::: Application Report

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Behavior of Bitumen in the Temperature Range of -6 °C to +90 °C

Relevant for:

Asphalt Industry

1 Introduction

Bitumen has to be rheologically characterized in the temperature range of T = 0 °C up to +70 °C. The sample's state changes under these conditions. A solid-like, rigid body becomes a free-flowing melt.

2 Experimental Setup

Temperature test as oscillation measurement of bitumen, measured with the modular compact rheometer MCR with a plate/plate measuring system.

3 Results and Discussion

The sample was measured with a PP 25 plate/plate measuring system, which corresponds to a plate diameter of d = 25 mm. At the highest measuring temperature of T = 90 °C the gap between the plates was set to h = 0.5 mm after 10 minutes of temperature equilibrium time.

As parameters for the oscillation measurement the angular frequency ω was set to constant 10 rad/s and the deformation amplitude γ was set as a logarithmic ramp from 25 % down to 0.01 %.

The following diagram shows the Storage Modulus G', the Loss Modulus G'' and the Loss or Damping Factor tanδ. The Storage Modulus describes the sample's elastic behavior and the Loss Modulus describes the sample's viscous behavior. The Loss Factor is calculated as the ratio of Loss Modulus and Storage Modulus which is equivalent to tanδ = G''/G'.

Bitumen is obtained from high temperature distillation. It is a mixture of various different petrochemical molecules connected in a physico-chemical network of forces. At low temperatures beneath the melting temperature these complex super-structures are rigid like a solid. Due to the so-called steric hardening, bitumen becomes inflexible and brittle. In this case G' > G'' or tanδ < 1 applies.

Therefore, at T = -6 °C the sample is an almost rigid solid with G' = $2.05*10^7$ Pa (= 20.5 MPa) and G'' = $5.07*10^6$ Pa (= 5.07 MPa) or tanδ = 0.25. The elastic portion is clearly dominant. The sample's molecules are „frozen“ and immobile.

With increasing temperature this mixture becomes softer. The values of G' decrease and those of G'' slightly increase first, whereas they also decrease at higher temperatures. Both moduli obtain the same value at T = 12 °C, thus tanδ = 1 applies. By then, the first paraffin components are melting, a few polar bondings between the molecule's functional groups break off and single small, freely moving, molecules separate freely flowing from the super-structures.

When continuing the supply of thermal energy, the super-structures are increasingly decomposed. Thus the bitumen mass becomes more and more flexible. Under the given shear stress it is easier than for the various small oil- and wax-like molecules and the resinous long-chained coils of macromolecules to slide off one another. However, the polymer chains usually are enclosed by interactions into the discrete, insoluble micelles or microparticles of the asphaltenes.

Above the melt temperature the test sample has a tough, but fluid-like character in molten state. In this case G'' > G' or tanδ > 1 is measured.

The fluid character of this viscoelastic melt manifests e.g. at T = +90 °C with G'' = 76.1 Pa and G' = 0.146 Pa or tanδ = 523 (> 1) respectively. In this temperature range the bitumen can be processed e.g. spread, much more easily. Due to the relatively small elastic portion less problems will arise, e.g. by stickiness or stringiness.

The rheological behavior of the natural product bitumen can specifically be influenced by adding synthetic polymers. Brittle natural bitumen can be made more impact resistant by adding polymers in the range of tanδ < 1.

4 Summary

The melting behavior of this polymer modified bitumen (PMB) changes according to the ratio of the mixture. With increasing temperature the entangled macromolecule chains of the synthetic polymers orientate in shear direction partly disentangling, thus vitally affecting the melt's flow behavior.

However, even at higher temperatures most of the polymer components of pure bitumen remain integrated in the inflexible; disperse asphaltenes particles due to polar bondings. Therefore the polymers of the pure bitumen have less influence on the rheological behavior than the added synthetic polymers.

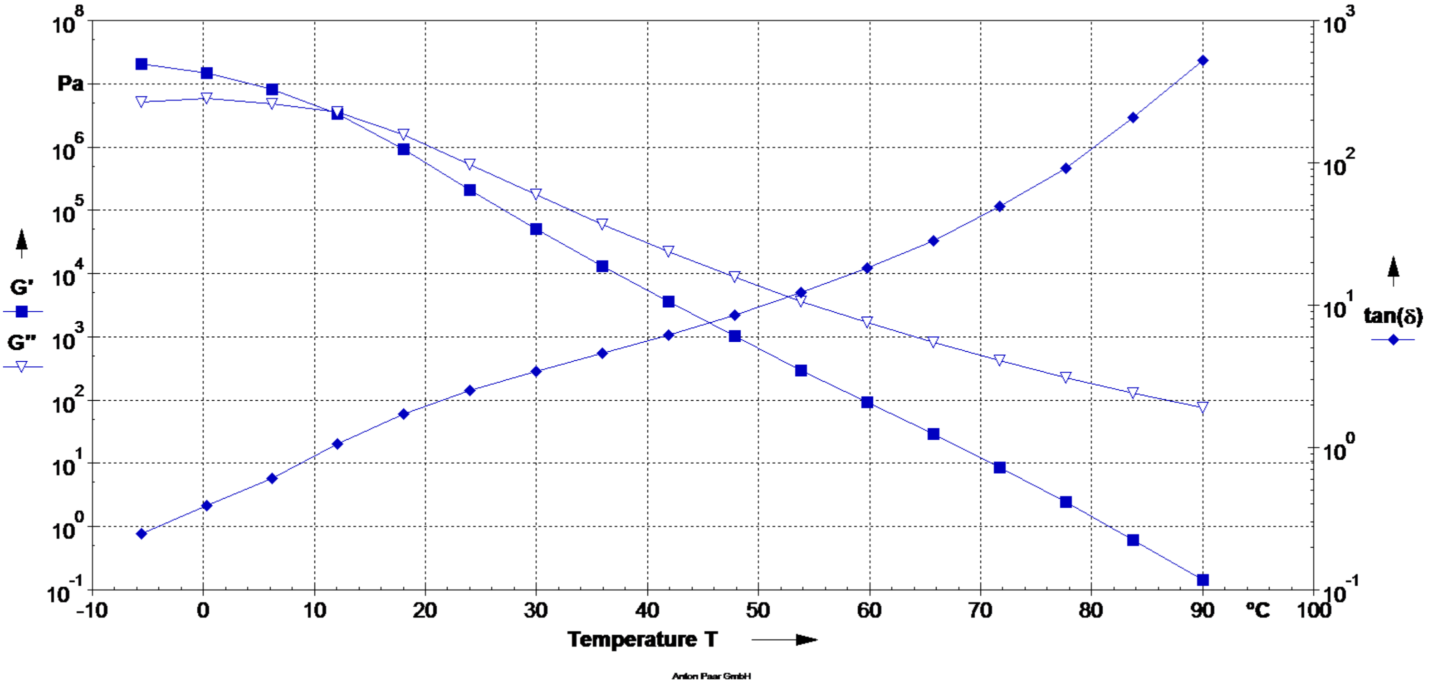

Fig. 1 Curves of the Storage Modulus G', the Loss Modulus G'' and the Loss Factor tanδ of bitumen, measured in the temperature range of T = -6 °C up to +90 °C.

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