

Changes of Properties of Bitumen Binders by Additives Application

Eva Remišová¹, Michal Holý¹

¹University of Žilina, Faculty of Civil Engineering, Univerzitná 8215/1, 01026 Žilina, Slovak Republic

eva.remisova@fstav.uniza.sk

Abstract. Requirements for properties of bituminous binders are determined in the European standards. The physico-chemical behaviour of bitumen depends on its colloidal structure (asphaltenes dispersed into an oily matrix constituted by saturates, aromatics and resins) that depends primarily on its crude source and processing. Bitumen properties are evaluated by group composition, elementary analysis, but more often conventional or functional tests. Bitumen for road uses is assessed according to the physical characteristics. For the purpose of improving the qualitative properties of bitumen and asphalts the additives are applied e.g. to increase elasticity, improving the heat stability, improving adhesion to aggregate, to decrease viscosity, increasing the resistance to aging, to prevent binder drainage from the aggregate surface, etc. The objective of presented paper is to assess and compare effect of additives on properties of bitumen binders. In paper, the results of bitumen properties, penetration, softening point, and dynamic viscosity of two paving grade bitumen 35/50, 50/70 and polymer modified bitumen PmB 45/80-75 are analyzed and also the changes of these properties by the application of selected additives (Sasobit, Licomont BS100, Wetfix BE and CWM) to improve adhesion to aggregate and improve workability. Measurements of properties have been performed according to the relevant European standards. The laboratory tests showed significantly increasing the softening point of paving grade bitumen 50/70 and 35/50 by 13 to 45°C. The effect of various additives on bitumen softening point is different. Penetration varies according to type of bitumen and type of used additive. The penetration values of modified bitumen PmB 45/80-75 with additives Sasobit and Licomont BS100 show increase of bitumen stiffness of 16 0.1mm and a shift in the gradation. The changes in penetration and in softening point significantly shown when calculating on Penetration index as a parameter of temperature susceptibility. The additives changed the viscosity of bitumen to lower values mostly with modified bitumen. In case of the additive Wetfix BE mix in 35/50 caused the viscosity increase. The additive changes the properties of original bituminous binders, and that can affect the properties of asphalt mixtures and asphalt layers.

1. Introduction

The bitumen binder in volume expression has minor proportion in asphalt mixture but it is the key element affecting resultant properties of asphalt mixture.

The basic purpose of bitumen binder is to “bind” the aggregate particles together. The visco-structural properties of bitumen, varying with temperature, predetermines the bitumen for using. The bitumen binder is expected to have such properties that ensure resistance of asphalt mixture to permanent deformation at high temperatures (elastoplastic properties, stiffness) and to possess



sufficient ductility (binder cohesion and tensile strength) at low temperature to prevent frost cracking [1].

In general bitumen binders are semisolid or solid at room temperature and liquid at a relatively high temperature. The basic properties of bitumen binder are:

- rheology properties (viscosity, stiffness modulus respectively complex shear modulus),
- cohesion,
- adhesion,
- and durability.

The physico-chemical behaviour of bitumen depends on its colloidal structure (asphaltenes dispersed into an oily matrix constituted by saturates, aromatics and resins) that depends primarily on its crude source and processing.

Properties of bitumen binders are affected by the temperature and time of load. Characterization of bitumen binders is required to determine the effect of temperature and stress on the relevant engineering properties for applications. The first application is the actual mix design process, where the asphalt should be of such grade as to produce a mix with aggregates that would be able to sustain the effect of traffic and the environment for the design life of the pavement [2, 3]. The second application of characterization test result is for the construction process, where binder must be transported from refinery, stored in a mixing plant, pumped through pipes and mixed with aggregates, transported to the job site and laid down and compacted at specific temperatures that would allow the completion of all those steps in the most convenient way [4].

For the purpose of improving the qualitative properties of bitumen and asphalts the modifiers and additives are applied e.g. to increase elasticity, improving the heat stability, improving adhesion to aggregate, to decrease viscosity, increasing the resistance to aging, to prevent binder drainage from the aggregate surface, etc. The additives can be categorizing by types as:

- modifiers (polymeric),
- anti-strip agents,
- adhesion promoters,
- emulsifiers,
- surfactants,
- thers (rejuvenators, warm mix additives, fibers, organic materials, and rubber modifiers) [5].

Different technologies used for mixing asphalt additives with asphalt include hot mix, cold mix, and warm mix. dditives are substances that can be added to the bitumen binder to alter characteristics of final mixture, to make them resistant to the detrimental effects of the load from traffic and the environment.

The modifier mainly affects thermos viscous and viscoelastic properties of original binder. The polymer is able to form a three-dimensional network structure within the modified bitumen. Polymer modification improves the temperature susceptibility of bitumen and can improve its resistance to permanent deformation, thermal and fatigue cracking [6]. While unmodified bitumen does not show elasticity, modified bitumen is highly elastic. Most commonly used modifier is polymer styrene-butadiene-styrene, SBS. As modifier is also used ethylene-vinyl-acetate and other polymers (polyethylene, polypropylene) and rubber.

Additives as different textiles, fibers, zeolites and others do not effect into bitumen structure, thereby modification no occurs. Nevertheless change of bitumen properties occurs. Modifiers can combine with additives to reach the markedly changes of properties of final asphalt mixture.

The rheological behaviour and viscoelastic properties of bitumen and modified bitumen are very important from a practical application and also in understanding the effect of polymer addition on mechanical properties, bitumen morphology and polymer-bitumen interactions.

The objective of contribution is to assess and compare effect of additives on properties of bitumen binders. At evaluation the standard test as penetration, softening point and viscosity were applied.

2. Methodology and experiments

2.1. Materials

The three type of bitumen binders were used in study, two unmodified binders 35/50 and 50/70, and one polymer modified bitumen PmB 45/80-75. The binders were mixed with common used additives as Sasobit, FT-paraffin, additive on base of synthetic waxes improving workability, decreases working temperature, improves adhesion to aggregate; Licomont BS100, additive on base of derivate of fatty amines improves temperature stability at range -30 to +80°C, improves adhesion to aggregate, decreases bitumen viscosity; Wetfix BE adhesion improving additive on base of derivate of fatty amines; and CWM surface active additive decreasing surface tension on interface bitumen/aggregate, which allows to cover aggregate and compaction the mixture at lower temperatures and improves adhesion to aggregate. The additives were applied in amounts that are recommended by their producers, additives Sasobit and Licomont BS100 in amount of 3.0 % by weight of binder and Wetfix BE, Wetfix AP-47 and CWM in amount of 0.4 %by weight of binder. The bitumen was heated to the temperature corresponding to the mixing temperature $\pm 5^{\circ}\text{C}$. The additive was added into sufficient quantity of heated bitumen and stir until completely mixed. Such treated bitumen was placed back in ventilated oven to obtain lost temperature.

A standard test method as penetration, softening point and dynamic viscosity were used to assessment of properties of tested bitumen binders and bitumen binders mixed with additives. The results are presented in average values.

2.2. Performed laboratory tests

Penetration test characterizes bitumen properties at service temperature 25°C. Penetration is expression of stiffness of bitumen binder and affects the stiffness of asphalt mixture. The binder with lower value of penetration increases the asphalt mixture stiffness. The penetration test was performed according to STN EN 1426 [7].

The softening point characterizes the binder at higher temperatures and depends on its viscosity. By increasing the temperature the bitumen as a thermoplastic material becomes softer until a fluid consistency. The value of this temperature (reached at the specified test conditions, when the binder viscosity is $10^6 \text{ mm}^2.\text{s}^{-1}$) is important for the behaviour of asphalt mixtures at higher temperatures, especially in summer. Higher temperature of the softening point increases the resistance of mixtures to permanent deformation. The softening point test was performed according to STN EN 1427 [8].

Viscosity is defined as the ratio of applied shear stress to applied shear strain and it is expression of the resistance of material (a fluid, a bitumen binder) to flow. Viscosity is a value of bitumen consistency at specific shear stress and specific temperature and it characterizes structural and thixotropic properties of bitumen. At constant shear stress and at different temperature the viscous curves that characterized bitumen temperature sensitivity are determined. The viscosity of bitumen binder as a property changing with temperature affects the workability of the bitumen binder and asphalt mixture in the whole production process. The binder in the production phase of the mixture must be sufficiently liquid (low viscosity) to mixing with aggregate, in the phase of processing of the asphalt mixture must have such viscous properties, which allow the laying and compaction of the mixture to the required thickness and bulk density. The dynamic viscosity test of binder was measured according to specification STN EN 13302 [9] at high temperatures about 120 – 180 ° C using a rotating spindle apparatus Brookfield viscometer model DV-II+Pro with cylindrical spindle SC4-27 and thermoset system.

3. Results and discussion

Measured results of samples show different change of properties towards reference samples without additives. Additives' influence depends on type of bitumen and additive. Figure 1 shows that penetration values of tested modified bitumen PmB 45/80-75 with additives Sasobit and Licomont BS100 are below the value of reference sample (out of specified ranges). They show increase of

bitumen stiffness of 16 0.1mm and a shift in the gradation. The differences in penetration results of bitumen 50/70 were in the range from -6 to +4 0.1mm, so they are not essentially different from penetration of reference sample.

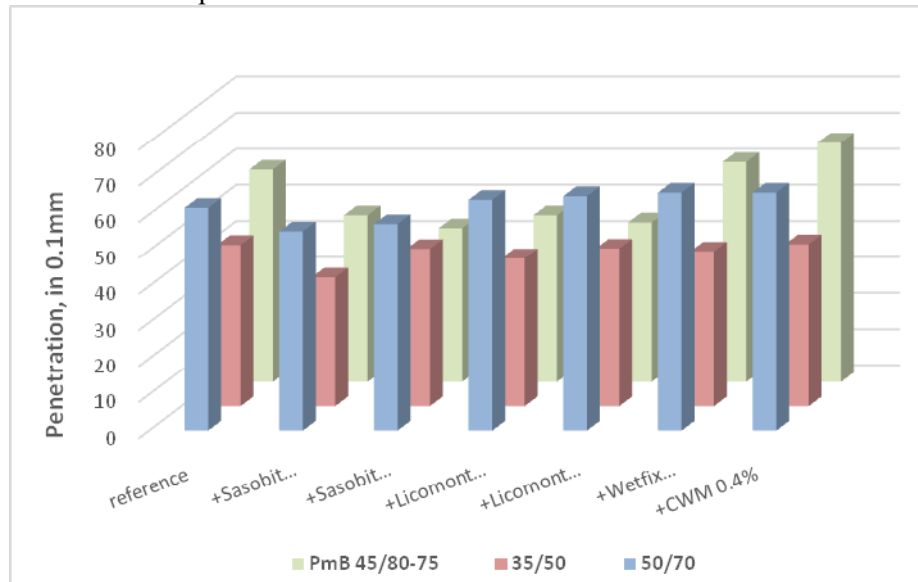


Figure 1. Comparison of penetration of tested samples - reference bitumen and bitumen with additives

In Figure 2 the results of softening point of tested binders and additives are showed. The effect of various additives on bitumen softening point is different. For all tested bitumen binders, the effect of additive Sasobit and Licomont BS100 is marked, the increase of softening point by 13 to 45°C. The application of additives Wetfix BE and CWM the value of softening point changed in the range from +2 to -2°C. The decrease of softening point was registered with bitumen 50/70.

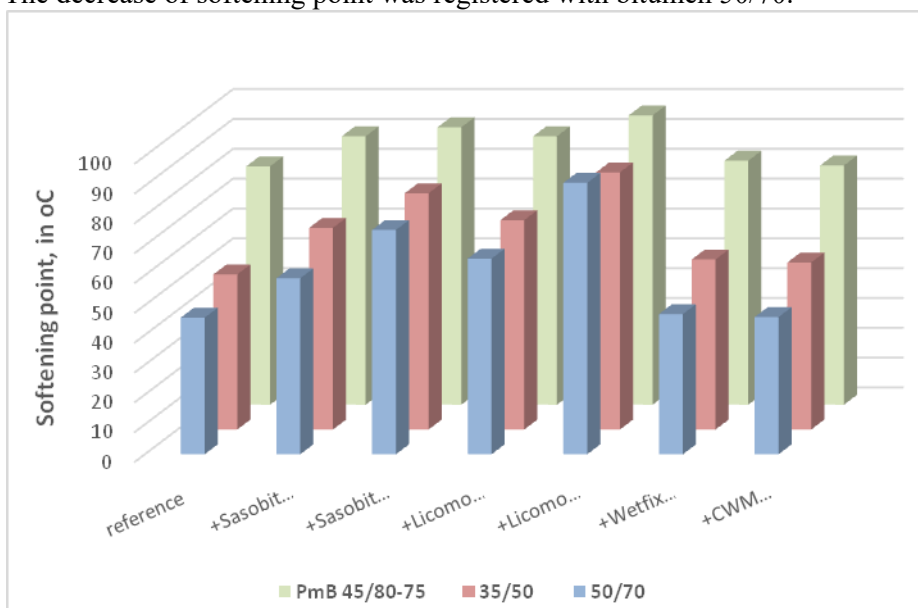


Figure 2. Comparison of softening point of tested samples - reference bitumen and bitumen with additives

The changes in penetration and in softening point significantly shown when calculating on Penetration index as a parameter of temperature susceptibility (Figure 3). In particular by additive Sasobit and Licomont BS100 application to unmodified bitumen 35/50 and 50/70 the values of PI significantly change and move binders to low temperature susceptible binders with PI above 2.

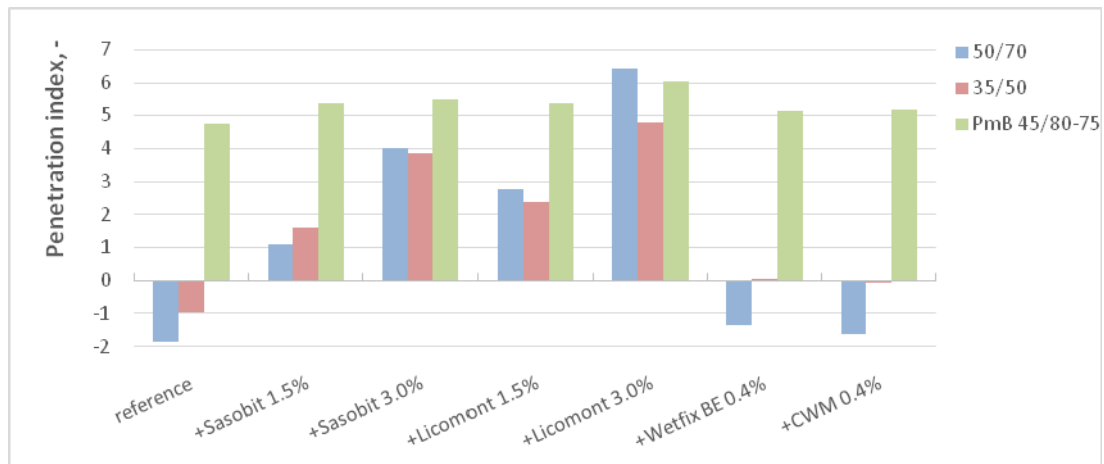


Figure 3. Comparison of Penetration index of tested samples - reference bitumen and bitumen with additives

The viscosity as a fundamental characteristics of a bitumen determines how the material will behave at a given temperature and over a temperature range. Next Figure 4 and Figure 5 show the results of viscosity at temperature 135 and 165°C.

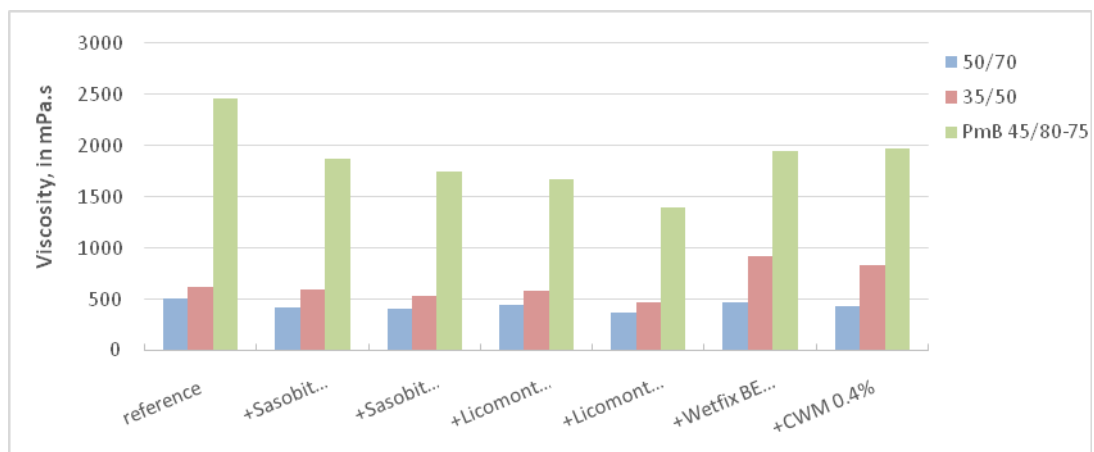


Figure 4. Viscosities of tested samples at temperature 135°C - reference bitumen and bitumen with additives

The results confirm known facts that viscosity of all tested binders decreases with increasing temperature. Modified bitumen has a higher values of viscosity than unmodified bitumen (35/50, 50/70). In [10, 11] there was documented the effect that the development of the viscosity curves of unmodified and modified bitumen is parallel from temperature 140°C so the dependences have uniform decreasing tendency.

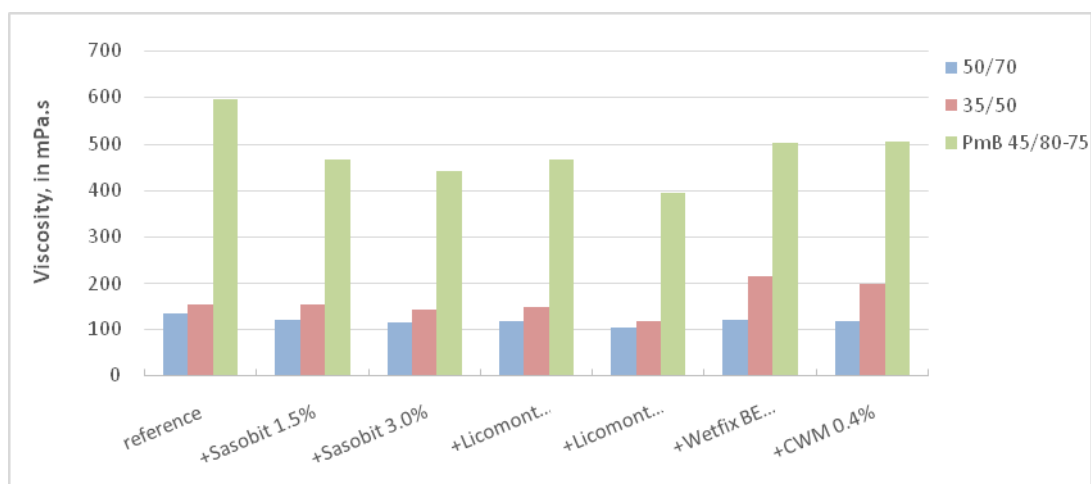


Figure 5. Viscosities of tested samples at temperature 165 °C - reference bitumen and bitumen with additives

Figures show a decrease of the viscosity values of modified bitumen (PmB 45/80-75) and unmodified bitumen (50/70) toward reference samples by additive application. The viscosity of modified bitumen with additives had values of 494 to 1069 mPa.s (at temperature 135°C) less than bitumen without additives. The smallest change in viscosity were determined with bitumen 35/50 (stiffer bitumen from the tested). In term of the tested additives, the additive Licomont BS100 (in dose of 3 % by weight of binder) caused the large decrease in viscosity values. In most cases there was a reduction in viscosity, other than the additives Wetfix BE and CWM combined with bitumen 35/50.

4. Conclusions

Additives are substances that can be added to the bitumen binder to modify bitumen characteristics and thereby to improve workability, the adhesion to aggregate, and the properties of final asphalt mixture. The objective of contribution was to assess and compare an effect of selected additives on properties of bitumen binders. The standard test as penetration, softening point and viscosity were used for evaluation.

The laboratory tests showed significantly increasing the softening point of paving grade bitumen 50/70 and 35/50 by 13 to 45°C. The effect of various additives on bitumen softening point is different. The decrease of softening point was registered for bitumen 50/70 with Wetfix BE.

Penetration varies according to type of bitumen and type of used additive. The penetration values of modified bitumen PmB 45/80-75 with additives Sasobit and Licomont BS100 show increase of bitumen stiffness of 16 0.1mm and a shift in the gradation. The changes in penetration and softening point significantly shown when calculating the Penetration index as a parameter of temperature susceptibility. The addition of some additives to unmodified bitumen 35/50 and 50/70 changed the PI values significantly and move binders to low temperature susceptible binders with PI above 2.

The important parameter of evaluation of bitumen properties is also the viscosity. The additives changed the viscosity of bitumen to lower values mostly of modified bitumen. The smallest change in viscosity were determined with bitumen 35/50 (stiffer bitumen from the tested). In case of the additive Wetfix BE mixed with bitumen 35/50, the additive caused the viscosity increase.

The additive changes the properties of original bituminous binders, and thus can affect the properties of asphalt mixtures and asphalt layers in road pavement, [13].

Acknowledgment(s)

The research is supported by the project VEGA 1/0300/17 Research of performance related and rheological properties of bituminous binders.

References

- [1] M. Decky, Remisova, E. and M. Juhas, „Impact climatic characteristics on dimensioning of road construction of road in tunnels in Slovakia”, *13th Multidisciplinary scientific geo-conference SGEM 2013*, pp. 659-666, 2013.
- [2] J. Celko, M. Kovac, and M. Decky, “Analysis of selected pavement serviceability parameters”, *Komunikacie*, vol. 13, pp. 56-62, ISSN 1335-4205, 2011.
- [3] D. Durcanska, M. Decky, R. Licbinsky, R. and J. Huzlik, “Project SPENS - sustainable pavement for European new member states”, *Komunikacie*, vol. 15, pp. 49-55, 2013.
- [4] R. B. Mallick, T. El-Korchi, “Pavement engineering. Principles and Practise”, CRC Press Taylor&Francis Group, ISBN 978-1-4200-6029-4, 2009.
- [5] Asphalt additives market – Global forecast to 2026, brochure, Copyright © 2016 MarketsandMarkets, 2016.
- [6] T. McNally, “Polymer Modified Bitumen. Properties and Characterisation”, 1st edition, Woodhead Publishing Limited, ISBN 9780857090485, 2011.
- [7] STN EN 1426 Bitumen and bituminous binders. Determination of needle penetration.
- [8] STN EN 1427 Bitumen and bituminous binders. Determination of the softening point. Ring and Ball method.
- [9] STN EN 13302 Bitumen and bituminous binders - Determination of dynamic viscosity of bituminous binder using a rotating spindle apparatus.
- [10] M. Holý, E. Remišová, “Evaluation of bitumen binders properties”, *Young Scientist 9th International Scientific Conference of Civil Engineering and Architecture*, 2017.
- [11] E. Remišová, V. Zatkaliková, F. Schlosser, “Study of rheological properties of bituminous binders in middle and high temperatures”, in: *Civil and Environmental Engineering*, De Gruyter, Vol.12, Issue 1/2016, pp.13-20. ISSN 2199-6512.
- [12] J. Komáromy, “The effect of selected additives on bituminous binders viscosity”, final project, University of Žilina, 2016.
- [13] E. Remisova, M. Decky and M. Kovac, “The influence of the asphalt mixture composition on the pavement surface texture and noise emissions production”, *14th International multidisciplinary scientific conference SGEM 2014*, vol. II, pp. p. 583-590, 2014.