Construction and Building Materials 47 (2013) 431–440

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

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

Assessment of the digestion time of asphalt rubber binder based on microscopy analysis

Liseane P. Thives [a], Jorge C. Pais [b,*], Paulo A.A. Pereira [b], Glicério Trichês [a], Sara R. Amorim [b]

[a] University Federal of Santa Catarina, Department of Civil Engineering, Rua João Pio Duarte, 88040-970 Florianópolis, Santa Catarina, Brazil
[b] University of Minho, Department of Civil Engineering, Campus of Azurém, 4800-058 Guimarães, Portugal

HIGHLIGHTS

- We study some asphalt rubbers with different crumb rubber types and contents.
- We assess the asphalt rubbers performance-related characteristics.
- We analyze the asphalt rubber surface through scanning electron microscopy images.
- We conclude that the scanning electron microscopy is an important tool for defining the digestion time of asphalt rubber.

ARTICLE INFO

Article history:
Received 30 January 2013
Received in revised form 26 March 2013
Accepted 4 May 2013
Available online 8 June 2013

Keywords:
Asphalt rubber
Crumb rubber
Digestion time
Scanning electron microscopy

ABSTRACT

One of the most promising techniques for increasing the performance of pavement rehabilitation is the use of asphalt rubber mixtures, which utilize crumb rubber from used tires for modifying the asphalt to produce asphalt rubber binder. Crumb rubber can be produced by two different types of grinding, ambient and cryogenic. The asphalt rubber binder used in asphalt rubber mixtures can be obtained through two different processes, terminal blending (produced at a refinery) and continuous blending (produced in a plant). Because the performance of the asphalt rubber binder depends on the elastomeric properties of the crumb rubber, the manufacturing process, especially the digestion time, influences these properties. The digestion time is responsible for the interaction between the crumb rubber and the straight asphalt, which is characterized by the amount of elastomeric properties transferred to the straight asphalt. This paper presents an assessment of the digestion time using conventional performance-related tests and scanning electron microscopy analyses, which examined the surface of asphalt rubber binder. In this study, two straight asphalts with different penetrations and two crumb rubbers, an ambient crumb rubber and a cryogenic crumb rubber, were considered. The asphalt rubber binders studied in this work were produced using different contents of crumb rubber and different digestion times. The objective of this work is to contribute to the assessment of the digestion time of asphalt rubber binder based on microscopy analysis. This paper concluded that scanning electron microscopy is an important tool for defining the digestion time of asphalt rubber binder.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

The disposal of used tires, in addition to other waste sub-products, is a serious environmental problem worldwide. To minimize environmental impacts, used tires have been applied in asphalt pavement through the use of crumb rubber in the modification of asphalt, which yields the asphalt rubber binder that is used to produce asphalt rubber mixtures. Examples for the application of asphalt rubber mixtures have been reported in the literature [1–4] and are defined in several specifications [5–8].

Crumb rubber differs in types and properties. There are more than a few different grades of granulated rubber. The particle size of ground rubber may range from as fine as 0.015 mm to as large as 2.0 mm, depending on the type of size reduction equipment and the intended application.

Crumb rubber consists of finely ground used tires and can be obtained using two methods, ambient and cryogenic grinding [9]. Ambient grinding is a mechanical process performed at ambient temperature in which there is an amount of heat generated while the rubber or tire is being processed to reduce its size. Ambient processing is typically required to provide irregularly shaped, torn particles with relatively large surface areas to promote interaction with the straight asphalt. The ambient grinding process has been widely adopted and is more efficient in obtaining the crumb

* Corresponding author. Tel.: +351 253 510 208; fax: +351 253 510 217.
E-mail address: jpais@civil.uminho.pt (J.C. Pais).

0950-0618/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2013.05.087

rubber. The final product of the ambient grinding process is generally an irregular particle with a high specific surface area. When working with granulators, more regular particles with lower specific surface areas can be obtained [10].

Cryogenic processing uses liquid nitrogen to freeze tire chips until it becomes brittle and then a hammer mill is used to shatter the frozen rubber into smooth particles with relatively small surface areas. These crumb rubber particles have lower specific surface areas than the ones obtained using the ambient grinding process [11,12]. This method is used to reduce particle sizes prior to grinding at ambient temperatures. Cryogenic grinding is a cleaner, slightly faster operation resulting in the production of fine mesh size crumb rubber [7].

Crumb rubber can be used in the modification of the asphalt, producing the asphalt rubber binder or replacing part of the small aggregates in asphalt mixtures [13–17]. The asphalt rubber binder usually has approximately 18–25% crumb rubber. The straight asphalt is initially preheated to approximately 190 °C in a tank under hermetic conditions and is then transported to a blending tank where crumb rubber is added. The digestion process, which is the incorporation of rubber into the conventional binder, continues for a period of 1–4 h at a temperature of 190 °C. The process is facilitated by mechanical agitation produced by a horizontal shaft [15]. This asphalt rubber binder can be used in asphalt mixtures for paving, chip seals, and surface treatments [18,19].

During the mixing of the asphalt with the crumb rubber, chemical and physical changes occur in both the asphalt and crumb rubber that distinguish asphalt rubber binder from a simple mixture of asphalt and crumb rubber. Furthermore, the reaction of asphalt and crumb rubber is affected by the digestion time (the time during which there is an interaction or contact between the asphalt and the rubber at high temperature, usually it is the mixing time of rubber into the asphalt) and temperature, the type and amount of mechanical energy, weight percentage and mesh size of the rubber, and the aromatic content of the asphalt [20–23].

The time and temperature of the digestion of crumb rubber with asphalt are known to have important effects on the resulting asphalt rubber binder [24]. The most significant effect is most likely the absorption of the aromatic oils of the asphalt by the rubber particles. This absorption process causes a softening and swelling of the rubber particles so that a comparatively large proportion of the binder consists of soft rubber. At the same time, the asphalt phase hardens due to the loss of these oils. These changes are all physical changes [25].

Increasing the time and temperature of the digestion of rubber crumb with asphalt improves the binder properties over an observed temperature range of 160–200 °C and digestion periods up to 2 h [25–28].

Incorporating higher contents of crumb rubber into conventional asphalt leads to the production of asphalt rubber binders with low penetration grades, high viscosities, high softening points, and high resiliencies [29–32].

The gain and subsequent loss of viscosity likely includes physical, chemical and thermal causes. The physical effect of adding crumb rubber particles is more pronounced in the early mixing stages, which is followed by a gain in viscosity due to the absorption of light fractions from the base asphalt mixes by the rubber grains. If the process of heat transfer continues further, then the rubber particles might soften, thus resulting in viscosity reduction [33].

The behavior of asphalt rubber binder depends on several factors, such as the origin, fabrication process and grain size distribution of the crumb rubber, the type of base asphalt used in the mixture, and the temperature and time of the mixing or digestion processes. Several authors have investigated the rheological and physical properties of asphalt modified with rubber for rubber contents of less than 20% by weight [11,34,35].

Improvements in rutting resistance, thermal cracking, fatigue damage, stripping, and temperature susceptibility have led asphalt rubber binder to be a viable substitute for conventional asphalt in many paving and maintenance applications, including hot mix, cold mix, chip seal, hot and cold crack filling, patching, recycling, and slurry seal [36–39].

This paper presents an assessment of the digestion time of asphalt rubber binders using conventional performance-related tests and scanning electron microscopy tests, which were used to examine the surface of the asphalt rubber binder. This study was conducted by analyzing two straight asphalts with different penetrations and two crumb rubbers, an ambient crumb rubber and a cryogenic crumb rubber. The asphalt rubber binders investigated in this work were produced using different crumb rubber contents and different digestion times. The objective of this work is to contribute to the assessment of the digestion time of asphalt rubber binders using microscopy analysis.

2. Materials and testing program

2.1. Crumb rubber modifier

In this study, two different crumb rubber modifiers are used. The first crumb rubber was obtained by grinding tires at ambient temperature, whereas the second one was obtained by grinding at cryogenic temperature. The crumb rubber gradation adopted here follows the Arizona Department of Transportation standards [5], as shown in Fig. 1. The ambient crumb rubber has particles ranging from 0.05 mm to 1.2 mm, while the cryogenic crumb rubber particles range from 0.2 mm to 0.8 mm. The differences between these two crumb rubbers are visible in the finer part of the gradation. The particles obtained from ambient grinding are smaller than those obtained by cryogenic grinding (ambient surface area is 19.3 m^2/kg and the cryogenic surface area is 13.6 m^2/kg). The differences in the surface areas between these two types of rubbers are sufficient to produce remarkable differences in the modified asphalt.

Both crumb rubbers were also characterized using X-ray diffraction (Figs. 2 and 3). The use of this technique allowed the chemical composition of each crumb rubber to be identified in the observed region. The elemental compositions of the surfaces of the two rubbers are similar, mainly because both are derived from used tires of cars and trucks. However, the rubber obtained from the cryogenic process presents a larger quantity of carbon. This result may not be associated with the grinding process, but is likely due to the origin, type and composition of the tires. A variety of chemical compounds, such as zinc and iron, are present at different concentrations in rubber tires, as shown by the X-ray diffraction results. Silicon is used in the production of metal alloys,

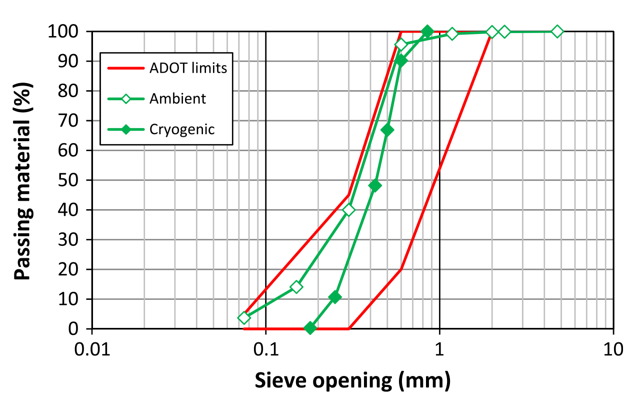

Fig. 1. Crumb rubber gradation.

Download English Version:

https://daneshyari.com/en/article/6725488

Download Persian Version:

https://daneshyari.com/article/6725488

Daneshyari.com