



Shear property, high-temperature rheological performance and low-temperature flexibility of asphalt mastics modified with bio-oil

Yong Lei^a, Hainian Wang^{a,*}, Xi Chen^a, Xu Yang^b, Zhanping You^{a,c}, Shi Dong^a, Junfeng Gao^a

^a School of Highway, Chang'an University, South Erhuan Middle Section, Xi'an 710064, China

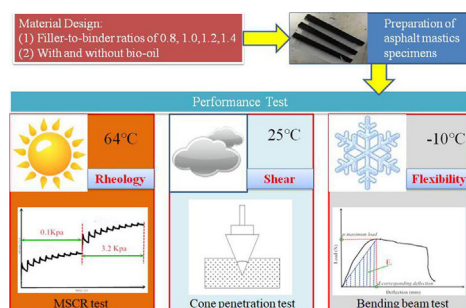
^b Department of Civil Engineering, Monash University, Clayton, VIC 3800, Australia

^c Department of Civil and Environmental Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA

HIGHLIGHTS

- Bio-oil affected the thermostability of asphalt binder.
- Bio-oil improved the high temperature stability of asphalt mastic.
- Filler enhanced the shear strength of asphalt mastic.
- J_{nr} decreased with the increasing filler-to-binder ratio.
- Bio-oil affected mechanical property of asphalt mastic at low temperature.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 19 July 2017

Received in revised form 15 January 2018

Accepted 10 April 2018

Keywords:

Bio-oil
Bio-modified asphalt
Petroleum-based asphalt
Asphalt mastic
Filler-to-binder ratio

ABSTRACT

Bio-oil is a sustainable and environment-friendly material. The application of bio-oil in paving material, especially into asphalt binder territory, has attracted great attentions. This study focuses on the effect of bio-oil on mechanical and rheological characteristics of asphalt mastic. Bio-oil acting as a modifier was incorporated into asphalt binder by a weight percentage of 15%. Eight types of asphalt mastics were fabricated by means of mixing binder with various amounts of mineral powder filler. The effect of bio-oil on the shear property, high-temperature rheological performance and low-temperature flexibility of asphalt mastics was investigated by the cone penetration test, multiple stress creep recovery test and bending beam test, respectively. The result showed that the critical thermostability temperature of petroleum-based asphalt binder was 1.5 times higher than that of bio-modified asphalt binder. The shear strength of asphalt mastic with and without bio-oil increased with an increase in filler-to-binder ratio. The incorporation of bio-oil enhanced the high temperature stability of asphalt mastic. Asphalt mastic with and without bio-oil exhibited a great anti-deformation potential at high temperature of 64 °C when the filler-to-binder ratio reaches to 1.2. Filler-to-binder ratio had little influence on the corresponding deflection of bio-modified asphalt mastic at −10 °C.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Bio-oil is an oily phase material produced from waste natural organics by a series of physical and chemical treatment including,

* Corresponding author.

E-mail address: wanghn@chd.edu.cn (H. Wang).

but not limited to, the fast pyrolysis technology and the high pressure liquidation technology [1]. In recent years, the rapid development in chemical industry makes bio-oil applied in many fields of energy engineering. A case is that the light phase in bio-oil was mixed with diesel and emulsified into bio-diesel, which has excellent combustion performance and cleaner emissions [2–3]. In terms of the heavy phase of bio-oil, named as masut, its

component is sophisticated. However, the element composition of masut is similar to that of petroleum-based asphalt [4], which lays foundation of mixing masut and asphalt together. In this research, the phrase ‘bio-oil’ shown in the following text is referred to as masut.

Road material researchers have treated bio-oil as modifier and incorporated it into asphalt to fabricate bio-modified asphalt, and investigated the performance of bio-modified asphalt binders and mixtures. Wang et al. selected shear method to fabricate bio-modified asphalts at 120 °C, and utilized dynamic shear rheometer (DSR) to investigate the influence of the content of bio-oil on the rheological properties of bio-modified asphalt [5]. Their study found that the rutting resistance index of bio-modified asphalt presents a decreasing trend with an increase in the bio-oil content. It indicated that the bio-oil had an adverse effect on high-temperature performance of asphalt. Niao et al. investigated the effect of the bio-oil content on mechanical property of bio-modified asphalt, and concluded that the addition of bio-oil improves the fatigue property and the anti-cracking ability of petroleum-based asphalt at low temperature [6]. Sun et al. produced bio-oil from waste cooking oil, and fabricated two types of bio-modified asphalts through blending bio-oil into SBS-modified asphalt and neat asphalt, respectively [7]. The results showed that bio-oil reduces the viscosity of asphalts, which results in an enhanced workability of bio-modified asphalt mixtures. Mousavi et al. used molecular dynamic simulation technology to study the modification mechanism of bio-oil to petroleum-based asphalt and found that the bio-oil makes the asphaltene in petroleum-based asphalt clustered [8]. Besides, the addition of bio-oil into asphalt had an effective contribution to fatigue cracking at intermediate temperature and anti-cracking property at low temperature. Mogawer et al. extracted bio-oil from swine manure and treated it as modifier to fabricate hot-mix recycled asphalt mixture [9]. The result from overlay tester showed that the bio-oil enhances fatigue characteristic and thermal cracking properties of recycled asphalt mixture. They thought that bio-oil had a positive effect on the blend of reclaimed asphalt and virgin asphalt. Fini et al. selected four bio-binders, derived from swine manure, wood pellet, corn stover and miscanthus pellet, to fabricate four bio-modified asphalts containing 10% bio-binder to conduct bending beam rheometer (BBR) test at temperatures of −24 °C, −18 °C and −12 °C, respectively. They described the correlation between creep compliance and loading time based on fractional viscoelastic model and found that the bio-binder containing oil produced from corn stover has the highest value for dissipated energy ratio and damping ratio compared with those of other bio-binders [10]. Moreover, Fini et al. also attempted to mix Polyphosphoric acid (PPA) into bio-modified asphalt to improve the high temperature performance [11]. Their study showed that the PPA makes the road performance of bio-modified asphalt mixture achieved an acceptable level at intermediate temperature and high temperature. Gong et al. treated bio-oil derived from waste cooking oil as rejuvenator to investigate the effect of bio-rejuvenator on regeneration and mechanical properties of short-term ageing asphalts, petroleum-based asphalt and SBS-modified asphalt [12]. The regeneration effect of bio-rejuvenator on ageing petroleum-based asphalt was different with that on SBS-modified asphalt. Bio-oil can be classified into saturates based on the composition analysis, and the principle of asphalt is made of four compositions: saturates, aromatic, asphaltene and resins. In addition, they found that bio-oil does not only weaken the clustering of the serious oxidized composition in ageing asphalt, but also strengthen the diffusion ability of asphalt.

According to the literature review above, bio-oil acted as modifier or rejuvenator has been investigated and applied in road material territory widely and deeply. However, there is a gap in

evaluating the performance of bio-modified asphalt mastic. Bio-oil has the potential to replace traditional asphalt binder, which has great significance of sustainability and environmental protection.

Based on recent theory, asphalt mixture belongs to the three grades dispersion system with spatial net structure. The third one, namely micro-dispersion or asphalt mastic, affects the deformation at high temperature, cracking property at low temperature and moisture susceptibility of asphalt mixture [13]. Asphalt mastic is made of mineral powder and asphalt binder, while mineral powder as the filler is the key composition of mastic, and the filler-to-binder ratio affects the behavior of mastic directly [14]. Generally, the common asphalt mixtures are required to control the filler-to-binder ratio within a range of 0.6–1.2 to ensure the workability and road performance of asphalt mixture. Comparison and analysis on the property of bio-modified asphalt mastic and petroleum-based asphalt mastic can provide theory reference to the application of bio-oil in road material. In this paper, different asphalt mastics were fabricated via changing the filler-to-binder ratios. The cone penetration test, multiple stress creep recovery (MSCR) test and bending beam test were utilized to systematically evaluate the shear property, rheological characteristic at high temperature and the resistance to cracking of asphalt mastics at low temperature, and to compare the performances between bio-modified asphalt mastic and petroleum-based asphalt mastic.

2. Research objectives and scope

This paper aims to study the effect of bio-oil on the mechanical and rheological characteristics of asphalt mastic at different temperatures. Bio-oil derived from corn stover was treated as modifier to fabricate bio-modified asphalt binder. The content of the bio-oil was 15% by weight of the bio-modified asphalt binder. Four filler-to-binder ratios of 0.8, 1.0, 1.2 and 1.4 were selected to fabricate the asphalt mastics. The cone penetration test was conducted to evaluate the shear strength of asphalt mastics at temperature of 25 °C. To explore the resistance to deformation, MSCR test was performed to investigate the high temperature performance of asphalt mastics. Bending beam test was utilized to evaluate the flexibility of asphalt mastic specimen at low temperature of −10 °C. Three duplicates were prepared and tested for each test. The technological progress of this study is shown in Fig. 1.

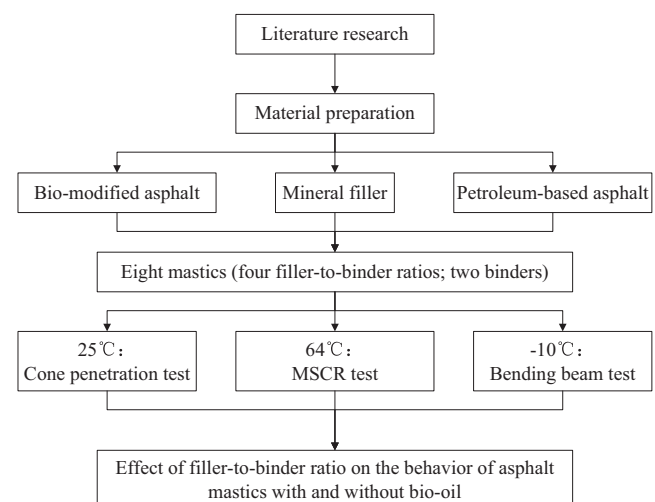


Fig. 1. The research roadmap.

Download English Version:

<https://daneshyari.com/en/article/6713338>

Download Persian Version:

<https://daneshyari.com/article/6713338>

[Daneshyari.com](https://daneshyari.com)