New Method for Temperature Reduction of Mastic Asphalt with Environmental and Technological Benefits

Mariyan Dimitrov[1], Bernhard Hofko[2], Markus Hospodka[3]
（[1] Vienna University of Technology， Institute for Transportation, Gusshausstrasse 28/230-3, 1040 Vienna, Austria, mariyan.dimitrov@tuwien.ac.at）
([2] Vienna University of Technology， Institute for Transportation, Gusshausstrasse 28/230-3, 1040 Vienna, Austria, bernhard.hofko@tuwien.ac.at)
([3] Vienna University of Technology， Institute for Transportation, Gusshausstrasse 28/230-3, 1040 Vienna, Austria, markus.hospodka@tuwien.ac.at)

ABSTRACT

Mastic asphalt (MA) mixes are produced at high temperatures (230°C to 250°C) to decrease the viscosity of the bituminous mastic and thus produce a flowable, self-compacting mixture. A lower producing temperature has the potential to decrease cost and energy demand, as well as health-relevant emissions of particulate matter throughout the life cycle. The state-of-the-art method for temperature reduction is wax modification of the bituminous binder to reduce its viscosity [1]. Therefore, a reference MA is compared to temperature reduced MAs: a state-of-the-art reduction by modification with wax and an alternative new method by substituting crushed by round aggregates. A temperature reduction of 30 K can be realized for both methods. In addition, we investigated a combination of wax modification and round aggregates with a possible reduction of 50 K.

Keywords: Mastic asphalt, temperature reduction, wax, round aggregates

1 INTRODUCTION

Among the different asphalt mix types, the mastic asphalt (MA) holds a special position due to its composition, application and load transfer. MA is applied in the field without compaction, it is merely poured. Different from other asphalt mix types, MA transfers load mainly by stiff mastic and not by coarse aggregate interaction. There is a wide range of applications for MA as sealing and surface layer on bridges [2], as road surface layer for city centers where compaction would endanger historic buildings or as surface layers for walk and cycle ways.

Since the mastic is responsible for load transfer, usually hard binders are employed for MA. To keep the viscosity of this hard binder low, high temperatures of up to 250°C are necessary for mixing and paving, which makes MA especially energy-intensive in production [3]. For these reasons, a temperature reduction in MA is seen crucial for enhanced energy efficiency.

In this paper the state-of-the-art modification with wax is compared to a new, efficient alternative for temperature reduction of MA in a comprehensive way [4-6]. In the new method for temperature reduction, crushed aggregates are substituted by round aggregates within the MA. This substitution brings a significant temperature reduction potential. The new approach is applicable to mastic asphalt, due to the fact that the load transfer is realized mainly by a stiff mastic and not by coarse aggregate interaction.

2 MATERIALS

For the presented research a mastic asphalt mixture with a maximum nominal aggregate size of 11 mm (MA 11) is used. The filler component is powdered limestone, the coarse fraction is totally crushed (TC) aggregates of porphyritic origin and totally round (TR) limestone, respectively. The binder is an SBS-modified PmB 25/55-65 (PG 82-16).

There are four wax types applied within the test program: amide wax (AW), Fischer-Tropsch wax (FTW), montan wax (MW) and polyethylene wax (PEW).

In this case, when totally crushed (TC) aggregates are substituted by totally round aggregates (TR), the filler component, the filler content, the binder type, the binder content and the grading curve remained unchanged for each tested mix.

3 TEST METHODS AND TEST PROGRAM

3.1 Rotational Viscometer (Bitumen Level)

The rotational viscometer (RV) is a test device to measure the dynamic viscosity of bituminous binders. FIGURE 1 shows the principle of the device.

The dynamic viscosity of bitumen obtained by RV is used to describe the workability of bitumen at mixing and production temperature [7].

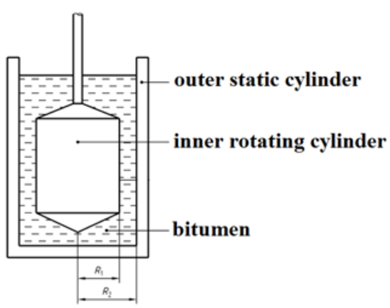

FIGURE 1 Principle of RV [7]

TABLE 1 Testing Program for RV

	0 wt.%	2 wt.%	4 wt.%	6 wt.%	10 wt.%	30 wt.%
PmB	3x					
AW		x	3x	x	x	x
FTW		x	x	x	x	x
MW		x	x	x		
PEW		x	x	x	x	

TABLE 1 shows the testing program for RV. The dynamic viscosity of the original binder (PmB) as well as of the binders modified with different waxes at concentration ranging from 2 wt.% to 30 wt.% based on bitumen mass is defined during this program.

For RV testing, the samples were heated in the device to 135°C and the dynamic viscosity was determined at 135°C, 140°C up to 250°C with temperature steps of 10 K. To determine the possible temperature reduction due to the wax modification, firstly was measured the viscosity of the original bitumen by 230°C. The equiviscous temperature (the temperature where the same dynamic viscosity occurs) was derived from RV test data of all tested samples.

3.2 Bending Beam Rheometer (Bitumen Level)

The Bending Beam Rheometer (BBR) is introduced as a low-temperature test method for asphalt binders within the Strategic Highway Research Program (SHRP). A principle of the test is shown in FIGURE 2. The test specimen is a slender beam of asphalt binder (125x12.5x6.25 mm) simply supported on both ends and loaded with a constant force (980 mN) at mid span for a total of 240 seconds. The deflection is monitored with time and this is used for the calculation of the creep stiffness as a function of time. The creep stiffness and the slope of the creep stiffness curve (m-value) are used in the SUPERPAVE specification. The creep stiffness is a measure of how the binder resists constant loading and the m-value is a measure for the relaxation behavior of the binder. The BBR test gives the Lower PG (Performance Grade) of the bitumen according to SUPERPAVE bitumen classification.

TABLE 2 shows the testing program of BBR.

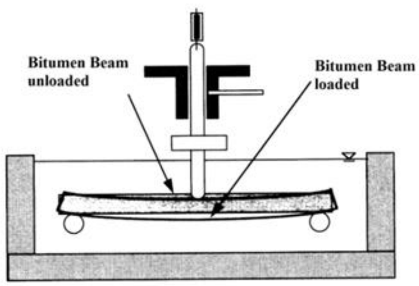

FIGURE 2 Principle of BBR [8]

TABLE 2 Testing Program for BBR

	0 wt.%	2 wt.%	4 wt.%	6 wt.%	10 wt.%
PmB	3x				
AW		3x	3x	3x	3x
FTW		3x	3x	3x	3x
PEW		3x	3x	3x	3x

3.3 Mixing Torque Measurements (Mix Level)

To assess the possible temperature reduction not only on bitumen level, but on larger scale, mixing torque measurements with a temperature sweep were carried out on different mastic asphalt mix samples.

The device for these measurements is an EN 12697-35 appropriate standard compulsory lab mixer as shown in FIGURE 3 with a capacity of 30 l and a reverse rotating mixer with variable speed from 25 to 60 RPM. The rotating drum can be heated up to 250°C. In addition, a torque measurement device records the mixing torque in Nm necessary to rotate the mixer at a constant speed. The mixing torque is used as a measure for the workability of the mix.

FIGURE 3 Lab mixer with torque measurement device

TABLE 3 Test Program for mixing torque measurements on mastic asphalt MA 11

TC*)	0/11	0/4	---
TR**)	---	4/11	0/11
MA 11 reference	3x	2x	2x
MA11 + 4 wt% AW	2x		2x
MA11 + 2,5 wt% AW			2x
MA11 + 10 wt% AW	2x		
MA11 + 4 wt% FTW	2x		
MA11 + 4 wt% PEW	2x		

TABLE 3 shows the test program carried out for mixing torque measurements on the mastic asphalt mix (MA 11). The non-modified mix is called MA11 reference. In addition, mixes with 4 wt.% and 10 wt.% of AW and with 4 wt.% of FTW and PEW are tested. The mix design of these mixes consist of 100% totally crushed aggregates (TC). As an alternative way to reduce the production temperature, an attempt is made by substituting all or part of the totally crushed aggregates by totally round aggregates (TR). For one mix the 4/11 fraction and for another mix the complete 0/11 fraction is substituted by TR. A combination between AW and TR is tested as well. It should be noted at this point, that the filler component, the filler content, the binder content and the grading curve remained unchanged for each tested mix. Aggregates and binder are preheated at 170°C and then mixed with 40 U/min for 5 min in also preheated at 170°C lab mixer. In all cases a constant asphalt mix mass of 22 kg is used for testing. After the initial mixing process, the actual mixing torque measurements starts at 170°C and 40 RPM for 300 sec. Subsequently, the mixer with the mix inside is heated to 190°C with intermediate mixing of 10 sec every 60 sec to ensure a homogeneous temperature distribution in the mix. When the set temperature is reached, another mixing torque measurement starts at 40 RPM for 300 sec. This procedure continues every 20 K until 250°C is reached.

4 RESULTS AND DISCUSSION

4.1 Temperature reduction on bitumen level

RV tests are carried out according to the test program listed in TABLE 1. FIGURE 4 shows the temperature reduction potential of bitumen samples with different wax types and wax quantity. The original non-modified binder PmB was tested as well. The benchmark value for calculation of the temperature reduction on the modified samples is its dynamic viscosity (77.2 mPa*s) at 230°C. FIGURE 4 shows us how lower is the temperature at which we reach this viscosity (77.2 mPa*s). The wax concentrations range from 2 wt.% to 30 wt.% based on the bitumen mass. The proportion of 10 wt.% and 30 wt.% of the wax additive was performed only tentatively. In practice, such a high contents are not applied. In conclusion from the results of the Rotational Viscometer test can be written that the amide wax is the additive with the highest temperature reduction potential.

To determine the influence of the wax additives on the properties of the bitumen at low temperatures, experiments with Bending Beam Rheometer according to EN 14771 are carried out. On the right diagram of FIGURE 4 are shown the results from BBR. There are not any 30 wt.% samples and any samples with montane wax in the BBR test program. As a result are shown the Lower PG (Performance Grade) values according to SUPERPAVE bitumen classification. From the diagram can be seen that the amide wax is the better additive again. The more wax additive is added, the worse the performance in the low performance range is. Up to 4 wt.% behave all additives similarly. From 6 wt.% the amide wax behaves significantly better than the other waxes.

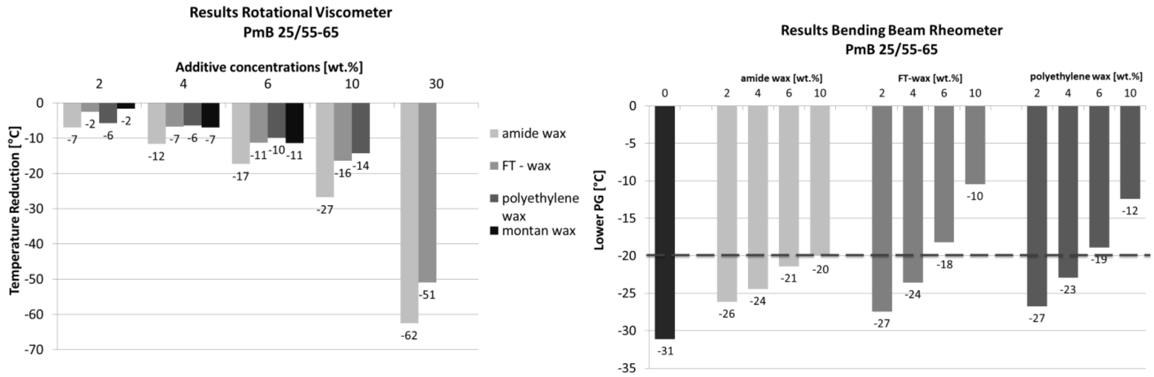

FIGURE 4 Results RV (left), results BBR (right)

4.2 Temperature reduction on mix level

The temperature reduction potential on mix level is shown in Figure 5. The temperature reduction is given in comparison to the reference mix. To derive the temperature reduction, the mixing torque of the reference mix at 230°C is taken as a benchmark. The wax concentration is given in percentage with regard to binder mass. For the waxes, AW shows the highest potential for reduction. Equal potential was found for the mix with 50% substitution by TR. For 100% TR and the combination of 100% TR with 2.5 wt.% or 4.0 wt.% of AW, the reduction potential is even higher ranging from -36 K to -51 K.

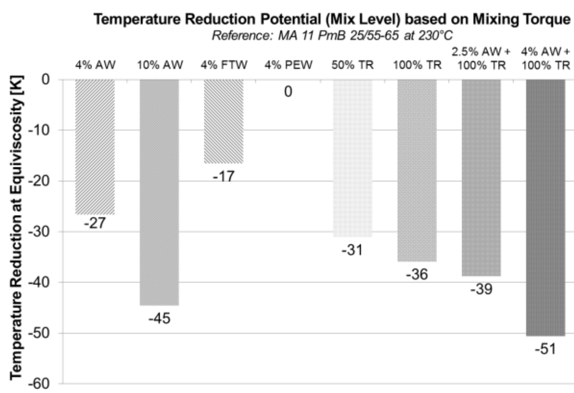

FIGURE 5 Temperature reduction potential on mix level based on mixing torque

5 SUMMARY

Within a recently completed study [9], optimized mastic asphalt mixes with regard to maximum temperature reduction and high level of mix performance are developed. This paper contains results of investigations on the temperature reduction potential of different waxes on binder and asphalt mix level and their influence to the binder at low temperatures. In addition, an alternative approach for temperature reduction by substituting crushed aggregates partly or completely by round aggregates is analysed as well.

To analyse the temperature reduction potential on binder level, an SBS-modified binder (PmB) with and without wax modification was tested in the rotational viscometer (RV) with temperature sweep at different wax concentrations. The temperature reduction potential on mix level was investigated in a standard compulsory lab mixer that is equipped with a device to measure the necessary mixing torque at a constant mixing speed. The mixing torque measurements were carried out with a temperature sweep from 170°C to 250°C. To determine the influence of the wax additives on the properties of the bitumen at low temperatures, experiments with Bending Beam Rheometer according to EN 14771 are carried out.

The following conclusions can be drawn from the results:

- From RV tests on binder level, amide wax (AW) showed the highest temperature reduction potential, followed by Fischer-Tropsch wax (FTW), montane wax (MW) and polyethylene wax (PEW).
- From BBR tests on binder level, the blends with amide wax (AW) have the best Lower PG values.
- On mix level the ranking of the waxes is the same as for the binder level at RV.
- Substitution of crushed aggregates by round aggregates has a high potential for temperature reduction in mastic asphalt. When 50 wt.% of the fraction is substituted by round aggregates, 31 K temperature reduction is possible. This is a similar reduction compared to addition of 4 wt.% AW to the binder (27K). When the complete 0/11 fraction is substituted it can be reduced by 36K. This shows that the use of round aggregates for mastic asphalt can be seen as an economic alternative for temperature reduction.

The next step of the research includes tests on performance of the different mixes [1]. The resistance to permanent deformation and to low-temperature cracking is investigated for the reference mix as well as for the wax-modified mixes and the mixes with round aggregates.

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