Warm Mix Asphalt / Low temperature asphalt

The new step in the WMA production: use of green additives

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Abstract

Warm Mix Asphalt (WMA) concepts are perfectly implemented in Europe through the application of different available technologies. A potential complication when using these techniques, is the lower temperature range for laying and compaction. This can result in a lower density of the asphalt layers. The present study is another effective WMA demonstration by using an established green additive, vegetal-base, that facilitates the asphalt mix production (even at lower than usual WMA temperatures) and extend the compaction temperature range over 90ºC. Laboratory test values and real experiences are shown by new environmental friendly additives, which provide noticeable temperature reduction while maintaining, or even increasing, the asphalt mix performances.

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1. INTRODUCTION

The asphalt industry is constantly searching for improvements in the areas of sustainability, greenhouse gases reduction, health and operators' safety.

WMA is a realistic way to overcome this challenge. The use of these mixes has been already demonstrated:
- environmental advantages: lower emissions
- savings: lower energy consumption
- constructive improvements: facilitate the workability of the mix, allowing longer transport distances when facing worse weather conditions, showing lower mix cooling rate due lower thermal gradient, quicker traffic restart
- and health improvements: lower workers exposure to high temperatures

All without a negative impact on the mix mechanical properties.

Multiple techniques to reduce the mixing and laying temperatures, have been developed since the mid-90s, leading to lower energy consumptions during asphalt manufacture. WMA technologies are producing asphalt at temperatures slightly above 100 °C with properties equivalent to that of conventional Hot Mix Asphalt (HMA) [1].

A typical WMA is applied at a temperature of 20 - 40 °C lower than its HMA equivalent. Less energy is involved and during the paving operations the mix temperature is inferior, and thus resulting in fewer emissions, lower exposure and improved working conditions for the operators. This lower exposure supports the goal of the European asphalt industry to reduce bitumen fumes during paving operations.

In 2015, Willemen Infra (Aswebo) started producing WMA at one of its four production units in Belgium. But due to low customer demand, and the fact that the government didn't demand this for official works, only a few thousand tons of WMA were produced between 2015 and 2019.

In order to accelerate research and innovation in the field of CO_2 reduction and minimization of energy consumption in the asphalt sector, the Flemish Government issued a number of large public tenders in 2018 that gave road builders the opportunity to produce and place asphalt at a reduced temperature. Asphalt producers were free in the choice of technology and additives. The only requirements were that the quality of the WMA should be equivalent (or better) than the hot mix variant and that, the chosen additives weren't harmful neither to humans nor the environment.

Since then, various asphalt producers in Flanders have worked hard to be able to offer the requested mixtures at reduced temperatures. During the first half of 2019 Willemen Infra has produced more than 43,500 tons of WMA and another 36,500 tons are planned before the end of this year.

This means that more than 10% of the annual production of Willemen Infra will be WMA. Once demonstrated and convinced of this beneficial and healthy progress, the company is currently adapting the other production units in Flanders to make this share even greater.

Figure 1: Left: asphalt produced at 165ºC; Right: asphalt produced at 130ºC

The lower mixing and paving temperatures minimize fume and odor 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%.

At present, WMA can be classified into 3 groups, depending on the physical-chemical mechanism they are based on. Reduction in working temperatures can be achieve by:

- Additives that modify the bitumen viscosity: waxes. This group of additives modifies the bitumen rheology. At high temperature range (> 100 °C) the viscosity of the resulting binder is significantly decreased, thus favoring a temperature reduction in the asphalt mix production. They improve the rheological properties at service temperatures, resulting in more rutting-resistant mixes. On the other hand, these additives show a potential disadvantage because the compaction temperature is very limited. Below wax crystallization temperature, the binder viscosity rises and the compaction can be a challenge. Usually, compaction temperatures are above 120 ° C in this type of technique.

- Additives based on surfactant behavior that modify chemically the bitumen and provide effective aggregate coating by reducing the surface tension to the binder. This "lubricant" effect improves the asphalt workability. In this case, there is no bitumen rheological modification. There is no rigid limitation in the asphalt compaction temperatures that could be around 80-110ºC.

- Processes that increase the binder specific surface by forming bitumen foam by water addition. To produce this foam effect, water and pressurized air, wet sand or mineral water donor additives can be dosed during the asphalt mix production. It is important to control foam "Reason for expansion" and "Half-life (t1 / 2)". These values are linked to the bitumen source (composition) and additives dosage. In these cases, compaction limit temperature would be above 100 °C.

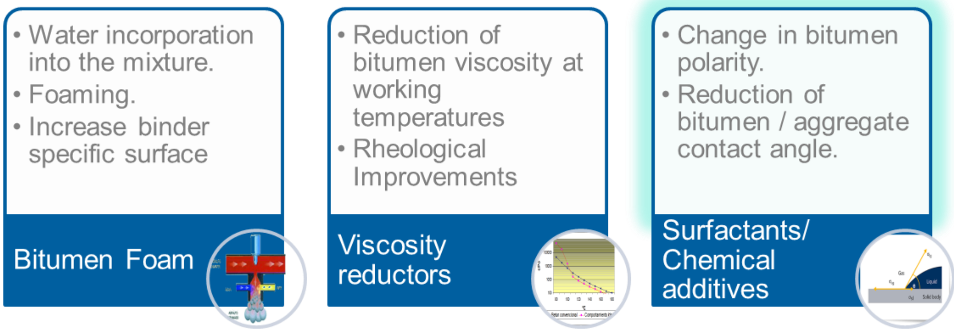

Figure 2: WMA techniques

2. CHEMICAL ADDITIVE

This paper presents laboratory WMA results achieved by Ravasol™ THERMO+, as "green" vegetal base additive.

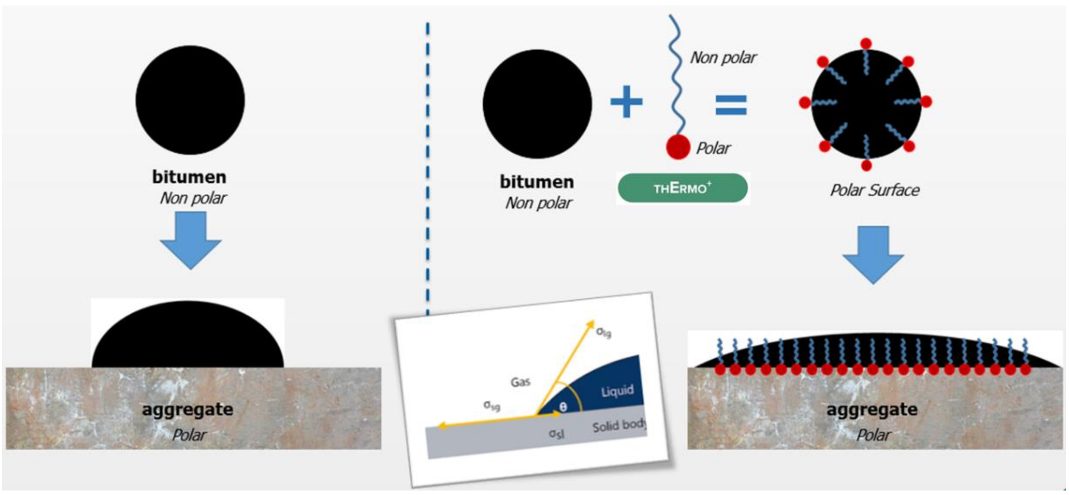

Figure 3: Chemical additive surfactants mechanism

2.1. Additive performance advantages

- Allows warm mix production at 110ºC and laying/compaction around 90ºC.
- Delivers rheological modification to the mix by decreasing its superficial tension and works as a compaction aid promoting higher workability to mixtures.

- Temperature reduction enables a quicker traffic restart.
- Improves the aggregate-binder adhesion, therefore increases moisture sensitivity values.
- It is chemically formulated to be soluble when poured into the bitumen. Can be added to any binder grade, including PMB.
- Odor-free product, heat-resistant and storage stable even for long period. When added to the bitumen, it won't lose any chemical property.
- High dosage provides a rejuvenating effect to the RAP/RAS, when milled material is used in the WMA mixes.
- Ensures less aging to binder and consequently better fatigue cracking resistance.

2.2. Environmental and safety advantages

- It does not contain VOCs or volatile substances. It is formulated with natural compounds that prevent hazardous label.
- Fumes and emission are sensitively reduced during production, laying and compaction. A total absence of fumes is observed around 110ºC.
- Fuel consumption reduction provides also significantly lower emissions of GHGs.
- Advantages for operators: comfortable and healthy, safe handling.

2.3. Economic advantages

- Allows the use of aggregate with poor bitumen affinity.
- Fuel consumption reduction correlated to lower temperature production.
- Allows a longer paving season even in extreme weather conditions, as well as longer distance hauls.

3. LABORATORY TEST RESULTS

This paper describes the laboratory test analysis carried out for a WMA special recipe, type AVS (EN 13108-1), with more than 25% Reclaimed Asphalt Pavement (RAP) content and high module behaviour.

Belgium asphalt mixture AVS has been manufactured by Willemen Infra, according to the mixture composition described in this Section.

AVS is the regional name for mixtures with higher stiffness, similar to the French EME (Enrobé à Module Elévé), with the aim to be applied as base-layer in heavy-duty road constructions.
In order to achieve this required stiffness, a hard paving grade bitumen was used. There are no requirements specified for the minimum binder content.

Additionally, some RAP amount was included in this asphalt recipe case, considering the requirement of never exceeding 20% of binder coming from the RAP in the final asphalt mixture.

Material description:

- Limestone Aggregates
- Limestone Sand
- Fillers
- 15/25 Bitumen
- WMA "green" additive (Ravasol™ THERMO+)
- RAP

Composition dosages are given in Table 1:

Table 1. AVS mixture composition

Material	Dosage (%, rounded)
Aggregates	64
RAP	27
Recovery filler	2
Added new filler	3
15/25 bitumen	4
WMA "green" additive	0,65% by weight of new bitumen (15/25)

The obtained laboratory gradation is shown in Figure 4 and meets D:14 requirements (NBN-EN 13108-1) according to table 2.

Table 2. AVS gradation

Sieve (mm)	% passing
20	100
14	90-100
2	10-50
0,063	0-12,0

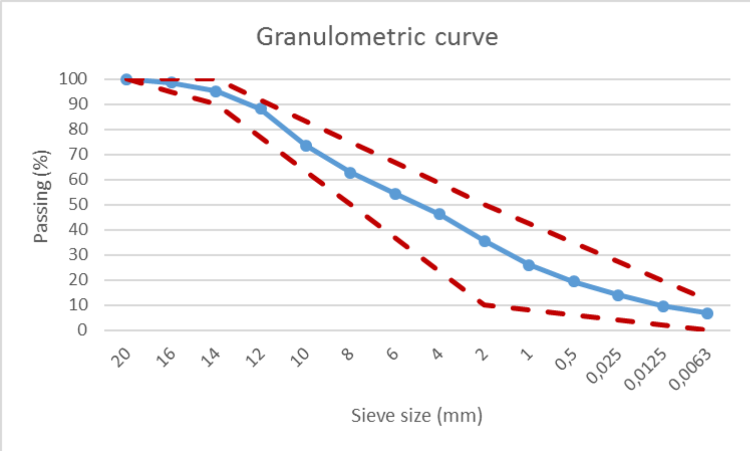

Figure 4: Grading chart for AVS

The tests described below, were carried out in the laboratories of Willemen Infra, OCW (research center) and AWV (government). There are strict performance requirements for wheel tracking, stiffness, fatigue and water sensitivity tests.

The AVS mixture was manufactured with the "green" additive and compacted at 120ºC as lower temperature (WMA), this was compared to the reference mix (HMA), manufactured without additive and compacted at the usual temperatures.

3.1. Voids Content (Gyratory Compactor)

The asphalt mixture was firstly assessed in terms of workability and compaction by a Gyratory Compactor Press conducted in accordance with EN 12697-31 Standard. In the WMA case, the compaction temperature was established at 120ºC. The void content was analysed at 100 cycles. In HMA case, the compaction was carried out at the usual temperature. Void content results are presented in Table 3 and the voids content evolution for several WMA specimens are represented in Figure 5.

Table 3. Voids content

Performance	WI-LAB-AVS-THERMO+ (WMA)	Reference (HMA)	Specification AVS
Voids content (%)	3,3	3,5	2,0-7,0

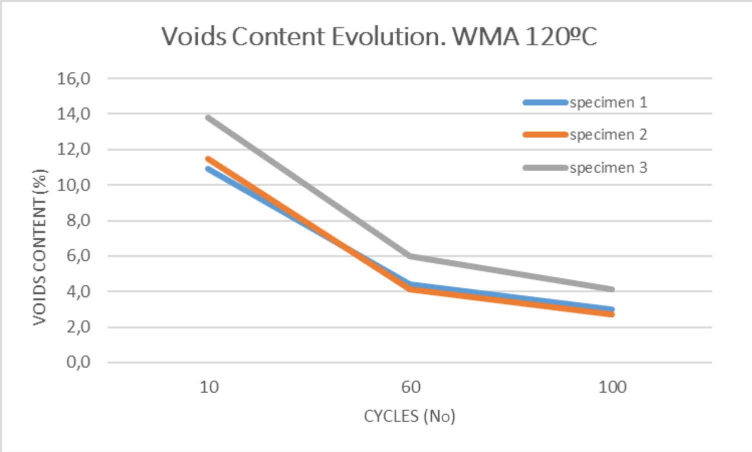

Figure 5: Voids content evolution

WMA ~~voids~~ content meets the required specification and achieves a lower value than HMA mix reference, in spite of the important reduction in the compaction temperature.

3.2. Water Sensitivity test

The asphalt mixture was then assessed in terms of water sensitivity according to EN 12697-12 Standard at the temperature of 15ºC. Specimens were previously compacted by Gyratory Compactor at 120ºC (in the case of the WMA) during 25 cycles.

ITS values are given in Table 4 reaching an ITSR positive value of 90% for WMA.

Table 4. ITSR calculation

Performance	Dry	Wet	ITSR (%)
ITS (MPa)	3,111	2,808	90

In Table 5, it is shown that WMA obtains higher value than HMA reference mix according to the AVS Specification:

Table 5. ITSR results

Performance	WI-LAB-AVS-THERMO+ (WMA)	Reference (HMA)	Specification AVS
ITSR (%)	90	88	≥ 80

3.3. Wheel Tracking Test

In order to assess the resistance to permanent deformation of the warm AVS, the wheel tracking test was carried out on two slabs of 50 mm thickness. The repeated wheel loading was carried out for 30.000 cycles at 50°C temperature in accordance with EN 12697-22 (large device, procedure A).

Results are given in Table 6 (compared with the HMA reference mix). In addition, in Figure 6, the Proportional Rut Depth (PRD) as a function of number of cycles are represented for the WMA specimens.

Table 6. Proportional Rut Depth results

Performance	WI-LAB-AVS-THERMO+ (WMA)	Reference (HMA)	Specification AVS
P~~RD~~ (%)	2,4	2,0	≤ 5,0

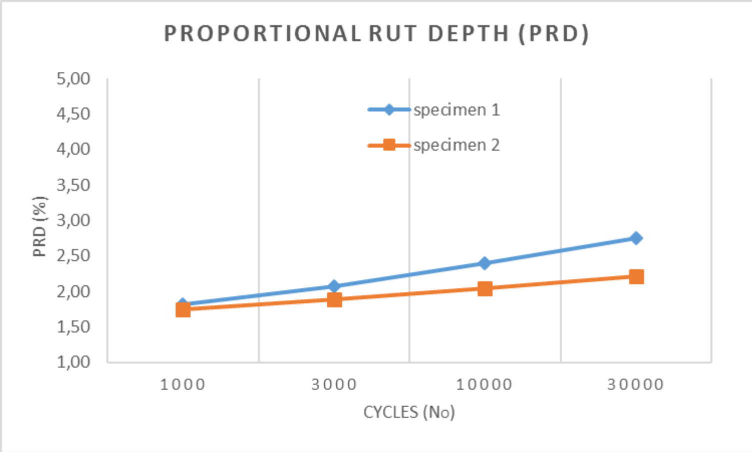

Figure 6: Proportional Rut Depth (PRD)

For the WMA, the PRD result is very similar to the HMA reference mix, although the oxidation process during manufacture and compaction is much higher in the reference mixture.

3.4. Stiffness

The stiffness modulus was measured on two-point bending machine for trapezoidal specimens in accordance with EN 12697-26 (Annex A). Tests were carried out at a frequency of 10 Hz and 15ºC and 30ºC temperatures for 4 different specimens.

Different temperatures results are presented in Table 7.

Table 7. Stiffness results

Performance	WI-LAB-AVS-THERMO+ (WMA)	Reference (HMA)	Specification AVS
Stiffness, 15ºC, 10Hz (MPa)	13.164	15.102	≥ 11000
Stiffness, 30ºC, 10Hz (MPa)	6.122	7.804	≥ 4000

Stiffness results meet the Specification requirements. HMA reference mix achieves higher results due to the bigger oxidation process originated during the manufacture and compaction steps. This oxidation effect is lower in the WMA case (lower manufacture and compaction temperature).

3.5. Fatigue

Resistance to fatigue was also measured on a two-point bending machine for trapezoidal specimens in accordance with EN 12697-24 (Annex A). Tests were carried out at 30 Hz frequency and 15ºC temperature for 18 different specimens.

Results are presented in Table 8 and Figure 7.

Table 8. Fatigue results

Performance	WI-LAB-AVS-THERMO+ (WMA)	Reference (HMA)	Specification AVS
ε_6, 15ºC, 30 Hz	164	143	≥ 130

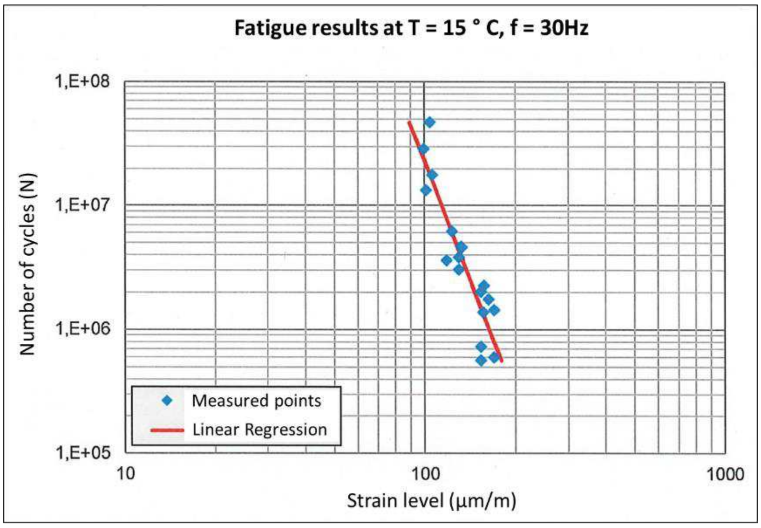

Figure 7: Fatigue curve (WMA)

Fatigue results meet the Specification requirements, but in WMA case, much better values are obtained facing HMA reference mix. It is also due to higher oxidation produced in the bitumen when the manufacturing and compaction temperatures are bigger.

4. CONCLUSIONS

- WMA provides environmental advantages (lower emissions), savings (lower energy consumption), constructive improvements (facilitate the workability of the mix and allow longer transport distances, facing worse weather conditions, showing lower mix cooling rate due lower thermal gradient, quicker traffic restart...) and occupational health (less exposure to high temperatures for the workers); all without negative affection of the mix mechanical properties.
- Flemish Government is encouraging the use of WMA. Asphalt producers are free in the choice of technology and additives. The main requirements are that the quality of the WMA should be equivalent (or better) than the HMA variant and the chosen additives are not harmful to humans or the environment.
- A "green" vegetal base WMA additive has been used in this study. This chemical additive (surfactant properties) provides positive characteristics to the asphalt and resulting in extra environmental and safety advantages.
- Belgium asphalt mixture AVS (EN 13108-1), asphalt with increased Stiffness, has been tested. This mixture includes 27% RAP content.
- Voids content meets the Specification requirement and achieves a lower value than the HMA reference mix, in spite of the significant reduction in the compaction temperature.
- A slightly higher ITSR value (90%) is obtained compared to the HMA reference mix.
- Regarding wheeltrack resistance, PRD result is very similar to the HMA reference mix, although the oxidation process during manufacture and compaction is much higher in the reference mixture.
- Stiffness result meets the Specification requirements and obtain slightly lower values than the HMA reference mix.
- Fatigue result meets much better values than the HMA reference mix.
- This study has confirmed the possibility of carrying out a high modulus WMA with more than 25% RAP content, obtaining very satisfactory mechanical results and using a "green" chemical additive.

REFERENCES

[1] EAPA – Position Paper, The use of Warm Mix Asphalt, 2014