Construction and Building Materials 175 (2018) 296–306

Contents lists available at ScienceDirect

Construction and Building Materials

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

Characterization of thermal insulating micro-surfacing modified by inorganic insulating material

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HIGHLIGHTS

- Novel micro surfacing modified by inorganic thermal insulating material was prepared.
- Thermal insulating micro surfacing could be barrier for heat absorbing or releasing.
- Synergistic effect of sepiolite and sericite contributes to heat-insulating property.

ARTICLE INFO

Article history:
Received 26 December 2017
Received in revised form 18 April 2018
Accepted 21 April 2018

Keywords:
Thermal insulating
Micro surfacing
Temperature variation
Pavement performance
Knudsen effect

ABSTRACT

In order to improve the thermal field of asphalt pavement, novel micro-surfacing modified by two types of inorganic insulating materials was prepared in this paper to achieve thermal insulating effect on asphalt road pavement. The thermal conductivity and micro structures of sepiolite and sericite were tested and characterized by thermal conductivity test and scanning electron microscope analysis (SEM), respectively. Based on laboratory and field experiments, the thermal insulating effects of micro surfacing with sepiolite and sericite on the asphalt road pavement were evaluated in the heating or cooling process, respectively. Specifically, the field test was performed during specific experimental periods selected from summer and winter, which included the extreme high and low temperatures during the whole year. The British pendulum slip test, wet-track abrasion loss test, rutting test and permeability test were conducted to assess the pavement performances of thermal insulating micro surfacing (TI micro surfacing). Finally, the mechanism of thermal insulating effect was explained based on the Knudsen Effect and SEM photo. The results showed that: (i) sepiolite and sericite had great potentials to achieve good thermal insulating effects on pavement originated from low thermal conductivity and special micro-structure; (ii) micro-surfacing sample with sepiolite and sericite increased the thermal resistance of pavement and slowed down the process of thermal conductivity between pavement and environment; (iii) In some situations, micro-surfacing with thermal insulating material could be a barrier for heat absorbing or releasing; (iv) the adding of sepiolite and sericite had no obviously negative impacts on pavement performances of micro-surfacing.

1. Introduction

The mechanical behavior of asphalt mixture is highly temperature dependent because of its typical viscoelastic characteristics [1]. Therefore the pavement temperature fields have important influences on pavement responses and long-term performance of asphalt pavement under moving vehicular loading [2]. Since thermal properties of asphalt concrete affect heat transfer in the asphalt pavement structure, it is possible to change pavement temperature fields and improve pavement performance by modifying thermal properties of asphalt mixtures [2]. Direct modification ways, including adding conductive or insulating fillers or replacing coarse aggregate with lightweight aggregate, can achieve the improvement of thermal performance of asphalt mixture [3–6]. However, these solutions may lead to the negative effect on the cohesion between asphalt binder and aggregate, durability and segregation of asphalt mixture [7–9]. Besides direct modification ways, heat reflective coating, used on the surface of pavement, is another solution to obtain the thermal effect on asphalt pavement

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https://doi.org/10.1016/j.conbuildmat.2018.04.170
0950-0618/

through reflecting solar radiation. Relevant studies show that the cooling effect of heat reflective coating on asphalt pavement could be up to 10 °C [10,11]. Nevertheless the application of heat reflective coating will result in the degradation of anti-skid property. Furthermore its service life can only be maintained for 1 or 2 years normally, which is obviously shorter than that of asphalt road pavement. Therefore, an effective solution to change the thermal fields of asphalt pavement and meet the requirement of service life is of great significance to achieve excellent property of asphalt road pavement under extreme temperature condition.

As an effective preventive maintenance method, micro-surfacing refers to the mixture consisting of polymer modified emulsified asphalt, coarse aggregate, mineral filler, water, and additive [12,13]. Micro-surfacing has been commonly used in pavement industries worldwide owing to its short curing time and flexibility to address slight distresses, correcting ruts, improving surface texture and ultimately extending pavement service life [14–16]. Meanwhile, its service life is usually more than 5 years, which could be consistent with that of asphalt road pavement.

Regarding its obvious advantages, aim of this paper was to prepare novel micro-surfacing with good thermal insulating property modified by selected inorganic insulating materials. As selected insulating materials, the thermal conductivity and micro structure of sepiolite and sericite were tested and analyzed by thermal conductivity test and scanning electron microscope analysis (SEM), respectively. Based on laboratory and field experiments, the thermal insulating effect of micro surfacing with sepiolite and sericite on the asphalt road pavement was evaluated in the heating or cooling process, respectively. The British pendulum slip test, wet-track abrasion loss test, rutting test and permeability test were conducted to assess the pavement performances of TI micro-surfacing. Finally, the mechanism of thermal insulating effect was explained by the Knudsen Effect and SEM photo.

2. Materials and preparation

2.1. Raw materials

2.1.1. Thermal insulating materials

As naturally inorganic material, sepiolite and sericite have unique micro-structures and characteristics that offer great potentials for their thermal insulating capacity. For sepiolite, abundant pore structure and high surface area makes it widely used in building insulating field [17]. Sericite has low thermal conductivity and excellent infrared ray shielding property [18,19]. In view of the above-mentioned facts, sepiolite and sericite powder were selected as the thermal insulating materials. The selected sepiolite and sericite were produced by mineral factory in Heibei, China. The prices of sepiolite and sericite are 638 CNY/t and 485 CNY/t, respectively. The chemical and physical parameters of these insulating materials are detailed in Table 1. Sepiolite and sericite (mass ratio of sepiolite/ sericite = 3:1) were added into micro surfacing through replacing the mineral filler and the adding weight was 6% by dry weight of aggregate according to the gradation information of micro surfacing. The technical indices of sepiolite and sericite met the requirements of ASTM D242 [20].

Table 1
Chemical and physical parameters of inorganic insulating materials.

Test	Sepiolite	Sericite
Purity (%)	≥96	≥95
Density(g·cm^{-3})	2.2	2.9
Fineness (mesh)	325	325
Specific surface area (m^2·g^{-1})	780	86
Oil absorption value (ml·100 g^{-1})	86	78
Suspension degree (24 h) (%)	>95	>90

2.1.2. Modified emulsified asphalt and aggregate

Styrene butadiene rubber (SBR) modified emulsified asphalt was used as binder in this study. The technical properties of SBR modified emulsified asphalt are detailed in the Table 2. The weight of SBR modified emulsified asphalt was 12.6% by dry weight of aggregate. Basalt was used as the aggregate in this paper and its technical qualities are shown in the Table 2.

2.1.3. Water

The salinity was below 5000 mg/L. Specifically, the sulfate content was below 2700 mg/L. The water used in micro surfacing was free of oil contamination. Furthermore, the PH of water used here was below 6. The weight of water was 8.4% by dry weight of aggregate.

2.1.4. Additive

In order to control the demulsification of modified emulsified asphalt mixture, ordinary Portland cement was selected as additive to prepare micro surfacing. Its weight was 2% by dry weight of aggregate.

2.2. Samples preparation

2.2.1. Modification of insulating materials

The modification of insulating materials was performed through using ball-milling and ultrasonic dispersion. The detailed modification procedures of insulating materials are shown as follows:

a. *Sieve the insulating materials:* Sepiolite and sericite were washed carefully with distilled water to remove dust and impurity, and dried at 80 °C for 5 h in pre-heated oven. Then, sepiolite and sericite were filtered through the 0.045 mm sieve and the treated powder was placed into a clean container.
b. *Mill insulating material powder with high-energy ball milling machine:* In order to increase specific surface area and improve thermal insulating capacity, sepiolite and sericite

Table 2
Technical properties of SBR modified emulsified asphalt and basalt aggregate.

Test (SBR Modified Emulsified)	Value	Specification	Test Method
Softening point of emulsified asphalt residue (°C)	64	>57	ASTM D36 [21]
Penetration of emulsified asphalt residue (25 °C, 100 g, 5 s) (0.1 mm)	76	40–90	ASTM D5 [22]
Ductility of emulsified asphalt residue (5°C) (cm)	58	>20	ASTM D113 [23]
Distillation of emulsified asphalt (%)	63.3	≥62	ASTM D6997 [24]
Storage of emulsified asphalt (1d) (%)	0.04	≤1	ASTM D6930 [25]
Residue on sieve (1.18 mm) (%)	0.03	≤0.1	ASTM D244 [26]
Test (Basalt aggregate)	Value	Specification	Test Method
Sand equivalent value (%)	72	>65	ASTM D2419 [27]
Soundness of aggregate (Na_2SO_4) (%)	8	≤15	ASTM C88 [28]