Journal of Materials Science & Technology 31 (2015) 320–324

Contents lists available at ScienceDirect

Journal of Materials Science & Technology

journal homepage: www.jmst.org

Effect of Preparation Temperature on the Aging Properties of Waste Polyethylene Modified Asphalt

Changqing Fang*, Mengya Zhang, Ruien Yu, Xiaolong Liu

School of Printing and Packing Engineering, Xi'an University of Technology, Xi'an 710048, China

ARTICLE INFO

Article history:
Received 31 December 2013
Received in revised form
25 January 2014
Accepted 16 April 2014
Available online 16 January 2015

Key words:
Waste plastics
Characterization
Temperature

In this study, waste polyethylene (WPE) was used as a modifier for base asphalt. In our previous studies, we have examined a variety of polymer modifiers for asphalt. By contrast, little research has focused on the preparation process, such as preparation time, preparation temperature and shear rate. The effect of preparation temperature on aging properties of WPE-modified asphalt was investigated in this work. The experimental materials were characterized by infrared spectroscopy (IR), thermo-gravimetric analysis (TG), and differential scanning calorimetry (DSC). The physical properties were determined by conducting asphalt penetration, softening point and ductility tests. The results show that increasing the preparation temperature results in an increased softening point of WPE-modified asphalt while decreased penetration and ductility. In addition, this variation was accentuated by aging the experimental materials. The modification process of WPE is a physical process. During the asphalt modification process, the WPE aged as the preparation temperature increased. The results revealed that 190 °C is the most suitable preparation temperature, and the post aged asphalt demonstrated improved high temperature stability.

1. Introduction

Packaging technology has made a great contribution to daily life, but its by-product, packaging waste, has generated a serious pollution problem. China is one of the world's top 10 producers and consumer of plastic products. The per capita consumption of plastic in China is about 46 kg annually. Statistical data show that the export of plastic products from China reached 4.067 million tons in the first half of 2012[1]. In 2011, the total waste output of Singapore was 0.733 million tons while the recycling rate was 11%[2]. According to a new report by Global Industry Analysts, Inc., global plastics consumption will reach 297.5 million tons by 2015[3]. Plastic wastes are discarded in the environment as waste plastics films, bags or throwaway tableware, and we are increasingly surrounded by these wastes. Plastic wastes are responsible for the visual pollution, and moreover, they are threatening Global ecology, because of their non-degradable molecular structure. In short, waste polyethylene (WPE) is a major source of this pollution.

There has been much effort to develop polymer modified asphalt using a variety of polymers[4–9]. Modification of asphalt using various polymers (e.g. rubber, resins, polymers, grinding rubber powder and other fillers) can be an effective way to decrease traffic noise, reduce maintenance cost, and enhance resistance to cracking and rutting etc.[10,11]. As is well known polymer modification of asphalt does not eliminate the aging problem. These aging processes can adversely impact asphalt properties including high-temperature rutting, low-temperature cracking, and shortening the lifetime of pavement[12–15]. In terms of modified asphalt preparation, mixing temperature can also influence the degree of asphalt aging. The aging process can be effectively delayed by strict control of mixing temperature or by decreasing the oxidation of mixture[16].

In this study, WPE was used as an additive for asphalt modification. The purpose of the research was to determine how the composite preparation temperature affects the aging properties of the WPE-modified asphalt. The temperature of modified asphalt preparation was strictly regulated. As part of this study, the performance of modified asphalt resulting from preparation at various temperatures was analyzed by infrared spectroscopy (IR), thermo-gravimetric analysis (TG), and differential scanning calorimeter (DSC) analysis. The penetration, softening point and low

* 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.2014.04.019

temperature ductility of the aged asphalt were also determined to ascertain the physical and mechanical properties of the composite.

2. Materials and Methods

2.1. Materials

In this work, 90A# asphalt was used as the base asphalt, its properties are shown in Table 1. Recycled WPE was used as the modifier for the experimental composite asphalt materials.

2.2. Preparation of modified asphalt

A JRJ 300-S from the Shanghai Specimen and Model Factory was used as the shearing, emulsifying equipment to prepare the modified asphalts. A series of samples was prepared at various temperatures, specifically: 150 °C, 175 °C, 190 °C and 205 °C, with a stirring time of 1.5 h and a shearing rate of 3700 r/min. The polymer modifier was gradually combined with the base asphalt during the shearing process to ensure that the modifier was uniformly dispersed in the asphalt. The polymer modifier was added to base asphalt at a weight ratio of 4%, i.e., adding 20 g modifier into 500 g base asphalt.

2.3. Aging treatment of the modified asphalt

Asphalt aging in a construction project can be simulated by rolling the material in a thin film oven test (RTFOT). This test can be described as follows: sample bottles were filled with 35 g modified asphalt, then placed in a rolling thin film oven (RTFO), and heated to 163 °C for 85 min. The modified asphalt samples prepared at 150 °C, 175 °C, 190 °C, 205 °C before aging were denoted as A, B, C and D. The modified asphalt samples prepared 150 °C, 175 °C, 190 °C, 205 °C after aging were denoted as A_1, B_1, C_1 and D_1.

2.4. Physical measurement of the modified asphalts

The performance of the physical and mechanical properties of the WPE-modified asphalts was determined using a battery of tests. The measurement of penetration, softening point and low temperature ductility of the pre-and-post aging asphalt were determined employing the GB/T4507-94, GB/T4509-94 and GB/T4508-94, respectively. The low temperature ductility measurement was determined at 5 °C.

2.5. Fourier transform infrared spectroscopy measurements

The modified asphalt infrared spectra were obtained using an Fourier transform infrared spectroscopy (FTIR, SHIMADIU FTIR-8400S (CE)) by casting melted asphalts onto KBr pellets and recording an average of 20 scans at a resolution of 16.0 cm^{-1}.

2.6. TG measurement

Thermo-gravimetric experiments were carried out in a METTLER TOLEDO TGA/DSC 1 analyzer with a Gos Controller GC10 STARe system. TG scans were conducted on asphalt samples ranging from 4 to 10 mg which were placed in an alumina ceramic crucible and heated under nitrogen (flow rate: 100 ml/min) from 100 to 700 °C, using a heating rate of 15 °C/min.

Table 1
Performance index of 90A# base asphalt

Penetration (25 °C, 100 g) (0.1 mm)	Softening point (ring and ball method) (°C)	Ductility (cm)
86.13	51.25	>200

2.7. DSC measurements

Differential scanning calorimetric experiments of the modified asphalts were carried out in a Mettler Toledo DSC823e in a temperature range from 25 °C to 200 °C at a heating rate of 10 °C/min under a nitrogen atmosphere (flow rate: 50 mL/min).

3. Results and Discussion

3.1. Physical indexes analysis

3.1.1. Penetration

Sample penetration at 25 °C was used in this research to indicate the viscosity of asphalt. Fig. 1 shows the effect of temperature on the penetration of 4% WPE modified asphalt. The penetration of asphalt decreased after asphalt aging. As a result, the influence of the asphalt aging event was reflected in the measurement of asphalt penetration in both pre and post aged asphalts. The data indicate that asphalt penetration decreases in pre-aged asphalt samples[17].

Fig. 1 shows that the degree of asphalt aging has a major influence on the penetration of modified asphalt. The longitudinal comparison of the penetration of pre and post aging asphalt shows that the aged asphalt exhibited lower penetration. This result demonstrates that asphalts with higher viscosity reflect less aging. The transverse comparison of the penetration shows that the penetrations of pre and post aging modified asphalt are basically the same. Penetration declined sharply from 150 °C to 190 °C. Although there is a slight increase for the samples prepared at 205 °C compared with the sample prepared at 150 °C, the penetration declined whether the sample was pre or post aged. It is also evident that WPE itself is aging, indicating a hardening of WPE and a loss of its modification effect during the preparation process. It can be concluded that the ranking of anti-aging performance at various temperatures is 150 °C > 205 °C > 175 °C > 190 °C. The penetration of modified asphalt apparently shifted at the preparation temperature of 190 °C.

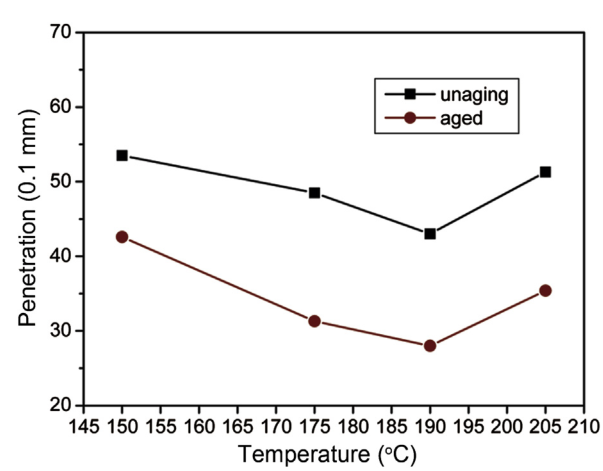

Fig. 1. Effect on the penetration of pre- and post-aging modified asphalt produced at different preparation temperatures.