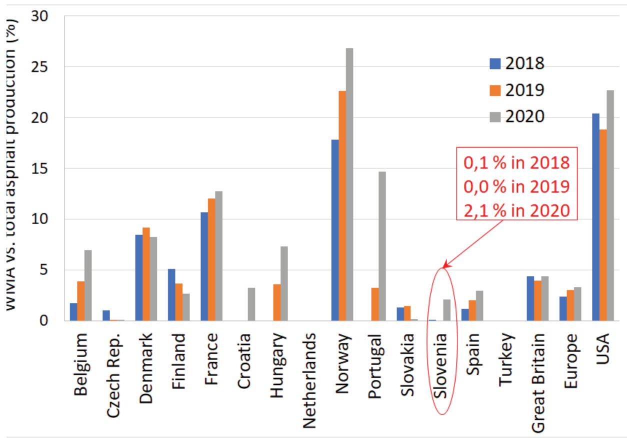

Figure 3: WMA vs. total asphalt production in the period 2018 – 2020 [13]

4 Conclusion

Warm Mix Asphalts (WMA) represents a large group of asphalt technologies that can significantly impact our ability to reduce greenhouse gas emissions and improve working conditions in the asphalt industry. With rising energy prices, these technologies are also becoming attractive to asphalt mix producers. In general, the use of WMA is gradually increasing in Europe, but it has not yet reached the level of use in the USA by far. Some European countries, such as Norway, Portugal, as well as Belgium, Hungary and Croatia, have made a big step towards increased use of WMA, while in Slovenia we are still somewhat hesitant when it comes to using WMA on a larger scale.

In recent years, Slovenia has gained a lot of experience and knowledge in the field of using warm mix asphalt. All research and practical experience show that warm asphalts can qualitatively replace the classic hot asphalt mixtures (HMA), with many additional positive economic, environmental and health effects. Unfortunately, most Slovenian asphalt plants have been technologically limited in the past and continue to be so today, making the use of foaming techniques are hindered. WMA production in Slovenia was and still is mainly focused on the use of organic additives, as they were readily available and easy to use in production. Since the demand for WMA in Slovenia was and unfortunately still is very low, the development of production technologies and research on the use of other possible additives and techniques are very slow. In order to initiate and promote the production and use of WMA, technical specifications and requirements for WMA should first be established. In this way, all qualitative and technical conditions for a wider use of WMA technologies will be met, which will allow designers and investors to create a demand and market opportunities for contractors. Higher demand for WMA will consequently boost the implementation, research and development of production technologies, creating additional opportunities to reduce production costs while having a positive impact on the environment and improving working conditions in the asphalt industry.

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