Available online at ScienceDirect
ScienceDirect
J. Mater. Sci. Technol., 2014, 30(12), 1304–1310
www.JMST.org

Preparation and Properties of Asphalt Modified with a Composite Composed of Waste Package Poly(vinyl chloride) and Organic Montmorillonite

Changqing Fang[*], *Xiaolong Liu, Ruien Yu, Pei Liu, Wanqing Lei*
College of Printing and Packing Engineering, Xi'an University of Technology, Xi'an 710048, China
[Manuscript received May 3, 2014, in revised form June 16, 2014, Available online 7 November 2014]

A composite composed of waste package poly(vinyl chloride) (WPVC) and organic montmorillonite (OMMT) was prepared by coextrusion, which is used for modifying asphalt. The micromorphology of the WPVC/OMMT composite and its effect on the macroscopic properties of asphalt were studied using a fluorescent microscope and an X-ray diffractometer (XRD). The introduction of OMMT allows the WPVC to be good dispersed in the asphalt matrix, as demonstrated by differential scanning calorimetry (DSC) and Fourier transform infrared spectroscopy (FTIR) analysis. The results indicate that asphalt modified by WPVC/OMMT composites with low OMMT content results in better high-temperature storage stability and physical properties of modified asphalt.

KEY WORDS: Composite; Waste plastics; Characteristics; Thermal properties

1. Introduction

Asphalt has a complex chemical structure that varies with its origin and preparation method. When the asphalt is used in a roadway, its surface temperature can vary from below 0 °C to more than 90 °C in response to environmental conditions. To improve its pavement performance, asphalt is frequently modified using a variety of polymeric materials. A polymer-modified asphalt (PMA) and usually contains polymer contents ranging from 3% to 8%, by weight[1].

Numerous polymers, such as block styrene–butadiene–styrene copolymers (SBS), styrene butadiene rubber (SBR), and ethylene–vinyl acetate copolymers (EVA), are finding their way into polymer-modified asphalt pavements leading to enhanced performance[2]. To be useful, the modifying polymer must be sufficiently compatible with the asphalt and does not cause phase separation during storage at high-temperatures. In addition, combining a polymer with asphalt must not lead to a substantial increase in the viscosity of the asphalt in its molten state, to ensure that existing road-building processes and apparatus can still be applied. Moreover, economic and environmental benefits should also be considered, specifically, the polymer should be inexpensive and not pose an environmental risk[3].

Poly(vinyl chloride) (PVC) is the world's third most utilized polymer, ranking just behind polyethylene (PE) and polyethylene terephthalate (PET), which can be processed into a wide variety of packaging products and used in food production, cleaning materials, textiles, beverage bottles, and medical devices. Yet, in recent years, the question of the disposal of PVC waste has gained increasing importance, resulting from the rapid growth of PVC wastes[4]. In our previous research[5], waste packaging polyethylene (WPE) was used as a polymer modifier to lower the cost of modified asphalt and provide an effective method for recycling PE waste.

Nanomaterials have a large specific surface area and high surface free energy. The interfacial atoms are disordered, which facilitates the process of dispersing these materials in a matrix. Organic montmorillonite (OMMT) is one of such nanomaterials, but when it is used in high content as an asphalt modifier, it is difficult to be dispersed homogeneously due to its poor compatibility which can be attributed to the high viscosity of asphalt and the high surface energy of nano material[5,6]. Therefore in this study, OMMT by different content was added into WPVC to prepare a WPVC/OMMT composite, which was then employed as a modifier for asphalt, in hope of improving dispersion of OMMT in the asphalt.

In this work, the preparation and properties of WPVC/OMMT composite were studied and the properties of asphalt that was modified using this composite were determined. For comparison,

[*] Corresponding author. Prof., Ph.D.; Tel.: +86 29 82312038; Fax: +86 29 82312512; E-mail address: fcqxaut@163.com (C. Fang).

http://dx.doi.org/10.1016/j.jmst.2014.11.001

Table 1 Properties of original materials

WPVC[5]	Main component	Density	Thickness	Melting point range
	PVC	1.35 g/cm^3	0.32 mm	160 °C−190 °C
OMMT[a]	Component	Apparent density	Humidity ratio	Diameter−thickness ratio
	Montmorillonite organic derivatives	0.35 g/cm^3	<3%	200
Asphalt[b]	Penetration (25 °C, 100 g, 5 s)	Softening point (ring & ball)		Ductility (5 °C, 1 cm/min)
	86.1 dmm	51.3 °C		>200 cm

[a] Data are provided by Zhejiang Fenghong New Material Co., Ltd. (China).
[b] Physical properties were conducted in accordance with ASTM D5, D36 and D113, respectively.

a controlled asphalt modified using only PVC was also examined. In addition, the compatibility of asphalt modified using the WPVC/OMMT composite was investigated and the effect of OMMT content on the high-temperature storage stability and physical properties of modified asphalt were discussed.

2. Materials and Experiment

2.1. Materials

WPVC was obtained from recycled commercial blister packaging consisting primarily of PVC. Nanosized OMMT was supplied by Zhejiang Fenghong New Material Co., Ltd. (China). The base asphalt 90A# was obtained from China Petroleum and Chemical Co., Ltd. Xi'an Branch. Properties of these materials are summarized in Table 1[7].

2.2. Preparation of WPVC/OMMT composite

WPVC/OMMT nanocomposites were prepared using an SHJ-35 co-rotating twin-screw extruder (Nanjing, China). The mixing ratios of the samples are listed in Table 2. Barrel temperatures of the extruder from feeding section to discharge port were 160 °C, 165 °C, 170 °C, 170 °C, 165 °C, 165 °C, 160 °C, 160 °C and 150 °C, respectively, and the speed of screw was 90 r/min. The resultant asphalt-modifying agent is shown in Fig. 1.

2.3. Preparation of modified asphalt

All of the modified asphalts were prepared using an FLUKO FM300 high shear emulsifier (Shanghai, China) at 150 °C at a shearing speed of 3750 r/min for 1 h. Following this mixing procedure the binders were kept at about 120 °C for 30 min to ensure full swelling of the modified agent, resulting in the experimental modified asphalts (as listed in Table 3). Prior to shearing with the emulsifier, the asphalt was heated in a small container until it flowed, and then the individual modifiers (WPVC/OMMT or WPVC) were added to each hot asphalt. The WPVC content of the final composite was 6 wt%.

Table 2 Component of the composites

Samples	WPVC (g)	OMMT (g)
A1	1000	50
A2	1000	150
A3	1000	250

2.4. Tests for WPVC/OMMT composite

2.4.1. Thermal properties test. Differential scanning calorimetry (DSC) was used to observe the thermal characters of WPVC/OMMT composites. DSC analysis was conducted using a DSC 823e differential scanning calorimeter (Mettler Toledo, Switzerland) at a scan rate of 10 °C/min, from 50 °C to 230 °C under argon.

2.4.2. XRD analysis. XRD analysis of the samples was conducted using an XRD-7000 diffractometer (Shimadzu, Japan), with a wave-length of 0.154056 nm (λ), a step size of 0.1° and 2θ angle from 2° to 10°.

2.5. Tests for asphalt modified by WPVC/OMMT composite

2.5.1. Physical properties and high-temperature storage stability test. Physical properties including penetration (25 °C), softening point and ductility (5 °C), were conducted in accordance with ASTM D36, D5 and D113, respectively.

Following preparation of the modified asphalts, some of the prepared modified asphalt was transferred into a glass tube (32 mm in diameter and 160 mm in height). The tube was sealed and stored vertically in an oven at 163 °C for 48 h, and taken out, cooled to room temperature. After curing, a small hammer was used to gently break the tube into pieces and the glass fragments were cleaned. Then the samples were cut horizontally into three equal sections. The samples taken from the top and bottom sections were used to evaluate the storage stability of the modified asphalts by measuring their softening point difference.

2.5.2. FTIR analysis. Modified asphalt samples were coated onto a potassium bromide (KBr) disc. The infrared spectra were recorded with an FTIR-8400S spectrometer (Shimadzu, Japan).

2.5.3. Morphological analysis. A Nikon 80i fluorescent microscope (Japan) with an optical magnification of 200 was used to investigate the morphology of the modified asphalts by determining the dispersed state of the modifier in the base asphalt.

3. Results and Discussion

3.1. Properties of WPVC/OMMT composite

3.1.1. XRD analysis. The structure of the polymer/OMMT composites can be classified into two categories, intercalated and exfoliated, as determined by XRD analysis which exhibited the position and the intensity of diffraction peaks in XRD patterns[8]. The XRD curves of OMMT and WPVC/OMMT composite are