Construction and Building Materials 124 (2016) 1028–1037

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effects of temperature and loading frequency on asphalt and filler interaction ability

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HIGHLIGHTS

- The *K-B-G** model was used to evaluate and analyze the influence of temperature and loading frequency on asphalt and filler interaction ability.
- The results show that the matrix asphalt binders' linear viscoelastic range decreases with the loading frequency increasing and increases with the temperature increasing, the linear viscoelastic range of asphalt mastics decreases with the filler volume fraction increasing at the constant temperature and loading frequency.
- *K-B-G** exponentially increases with the temperature increasing and linearly decreases with the loading frequency increasing.
- The significance analysis of temperature and loading frequency was conducted by using grey correlated method, and finding that the temperature has deeper influence degree than loading frequency.

ARTICLE INFO

Article history:
Received 7 May 2016
Received in revised form 23 July 2016
Accepted 29 August 2016

Keywords:
Asphalt
Filler
Interaction
*K-B-G** model
Temperature
Loading frequency

ABSTRACT

The asphalt and filler interaction plays a significant role on the performances of asphalt mastics and mixtures, and the asphalt and filler interaction ability is affected by the temperature and loading frequency. In this paper, two kinds of matrix asphalt binders and three kinds of fillers were selected to prepare asphalt mastic with different filler volume fractions, and the dynamic shear rheological properties of asphalt mastics were measured. The linear viscoelastic range of matrix asphalt binder and mastic was analyzed firstly. Then the *K-B-G** model was used to evaluate and analyze the influence of temperature and loading frequency on asphalt and filler interaction ability. The results show that the linear viscoelastic range of matrix asphalt binders decreases with the loading frequency increasing and increases with the temperature increasing, the linear viscoelastic range of asphalt mastics decreases with the filler volume fraction increasing at the constant temperature and loading frequency. *K-B-G** exponentially increases with the temperature increasing and linearly decreases with the loading frequency increasing. The significance analysis of temperature and loading frequency was conducted by using grey correlated method, and finding that the temperature has deeper influence than loading frequency.

1. Introduction

Asphalt mixture is a composite material consisting of aggregates of varying sizes, asphalt binder and air voids. Coarse and fine aggregates in asphalt mixtures are effectively coated by asphalt mastic that is formed by the interaction between asphalt binder and fillers which consist of particulate matter less than 0.075 mm in diameter [1]. Asphalt mastic constitutes the weakest phase of asphalt mixture and has significant effects on the overall road performances of asphalt mixtures [2]. A great deal of research has been conducted to understand the road performances of asphalt binders and mixtures, and it has long been recognized that the interaction between asphalt binder and fillers plays a significant role on the asphalt mastic and mixture [3–8]. The interaction between asphalt binder and fillers is very complex physico-chemical processes and related to various factors, including the internal and external factors. The internal factors are referred to the material properties, such as the acid-base properties and

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http://dx.doi.org/10.1016/j.conbuildmat.2016.08.151

surface characteristics of fillers, and the components and properties of asphalt binders, and the effects of internal material properties have been researched a lot [9–13]. However, relatively little research has been conducted on the external factors, such as temperature and loading frequency.

In this paper, some literatures of asphalt and filler interaction will be reviewed, and the evaluating models for asphalt and filler interaction are widely compared to determine the most suitable model and index. Also, experiments are conducted to analyze the asphalt and filler interaction at different temperatures and loading frequencies, and the effects of temperature and loading frequency on the interaction ability are revealed.

2. Literature reviews of asphalt and filler interaction

To evaluate the asphalt and filler interaction, the simplest method is the adhesion test, including the boiling water test and static immersion test. However, these are all qualitative tests, and actually reflect the anti-striping property of asphalt-aggregate system in water, which is limited for the evaluation of the asphalt and filler interaction [14,15]. Actually, the chemical components of asphalt on the surface of filler is rearranged when the asphalt and filler are mixed, and a layer of diffusion solvation membrane is formed according to the theory which was proposed by Л A Repin tyuter [16]. The asphalt within this film thickness is called structure asphalt, and the asphalt outside this film thickness is called free asphalt. The stronger asphalt and filler interaction is, the greater the proportion of structural asphalt is, and the worse the rheological interface ability of asphalt and filler is. The weaker asphalt and filler interaction is, the lower the proportion of structural asphalt is, and the better the rheological interface ability of asphalt and filler is [17]. So the asphalt and filler interaction ability can be reflected by the change of the rheological characteristics of asphalt mastic.

Recently, in an attempt to quantitatively evaluate the asphalt and filler interaction ability, a rheology-based composite model has been employed. The model is a modified version of Kerner equation by Lewis and Nielsen from the complex viscosity and complex modulus [18–21]. On the other hand, Ziegel et al. [22] and Kubat et al. [23] respectively proposed the models to estimate the variation of phase angel for two-phase filling system consisting of matrix and filler, and two coefficients were introduced to evaluate the interaction based on the variation of phase angel. Over the years, researchers always focus on asphalt and filler interaction ability evaluation models and the effects of material characteristics on asphalt and filler interaction ability. The evaluation models can be divided into three major types based on rheological properties, and as shown in Fig. 1.

In order to set aside the effects of matrix asphalt binder on the rheological properties of asphalt mastic, Tan et al. [24] firstly defined the complex viscosity coefficient $\triangle\eta^*$ to evaluate asphalt and aggregate interaction ability. The relevant results show that the discrimination is not obvious for different asphalts and aggregates. Guo [25] evaluated asphalt and filler interaction ability by the intrinsic viscosity $[\eta]$ which represents the interaction level of solid particle and liquid when the concentration is zero. These results show that the intrinsic viscosity can reflect the irregularity and dispersion of mineral filler in asphalt mastic to some extent. However, the intrinsic viscosity sensitivity is not enough to estimate interaction ability of asphalt and filler, but also the rule is not obvious. Droste et al. [26] firstly proposed the physico-chemical interaction model that represents the mechanical and chemical reinforcement of the filler. Clopotel et al. [27] assumed that the change in the viscosity of the matrix asphalt is entirely due to the change in the glass transition temperature, then Arrhenius or the WLF equation can be used to express relative viscosity in terms of the shift in glass transition. So the asphalt and filler interaction ability can be analyzed and evaluated by glass transition temperature and physico-chemical interaction model.

Unlike complex viscosity, others establish evaluation models of asphalt and filler interaction ability from the perspective of the phase angle and complex modulus. Wu [28] used the *K-B-δ* and *L-A-δ* models which were proposed by Ziegel [22] and Ibrarra [29] respectively to estimate asphalt and aggregate interaction

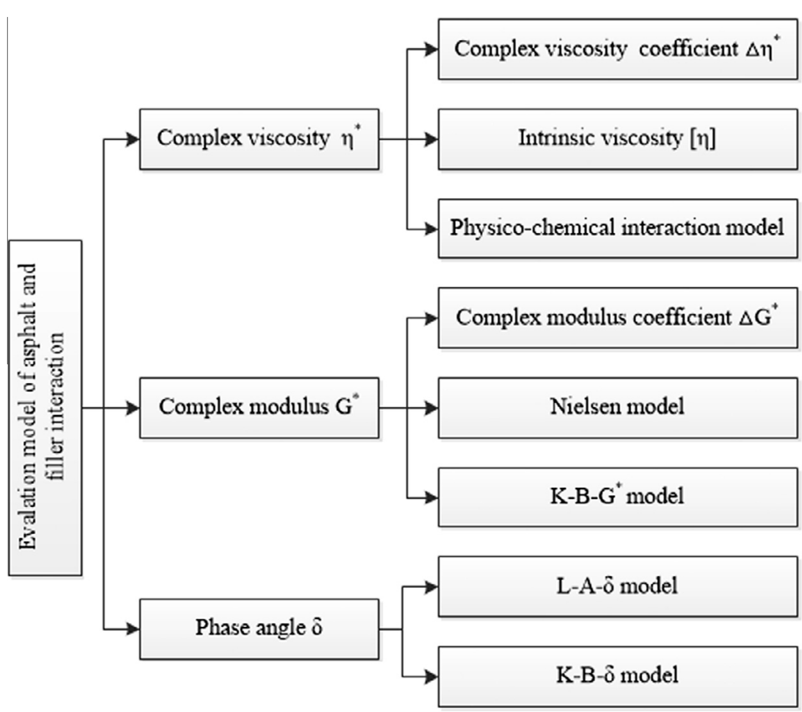

Fig. 1. Evaluation models of asphalt and filler interaction ability.