Construction and Building Materials 141 (2017) 608–618

Contents lists available at ScienceDirect

Construction and Building Materials

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

Development and performance of sand fog seal with cooling and air purification effects

Tengteng Guo, Chaohui Wang *, Xue Yang, Xiaolong Sun

School of Highway, Chang'an University, Xi'an, Shaanxi 710064, China

HIGHLIGHTS

- Two types sand fog seals with cooling and air purification effects are developed.
- The thermal-insulation device and air purification testing equipment are developed.
- The cooling, air purification effects, performance and microstructures are confirmed.

ARTICLE INFO

Article history:
Received 5 November 2016
Received in revised form 10 February 2017
Accepted 1 March 2017
Available online 22 March 2017

Keywords:
Road engineering
Sand fog seal
Cooling effect
Air purification
Performance

ABSTRACT

Two types of environment-friendly SFS (sand fog seals) with cooling and air purification effects are developed to achieve environmental effects under the condition of good road performance. In this work, the cooling and air purification effects at different temperature ranges are studied using a thermal-insulation device and air purification testing equipment developed independently by our research group. Meanwhile, the pavement performances are confirmed using artificial laying sand instrument, pendulum instrument and pavement seepage meter. Finally, the microstructures are analyzed using the scanning electronic microscopy and fourier transform infrared spectroscopy. The cooling and purifying mechanisms are discussed based on relevant chemical theory. Results show that the optimum spraying amount of environment-friendly SFS materials is 0.75 kg/m^2, the highest cooling effect can reach more than 5 °C, and the purification rates of carbon oxides, nitrogen oxides, and sulfur dioxides can reach more than 16%. In addition, the purification rates of particulate matters with particle size below 2.5 (PM2.5) and below 10 μm (PM10) are about 20%. Results also reveal that these two types of environment-friendly SFS have good road performances, and the functional modifier distributes evenly and stably in fog seal materials. The self-polarization effect of the functional modifier likewise contributes to the cooling and air purification effects.

1. Instruction

Early maintenance is crucial for reducing the early distresses of asphalt pavement. Consequently, a gradual change from traditional maintenance methods, which are passive and emergent, to scientific and modern preventive maintenance methods is transpiring [1]. Pavement preventive maintenance is an advanced highway maintenance technology with high cost–benefit ratio, especially in preventing early distresses and delaying pavement failure, thereby presenting wide applications in road engineering [2]. However, the majority of existing maintenance methods can only mitigate high-temperature distresses, such as rutting, but not solve them thoroughly [3–4]. The heat absorption of asphalt pavement also exacerbates the urban heat island effect [5]. Air pollution is aggravated by increasing automobile exhaust emissions due to the increase of road traffic mileage and number of vehicles [6–8]. These problems have seriously restricted the construction of resource-conserving and environment-friendly roads. Therefore, developing a new preventive maintenance material is being seriously considered both in the fields of road construction and road materials. This new material can both satisfy the requirements of road performance, and mitigate rutting distresses and air pollution by lowering the pavement temperature and absorbing automobile exhaust.

SFS is gradually gaining global use as an excellent preventive maintenance technology for asphalt pavement [9,10]. Numerous studies have been conducted on the performance of fog seals, Pratico et al., put forward the evaluation method of surface texture in SFS pavement [11]. Additionally, Im et al. investigated the

* Corresponding author.
E-mail address: wchh0205@chd.edu.cn (C. Wang).

http://dx.doi.org/10.1016/j.conbuildmat.2017.03.003
0950-0618/

emulsion curing and adhesion property of SFS by conducing evaporation and pneumatic adhesion tests, and then evaluated the performance of SFS spraying on stone seals [10,12], while Cheng et al. offered an overview of evaluation methods involved in the performance of fog seals for gap-graded and open-graded asphalt pavement [13]. Qureshi et al. also studied the surface friction and durability evaluation of SFS with asphalt regenerant and cationic slow-crack emulsified asphalt [14]. Prapaitrakul et al. evaluated the restoring function of the SFS, especially the restoration of asphalt bonding performance, and then carried out a paired test to compare the influence caused by two additives [15–16]. Heritage outlined the application of a rare double-fog seal technique in an Oklahoma highway [17]. Larry et al. evaluated the skid resistance performance of SFS via an indoor accelerated loading test [18], while Tran et al. studied the skid resistance performance and durability of SFS on OGFC pavement [19]. Other researchers also carried out studies on this technology, such as Zhangs et al., who started a research on the anti-permeability and skid resistance performance of the SFS and the application of the technology in highway maintenance [20–21]. At present, no research has focused on the functional fog seal with environmental effects. Developing a functional fog seal and meeting the requirements of pavement performance at the same time are important. A fog seal with such feature can help promote the construction of a resource-conserving and environment-friendly roads.

In this study, two functional basic materials are selected according to the design idea and sand requirements of the traditional SFS. Two functional modifiers are also fabricated after mechanical activation, purification, vacuum drying, dispersion, and optimization, and then two environment-friendly SFS with cooling and air purification effects are developed. In the next section, the research group systematically studies the cooling and air purification effects of SFS and its road performance. Finally, the microstructures of the two environment-friendly SFS materials, as well as the mechanism of their cooling and air purification effects are discussed based on microscopic testing and relevant chemical theory.

2. Materials and testing methods

2.1. Functional modifier

2.1.1. Functional basic materials

Basic materials A and B are selected to develop an environment-friendly SFS according to the requirements of sand used in fog seal, the principles of cooling and air purification, and other comprehensive factors, including environmental and no harmful, resource reserves, difficulties in development and cost, and the compatibility of materials and carrier involved in preventive maintenance [23]. These factors influence the cohesiveness of the carrier and road surface, producing conditions, and sustainable utilization, among many others. The properties of material A and B are shown in Table 1.

2.1.2. Preparation of functional modifier

For the similar properties of basic materials A and B, no considerations are taken as to the compound between the materials during the following preparation process:

a. *Mechanical activation:* Basic materials A and B are prepared by mechanical activation under the protection of anhydrous ethanol and inert gas until the particle size reaches 50–60 mesh.
b. *Purification:* Chemical analysis, mechanical analysis, and scanning electron microscopy (SEM) are performed after mechanical activation to confirm the impurity content, particle size, and appearance characteristics. After purification, the impurity content can be precisely controlled within 0.23–0.28%.
c. *Drying and dispersing:* Vacuum drying is used to dry and disperse the basic materials A and B.
d. *Optimization treatment:* Mix polyacrylamide and methylpentanolone with materials A and B respectively, stir manually for 10 min, and then stir for 40 min by a blender. During the stirring process, the speed is 1500 r/min in the first 20 min, and then the speed increases to 5500 r/min for the remaining 20 min.

After mechanical activation, purification, drying, dispersion, and optimization, two new modifiers (named WPA (Wang Protective Asphalt) and WHA (Wang Healthy Asphalt) with cooling and air purification effects are prepared. WPA modifier is prepared with basic material A, and WHA is prepared with basic material B.

2.2. Other materials

2.2.1. Modified emulsified asphalt

In this work, SBR (Styrene, 1,3-butadiene polymer) modified emulsified asphalt is selected as a bonding material. Technical indicators of the emulsified asphalt are tested according to the *Standard Test Methods and Practices for Emulsified Asphalts (ASTM D 244-2009)* [24]. The testing results are shown in Table 2.

2.2.2. Additive

As modified emulsified asphalt belongs to the dual compound system of thermodynamic instability, it has worse storage stability than emulsified asphalt because of the additional uncertainties caused by latex [19,22]. To solve the problem, the present study uses additives $CaCl_2$ as a stabilizer and its effective content is more than 96%.

2.2.3. Water

There are high requirements for water in the SFS, and the quality of water plays a vital role in the seal quality. Therefore, the water used in this research is drinking water without insoluble impurities but has pH 7.

Table 1
Basic properties indicators of basic material A and B.

Material	Color	Density (g/cm^3)	Grain size (mm)	Acid and alkali resistance	Mohs' hardness	Thermoelectric coefficient ($\mu V{\cdot}{}^{\circ}C^{-1}$)	Crystal structure	Chemical composition
A	Yellow	4.92	0.3	Stable at any concentration of acid, alkali substance	9–10	530–496	NaCl-type	Fe 46.55%, S 53.45%
B	Black	5.06	0.3	Stable at any concentration of acid, alkali substance	9–10	602–681	Trigonal system	Fe 69.94%, O 30.06, sometimes with TiO_2, SiO_2, Al_2O_3 and other mixed materials