Construction and Building Materials 38 (2013) 327–337

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

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

Rheological properties and chemical analysis of nanoclay and carbon microfiber modified asphalt with Fourier transform infrared spectroscopy

Hui Yao [a,b], Zhanping You [b,*], Liang Li [a], Shu Wei Goh [b,1], Chee Huei Lee [c,2], Yoke Khin Yap [c,3], Xianming Shi [d]

[a] School of Civil Engineering and Architecture, Central South University, Changsha, Hunan 410075, China
[b] Department of Civil and Environmental Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295, USA
[c] Department of Physics, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295, USA
[d] Western Transportation Institute and Civil Engineering Department, Montana State University, Bozeman, MT 59717-4250, USA

HIGHLIGHTS

- Asphalt binders blended with four nano/micro-modifiers were used.
- The complex shear modulus was measured with DSR.
- The chemical bonding of asphalt binders was analyzed through FTIR.
- The addition of four modifiers can delay the aging and oxidation effect.

ARTICLE INFO

Article history:
Received 9 January 2012
Received in revised form 18 July 2012
Accepted 4 August 2012
Available online 29 September 2012

Keywords:
Asphalt
Complex shear modulus
Fourier transform infrared spectroscopy
FTIR
Wave number
Rheological property
Chemical analysis
Nanoclay
Carbon microfiber

ABSTRACT

This work aims to improve the rutting and fatigue cracking resistance of asphalt binders using selected nano- or micro-sized materials and to shed light on the microstructure changes induced by such modification to asphalt binders. The four modifiers (Nanomer I.44P, carbon microfiber, non-modified nanoclay and polymer modified nanoclay) were added into the control asphalt binder (PG 58-34). The Superpave™ tests and Fourier transform infrared spectroscopy (FTIR) measurements were conducted for obtaining the complex shear modulus G^* and microstructure distribution of modified asphalt binders. Meanwhile, the short-term and long-term aging processes of asphalt binders are simulated by rolling thin film oven (RTFO) and pressure aging vessel (PAV) tests. From the dynamic shear rheometer (DSR) and FTIR tests results, the complex shear modulus G^* values of nano- or micro-materials (Nanomer I.44P, non-modified nanoclay and carbon microfiber) modified asphalt binders increase, and the performance of resistance to rutting is improved compared to the control asphalt binder. The addition of polymer modified nanoclay (PMN) into the control asphalt binder decreases the complex shear modulus, and enhances the resistance to fatigue cracking. Moreover, the addition of four modifiers into the control asphalt binder can delay and weaken the aging and oxidation effect.

1. Introduction

Asphalt materials are obtained from crude petroleum as byproducts. About 90–95% by weight of asphalt consist of hydrogen and carbon, and two types' atoms (heteroatoms and metals) are in the remaining portion of asphalt. The heteroatoms contain the nitrogen, oxygen and sulfur, which replace the carbon by heat or shear stress. These contribute to the physical and chemical performance by causing much of the interaction between molecules. Metal atoms, such as vanadium, nickel and iron, are represented in trace quantities, typically far less than 1% [1,2]. Asphalt compositions are so complicated and composed of organic molecules, which can react with oxygen from the environment air. Also, the molecules in asphalt binders can affect the aging and oxidation extent and molecular reactions depend on temperature, modifier type and concentration. The oxidation also changes the structure and composition of asphalt. Generally speaking, the oxidation makes the asphalt stiffer and brittle [3–5]. So, in asphalt pavement service years, when the rutting and fatigue cracking appear, it depends on the oxidation rate [6,7].

* Corresponding author. Tel.: +1 906 487 1059; fax: +1 906 487 1620.
E-mail addresses: huiyao@mtu.edu (H. Yao), zyou@mtu.edu (Z. You), liliang_csu@126.com (L. Li), sgoh@mtu.edu (S.W. Goh), chlee@mtu.edu (C.H. Lee), ykyap@mtu.edu (Y.K. Yap), Xianming_s@coe.montana.edu (X. Shi).
[1] Tel.: +1 906 487 1059.
[2] Tel.: +1 906 487 3008.
[3] Tel.: +1 906 487 2900.

0950-0618/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2012.08.004

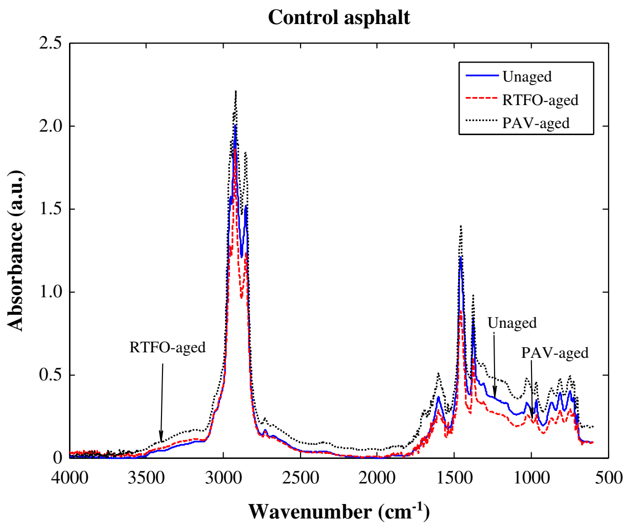
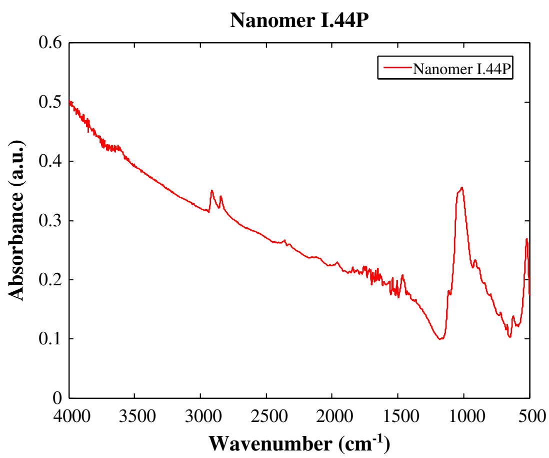


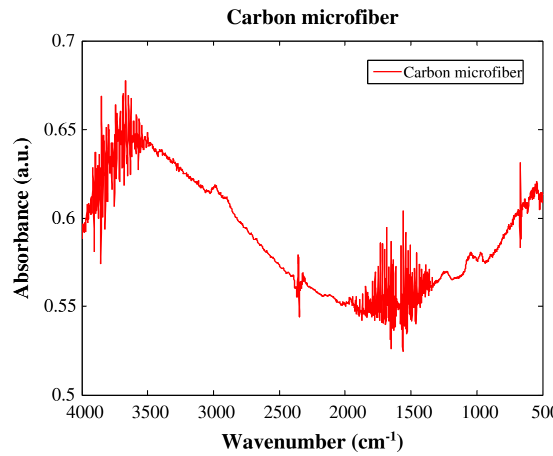
Fig. 1. FTIR spectra of control asphalt binder.



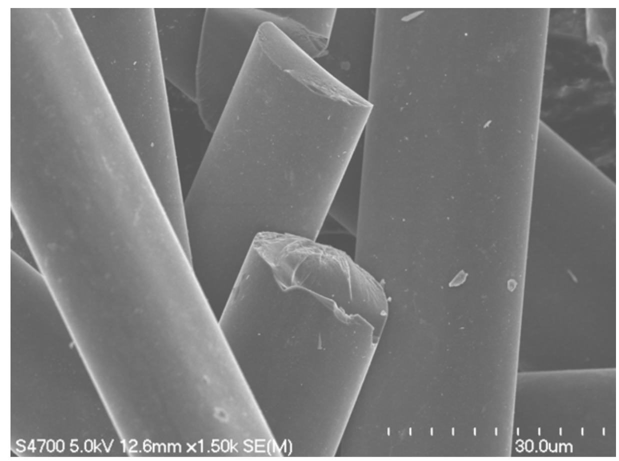
(a) FTIR spectra of NI.44P

(b) SEM image of NI.44P

Fig. 2. The SEM image and FTIR spectra of Nanomer I.44P.



(a) FTIR spectra of MCF



(b) SEM image of MCF

Fig. 3. The SEM image and FTIR spectra of carbon microfiber.

Asphalt binder is widely used for road pavement construction. Due to the limitation of temperature susceptibility, the low-temperature and high-temperature performance of asphalt binders need to be improved. Therefore, the asphalt modification research emerges as the times require, and develop prosperously. In general, the fibers and polymers, such as carbon fibers, styrene–butadiene–styrene (SBS), styrene–butadiene–rubber (SBR), ethylene glycidyl acrylate (EGA) terpolymer, crumb rubber, and are used broadly in the construction [8–19]. Research showed the fiber-reinforced asphalt materials (FRAM) improved the resistance to aging, fatigue cracking and moisture damage. Polypropylene fibers, polyester fibers, asbestos fibers, cellulose fibers, carbon fibers, glass fibers and nylon fibers have been used to enhance the performance of asphalt concrete [20–22]. It is obvious that the SBS material has been using in the entire world, and the properties and aging influence of SBS modified asphalt binder were investigated by dynamic shear rheometer (DSR), Fourier transform infrared spectroscopy (FTIR), atomic force microscopy (AFM), rolling thin film oven (RTFO), pressure aging vessel (PAV) tests. These results showed that SBS could significantly improve the low-temperature performance of asphalt concrete [12,13,23,24]. SBR is an important asphalt modifier in the pavement construction. Through the SBR modification in the asphalt binders, the low-temperature ductility and elastic recovery were enhanced; also, the viscosity was increased [14,15,25]. In addition, EGA has been used for roads since 1991, and EGA modifier solved the separation problem of asphalt storing and transportation. It is shown that the moisture damage of EGA modified asphalt mixture also decreased in the research [14]. In recent years, crumb rubber modifier (CRM) has been increasingly used in re-