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Effects of commercial waxes on asphalt concrete mixtures performance at low and medium temperatures

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Abstract

Effects of adding two commercial waxes to three 160/220 penetration grade bitumens in asphalt concrete mixtures were studied using tensile stress restrained specimen test (TSRST), dynamic creep test and complex modulus test. Significant physical hardening of binders, observed in binder testing, could not be observed using TSRST. The reason could be that low temperature physical hardening does not have a large effect on fracture properties of the asphalt mix or that TSRST is a non-suitable test for showing these effects. In dynamic creep testing, the smallest strains were recorded for the asphalt mixture containing non-waxy bitumen and FT-paraffin, indicating better resistance to rutting. In complex modulus testing, adding of 6% commercial wax clearly increased the modulus and decreased the phase angle, an effect more pronounced for the mixture containing FT-paraffin compared to the one containing polyethylene wax.

Keywords: Bitumen wax; Asphalt mixtures; Rheology; Low temperature cracking; TSRST; Dynamic creep

1. Introduction

Wax in bitumen often has been considered as a negative indication of the quality of bitumen. However, natural wax is part of most bitumens, and commercial waxes are added to bitumen in order to achieve certain properties. This paper deals with such wax modified bitumens in asphalt concrete mixtures, focusing on mechanical properties of the mixtures at low and medium temperatures. Binder rheological effects of wax modification as well as ageing properties of the wax-modified bitumens involved in this study are evaluated more in detail elsewhere (Edwards et al., submitted for publication-a–c).

Factors influencing the effect of waxes in bitumen are chemical composition (source of bitumen) and rheological behaviour of the bitumen as well as content, composition and crystallinity of the wax. The presence of large crystals (macrocrystalline wax) in bitumen for road construction is considered to be most problematic. Nowadays, natural waxes in straight run bitumen generally are microcrystalline and/or amorphous and not particularly harmful with regard to binder properties. Furthermore, increased sensitivity to cracking or plastic deformation in asphalt pavements is not likely to appear due to the occurrence of natural bitumen wax. However, in the case of blown bitumens and/or wax modified bitumens in road construction (frequently used in the US and Canada), the effects on asphalt concrete properties may vary considerably (Hesp, 2004).

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2. Experimental

2.1. Bitumen and wax modifiers

The binder mixtures used in this study were selected from earlier studies concerning rheological effects on bitumens (Edwards et al., submitted for publication-a,b) and influence on ageing properties (Edwards et al., submitted for publication-c) due to the addition of commercial waxes. The selection of binder mixtures was limited due to the limited amounts of bitumen available for the preparation of asphalt concrete test slabs.

Three different bitumens of penetration grade 160/220 were used in the study. One was a non-waxy bitumen, denoted NV, and the other two, denoted ME and WB, contained approximately 3.8 and 2.0 wt.% natural bitumen wax, respectively, according to Differential Scanning Calorimetry (DSC) measurements. The bitumens were modified with two types of commercial wax, FT-paraffin and a polyethylene wax. The content of added wax was 6% by weight.

FT-paraffin, denoted wax S, is a typical so-called bitumen flow improver, which is used for asphalt pavements and mastic asphalt to reduce the mixing temperature. It also gives a certain stiffening effect (increase in softening point and decrease in penetration value). When comparing FT paraffin to other flow improvers such as montan wax (Edwards et al., submitted for publication-a), adding of wax S showed the highest stiffening effect to the bitumens studied, which was the reason for choosing it in this particular study. Polyethylene wax, denoted wax PW, normally is not used as flow improver or modifier in asphalt mixtures. However, adding PW, especially to the non-waxy bitumen NV, showed considerable positive effects (increased stiffness) on the rheological behaviour at medium and higher temperatures (Edwards et al., submitted for publication-a), which was the reason behind the choice of that additive for this asphalt mixture study. More detailed characteristics of the bitumens and waxes are given in Edwards et al. (submitted for publication-a,b).

Bitumen/wax mixtures were prepared by adding calculated amount of wax to approximately 250 g of bitumen, after which the mixture was heated 30 min at 155 °C. Prior to this preparation, the original binders were heated in larger buckets for about 3 h at the same temperature and subdivided. The binder mixtures were then placed in preheated blocks and homogenized by shaking 90 s. Only one level of wax content (6%) was used in this study, and chosen in order to obtain, if possible, significant effects in the asphalt concrete testing.

2.2. Asphalt mixtures

A dense graded asphalt concrete according to Swedish road standards (ATB VÄG, 2004) with maximum aggregate size of 11 mm was prepared. A crushed granite material was used, and the nominal binder content was 6.2% by weight. The measured particle size distribution of the aggregate used is shown in Fig. 1. The target air void content was 2.0–3.5% by volume. Measured air void content is indicated in the corresponding data tables, and found to vary between 1.5% and 5.0%.

The mixtures were manufactured by Nynäs in Sweden and compacted to slabs using a laboratory rolling wheel compactor (MAP Spechbach-le-bas, France). The final dimensions of each slab were 600 × 400 × 100 mm. In total, 5 slabs were prepared for the study. The temperature for mixing and compaction was 155 °C. From each slab, eight cylindrical specimens (diameter 54 mm) were cored for the thermal stress restrained specimen test (TSRST), two specimens (diameter 150 mm) for the dynamic creep test and another two for the complex modulus test (diameter 80 mm). Four TSRST specimens from each slab were subjected to thermal ageing in a draft oven at 85 °C for 42 days.

2.3. Methods of analysis—binders

The binders were analyzed using rheological methods (Dynamic Mechanical Analysis (DMA), Bending Beam Rheometer (BBR), softening point (EN 1427), penetration at 25 °C (EN 1426), dynamic viscosity (EN 12596), kinematic viscosity (EN 12595), breaking point

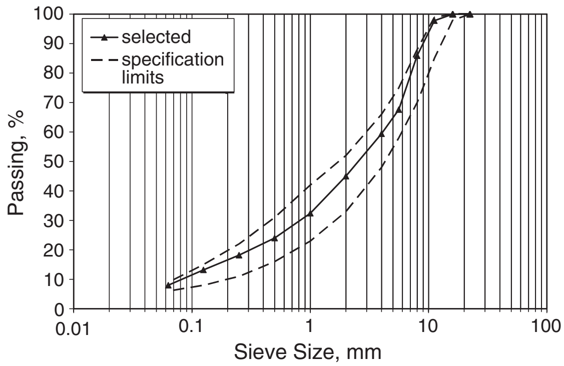

Fig. 1. Particle size distribution of the aggregate used and limits according to ATB VÄG, 2004.