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Laboratory evaluation of short and long term performance of hot-poured sealants

Feng Li [a], Siqi Zhou [a], Wenyuan Cai [a], Yuchuan Du [b], Li Li [c,b,*]

[a] School of Transportation Science and Engineering, Beihang University, 100191 Beijing, China
[b] Key Laboratory of Road and Traffic Engineering of the Ministry of Education, Tongji University, 201804 Shanghai, China
[c] Department of Civil Engineering, Shanghai University, 200444 Shanghai, China

HIGHLIGHTS

- Four tests were used to evaluate the short term performance of sealants.
- Two tests were used to evaluate the thermal and immersion stability of sealants.
- An evaluation system of short and long term performance was presented.

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ABSTRACT

Hot-poured sealants are commonly applied to repair cracks on asphalt pavements. However, existing methods of performance evaluation do not fully reflect the performance of hot-poured sealant for pavement application. Therefore, this article proposes different tests, melting point and melt flow index of packing films, sealant viscosity, segregation, thermal aging performance, and bond after water immersion, to specifically address identified problems and evaluate the short and long term performance of hot-poured sealant. A sealant performance ranking system was proposed based on the tests of nine sealants. The indicators of current performance evaluation, installation performance as well as thermal and immersion stability were weighted in this system. Different test results were classified and scored and then nine sealants were ranked quantitatively. The proposed system provides a more comprehensive evaluation of field performance of hot-poured sealant compared to existing performance evaluation methods, and correctly ranks the sealants in terms of their practical performance. Therefore, the proposed tests can be employed to complement current performance evaluation indicators.

1. Introduction

1.1. Background

Cracking is one of the main distresses to asphalt pavement. Applying hot-poured sealants to fill and seal the crack, preventing water permeating inside the pavement structure, is an internationally recognized effective means to slow pavement distress and extend pavement service life [1,2]. Different countries have developed relevant standards in order to evaluate the field performance of hot-poured sealants [3–5], but ASTM sets forth relatively comprehensive testing methods and technical requirements [6–8], and is the main sealant standard system worldwide.

In 2009, China's Ministry of Transport issued the industry standard for hot-poured sealant JT/T 740 (revised in 2015) [9]. JT/T 740 specifies five evaluation indicators: cone penetration, softening point, flow, resilience, and bond, with testing methods consistent with ASTM D5329 and D36. After several years of application, this standard has been shown to distinguish performance of different sealants and has promoted sealant quality improvements across China. Before implementation, no domestic sealants could meet the requirements under JT/T 740, aside from a few largely imported sealants. However, at least a dozen Chinese sealant manufacturers are now producing materials that meet JT/T 740. Despite this, problems remain during application of sealants. Many problems arise during installation: the packaging film is difficult to melt, and the sealant has high viscosity and is prone to segregation. These problems severely affect the efficiency of crack sealing and filling, and can clog the nozzle on the crack sealing machine, compromising sealant effectiveness. During service, materials meeting

* Corresponding author at: Department of Civil Engineering, Shanghai University, 200444 Shanghai, China.
E-mail address: lilian.li@qq.com (L. Li).

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the laboratory evaluation of industry standard also demonstrate failures, such as adhesion failure, and do not always display excellent long term performance. Thus, current performance evaluation indicators do not fully reflect short term (e.g., melting property of the packaging films, viscosity, or segregation) or long term (e.g., thermal stability or immersion stability) sealant performance.

1.2. Previous studies

Numerous literature reviews have shown doubt regarding the correlation between laboratory based ASTM standards and hot-poured sealant field performance. Researchers have proposed a variety of testing methods to better evaluate sealant field performance. Soliman et al. [10] conducted the bending beam rheometer (BBR) tests, and proposed sealant evaluation indicators of load drop tension at −30 °C and the complex shear modulus (G^*) at 5 °C. Soliman and Shalaby [11] adopted the indicators of glass transition temperature and low temperature stiffness to evaluate low temperature performance of sealants, showing that these indicators have better correlation with the field performance and that the glass transition temperature shall be 10 °C–15 °C lower than the material service temperature to maintain good field performance. Al-Qadi et al. [12–14] and Al-Qadi and Fini [12–14] performed a series of modified Superpave tests, where they modified parameters such as specimen size and test temperature based on sealant characteristics, and evaluated the low temperature performance of sealants with using a crack sealant bending beam rheometer (CSBBR) and the crack sealant adhesion test (CSADT). Yang et al. [15] and Ozer et al. [16] performed field validation of sealant performance, showing strong correlation between rheological index and pavement sealant performance. Fini and Al-Qadi [17] developed the pressurized blister test to test bond strength at the interface between the sealant and asphalt concrete and proposed the interfacial fracture energy indicator. Hu et al. [18] proposed a low temperature tension fatigue test using the overlay tester (OT) with tensile displacement of 2.54 mm and the maximum number of cycles up to 2000. Li and Huang [19] utilized a three parameter solid model to fit bond test data, and proposed the relaxation index to evaluate relaxation performance of sealants at low temperature.

However, the above indicators do not consider the influence of installation, although the installation process is a significant factor influencing field performance. Collins et al. [20] studied the cooling rate of sealants during installation, and showed that sealant temperature could decrease by more than 50 °C immediately after it was injected into the crack groove, and decreased to 40 °C on the surface after 15 min. Masson et al. [21] measured sealant temperature at three different locations in the heating kettle of the crack sealing machine and showed large differences between the actual and the recommended installation temperature for the sealant due to non-uniform temperature inside the heating kettle. To analyze sealant degradation, Masson et al. [22] studied the preheating process before sealant installation, and showed that extended pre-installation heating at medium temperature (e.g., 150 °C) can cause degradation of the sealant. Masson et al. [23] also studied sealant degradation during installation, showing significant sealant degradation even at the recommended installation temperature. These research findings explain why some sealants with good laboratory evaluation results demonstrate early damage.

Al-Qadi et al. [24] evaluated sealant installation viscosity, and proposed a rotational viscosity index at the recommended installation temperature and constant rotational speed of 60 rpm, whereas Li et al. [25] proposed a rotational viscosity index at 190 °C with viscosity at 50% of the torsional moment taken as the representative value.

Environmental influence on long term sealant service performance is also attracting research. Ozer et al. [26] analyzed sealant aging under the environmental influences, and showed that the environmental factors can significantly influence sealant high and low temperature performance. Lamarre et al. [27] employed the direct adhesion test and analyzed the change in adhesion strength and surface energy of the sealant before and after immersion, showing that immersion significantly influenced sealant adhesion properties. Their direct adhesion test was performed at −12 °C and the sealant was immersed to water at 26 °C for 22 h. Yeargin et al. [28] analyzed changes in sealant modulus and viscosity before and after immersion for 7 days at 25 °C, showing that immersion significantly influenced sealant cohesion properties.

1.3. Objectives of this study

Regarding the problems identified in the application of hot-poured sealants in China, this article evaluated appropriate testing methods for hot-poured sealant performance evaluation and studied the short term (e.g., melting property of the packaging films, viscosity, and segregation) and long term (e.g., thermal stability and immersion stability) performance, to evaluate hot-poured pavement sealant field performance to provide a laboratory based testing regime that complements the existing evaluation indicator system.

2. Materials and experiment design

2.1. Test samples

Nine hot-poured sealants commonly employed in northern China were selected for testing, as detailed in Table 1. Following JT/T 740, all sealants used have a bond test temperature of −30 °C.

2.2. Experiment design

2.2.1. Melting point and melting index for packaging film

In actual application, the nozzle of the crack sealing machine is sometimes clogged during crack sealing. One of the reasons is the high melting point and poor melting performance of packaging films, which remain only partially melted, and block the nozzle. Therefore, this article used the differential scanning calorimeter (DSC) to measure the melting point and the melt flow tester to measure the melt flow index of packaging film.

The DSC measures the relationship between temperature and heat flow related to thermal transformation inside the material. The sample and reference are heated separately, then maintained at the same temperature. If the sample undergoes phase transition or weight loss, this generates a temperature difference between the sample and reference, and the system compensates to maintain the same temperature. The power required for this compensation is equivalent to the change in heat of the sample. Recording heat flow versus temperature provides the DSC curve, from which melting point and melting peak area of the material can be obtained.

The melt flow index test was conducted following ASTM D1238 [29]. Melt flow index is a measure of the ease of flow of a thermoplastic material, which is the quantity of fluid flowing out of a round tube of diameter 2.095 mm, measured in grams. The quantity of material delivered through the standard capillary tubes was measured in g/10 min at 190 °C and 2.16 kg pressure. The test method employed was to melt the plastic pallets under a particular temperature and pressure and weigh the plastic fluid flowing out of the tube in a given time. Higher mass indicates better ease of flow of the material, and vice versa.