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Effectiveness of rejuvenator seal materials on performance of asphalt pavement

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HIGHLIGHTS

- The method for evaluate the effectiveness of rejuvenator seal materials (RSM) is provided.
- Diffusion process between RSM and aged asphalt is studied.
- Effective penetration depth of RSM was determined by carbonyl area index and predicted ductility of extracted binder.

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ABSTRACT

The objective of this paper is to investigate the effectiveness of Rejuvenator Seal Materials (RSM) on the behavior of Hot Asphalt Mixtures (HMA). Firstly, temperature sweep test was conducted to determine the effectiveness of extracted process. Secondly, the penetration depth of RSM on HMA was studied by means of rheology test and FTIR test. Lastly, the diffusion test of RSM on aged asphalt binder was also performed. The effective penetration depth of RSM was determined by carbonyl area index and predicted ductility of extracted binder. The results indicated that the RSM can effectively soften the aged asphalt binder in 0–10 mm depth in the asphalt mixture. Furthermore, different RSM exhibit different effective penetration depth in HMA and different diffusion effect with asphalt binder. The results of this paper will help the practice to have better understanding on the effectiveness evaluation of RSM for HMA and give recommendations to guide future field application of RSM.

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1. Introduction

Preventive maintenance of asphalt pavement becomes increasingly important in these years world widely. Many kinds of preventive maintenance methods are used to protect the asphalt pavement, such as micro-surfacing, slurry seal, rejuvenator seal and chip seal. Among these methods, rejuvenator materials seal is a preventive maintenance method for new constructed pavement at early age, particularly after 3-4 years of construction. Rejuvenator has been typically used to rejuvenate the aged asphalt mixture by mixing with them at 140–150 °C. According to previous studies [1–3], rejuvenator can effectively soften the aged asphalt mixture and improve the performance of recycled HMA. Unlike the rejuvenator mixed with HMA, Rejuvenator Seal Materials (RSM) are usually sprayed onto the surface of asphalt pavement to soften the oxidized asphalt binder and hence aim to extend the service life of the pavement [4–6].

Rejuvenator seal material has been used in asphalt pavement maintenance since 1970s in United States. Preventive maintenance method should have as less of effect as possible on the traffic and has higher cost-benefit ratio, and thus the maintenance timing for asphalt pavement is ahead as compared with traditional maintenance timing to catch high cost-benefit ratio. As a result, the application of rejuvenator materials seal for asphalt pavement is continuous increasing in China. Rejuvenating effect of RSM on HMA has been studied. Brownridge validated that RSM can decrease the viscosity of asphalt binder in the top portion of the pavement [7]. Chui-Te Chiu conducted research on the influence of RSM on asphalt mixture and concluded that RSM can decrease the viscosity of asphalt binder in the 0–10 mm depth of asphalt pavement [8]. Lin studied the rejuvenating effect of RSM on aged asphalt binder and mixtures. The results preliminarily indicated that the RSM can soften both aged asphalt binder and aged mixtures [9,10]. Fwa studied the performance of one RSM treated asphalt mixtures in

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laboratory and reported that the RSM had rejuvenating effect on the asphalt binder and protective effect on the asphalt mixture from damage resulted from moisture, gasoline, diesel and weathering [11]. King conducted research to determine the effect of RSM on the long-term performance of asphalt pavements. The report concluded that RSM seals appeared to protect the surface by reducing permeability to moisture for several years after application, and the RSM seals decreased the surface cracking of pavement [12]. In addition, other studies also indicate the RSM can prevent aging of the binder in pavement or airfield [13–16].

However, the effectiveness of RSM on HMA, which is the most important issue in applying RSM, has not been researched in the literatures. In most cases, the effectiveness of RSM on asphalt pavement depends on the penetration depth of RSM in asphalt mixture and diffusion depth of RSM within aged asphalt binders. However, researchers mainly focus on the rejuvenating effect of RSM, the penetration depth and diffusion effect of RSM has not been studied. Moreover, the rejuvenating mechanism between RSM and asphalt binder also has not been comprehensively researched, which strongly restrict the further application of RSM in the field. The existed critical problems of RSM provide the motivation to undertake this research.

The objective of this paper is to investigate the effectiveness of RSM on asphalt pavement, including two critical parameters-the penetration depth and diffusion of RSM. Firstly, the penetration depth of RSM on asphalt pavement is studied by quantify the performance changes of asphalt binder along the vertical position. The diffusion between RSM and aged asphalt binder has also been studied. From this study, the effectiveness of evaluating and applying RSM on asphalt pavement can be better understood. The effectiveness evaluation methods for RSM are also provided and recommended.

2. Materials and experiments

2.1. Materials

Three types of RSMs, which represent three widely used asphalt surface treatment products in the market, were chosen and named as C, L and J in this research. Basically, these materials were mainly composed of petroleum solvent, and rejuvenator. The basic properties of RSM are given in Table 1.

The base asphalt used in this study was obtained from Panjin asphalt Co., Ltd. The basic properties of this binder of base asphalt binder are shown in Table 2.

HMA used in this paper was designed by Marshall Methods. The basalt aggregates gradation is shown in Fig. 1. The optimum asphalt content was 5.0% by weight of aggregates. It is noted that the air void of HMA used in this study was designed between 7% and 8%.

After HMA specimens were prepared, the specimens were subjected to long-term aging according to AASHTO R30 specification [17]. HMA specimens were placed in oven with the temperature of 85 °C for 120 h. It is noted that the asphalt binder in surface of HMA may have deeper aging level than that of inner binder in HMA [18,19], and thus the binder in same vertical position is used for comparative. After this aging process, three kinds of RSM were sprayed onto the surface of aged specimens with the dosage of 300 g/m^2. The treated specimens were then placed in room temperature for 48 h. After that, the treated specimens were cut into four slices and the first three slices were obtained with the thickness of 10 mm for extracting the asphalt binder. The cutting geometry is shown in Fig. 2. It is noted that the RSM on the surface of first slice of HMA was removed by trichloroethylene.

2.2. Experiments

2.2.1. Extraction process of asphalt binder

In order to determine the penetration depth of RSM in asphalt mixture, the asphalt binder in the slices from different positions of HMA was extracted. Fig. 3 shows the new extraction process used in this study. As seen in this figure, the new extraction process was divided in four steps. Firstly, the HMA sample was cut into slices with the thickness of 10 mm. Secondly, HMA slices were dissolved in trichloroethylene for 30 min and then the solution mixed with asphalt binder, trichloroethylene and mineral filler were transferred to centrifuge tube. Thirdly, the centrifuge tube with asphalt binder, trichloroethylene and mineral filler was centrifuged with the speed of 5000 rpm/min for 15 min to remove the mineral filler.

Table 1
Basic properties of RSM.

Sample	Density (g/cm^3)	Solid content (%)	Boiling point (°C)	Viscosity (mPa s 25 °C)
C	1.01	58	⩾80	10
J	1.04	63	⩾80	150
L	1.02	60	⩾80	20

Table 2
Basic properties of base asphalt binder.

Sample	Penetration (0.1 mm)	Softening point (°C)	Ductility (cm)	Viscosity (Pa s 60 °C)
Base asphalt	75	44.5	167	465.5
TFOT	56.7	49.8	134	677.8
PAV	32.2	56.8	15.2	1443.2

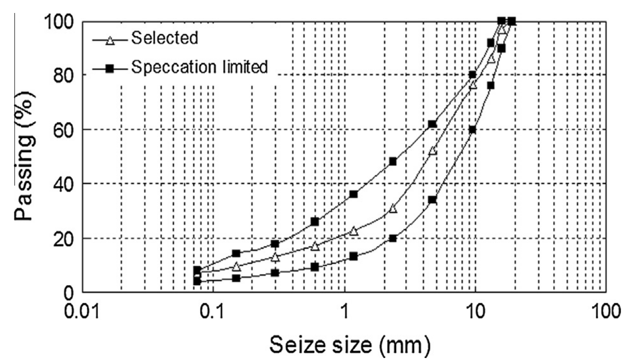

Fig. 1. Grading curves of aggregates.

Lastly, the centrifuged solution with asphalt binder and trichloroethylene were placed in oven at 60 °C for 24 h to remove trichloroethylene. After these four steps, the recovered asphalt binder from asphalt mixture can be obtained.

2.2.2. Rheological properties test

DSR are conducted to investigate the rheological performance of recovered asphalt binder. The Rheological test was performed at a frequency of 10 rad/s (1.59 Hz) with temperature between 30 °C and 80 °C according to AASHTO PP6 specification [20]. Complex shear modulus (G^*) and phase angle (δ) were obtained during the test.

2.2.3. FTIR

Fourier transform infrared spectrometry (FTIR) was used to characterize the functional groups of extracted asphalt binder. Asphalt binder was dissolved by trichloroethylene and then dropped onto the KBr table and dried for the FTIR analysis. FTIR was also used to characterize the base asphalt binder as reference. During the test, the thickness of film is appropriately 150 μm for each sample.

2.2.4. Penetration test

Penetration test is used to study the diffusion of RSM in aged asphalt binder, which is an important concern for applying RSM. Fig. 4 illustrates the diagram of penetration test. As seen in this figure, the left picture show the diagram of penetration test of control aged asphalt binder, while the right picture show the diagram of RSM treated aged asphalt binder. During the penetration test, D1 is the penetration depth in aged asphalt binder, while D2 is the penetration depth in aged asphalt binder with diffused RSM after certain diffusion time. It is noted that the penetration D2 contains of thickness of RSM and D1.

3. Results and discussion

3.1. Verification of extraction process

Firstly, the new extraction process for asphalt binder used in this study is vivificated to ensure the accuracy of the test. Three asphalt binder samples are used. One is un-extracted and unaged

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