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Experimental investigation of preventive maintenance materials of porous asphalt mixture based on high viscosity modified bitumen ☆

Bin Xu [a], Jingyun Chen [a], Mingliang Li [b], Dongwei Cao [b,*], Shujiang Ping [b], Yanjun Zhang [b], Weiying Wang [a]

[a] Dalian University of Technology, No. 2 Road Linggong, Ganjingzi District, Dalian 116024, PR China
[b] Research Institute of Highway Ministry of Transport, No. 8 Road Xitucheng, Haidian District, Beijing 100088, PR China

HIGHLIGHTS

- Four types of preventive maintenance materials of porous asphalt are developed and selected for comparison.
- The properties of different preventive maintenance materials are measured and analyzed.
- The maintenance effect of porous asphalt mixture is investigated.
- It provides support for preventive maintenance engineering on porous asphalt.

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ABSTRACT

Porous asphalt wearing course has been widely used all over the world. Due to the high porosity and the good stone quality, porous asphalt provides good skid resistance, noise reduction ability and reduces significantly splash and spray in wet conditions. In Asian countries, high viscosity modified bitumen is commonly used as binder of porous asphalt mixture to increase the anti-raveling and rutting resistance property. However, because of the open gradation and rapid aging of the binder, raveling and raveling-induced pitting are still the most common type of destruction for porous asphalt wearing course in long term service. To prevent the occurrence of raveling, a study on the preventive maintenance materials for porous asphalt wearing course based on high viscosity modified bitumen is conducted.

Based on the mechanisms of the raveling destruction, the properties for preventive maintenance materials to be developed are proposed correspondingly. Then laboratory measurements are carried out to investigate the performance of the materials, including tests on apparent viscosity, cohesion, adhesion to stone, rejuvenation effect and properties of porous asphalt mixture treated with the preventive materials. Based on the experiment results and the analyses, the performances of different preventive maintenance materials are concluded. It provides a technical support for preventive maintenance engineering on porous asphalt using high viscosity modified bitumen as binder.

1. Introduction

Porous asphalt is defined as a wearing course with porosity around 20% and stone-on-stone interlocked structure. Such pavement has the technical features of good anti-slipping performance, low noise, restraining water splash and spray on rainy days, mitigating glaring lights when driving at night and so on [1].

Originating from Europe in the 1960s, porous asphalt wearing course was mainly used to improve the traffic safety and reduce traffic noise in areas with dense population and road networks; in the same period, the United States (US) also started to use open-graded friction course (OGFC), mainly to improve the anti-slipping performance of the freeways pavement. In the 1980s, Japan imported the porous asphalt technique from Europe. Based on the local climate and transport conditions, a specific porous asphalt technique was formed and extensively promoted in Japan. In China, porous asphalt was applied relatively later; small-scales test were conducted in 1980s, but none were successful; in the beginning of 21st century, when high-viscosity modified bitumen was adopted as binder of the porous asphalt, the high temperature performance and the anti-raveling property of porous asphalt are

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* Corresponding author.
E-mail address: dongweidenis@gmail.com (D. Cao).

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highly improved. This type of pavement then started to be applied in highways in China.

Nevertheless, as porous asphalt wearing course has large air voids content, typical damages tend to appear under repetitive traffic loading and complex climate, including raveling, brittle cracking, pitting or a combination of them [2]. Molenaar [3] and Hagos [4] revealed that the most important disaster in porous asphalt wearing course is raveling (loss of the aggregate on the upper surface), which could significantly reduce the life expectancy of this type of pavement. Huber [5] discovered from a survey on the OGFC application in US that raveling is the most serious problem challenging the application of porous asphalt. Miradi [6] assumed that the raveling scale of porous asphalt will increase with the service time of the pavement. Once raveling occurs in certain area on porous asphalt, subsequent stone raveling will speed up, representing a "Domino effect". Based on the Akihiro [7] study, it is very important that a constraint on the life cycle of porous asphalt is raveling, and only with a good solution to raveling can a longer life of porous asphalt be expected. Hagos [4] concluded that the process of bitumen aging in porous asphalt is faster than that in dense-graded asphalt pavement; as a result of high air voids content, the degree of bitumen aging differs from the outside to the inside. Bitumen aging makes the bitumen binder brittle, and the strain level and stress are also relaxes; this will accumulate into subtle diseases in porous asphalt under traffic loading and climate conditions, and finally leads to failure of bonding and raveling. Mo [8] states that damages in porous asphalt are mainly caused by the binding failure between aggregate and bitumen mortar; he examined the cause of raveling by building a theoretic model to predict the life expectancy of porous asphalt and proposed a reasonable maintenance method correspondingly.

In view of this typical destruction of porous asphalt, in addition to effective measures taken in the design and construction of the pavement, effective prevention and preservation in the service period are also necessary. A design-construction-maintenance system needs to be set up to increase the service life of porous asphalt. Many authors [7,9] have made systematic research on the design and construction of porous asphalt wearing course and achieved fruitful results. However, few research has been conducted on preventive maintenance of this type of pavement, especially in China. Currently, preventive maintenance techniques are frequently used on dense-graded asphalt pavement. Related studies [10–12] indicate that preventive maintenance measures contribute to reducing or even rejuvenating aged bitumen. When used in dense pavement, they also prevent air and moisture erosion to the pavement, which effectively postpone thermo-oxidative aging in the bitumen and aggregate looseness. Research on the preventive maintenance technology of porous asphalt wearing course did not appear until recently. Hiromistsu [13] suggested that the main method of structural preventive maintenance for porous asphalt is surface enhancement with permeable curing agent. The US started to study the application of rejuvenator for preventive maintenance of dense and open graded asphalt friction course in the 1970s; experimental observation suggested that this technology can provide an additional unaged bitumen film for the pavement and prevent raveling [14]. Zhang [15] carried out a research on the preventive maintenance techno of porous asphalt with support of the LVO (levensduur verlengend onderhoud)–ZOAB (zeer open asfalt beton) project in the Netherlands. In his study, tests were carried out on PA mixtures with penetration bitumen and PMBs (polymer modified bitumen). It was accomplished mainly by spraying rejuvenator over a porous asphalt road surface. By rejuvenating the aged bitumen, the aggregate loss is prevented and the service life of the pavement is extended. Considering that the typical binder for porous asphalt mixture in a part of Asian countries is high-viscosity modified bitumen, study on preventive maintenance materials of porous asphalt mixture based on high viscosity modified bitumen is to be conducted in this paper.

In this study, four preventive maintenance materials were developed and selected as the optional maintenance materials. Performance of the four materials as well as the properties of the porous asphalt mixtures treated with the four materials were investigated and analyzed. The research approach for the paper is presented in Fig. 1.

2. Materials and test methods

2.1. Materials and preparation

2.1.1. Preventive maintenance materials

Four preventive maintenance materials were developed and selected for comparison. Material 1 is a reductive material (RJ), mainly composed of naphthenic oil and designed to rejuvenate and recover the performance of the aged bitumen. Material 2 is an adherence-enhancing material (CEM), which is prepared from a bitumen base raw material, adding with small amount of kaolin of 80–120 mesh size. Material 3 is a polymerizing material (GL1) mainly composed of alpha cyano acrylic resin and organic solvent. Material 4 is emulsified bitumen (EA) which is commonly used in preventive maintenance of dense pavement.

2.1.2. High viscosity modified bitumen

The Shuanglong 70# matrix bitumen is used for preparing high viscosity modified bitumen. The basic properties of the matrix bitumen are shown in Table 1.

The procedure of preparation of high viscosity modified bitumen in the laboratory is as follows:

First, the matrix bitumen is heated to 140 °C and melt in an iron container. Then, high viscosity modified bitumen is made by mixing the bitumen with the high viscosity additives by a shearing speed of 3000 r/min in a mixer. The mass fraction between the high viscosity additives and the bitumen is 12:88. The mixing process lasts for 50 min at 165–180 °C. In the end, the modified bitumen is cured in the 160 °C oven for 15 min.

2.1.3. Porous asphalt mixture

2.1.3.1. Field core. Field cores were drilled from a highway in Jiangsu province in China. The diameter of the core is 100 mm.

2.1.3.2. Laboratory-prepared specimen. Specimens with a size 30 cm × 30 cm × 5 cm were prepared by wheel rolling method in the laboratory. The gradation of the mixture is presented in Table 2. The high-viscosity bitumen (88% matrix bitumen with 12% high-viscosity additives, by mass) content is 4.7% by mass of the mineral aggregates. In the same way, the amount of binder for total mixture is 4.49%.

2.2. Test methods

2.2.1. Performance testing of preventive maintenance material

To examine the performance of different preventive maintenance materials, apparent viscosity test, cohesion test and adhesion (to stone) test were conducted to the materials.

2.2.1.1. Apparent viscosity test of material. The apparent viscosity of the maintenance materials was measured using Brookfield field viscometer rotation method. The test was conducted under room temperature (18–22 °C) with rotor 21# [16]. The measurement error was within 3.5% of the average value.