Experience of adding wax to bitumen and asphalt mixture products

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Abstract

As a consequence of lower limit values for bitumen emissions in connection with asphalt works and more severe requirements for lower carbon dioxide emissions, new temperature reducing asphalt technologies have been developed.

One way of reducing asphalt mixing temperatures is by adding special commercial wax products. Such waxes show a viscosity depressant/flow improving effect on binder and asphalt mix at higher temperature. The main purpose of adding the wax is to reduce the asphalt mixing temperature in order to reduce energy consumption as well as emissions of bitumen smoke and aerosol. As a rule, the workability of the asphalt is improved as well. Below the laying and compaction temperature, there may also be an increase in viscosity due to wax crystallization, and by this some stiffening effect. Consequently, the asphalt pavement should gain better resistance to plastic deformation. Additionally, lower void content due to better compaction properties should make the pavement more durable. Other pavement properties such as crack susceptibility, fatigue resistance, and adhesion may however also be affected by the flow improver. Different bitumen compositions are more or less sensitive to these additives. Consequently, bitumen of different origin ought to be specially studied, in order to at least adjust the flow improver to the bitumen and avoid deterioration of the properties as a result of adding the flow improver.

Particularly suitable products for addition of flow improvers are stiff polymer modified bitumen products. With no flow improvers, these bitumens require high laying temperature, which may result in degradation of the polymer and not designed performance of the pavement on the road. Mastic asphalt products normally require higher working temperatures than asphalt concrete, and the use of wax additives in mastic asphalt has increased.

Experience from the literature is presented in this paper and advantages and drawbacks of adding commercial wax products to bitumen and asphalt mixture products are discussed.

Keywords: bitumen, wax, flow improver, temperature reduction.

1. Introduction

The influence of natural wax on bitumen and asphalt concrete has been discussed within the asphalt industry for a very long time, implying negative as well as positive effects. These bitumen waxes often are divided into two or three general groups; macrocrystalline, microcrystalline and amorphous or non-crystalline wax. The waxes show different impact on bitumen properties. The presence of macrocrystalline wax is considered most problematic, as it may decrease viscosity / complex modulus at high temperatures, possibly making the asphalt pavement more sensitive to permanent deformation, especially during hot summer weather. However, generally natural wax in straight run bitumen is currently low in content and of a kind not likely to be harmful to binder properties, i.e. natural wax in bitumen is not likely to increase for instance the sensitivity to plastic deformation or cracking of a pavement. On the other hand, wax could unintentionally be produced through certain refining procedures.

As a rule, natural waxes in bitumen melt between about 20 and 70°C, while waxes used as flow improver melt at higher temperature. The crystallization range for a wax flow improver depends on the distribution of the carbon chain length and varies between different products. Molecules with long carbon chains crystallize at higher temperature than molecules with shorter chains. During crystallization, heat is released.

2. Wax additives in bitumen

Typical viscosity lowering products used for asphalt pavements are FT-paraffin, montan wax, oxidized polyethylene wax, thermoplastic resins, fatty acid amide and zeolites. Most used in practice are FT-paraffins and montan waxes. Normally, the addition of wax is 2-4 % by weight. A combination of FT-paraffin and montan wax is used in practice as well.

Structurally, FT-paraffin is similar to natural paraffin wax in bitumen. The difference between bitumen paraffin wax and FT-paraffin lies in the considerably longer molecules of FT-paraffin, of which n-alkanes lie in the range of 40 to 115 carbon atoms. The longer molecules result in a considerably larger melting range for the pure FT-paraffins (65-120°C), and a congealing point of about 100°C. FT-paraffin is produced in a so-called Fischer Tropsch synthesis, where carbon monoxide is converted into higher hydrocarbons and oxygenates in catalytic hydrogenation followed by a distillation process.

Montan vax is a partly bituminized fossil ester wax, which can be extracted from brown coal. It has a more complicated structure compared to FT-paraffin and is available in a number of product variants depending on range of use (type of bituminous product). Since the beginning of the 1980’s, montan wax has been used as additive in mastic asphalt in Germany for obtaining better workability of asphalt mixtures [Grosshans 1985]. Montan waxes have been modified specifically for this purpose, but also with the intension of improving, for instance, asphalt pavement adhesion properties.

Zeolites are crystalline hydrated aluminium silicates. They exist in nature and are also produced synthetically. Zeolites have the ability to hold and release certain quantities of water. For lowering the asphalt mixing temperature, special zeolites have been developed. When adding this flow improver to the mixture, at the same time as the binder is added, a water based vapour and foaming effect is created, giving an improved workability of the mix. No extra stiffening effects below the paving temperature are gained by the addition of zeolites.

2.1 Impact of wax additives

Generally, the main purpose of adding wax to bitumen is to lower the viscosity within a certain temperature range, which in turn may lead to better workability, maybe a longer paving season and less needed roller compaction (for asphalt concrete mixtures).

Energy consumption reductions are considered to be a very important benefit of wax addition (and other similar techniques). Production costs at the asphalt plant may be lower due to lower production temperature and shorter production time. Less wear of equipment in the plant is another possible favourable consequence. On the other hand, production costs may increase by the extra cost of wax, and, if equipment modification is needed, for the new production process.

Lower production temperature also means reduced emissions, which otherwise may be a problem, or even injurious to health, during asphalt production and paving. Bitumen fumes in connection with indoor asphalt works (parking decks and within the mastic asphalt flooring sector) are known to be most problematic. A reduction of the production and application temperatures of about 20°C may lead to a corresponding reduction of emissions by more than 70% [Sandmann 2007].

Obviously, wax as flow improver shows a softening effect on the binder and asphalt mix at higher temperature (above 80°C). In addition to that, a stiffening effect occurs below the paving temperature as a result of wax crystallization. Consequently, the asphalt pavement resistance to permanent deformation may improve as well.

Rheological effects of adding wax to bitumen can be studied using dynamic mechanical analysis (DMA). In DMA, the ratio of peak stress to peak strain is defined as the complex modulus │G*│, which is a measure of the overall resistance to deformation of the sample tested. The phase difference between stress and strain is defined as the phase angle δ, and is a measure of the viscoelastic character of the sample. For a completely viscous liquid, the phase angle is 90° and for an ideal elastic solid material, the phase angle is 0°. Complex modulus and phase angle of bitumens are functions of temperature and frequency, which may be changed by the addition of different additives such as waxes and polymers. Rheological effects by DMA from adding wax to a polymer modified binder is shown in Figure 1.

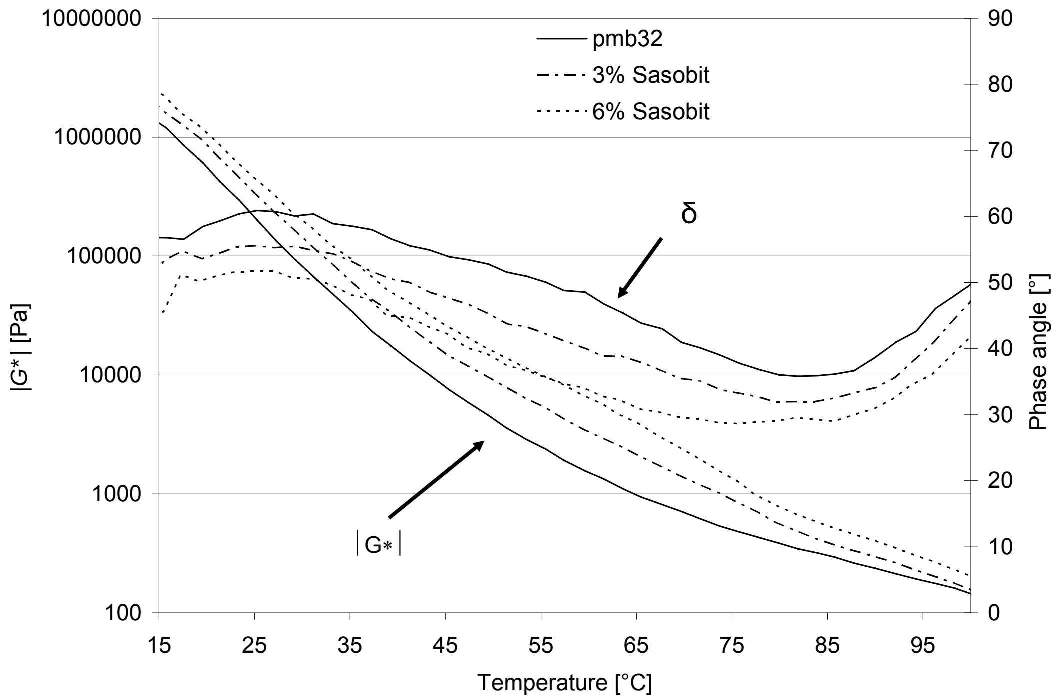

Figure 1. Temperature sweeps from 10 to 100°C at a frequency of 1 rad/s for a polymer modified binder containing added wax.

3. Experimental studies

Laboratory and field studies are being performed for a large set of wax/binder systems in for instance Germany. The project is a joint project between BASt (Bundesastalt für Strassenwesen), BMVBW (Bundesministerium für Verkehr, Bau- und Wohnungswesen) bitumen producers, wax producers and others. Test sections were constructed in June 2004 on the motorway A7 near Flensburg, and will be studied for at least a period of eight years. The aim of that project is to develop some asphalt requirements specifications for so-called TA Asphalt (temperaturabsenkende) in Germany [Bielenberg et al. 2006]. Other test sections were also constructed near Schwerin 2004. In both cases, polymer modified bitumen (Pmb 45 A) was used as reference.

A technical temperature reduction procedure known to be used in France for mastic asphalt is called Néophalte®Low-Temperature [Dean 2004].

3.1 Recent Swedish studies

Several Swedish laboratory studies regarding effects of wax additives on bitumen and asphalt concrete properties have been performed. The studies referred to in this case include some bitumens of penetration grade 160/220 but different origins, one polymer modified bitumen, one FT-paraffin wax (Sasobit) and two montan waxes (Asphaltan A and B). Asphaltan A was used only for the polymer modified product.

Particularly suitable products for addition of flow improving wax products are polymer modified mastic asphalt products. In Sweden, mastic asphalt for bridges, parking decks etc. always contain polymer modified bitumen (pmb). Mixing and laying temperatures are between 200 and 230°C, depending on laying conditions (higher temperature when manually applied). In order to decrease this temperature to not more than 200°C, the wax additives Sasobit and Asphaltan A have been used in laboratory binder studies. Further laboratory testing is currently performed on mastic asphalt test specimens containing selected binder mixtures. Indentation value at 40°C is determined as well as dimensional stability at 80°C (according to EN 12970, Annex B). The tensile stress restrained specimen test (TSRST) is used to get further knowledge on low temperature performance of mastic asphalt containing polymer- and wax modified binders. A slump test is under developments as well.

4. Conclusions

The most important conclusions drawn from the experimental studies involving penetration bitumen and wax are listed below [Edwards 2005].

- Magnitude and type of effect of additive on bitumen rheology depend on the bitumen itself as well as type and amount of additive. Bitumen composition is of decisive importance.
- None of the wax additives showed any negative sudden complex modulus lowering effect at higher temperatures, thereby possibly affecting rutting resistance in a negative way.
- Physical hardening as determined by BBR at -25°C showed a higher hardening index for the two bitumens containing natural wax than for the two non-waxy bitumens. Adding FT-paraffin decreased the hardening index for all bitumens. Also montan wax showed this effect, but not for all bitumens.

- No correlation between physical hardening index (PHI) and wax content by DSC was found, and consequently, enthalpy change by DSC was not considered to be a good indicator of physical hardening.
- Addition of the waxes used showed no or marginally positive influence on bitumen ageing properties for the bitumens and test conditions used.
- Comparison of asphalt mixture and corresponding binder test results showed that the effects on asphalt mixtures from added wax were less evident.
- It is recommended to carefully evaluate in the laboratory effects of adding any type of commercial additive to some bitumen intended for modification before using it in practice.

In summary, the effects of adding wax to bitumen varied depending on bitumen and temperature range studied, and were mainly of positive or vague nature. However, this work did not focus on flow improving effects at mixing and laying temperatures but rather on additional stiffening effects at temperatures below asphalt concrete compaction temperature.

Conclusions from the polymer modified mastic asphalt studies so far are:

- Both waxes show a flow improving/viscosity depressant impact on the pmb used at higher temperatures, indicating possible lower mixing and laying temperatures for mastic asphalt products, if modified with such waxes.
- Concerning binder performance at temperatures lower than approximately 100°C, there is a stiffening effect due to wax modification, indicating a certain positive effect on stability.
- However, this stiffening effect appears also at very low temperatures, indicating a negative impact on crack susceptibility, larger by the addition of Sasobit than by the addition of Asphaltan A. Most affected is the lower limit m-value temperature by BBR.

5. References

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