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Improvement of evaluation indicator of interfacial interaction between asphalt binder and mineral fillers

Meng Guo[a,b,*], Yiqiu Tan[b,*], Yue Hou[a], Linbing Wang[c], Yiqi Wang[d]

[a] National Center for Materials Service Safety, University of Science and Technology Beijing, Beijing 100083, China
[b] School of Transportation Science and Engineering, Harbin Institute of Technology, Harbin 150090, China
[c] Joint USTB-Virginia Tech Lab on Multifunctional Materials, University of Science and Technology Beijing, Beijing 100083, China, Virginia Tech, Blacksburg 24061, USA
[d] College of Civil and Architectural Engineering, Heilongjiang Institute of Technology, Harbin 150050, China

HIGHLIGHTS

- Compared to *A* & *B*, *C* had the least sensitivity to the volume fraction of fillers.
- Compared to *A* & *B*, *C* had a higher determination coefficient using improved method.
- The interfacial interaction became stronger with the temperature increasing.
- Fillers with higher specific surface area had a stronger interaction with binder.

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ABSTRACT

The interfacial behavior between asphalt binder and mineral fillers directly effects the performance of asphalt mastics or asphalt mixture. However, the understanding about the interfacial interaction between these components is very limited, although the role of individual ingredients on its performance is readily recognized. In order to study the interactions between asphalt binder and mineral fillers, it is necessary to propose an effective evaluation indicator. In this research, dynamic mechanical analysis (DMA) was used to obtain the viscoelastic parameters of different asphalt binder and asphalt mastics. The interfacial interaction parameters between asphalt binder and fillers were calculated based on the viscoelastic parameters and relevant theoretical models. The interaction parameters were compared and the calculated methods were improved. The results show that compared to interfacial interaction parameters Luis Ibrarra-*A* and K. Ziegel-*B*, *C* value based on Palierne theoretical model had the least sensitivity to the volume fraction of fillers. The checking of fitting goodness of improved interaction parameter *C* value shows a high determination coefficient. It demonstrates that the *C* value can effectively evaluate the interfacial interaction. The interfacial interaction becomes stronger with the temperature increasing. The higher the specific surface area of filler, he stronger the interfacial interaction between it and asphalt binder.

1. Introduction

The asphalt mixture is composed by asphalt binder, mineral filler, aggregate and voids. Its performance is not only related to the material properties of each component, but also affected by the interactions between different materials, such as the interaction between asphalt binder and filler and the interaction between asphalt mastic and aggregate. In the context of this paper, asphalt mastic is defined as the mixture of asphalt binder and filler particles (particles finer than 75 μm or passing ASTM standard sieve number 200). Although the size of mineral filler particle is small, its surface area takes more than 90% of the total surface area of mineral aggregates in asphalt mixture. Therefore, the interfacial effect between mineral filler and asphalt binder will significantly affect the performance of asphalt mixture. Different interactions between asphalt binder and filler between will form different

* Corresponding authors at: National Center for Materials Service Safety, University of Science and Technology Beijing, 30 Xueyuan Road, Haidian District, Beijing 100083, China (M. Guo). School of Transportation Science and Engineering, Harbin Institute of Technology, 73 Huanghe Road, Nangang District, Harbin 150090, Heilongjiang, China (Y.Q. Tan).

E-mail addresses: mguo@ustb.edu.cn (M. Guo), tanyiqiu@hit.edu.cn (Y. Tan), yhou@ustb.edu.cn (Y. Hou), lbwang@ustb.edu.cn (L. Wang), wangyiqi@hljit.edu.cn (Y. Wang).

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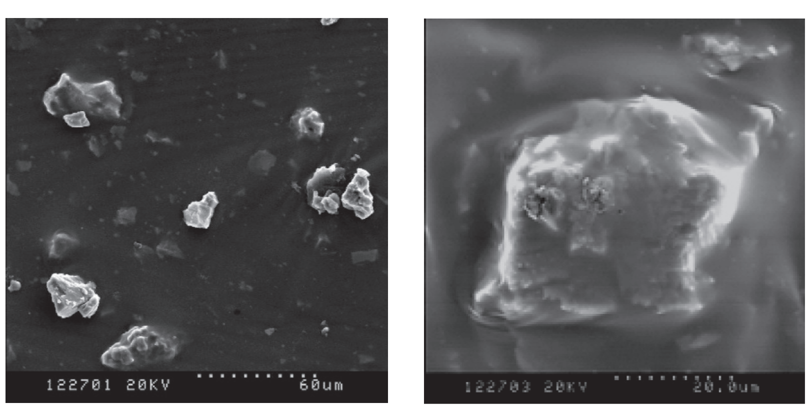
interfaces, and further affect the overall asphalt pavement performance. Understanding the mechanism of the interface behavior between asphalt binder and mineral filler can also help the pavement engineers invent and improve the performance of asphalt pavement [1–6]. Up to now, there still lacks relevant research on the interfacial interaction in asphalt mixture. The existing researches are mostly focused on empirical adhesion characteristics. Although the mechanism of interaction between asphalt binder and mineral aggregate has been investigated by adsorption tests and relevant chemical and rheological analysis [7], there is still not a recognized method and indicator to quantitatively evaluate the interaction.

In the early age of asphalt mastic study, the researchers studied the effect of filler on the asphalt mastic performance. Their results showed that the physical indexes including the filler particle size, shape, texture, porosity, mineral composition will affect the performance of asphalt mastic greatly, and the degree of influence is dependent on the different types of asphalt binders, indicating the existence of the interaction between asphalt binder and mineral aggregate. Subsequent studies have paid more attention to the establishment of mechanics-empirical model without considering the interfacial interaction, which makes the model results inaccurate [8–14]. At present, there is no clear understanding on the interfacial effect between asphalt binder and mineral filler. Studies on the interactions between the two, the influence law and the relationship with the performance of the road are still in the preliminary stage.

Usually, the methods to study the interfacial behavior between asphalt binder and filler include surface physical and chemical methods, micro/nano characterization techniques and dynamic mechanical analysis. Typical surface physical and chemical method is to measure the surface energy and its components of asphalt binder and mineral filler, and later calculate the adhesion work [15–16]. The advantage of this method is that it can provide a more accurate calculation result on the interfacial bonding properties between asphalt binder and mineral filler. However, this method can only reflect the behavior of the interface in ideal state, and fails to consider the influences of actual filler surface porosity, filler uneven distribution and other factors. It also cannot reflect the effects of interaction temperature, interaction time and other conditions on the interaction strength.

Micro/nano characterization techniques are mainly divided into two types: surface morphology observation and composition analysis technique. The surface morphology observation is to observe the interface behavior between asphalt binder and filler using scanning electron microscopy (SEM) and atomic force microscopy (AFM). Shao et al. first studied the asphalt mastic microstructure using scanning electron microscopy (SEM), where the asphalt mastic interface morphology are shown in Fig. 1 [17]. Guo et al. conducted researches on the interface behavior using AFM and infrared spectrum, and the influence of surface condition and asphalt binder grade on adhesion work was obtained [18]. Hou et al. used AFM to study the interface evolution in asphalt samples at different temperature [19]. Sha et al. studied the micro structure of the cement emulsified asphalt interface, and concluded that the interfacial microstructure affects the overall performance of the concrete [20]. Khattak et al. studied the adhesion between asphalt binder and aggregate through overlap shear test and scanning electron microscopic. The results show that, at low temperature, adhesion strength loss is the main cause for asphalt mixture deterioration [21]. Shinhe used different scanning calorimetry equipment to determine the adhesion between asphalt binder and filler [22]. Guo et al. used AFM to characterize the morphology and mechanical property of asphalt binder at different distances to filler surface, and analyzed the mechanism of interfacial interaction between asphalt binder and mineral fillers [23]. It is therefore concluded that, the surface morphology observation method is more intuitive, but the system is more complicated. Because of the differences of surface free energy between the two materials, the interfacial behavior of the surface is quite different from the inside actual interface. Component analysis techniques typically include infrared spectroscopy analysis, gel permeation chromatography, asphalt binder component analysis, etc. A preliminary analysis of sample preparation is a very important procedure. It can be achieved by the adsorption and desorption principle [17].

Since the mineral filler particles are extremely small, it is extremely difficult to measure the adhesion strength between the asphalt binder and filler particles from the mechanical point of view. Therefore, researchers often study the interfacial behavior indirectly by measuring the dynamic mechanical behavior of asphalt mastic at different filler/asphalt binder ratios. In 1971, David systematically studied the mechanical characteristics of asphalt mastic. His results show that the interfacial behavior between asphalt binder and mineral filler will significantly affect the mechanical behavior of the mastic [24]. Hou et al. determined the mechanical behavior of asphalt binder at low temperature [25]. In 2009, Wu et al. found that temperature, asphalt binder, filler acid-base, filler particle size will have significant impacts on the interaction capability [26]. In 2012, Guo et al. studied the phase behavior of asphalt mastic using dynamic mechanical analysis. He also discovered that filler lithology and limestone particle size will affect the interface structure and properties [18]. The dynamic



(a) Micro morphology of asphalt mastics (b) Partial enlarged view of mineral filler

Fig. 1. Micromorphology of interface of asphalt mastics [17].