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# Nano-sized morphology of asphalt components separated from weathered asphalt binders

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## HIGHLIGHTS

- AFM index $R_q$ of asphalt components all become bigger as the aging degree increased.
- Four asphalt components present different nano-sized morphologies.
- Morphology changes of components in different ways and at different speeds.
- Asphaltenes and resins relate to "bee-like structure" by color, roughness and dispersed phase.
- Asphaltenes affect scatter and size behavior of "bee-like structure", while resins affect size.

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## ABSTRACT

Aging of an asphalt binder results in the changes in its structure and percentage of every component of the asphalt binder. The aim of the research was to explore the change in nano-sized micro-structure of the four common asphalt components by atomic force microscope (AFM) technologies, and the change in quantity of the component during an aging process. In this study, an open-graded friction courses (OGFC) mixture was at first weathered by an accelerated weathering machine (AWM). Weathered asphalt binders were then recovered from the weathered mixtures by the Abson method, consequently separated into four common components, i.e., saturate, aromatic, resin and asphaltene (SARA). The test results indicated as follows: 1) the four components appeared different nano-sized morphology images: "moon-like spots" were found for asphaltene; "small irregular spots" for resin, "micro-particle structures" for aromatic component while "membrane-like structures" for saturate; 2) weathering caused the changes in the morphology of the components in different way and at different speed; 3) AFM index $R_q$ of the four asphalt components all became bigger as the weathering time increased, although that the $R_q$ of asphaltene and aromatic increased much faster than that of the other two.



## 1. Introduction

Asphalt mixtures have been preferably selected for pavement construction and maintenance of various grades of highway, which is partially due to the improvement of asphalt pavement technologies. The aging of asphalt binder always, however, causes various problems to asphalt pavement failures. Asphalt binder easily becomes hard and brittle after aging, which seriously affects the performance of asphalt pavements such as low-temperature crack resistance, high-temperature stability and water susceptibility [1–3]. The maintenance for the aging-caused asphalt pavement deterioration will not only consume huge natural resources of both the aggregate and asphalt binder, but also shorten the service life to the traffic.

In order to reproduce the aging of asphalt binders that appears in the field, some countries have examined the aging through an accelerated weathering process considering of a combination of such typical weathering factors as temperature, oxygen, sunlight and water. An accelerated weathering machine (AWM) was fabricated to accommodate the weather process [4] since real aging condition of the actual asphalt pavement can be better simulated by such a weathering process than any single factor [5,6]. Accelerated aging specifications of asphalt materials, considering weathering factors of heat, light and water, were proposed by American Society for Testing and Materials (ASTM D 4798-2004).

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In fact, aging causes the changes of chemical compositions of an asphalt binder by a series of oxidation such as polymerization and decomposition that will alter the structure of the asphalt binder, and the distributions of its component of SARA [7–10]. Both these changes will affect the mechanic behavior of an asphalt binder [11–12]. In general, certain converting rules may exist among SARA during aging, i.e., resin converts into asphaltene, however the asphaltene may appeared different micro-structure before and after this converting by aging [13–15]. More details on the way converting from one component to another, and on the change in the mechanic behavior of aged asphalt component could be investigate by advanced microscopic techniques to understand better the mechanism of asphalt binder aging.

Atomic force microscopy (AFM) has been used more and more widely in the study of asphalt binders to exam their nano-sized structures and nano mechanics [16–20]. It is now feasible to observe the nano-structure (typically such as "bee-like structure") and calculate quantitatively the nano-mechanic properties of asphalt binders by applying the advanced AFM technologies [21,22]. The visual results obtained from AFM testing were highly dependent on aging degree, namely, the nano-structure, adhesion and modulus of asphalt binders measured by AFM considerably changed as the aging deepened [23–25]. Hung. et al used AFM to observe morphology variations of asphalt binders, especially the "bee-like structure" under tensile stress state [26].

The aim of the research was mainly to explore the nano-structures of the SARA of asphalt binders by their changes in morphology and the converting way among the SARA during an aging process and understand better the micro-level mechanism of aging. The detailed objectives were: (1) to probe the nano-sized morphology of the asphalt components, SARA, separated from weathered asphalt mixtures in the AWM; (2) to study the weathering effect on the nano-sized morphology of the asphalt components; (3) to characterize nano-sized morphology of the asphalt components by AFM indexes.

## 2. Materials and methods

### 2.1. Materials

A gradation of OGFC-13 was used for weathering in the AWM in the study because aging was normally obtained the most seriously among different mixtures owe to its highest void ratio. The mixtures were fabricated by a SBS modified asphalt binder and basalt mineral aggregates. The properties of the binder and aggregates will be presented in the sections below.

### 2.2. SBS modified asphalt binder

The modified asphalt binder was produced by mixing Ssangyong base asphalt with 4.0% SBS in the weight of the modified binder in an asphalt plant (Sanchuang Pavement Construction Co. Ltd, Suzhou, Jiangsu Province, China). This amount of SBS was used to make the modified binder to meet a grade of PG76-22. Table 1 presented the properties of both the base binder and the modified asphalt binder measured by following Technical Specifications for Construction of Highway Asphalt Pavement (JTG F40-2004) [27].

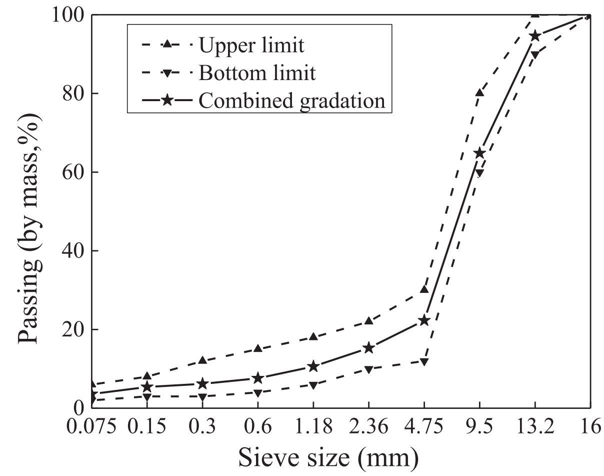


**Fig. 1.** Combined Gradation of OGFC-13.

### 2.3. Aggregates

The aggregates used in this project are basalt and the mineral filler is limestone. All of aggregates were supplied by Sanchuang Pavement Construction Co. Ltd. The nominal maximum size of the gradation is 13 mm for OGFC. The gradation of the aggregates met the specifications of JTG F40-2004, see Fig. 1, and the physical and mechanical properties of the aggregates and the mineral filler also met the specifications, see Tables 2 and 3.

### 2.4. Asphalt mixtures specimens

The Marshal samples and rutting-test slab samples were fabricated according to the specifications of JTG E-2011 [28] for the weathering in the AWM. The void ratio of the samples was 20 ± 1% and the optimum asphalt content (OACs) was 5.4% based on the design made for the project. A cellulose fiber was 0.25% in the weight of the asphalt mixture. All the volume properties of the Marshall met the requirements of the specifications of JTG F40-2004.

## 3. Test methods

### 3.1. Aging by AWM

The AWM is essential an accelerated aging chamber built with several capacities to simulate environment factors such as heating, rain, oxygen and ultra-violate. These simulating environment factors can be accommodated when the machine runs so that the aging effect of asphalt mixtures, placed in the chamber, can be well-reflected those of asphalt pavement in the fields. The test parameters including the durations of ultraviolet-light (UV) and the rain, the strength of UV, the temperature in the chamber, were referred to ASTM. The AWM is shown in Fig. 2 and works in the way as follows:

**Table 1**
Properties of Ssangyong base asphalt and SBS modified asphalt.

| Asphalt sample | Penetration (25 °C, 5 s, 100 g) (mm) | Ductility (5cm/min) (cm) | Softening point (R&B) (°C) | Dynamic viscosity (Pa.s) |
|---|---|---|---|---|
| Base asphalt | 7.2 | 108 (15 °C) | 62.5 | 263 (60 °C) |
| Modified asphalt | 5.1 | 42.2 (5°C) | 75.8 | 2.1 (135 °C) |