Properties of Bituminous Binders Exposed to Ageing Process

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Properties of Bituminous Binders Exposed to Ageing Process

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Abstract. During the production technology of asphalt mixture and road pavement construction, the bitumen binder is exposed to the influence of oxygen, and the oxidative aging of bitumen occurs. Changes of bitumen as a result of phenomena associated with evaporation and oxidation changes express in hardening. To improve the quality of bitumen and asphalt mixtures, an organic and inorganic additive are added. The paper reviews the change in the properties of paving grade and polymer modified bitumen by the effect of aging and the change of bitumen properties with the Licomont BS100 and Wetfix BE additives. Additive Wetfix BE, improving adhesion between bitumen and aggregate, had little influence on the empirical properties of tested bitumens. The Licomont BS100 additive caused an increase of the softening point and reduced the viscosity at higher temperatures of 120 to 180 °C, which allows reducing the working temperatures during the production, laying and compaction of the asphalt mixtures. The results confirmed the hardening of the binder after both short and long-term aging, which was reflected by a decrease in penetration and an increase in the softening point. The effect of aging by RTFOT generally showed an increase in bitumen viscosity without and with the additives. The greatest increase in viscosity was for bitumen PmB 45/80-75, the smallest change in values was for bitumen 50/70. Additives added to bitumen decreased the viscosity, except for Wetfix BE in bitumen 35/50. By comparing the bitumen viscosity results after aging without and with additives, the effects of additives on the bitumen viscosity are less prominent than those of bitumen without aging. Only with the Wetfix BE additive in bitumen 50/70, the viscosity change of the aged binder was greater than that of the unaged one.

1. Introduction

Bitumen binder is subject to aging and changes in mechanical and chemical properties over time. The binder is aged due to the effects of the environment (UV radiation, oxidation by air), repeated loading, etc. During asphalt production, the bitumen is exposed to high temperature. The bitumen in the form of constantly renewing a thin film on the aggregate surface is subjected to the oxidation process; this short-term aging is referred to as “production-structural”. After spreading the asphalt mixture, aging in the pavements continues during pavement service life, long-term “service” aging, which is characterized by relatively slow kinetics over several years. Once the asphalt mixture lifetime has been reached, there may arise different types of pavement failures, such as cracks and potholes.

The main mechanism of aging is irreversible and it is characterized by chemical changes of the binder. Processes contributing to this type of aging include oxidation, loss of volatile components and exuding of oil components from bitumen into the aggregate [1]. The thermal oxidation aging takes place during the storage and processing of bitumen binders. Structurally oxidative aging occurs from lower temperatures, under sunlight and UV radiation on the pavement surface. Volatilization of lighter bitumen components is only a small part of total changes, and it is an irreversible process. Bitumen with a higher content of asphaltenes and maltenes with low values of penetration, has a higher loss of mass due to volatilization, compared to bitumen with a low asphaltenes content. Changes due to volatilization or oxidation are indicated by hardening of the bitumen. These changes are shown only on the surface, the oxidative effect of air oxygen acts in depth of 0.05 mm.

In general, the bitumen binder is aging, the binder viscosity is increasing and the binder becomes hard and brittle. Oxidative behaviour of bitumen is therefore one of the critical factors, which contributes to the performance of asphalt pavements. Optimal performance and properties depend on flow and rheological properties of the bitumen. The changes of flow properties with time are undesirable and often lead to a reduction of the performance or even to pavement failures.

In order to improve the quality properties of bitumen and/or properties of asphalt mixtures, additives and modifiers are added, e.g. to increase an elasticity, to improve elastoplastic properties, to improve an adhesion of bitumen to aggregate, to improve workability by reducing the viscosity or the surface tension at the interface bitumen/aggregate, to increase aging resistance, etc. By adding the additives to bitumen binder during the process of handling, processing and spreading of the asphalt mixture, there is a thermal stress and there may be changes in other properties. The contribution is focused on the effect of selected additives on bitumen binder properties and properties after exposure to short-term aging, which is simulated in the laboratory conditions using a RTFOT test.

2. Experimental measuring

The aim of the experimental program is to monitor the change of properties of bitumen binders in laboratory conditions using selected additives and to monitor the changes after the exposure of samples to the technological-structural ageing of bitumen in a laboratory by RTFOT test (Rolling Thin Film Oven Test). The combined effect of heat and air on the bitumen binder is determined by changing the weight of the binder and changing binder properties. The binders were tested on basic properties as penetration according to EN 1426 [2] and softening point according to EN 1427 [3] and impact of selected additives (Licomont BS100 and Wetfix BE) on these properties as well as the change in properties after the short-term ageing according to EN 12607-1 [4] (Figure 1). In order to meet the objectives of the work, experimental measurements of bituminous binders' properties were performed on samples of paving grade binders 50/70, 35/50 and polymer modified bitumen 45/80-75.

Figure 1. The apparatus of performed test

3. Results and discussion

In the following sections, the results of the penetration, softening point and dynamic viscosity of 50/70 and 35/50 bitumen and modified bitumen PMB 45/80-75 without additives and bitumen with the additive Licomont BS100 and Wetfix BE. Bitumen without and with additives were further subjected to short-term aging with RTFOT in order to determine the impact of additives on the binder during the production of the asphalt mixture. The test results are shown in Table 1. As stated in [5], the bitumen properties vary according to the type of bitumen and type of used additive. Additive Wetfix BE, improving adhesion between bitumen and aggregate, had little influence on the penetration and softening point of tested bitumens. The Licomont BS100, additive on the base of derivate of fatty amines, caused an increase the softening point of all tested bitumen binders. A positive influence of the FT wax modification on the 50/70 binder was verified in many works [6]. In modified PmB 45/80-75 bitumen, a decrease in penetration was recorded markedly by effect of the Licomont BS100 additive.

Table 1. The properties of bitumen binders without and with additives

Test	50/70	50/70 +Licomont BS100	50/70 +Wetfix BE	35/50	35/50 +Licomont BS100	35/50 +Wetfix BE	PmB 45/80-75	PmB 45/80-75 +Licomont BS100	PmB 45/80-75 +Wetfix BE
Penetration at 25 °C (0.1 mm)	62	65	66	45	44	43	59	44	61
Softening point (°C)	48	91	47	56	86	57	80	97	82

A test simulating aging of the binder during production, spreading, and compaction of asphalts was performed in accordance with EN 12 607-1. For all samples, a decrease in weight was recorded after RTFOT (Figure 2). The short-term aging most affected the bitumen 35/50. By adding the Licomont BS100 additive, the loss of weight was increased in all binders. By adding the Wetfix BE to the modified bitumen, its weight loss by influence of heat and air decreased, while adding Wetfix BE to the paving grade bitumen caused it to remain the same as for bitumen without the additive.

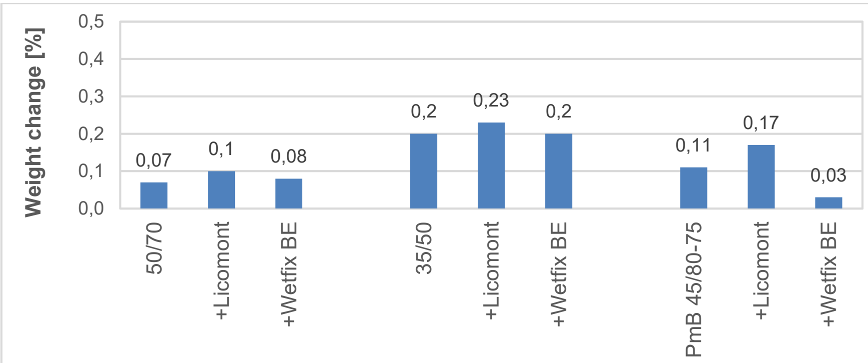

Figure 2. The change of weight of bitumen without and with additives in percentage due to short-term aging

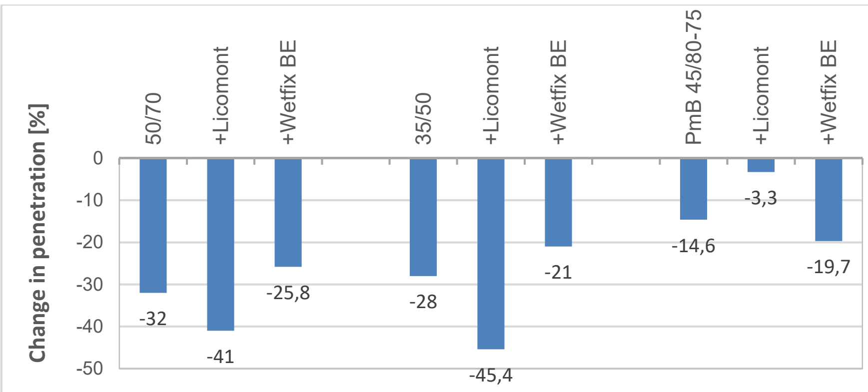

Figure 3. The decrease of bitumen penetration without and with additives due to short-term aging

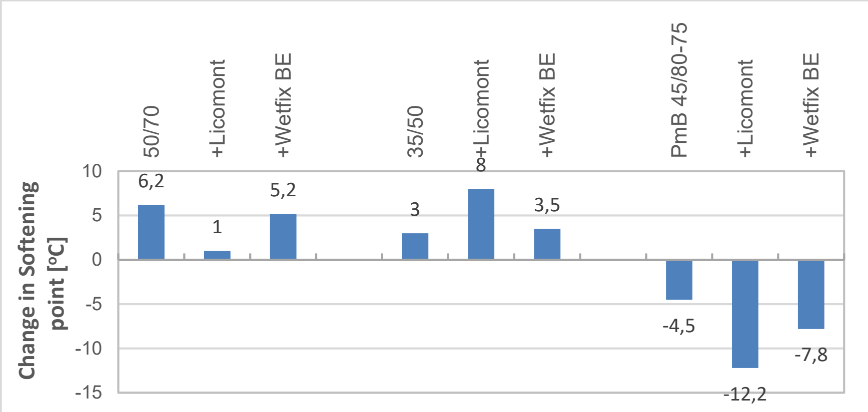

Figure 4. The increase / decrease of bitumen softening point without and with additives due to short-term aging

All of tested binders, after aging process, have a reduced penetration, thus increasing the hardness of bitumen (Figure 3). From the additive point of view, addition of the Licomont BS100 additive to paving bitumen leads to a greater penetration change (41 % and 45.4 %) than for paving bitumen without additives. On the other hand, by adding Wetfix BE additive, penetration changes are smaller (decreases of 25.8 % and 20.9 %). In modified bitumen without and with additives, the values of penetration changes are the smallest. The softening point indicates the temperature at which the bitumen loses its stiffness and may cause deformation in the road. For PG bitumen, the increase in temperature of softening point by RTFOT test was recorded and in case of bitumen PmB 45/80-75 there was a decrease in the softening point (Figure 4). The additive Licomont BS100 effect after short-term aging was more marked compared to Wetfix BE, the effect depended on the type of bitumen.

For all three bitumen, the viscosity increased due to heat and air by RTFOT method (Figures 5-7). The viscosity of modified bitumen increased most. The smallest change in values was at bitumen 50/70, the viscosity values before and after RTFOT were nearly the same. By adding the additives Licomont BS100 and Wetfix BE to the binder (except for 35/50 bitumen), a viscosity decrease was recorded. After RTFOT aging, an increase in viscosity values of all bitumen without and with additives was measured. Additive Licomont BS100 also reduces the bitumen viscosity by aging.

Bitumen aging causes hardening, resulting in a decrease in penetration and an increase in the softening point. The hardening of bitumen due to volatilization and oxidation could be evaluated by a parameter based on the viscosity (the viscosity-temperature susceptibility VTS). According to [7], the ASTM model given by equation defines the VTS relationship:

$$VTS = (loglog\eta_{T2} - loglog\eta_{T1})/(logT_1 - logT_2) \quad (1)$$

$$log\ log\ \eta = A + VTS.\ log\ T \quad (2)$$

where η is viscosity, *A* is regression intercept, *VTS* is regression slope and *T* is temperature. The lower the *VTS*, the lower the temperature susceptibility. The temperature sensitivity expressed by the *VTS* parameter in the temperature range of 120 °C to 180 °C changes with the addition of additives, mostly the bitumen 50/70 and at least the bitumen 35/50 (Figures 5-7). After production aging, the values of bitumen with and without additives are approximately the same for tested bitumen. An increase in the temperature sensitivity *VTS* of bitumen 50/70 with additives (compared to bitumen without additives) was recorded.

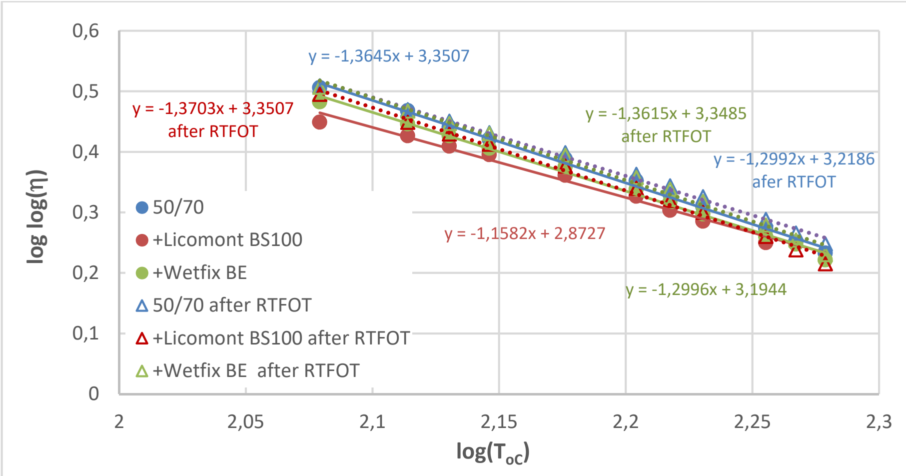

Figure 5. The A and VTS parameters for binder 50/70 (rotational viscometer)

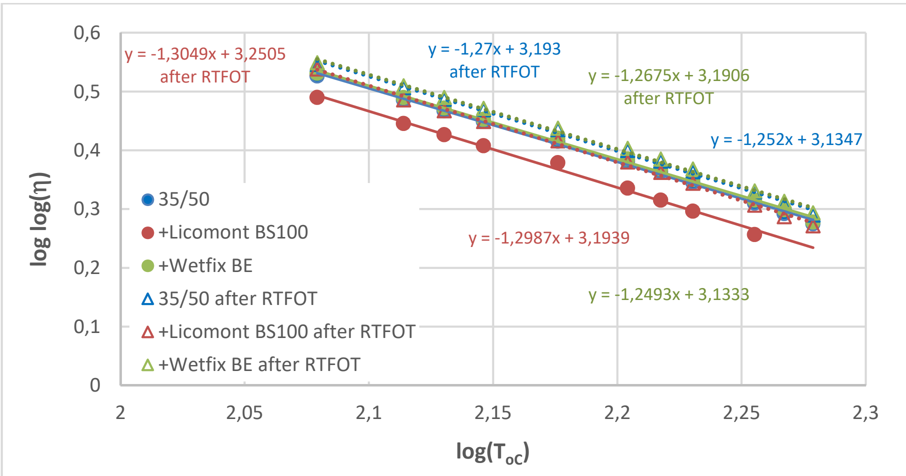

Figure 6. The A and VTS parameters for binder 35/50 (rotational viscometer)

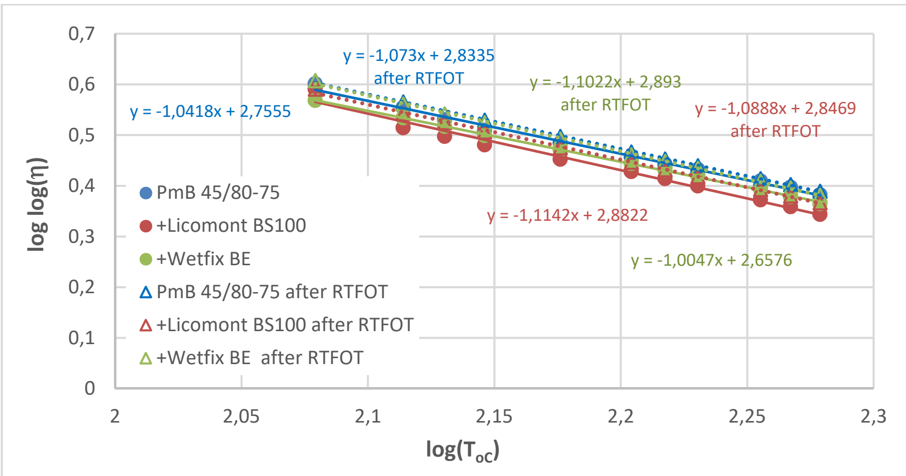

Figure 7. The A and VTS parameter for bitumen PmB 45/80-75 (rotational viscometer)

4. Conclusion

The paper deals with bitumen binders, determination of their properties and changes of these properties after the addition of selected additives and the effect of short-term oxidative aging by heat and air effects by the RTFOT method. The results of measurements of the basic properties of penetration and the softening point of binders with additives indicated different changes in properties compared to reference samples without additives. In the case of paving grade bitumen, change in penetration did not cause a change in bitumen grading. The significant increase in the softening point of PG bitumen with Licomont BS100 shifts the properties of such modified bitumen to the values typical for PmB bitumen. For assessing whether the treated bitumen can be considered as "modified", it is necessary to verify, in particular, its elastic behaviour (e.g. elastic recovery test, DSR test).

By adding Wetfix BE, the bitumen became softer. The type of bitumen and the type of additive affected the change in the properties of bitumen binders. Significant changes in bitumen properties may have a negative impact on the quality of produced asphalt mixtures and on road quality. By obtaining knowledge of the properties and behaviour of bitumen during production asphalts and road life cycle, we can prevent its early degradation.

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