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ScienceDirect

Procedia Engineering 190 (2017) 207 – 214

Procedia Engineering

www.elsevier.com/locate/procedia

Structural and Physical Aspects of Construction Engineering

# Study of the Visco-Elastic Parameters of Asphalt Concrete

Ján Mandula[a], Tomáš Olexa[a,*]

[a]*Institute of Structural Engineering, Faculty of Civil Engineering, Technical University of Košice, Vysokoškolská 4, 042 00 Košice, Slovakia*

**Abstract**

The asphalt mixture as the basic construction material in roads is described with specific deformation parameters. These are negatively influenced by temperature, and this is one of the problems which cause short pavement lifespan. Increasing temperature affects the behavior of bitumen-bonded materials from elastic to viscous state. Observation of this problem was made in this study by measuring the phase angle during dynamic bending tests. Temperature dependence of the phase angle was observed for three different temperatures and five chosen frequencies. Another aim of the study was to observe the relationship of the phase angle to the fatigue lifespan for one specific temperature and frequency. The evaluation was done using the classical AASHTO method as well as the chosen dissipated energy ratio method.



Peer-review under responsibility of the organizing committee of SPACE 2016

*Keywords:* Asphalt concrete; phase angle; dissipated energy

## 1. Introduction

Asphalt mixtures consist of the optimum combination of two basic ingredients, the aggregate (various fractions) and asphalt binder, and other optional additives. The combination is designed to meet the diverse and often conflicting performance parameters, for example, resistance to fatigue, deformation, cracking, and moisture damage, durability, skid resistance, and workability and economy. The mix designer generally manipulates three variables, namely type of aggregates, asphalt binder, and the ratio of asphalt binder to aggregates, and thus seeks to achieve the above-mentioned performance requirements. The components of an asphalt mixture play an important role in asphalt mixture behavior during the service period, so from the beginning of the design process it is very important to know their influence. Nowadays we face important changes in the way bitumen and aggregates are tested, and the development

* Corresponding author. Tel.: +421-055-6024328; fax: +421-055-6024328.
*E-mail address:* tomas.olexa@tuke.sk



Peer-review under responsibility of the organizing committee of SPACE 2016
doi:10.1016/j.proeng.2017.05.328

of new evaluation techniques for asphalt mixture components is essential to improving our understanding of the chemical composition and behavior of different binders and aggregates in order to develop performance-based specifications. On the other hand mixture performance parameters can be also improved by different kinds of additives.

Aggregates used in asphalt mixtures have to fulfill specific standard parameters. Shape index and impact resistance are the two main parameters which have to be met. Grains of aggregate create a load-bearing structure, and so their shape has to be angular. The aggregate skeleton consists of various aggregate fractions to reduce air void content in the mixture. Aggregates are the key materials used in the construction sector and form the largest portion of an asphalt pavement. Aggregates are generally derived from stone minerals, and are sometimes further mechanically processed to suit specific applications. Synthetic aggregates, most commonly blast furnace slag from the steel industry, slate wastes and ashes, are also used in the construction of asphalt pavements for its accurate characterization according to the material properties. Fine aggregate is called the filler. Adding filler to the mixture decreases air void volume, increases the rigidity of the mixture and influences the optimum bitumen percentage for the mixture. Previous research has proved that there is an optimum percentage of filler for the maximum life duration with fatigue, and the filler volume is very important in the minimization of air void volume in aggregates. The scientific literature pins up an optimum percentage of 5-11% of filler by weight. Filler increases the viscosity of excessively fluid binders, and also of all the binders heated up to high temperatures. This is the main reason why in some asphalt mixtures a greater quantity of bitumen can be used to increase the cohesion and the impermeability, without danger of the mixture becoming unstable or binder stains appearing on the asphalt mixture surface.

The second main part of the asphalt mixture is the bitumen binder. The bitumen or asphalt is a general description for the adhesive or glue used in asphalt pavements, either petroleum-derived or naturally-occurring material (e.g. Trinidad natural asphalt). The asphalt binder is what gives an asphalt pavement its flexibility, binds the aggregate together, and gives waterproofing properties to the road structure. Particularly since the binder content is a key mixture design parameter, the binder grade plays a significant role in the performance of a pavement. Selecting the binder grade is essential in ensuring that the asphalt will not experience significant levels of distress under the prevailing climatic conditions. Asphalt binders are visco-elastic materials in nature whose resistance to deformation under loads is sensitive to loading time and temperature. Less viscous asphalts make the mixture less stiff and therefore more susceptible to irrecoverable deformations. On the other hand, if the asphalt is too hard, it will be fragile at low temperatures, ultimately leading to cracking under traffic loading. [1]

### *1.1. Visco-elastic behavior of the asphalt mixture*

Visco-elasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like honey, resist shear flow and strain linearly with time when stress is applied. Elastic materials strain when stretched and quickly return to their original state once the stress is removed. Visco-elastic materials have elements of both of these properties, and as such exhibit time-dependent strain. Whereas elasticity is usually the result of bond stretching along crystallographic planes in an ordered solid, viscosity is the result of the diffusion of atoms or molecules inside an amorphous material.

Asphalt mixture as a combination of aggregate and bitumen binder has visco-elastic parameters. When a visco-elastic asphalt mixture is subjected to sinusoidal varying stress, the steady state will eventually be reached in which the resulting strain is also sinusoidal, having the same angular frequency but retarded in phase by an angle ($\varphi$) This is analogous to the delayed strain observed in creep experiments [2], and it means that the material structure is linear.

This specific kind of material also needs specific rheological models for designing the bearing structure. Combined rheological models of asphalt mixtures reflect on both components: viscous behavior and elastic behavior. These models combine an elastic model of linear elastic spring with a viscous model of linear dash pot. The combination may be done in different ways, so there are several different rheological models. The best-known rheological models of asphalt mixtures are for example the Maxwell model (serial arrangement of sub-models) and the Kelvin (Voigt) model (parallel arrangement of sub-models).

Phase angle or phase delay is main indicator of which behavior is dominant. When the phase angle is closer to 0 °, elastic behavior is dominant in the material, and when the phase angle is closer to 90° viscous behavior is dominant. When elastic behavior is distinct, the stiffness of the asphalt mixture is higher, but screen cracks also occur because