Journal of Cleaner Production xxx (2016) 1–11

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Chemical characterization and oxidative aging of bio-asphalt and its compatibility with petroleum asphalt

Xu Yang [a], Julian Mills-Beale [b], Zhanping You [c, *]

[a] Department of Civil and Environmental Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI, 49931, USA
[b] Department of Civil Engineering, California Baptist University, 8432 Magnolia Ave., Riverside, CA, 92504, USA
[c] Department of Civil and Environmental Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI, 49931-1295, USA

ARTICLE INFO

Article history:
Received 18 May 2016
Received in revised form
26 October 2016
Accepted 16 November 2016
Available online xxx

Keywords:
Bio-oil
Bio-asphalt
Elemental composition
Compatibility
Chemical compounds
Fourier Transform Infrared Spectroscopy (FTIR)
Automated Flocculation Titrimetry (AFT)

ABSTRACT

The objective of this paper is to characterize the elemental composition, chemical compounds, oxidative aging and the compatibility of bio-asphalt modified with bio-oil. A petroleum asphalt was modified with treated and untreated bio-oil at 2%, 5% and 10% by weight to prepare bio-asphalt, respectively. Gas chromatography–mass spectrometry (GC-MS) was employed to characterize the chemical compounds in the bio-oil. The Fourier Transform Infrared Spectroscopy (FTIR) was utilized to explore the influence of bio-oil on the aging performance of asphalt. The compatibility of bio-oil with petroleum asphalt was investigated using automated flocculation titrimetry (AFT) based on flocculation stability. The elemental composition analysis revealed a higher amount of oxygen in the bio-oil. The GC-MS results showed the presence of chemical compounds with low boiling temperatures, which have potential environmental impacts and health concerns if used in hot mix asphalt. The FTIR results indicated the presence of aromatic and nitrogenous compounds, alcohols, ethers, ketones, carboxylic acids, aldehydes, esters, acyls, alkanes, polymeric O–H, NH_2 and water. The AFT results implied a stable and compatible mixture of 2% bio-asphalt. The study also suggested that with an increase in the fraction of bio-oil, the compatibility with petroleum asphalt would decrease.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Asphalt pavement engineers and researchers have been seeking materials that would guarantee the structural integrity and performance of asphalt pavement without compromising the environment. Warm mix asphalt with lower emissions (Almeida-Costa and Benta, 2016; Dinis-Almeida and Afonso, 2015; Sol-Sánchez et al., 2016), recycled asphalt and concrete pavements (Mills-Beale and You, 2010; Shu et al., 2012), and asphalt with scrap tire rubbers (Fakhri and Saberi, 2016; Oliveira et al., 2013) are cleaner materials that have been well explored in industry. Bio-oils derived from biomasses present an innovative and interesting alternative to the existing petroleum-based asphalt due to its renewability and environmental friendliness (Fini et al., 2010; Podolsky et al., 2016). The blending of bio-oil and traditional petroleum asphalt is also referred to as bio-asphalt. In addition to easing the pressure on existing landfills, the production of bio-oil from wood waste will reduce the continued dependence on crude resources for asphalt. Crude oil consumption has experienced a significant increase in recent years in the United States. The 19.3 million acres of timber land, 385 million cubic feet of trees and 458.2 million cubic feet of unused annual growth and residues in Michigan present an ideal opportunity for the exploration of bio-asphalt development in the state (Mueller et al., 2010). Additionally, the rising dumping fees associated with hauling wood waste over long distances to dumping sites can be compensated if the waste can be developed into an economically beneficial bio-asphalt product. Compared to petroleum asphalt, the benefits of bio-oil are mainly the renewability and recycling of waste. As mentioned above, Michigan has a large amount of wood resources that can be potentially used to generate bio-oils. Most importantly, bio-oils can be generated from many waste materials, which are costly to deal with if not properly recycled.

According to the review by Yan et al. (2015), 20% of the transportation fuels will be produced from lignocellulosic biomass as an alternative of traditional fossil fuel by 2030. The generation of bio-oil is similar to the approaches of producing bio-fuels. Many types

* Corresponding author.
E-mail addresses: xyang2@mtu.edu (X. Yang), jmillsbe@calbaptist.edu (J. Mills-Beale), zyou@mtu.edu (Z. You).

http://dx.doi.org/10.1016/j.jclepro.2016.11.100
0959-6526/© 2016 Elsevier Ltd. All rights reserved.

Abbreviations

AFT	Automated Flocculation Titrimetry
BTX	Benzene, touelene and xyrenes
CHON	Carbon, hydrogen, oxygen, and nitrogen
FTIR	Fourier Transform Infrared Spectroscopy
FR	Flocculation ratio
GC-MS	Gas Chromatography Mass Spectrography
$I_{C=O}$	Carbonyl index
$I_{S=O}$	Sulphoxide index
NTB	Non-treated bio-oil
PAV	Pressure aging vessel
RTFO	Rolling thin film oven
SARA	Saturates, aromatics, resin, and asphaltene
S_{BN}	Solubility number
TB	Treated bio-oil

of biomass materials can be used for bio-oil development, such as animal waste (Fini et al., 2011; You et al., 2011), wood waste (Yang et al., 2013, 2014a), agricultural waste (Raouf and Williams, 2010), microalgae (Chailleux et al., 2012), and waste cooking oil (Sun et al., 2016). Thermochemical processes such as hydrolysis, pyrolysis, gasification and liquefaction are used to turn biomasses into bio-products (Pandey et al., 2015). Hydrolysis is a common approach to produce the bio-product furfural which can be used to generate furfuryl alcohol (Yan et al., 2014). Among them, fast pyrolysis is the most widely used technique due to various advantages such as simplicity, high yield rate and low cost (Akhtar et al., 2010; Bridgwater and Peacocke, 2000; Mohan et al., 2006). The yield rate for corn stover, wheat straw, or switch grass can be as high as 78% by weight using the fast pyrolysis (Laird et al., 2009). Three components can be generated from the fast pyrolysis: bio-char, gases, and liquids. The liquid is regarded as the bio-oil. The yield rate is also affected by the temperature (Silva et al., 2016; Westerhof et al., 2009). Some researchers have proposed approaches to estimate the pyrolysis output based on the feedstock properties and the reaction condition (Lim et al., 2016). A certain moisture content is contained in raw bio-oils depending on the type of biomass. The components of bio-oils can be separated through fractional distillation. The fraction distillation for corn stover bio-oil showed that water is in the light fraction; aromatic and oxygenated compounds are in the light to middle fractions; and phenolic compounds fall into the heavy fraction (Capunitan and Capareda, 2013). The water contents of bio-oil developed from some vegetal sources can be higher than 40% (Williams and Tang, 2009). It was reported that the components of bio-oil can also fall into the four typical compounds in petroleum asphalt, which are saturates, aromatics, resin, and asphaltenes (Fini et al., 2011; Miao and Wu, 2004). The pH of bio-oils was reported to be in the range between 2.5 and 3.5 (Ba et al., 2004; Czernik and Bridgwater, 2004). The elemental composition of bio-oils is different from petroleum asphalt, with a noticeably higher content of oxygen in bio-oils, and the elemental composition of bio-oils from different biomasses may vary significantly (Czernik and Bridgwater, 2004; Fini et al., 2011; Metwally and Williams, 2010).

Asphalt by nature, is adhesive to bond aggregates together when applied in the pavement industry. Since bio-oil has similar chemical compounds as that in petroleum asphalt, many previous studies have explored the potential of using bio-oil in the pavement industry (Fini et al., 2011; Raouf and Williams, 2011; Wen et al., 2012; Yang et al., 2013). The easiest way of applying bio-oil to the pavement industry is to blend bio-oil into petroleum asphalt to form bio-asphalt. The pavement purposed performance of bio-asphalt binders and bio-asphalt mixtures have been investigated recently (Sun et al., 2016; Yang et al., 2014a). The performance of bio-asphalts developed from different bio-oil sources can vary significantly. For instance, the forest waste bio-asphalts were found to increase the high temperature performance of traditional asphalt while adversely affecting the low temperature binder properties (Raouf and Williams, 2011; Williams and Tang, 2009; Yang et al., 2013). On the contrary, the bio-asphalt from swine waste and cooking oil was found to weaken the high temperature performance but improve the low temperature performance (Fini et al., 2011; Sun et al., 2016; Wen et al., 2012). Additional additives were sometimes blended into bio-asphalt to improve performance in certain aspects, such as nanomaterials (Onochie et al., 2013) and crumb rubber (Peralta et al., 2012). Meanwhile, many previous studies have indicated that the aging of bio-asphalt is quicker than petroleum asphalt (Mills-Beale et al., 2014; Onochie et al., 2013). Yang et al. (2014b) attributed the aging of wood waste bio-asphalt to the loss of lightweight molecular components, oxidation, and polymerization. In regards to the performance of asphalt mixture containing bio-asphalt, it was reported that the waste wood bio-asphalt can improve fatigue resistance and has no significant effect on rutting or tensile strength (Yang et al., 2014a). The study on the high reclaimed asphalt pavement containing swine waste bio-asphalt showed that the presence of bio-asphalt can improve workability, fatigue and cracking resistance, and has no adverse effect on moisture susceptibility and rutting resistance (Mogawer et al., 2016).

Bio oil has also been used as an additive and rejuvenator for petroleum asphalt. Gong et al. (2016) found that the bio-oil derived from biodiesel residue can improve the performance of aged asphalt because it can compensate the loss of lightweight components and may interact with the polymers in modified asphalt. Oldham et al. (2015) investigated the bio-oils generated from swine manure as a rejuvenator for asphalt binder containing asphalt shingles and found that the addition of such bio-oil can lead to a reduction in viscosity and an improvement in fracture energy. Garcia et al. (2016) investigated the potential of using sunflower oil capsules as a rejuvenator to extend the life of asphalt mixture. Podolsky et al. (2016) found that the bio-additive derived from corn biomass, can serve as a warm mix additive and reduce the mixing and compaction temperatures by as much as 30 °C.

To thoroughly understand the paving performance of wood waste bio-asphalt, it is important to understand the basic properties of bio-oil and bio-asphalt. Although the rheological and mechanical performance of wood waste bio-asphalt and the elemental analysis has been reported in some previous studies, the lack of understanding of the elemental composition, chemical compounds, oxidative aging and the compatibility of bio-asphalt is inadequate for immediate implementation of bio-asphalt. To build on the body of knowledge available on wood waste bio-asphalt, it is pertinent to understand the aging behavior from the standpoint of the chemical functional group and also investigate the molecular asphaltene-maltene precipitation behavior. The impact of the chemical compounds on the environment and health during asphalt mix production has not been reported in previous studies. The compatibility between petroleum asphalt and bio-oil has been rarely investigated in existing literature. This study will fill these research gaps based on the literature review.

The objective of this paper is to characterize the elemental composition, chemical compounds, oxidative aging and the compatibility of bio-asphalt modified with bio-oil. The expected contribution of this study is to reveal the feasibility of using bio-oil in pavement engineering and the potential concerns to be faced. In order to achieve the research objective, the following research

Please cite this article in press as: Yang, X., et al., Chemical characterization and oxidative aging of bio-asphalt and its compatibility with petroleum asphalt, Journal of Cleaner Production (2016), http://dx.doi.org/10.1016/j.jclepro.2016.11.100

Download English Version:

https://daneshyari.com/en/article/5480357

Download Persian Version:

https://daneshyari.com/article/5480357

Daneshyari.com