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ScienceDirect

Ciência & Tecnologia dos Materiais 29 (2017) e204–e209

Ciência & Tecnologia dos MATERIAIS

http://ees.elsevier.com/ctmat

Special Issue "Materiais 2015"

Effect of incorporating different waste materials in bitumen

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Abstract

The increasing environmental concern about waste materials and the necessity of improving the performance of asphalt mixtures prompted the study of incorporating different waste materials in conventional bitumen. The reuse of waste materials can present benefits at an environmental and economic level, and some wastes can be used to improve the pavement performance. Thus, the purpose of this study is to evaluate the incorporation of different waste materials in bitumen, namely waste motor oil and different polymers. In order to accomplish this goal, 10% of waste motor oil and 5% of polymers (high density polyethylene, crumb rubber and styrene-butadiene-styrene) were added to a conventional bitumen and the resulting modified bitumens were characterized through basic and rheological tests. From this work, it can be concluded that the incorporation of different waste materials improves some important properties of the conventional bitumen. Such improvements might indicate a good behaviour at medium/high temperatures and an increase of fatigue and rutting resistance. Therefore, these modified bitumens with waste materials can contribute to a sustainable development of road paving industry due to their performance and environmental advantages.

Keywords: Modified bitumen; binder properties; waste materials; waste motor oil; polymers.

1. Introduction

The main problems of asphalt mixtures are rutting and cracking mainly due to the thermal susceptibility and ageing of conventional bitumen [1]. Besides these problems, the increasing traffic volume and loads applied in road pavements could compromise the durability and performance of asphalt mixtures [2,3].

Such factors demonstrate the need of developing binders with improved characteristics in comparison with those of conventional bitumens, or in other words, modified bitumens. The mostly used modifiers or additives in road paving industry are polymers [4]. The polymers decrease the thermal susceptibility and permanent deformation, and increase the resistance to cracking of asphalt mixtures, thus expanding the bitumens' durability and operating temperatures range [5]. The polymer modified bitumens typically have higher elastic response, cohesion, ductility, softening point temperature and viscosity than conventional ones [6,7].

Although polymers are used in small amounts in modified bitumen (the typical percentage is 5% to 6% [5]), the utilization of virgin polymers in bitumen modification has a high cost. Consequently, it is crucial to find an alternative for these virgin polymers, namely by using waste polymers. In fact, the characteristics of a bitumen modified with waste polymers is similar to those obtained when using virgin polymers, and the first solution presents economic and environmental advantages [3]. Some examples of waste polymers already used are ethylene-vinyl acetate (EVA), high and low density polyethylene (HDPE and LDPE) and crumb rubber.

The HDPE is found in packages and plastic bottles and it increases significantly the stability and

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http://dx.doi.org/10.1016/j.ctmat.2016.07.003

durability of asphalt mixtures [8,9]. In turn, the crumb rubber, from used tires, is a waste of fast accumulation and it is difficult to eliminate. When added to bitumen, the crumb rubber decreases the permanent deformation, cracking and reflective cracking [10]. These different waste materials present environmental and economic benefits, and they can improve asphalt mixtures' performance.

Even though the used styrene-butadiene-styrene (SBS) was not a waste material, this polymer is probably one of the most used and suitable for modifying bitumens [1,11]. The SBS improves elastic response and increases rutting and cracking resistance [12]. Moreover, the bitumen modified with this polymer presents lower penetration values and higher softening temperatures [4,13].

Another waste material which can be used as additive in asphalt mixtures is waste motor oil. It is typically used as rejuvenator in recycled asphalt mixtures to restore the initial properties of the aged bitumen of the reclaimed asphalt pavement, namely by adding volatile fraction or maltenes. The motor oil also reduces the bitumen viscosity and the mixing and compaction temperatures [14]. Furthermore, waste motor oil could add value to paving industry if it was used as a partial substitute of bitumen [15].

The aim of this study is to evaluate the effect of incorporating waste materials (waste polymers and motor oil) in bitumen through basic and rheological characterization tests. These modified bitumens with waste materials should be compared to a conventional bitumen and a commercial modified bitumen, in order to identify possible improvements in their behaviour.

2. Materials and Methods

2.1. Materials

The waste materials used in this study were the high density polyethylene, crumb rubber and the motor oil. In addition to these materials, a conventional bitumen and one of the most common polymers applied in paving industry, the SBS, were also utilized.

As regards to the polymers used, the HDPE and SBS were supplied by *Gintegral* and *Indústria Invicta*, respectively, both with a maximum dimension of 4 mm. Moreover, the crumb rubber supplied by *Recipneu* has a dimension of 0.18 to 0.60 mm. In order to obtain the melting and/or glass transition temperatures of the different polymers, differential scanning calorimetry (DSC) tests were performed. The sample of polymer was heated in a range of temperatures of -60ºC to 160ºC, with a heating rate of 10ºC/min. The HDPE presented a melting temperature of 131ºC and the SBS a glass transition temperature of 74ºC. It should be noted that the equipment used (DSC-Diamond Pyris) does not allow to achieve temperatures below -60°C, which made some of the glass transition temperatures impossible to obtain. In fact, the glass transition temperatures of HDPE, crumb rubber and the butadiene block of SBS were impossible to obtain because their values were typically lower than -60ºC [16-18].

The thermal behaviour of the waste motor oil, obtained from heavy vehicles without any kind of treatment, was evaluated with the dynamic viscosity test [19], and is presented in Fig. 1. As expected, the waste motor oil exhibited a very low viscosity, between 0.1 and 0.005 Pa s, over the test temperature range of 30 to 180ºC.

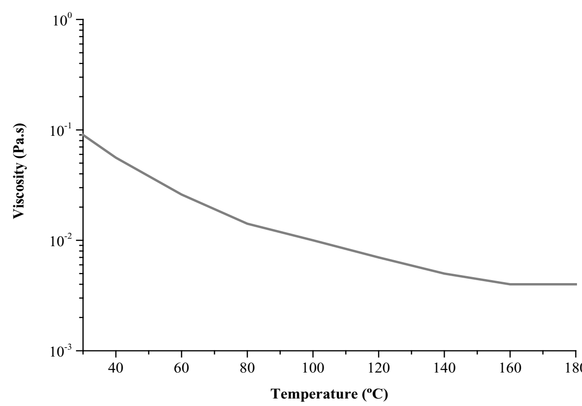

Fig. 1. Dynamic viscosity of the waste motor oil.

The conventional bitumen, used as base and control material in this study, presents a penetration of 46 dmm, a softening temperature of 52ºC and a resilience of 9%. Concerning the commercial modified bitumen Elaster 13/60, also used as a control material, it presented a penetration of 37 dmm, a softening temperature of 66ºC and a resilience of 21%. Both bitumens were supplied by CEPSA Portugal.

2.2. Methods

The production of the modified bitumens was carried out in two phases: 1) firstly, by adding waste motor oil and different polymers (high density polyethylene, styrene-butadiene-styrene and crumb rubber) to the conventional bitumen, using a low shear mixer, in order to obtain an initial blend at a temperature of 180°C; 2) then, those initial blends were placed in a high shear mixer at 7200 rpm, at 180°C, for additional 20 min, in order to grind the polymers and obtain a homogeneous polymer modified binder.