Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 153 (2016) 584 – 589

Procedia Engineering

www.elsevier.com/locate/procedia

XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering"

Evaluation of bituminous binder in relation to resistance to permanent deformation

Eva Remišová [a]*, Viera Zatkalíková [b]

[a] University of Žilina, Department of Highway Engineering, Faculty of Civil Engineering, Univerzitna 8215/1, Žilina 01026, Slovakia
[b] University of Žilina, Department of Materials Engineering, Faculty of Mechanical Engineering, Univerzitna 8215/1, Žilina 01026, Slovakia

Abstract

Bituminous binders are thermoplastic liquids which behave as viscoelastic materials. Their deformation behavior can be determined by rheological parameters. The changes of both viscous and elastic properties with temperature and time are measured as the response of the material to deformation by periodic forces. The paper presents the most used parameters and rheological properties for the characterization of the rutting resistance of bituminous binders and asphalt mixtures. Rheological properties (G*, δ, η*) are determined for four bituminous binders (unmodified and polymer modified) at temperature 46 – 60 °C (80 °C). And resistance to deformation of asphalt concrete mixtures is determined by rutting test. The higher value of complex shear modulus, the stiffer bituminous binder is able to resist deformation.

Peer-review under responsibility of the organizing committee of the XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering".

Keywords: bitumen; rheology; complex shear modulus; asphalt; permanent deformation

1. Introduction

The increasing traffic conditions such as higher traffic volume and higher traffic axle loads demand higher performance pavements. The quality of built asphalts and used bituminous binders is one of the requirements for the satisfactory pavements. Loading forms the deformation in asphalt layers. The permanent deformation is condition of pavement failure caused accumulation of small amounts of deformation that occurs each time a load is applied.

* Eva Remišová. Tel.: +421-41-5135949.
E-mail address: eva.remisova@fstav.uniza.sk

Peer-review under responsibility of the organizing committee of the XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering".
doi:10.1016/j.proeng.2016.08.196

Rutting of asphalt mixture typically occurs during the summer under higher air and pavement temperatures when excessively deformation increases according to amount of load cycles. After unloading the elastic deformation immediately goes back due to materials elastic and relaxation properties. But certain part of deformation (plastic – permanent) remains rest irreversible cause of viscous material properties. The development of permanent deformation is influenced especially asphalt composition and material properties (aggregate, bituminous binder).

The bituminous binder is colloidal system consisting of high molecular weight asphlaltene micelles dispersed in a lower molecular weight oily medium maltenes. This colloidal structure defines the rheological properties of bitumen ranging from sol (Newtonian dominated behaviour) to gel (non-Newtonian dominated behaviour). Bituminous binders are thermoplastic liquids which behave as viscoelastic materials [1]. There are many methods available to determine the rheological properties, the cyclic (oscillatory) and creep tests tend to be the best two techniques for representing the uniqueness of bitumen behavior. The mechanical response of bitumen is a continuous function of time and temperature, an infinite number of loading conditions and responses constitute its overall behavior [2].
The changes of both viscous and elastic properties with temperature and time are measured as the response of the material to deformation by periodic forces (during forced vibration or small-amplitude oscillatory shear). A sinusoidal oscillatory shear stress is used to a sample and the resulting shear strain is measured [3]:

$$\tau(t) = \tau_0 . \sin \omega t \tag{1}$$

and

$$\gamma(t) = \gamma_0 . \sin(\omega . t + \delta) \tag{2}$$

where τ_0 is the stress amplitude (Pa), ω angular frequency (rad.s^{-1}), t time (s), γ_0 the strain amplitude and δ the phase angle of the measured material between the preset and the resulting curve (^{o}). Stress and strain are not in phase, the strain delays behind the stress by a phase angle.
The complex shear modulus G* (Pa) as the resistance to deformation is defined as a ratio of the values of the sinusoidal functions of τ(t) and γ(t):

$$G^* = \frac{\tau(t)}{\gamma(t)} \tag{3}$$

Complex shear modulus, in complex form, consists from two parts - G' (storage modulus) represents elastic behavior of material and is a measure of the deformation energy stores during the shear process, and G'' (loss modulus) represents the viscous behavior of material and is a measure of the deformation energy dissipated during a shear process [3]. Both the modulus are simply indicators of the resistance of a bitumen to deformation under a given set of loading conditions.

The linear visco-elastic properties of bitumen are generally and conveniently represented in terms of complex modulus and phase angle master curves. The behaviour of bitumen becomes more complex with the presence of waxy elements, high asphaltene contents and crystalline structures, as well as polymer modification [4].

2. Experimental

2.1. Materials

Four type of bitumen binders were used for evaluation rheological properties two pave grade bitumen CA 50/70 and CA 70/100 and two polymer modified bitumen Kraton and Sealoflex. Properties of used bitumen binders are in Table 1. Asphalt concrete AC 11 was used to evaluate of resistance to permanent deformation and to compare properties of used bitumens and asphalts. For all mixtures were used the same aggregates (andesite coarse aggregate and limestone fine aggregate) with same aggregate gradation (Fig. 1). The mixtures differed only in used bitumen type (paving grade bitumen and polymer modified bitumen).