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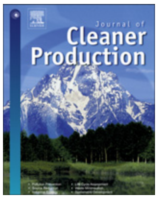

Use of a warm mix asphalt additive to reduce the production temperatures and to improve the performance of asphalt rubber mixtures

Joel R.M. Oliveira [a,*], Hugo M.R.D. Silva [a], Liliana P.F. Abreu [b], Sara R.M. Fernandes [b]

[a] C-TAC, Department of Civil Engineering, University of Minho, 4800-058 Guimarães, Portugal
[b] Department of Civil Engineering, University of Minho, 4800-058 Guimarães, Portugal

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ABSTRACT

Asphalt rubber mixtures are often described as environmentally friendly mixtures due to the incorporation of recycled rubber from used tires and due to their improved service life. In fact, their fatigue cracking and rut resistance properties are better than those of conventional asphalt concrete mixtures. However, asphalt rubber mixtures demand higher production temperatures than conventional mixtures due to the higher viscosity of the asphalt rubber binder. The objective of this paper is to assess the efficiency of using a surfactant based additive in the production of warm mix asphalts, by lowering the mixing temperatures of asphalt rubber and asphalt concrete mixtures without changing their performance. Several laboratory tests were carried out on asphalt rubber and asphalt concrete mixtures, with and without the additive, in order to evaluate and compare the performance of the mixtures. It was concluded that the incorporation of small amounts of a surfactant based additive allowed reducing the production temperatures of both types of mixture by 30 °C without compromising their performance, and this can be seen as a great step forward towards the production of cleaner asphalt rubber mixtures.

1. Introduction

According to Singh et al. (2009), worldwide generation of waste tires amounts to 5 Mt/y, representing 2% of total annual solid waste, and their disposal has proved to be extremely difficult due to their highly resistant chemical, biological and physical properties. The United States (US) discarded around 290 million tires in 2003, and in the same year the European Union (EU) generated approximately 260 million waste tires.

Waste management is critical problem for a sustainable development. In fact, this subject interconnects several areas, not only the environment, but also the economy, the security and other social issues (Hamzah et al., 2010). The need to create more sustainable technologies in the construction industry has lead to the incorporation of waste tires in the production of both concrete and asphalt mixtures. Some examples of the use of ground tire rubber in cementitious materials can be found in the literature in order to reduce the structural weight (Pelisser et al., 2012) and/or evaluate their durability (Richardson et al., 2012; Bravo and de Brito, 2012). Several other studies have been carried out regarding the assessment of the performance of asphalt mixtures with incorporation of crumb rubber obtained from recycled tires in the lab (Fontes et al., 2010; Pasquini et al., 2011) or in the field (Chui-Te, 2008), either using the wet process (Fontes et al., 2010; Pasquini et al., 2011) or the dry process (Moreno et al., 2012, 2011; Weidong, 2007). Other studies were performed to evaluate the use of crumb rubber in reclaimed asphalt pavement (RAP) mixtures (Xiao et al., 2009a) or to assess the acoustic performance of asphalt rubber (AR) mixtures (Paje et al., 2010).

The addition of crumb rubber to virgin bitumen (Peralta et al., 2010) produces binders with improved resistance to rutting (Fontes et al., 2010), fatigue cracking, and thermal cracking while allowing a reduction on the thickness of asphalt overlays and reflective cracking potential (Thodesen et al., 2009; Lee et al., 2008), possibly with the use of specific additives (Miriam, 2009). However, the production temperatures of the resulting AR mixtures are usually very high (Akisetty et al., 2009). Thus, this type of mixture is a potentially successful application of the warm mix asphalt (WMA) technology, as has recently been object of study (Akisetty et al., 2009, 2011; Xiao et al., 2009b).

In fact, in order to reduce the production temperature and, consequently, the energy consumption in the manufacture of asphalt mixtures, a new concept was developed and has been tested and implemented in the last few years. This is the WMA

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* Corresponding author. Tel.: +351 253 510200; fax: +351 253 510217.
E-mail addresses: joliveira@civil.uminho.pt (J.R.M. Oliveira), hugo@civil.uminho.pt (H.M.R.D. Silva), a51302@alunos.uminho.pt (L.P.F. Abreu), a54268@alunos.uminho.pt (S.R.M. Fernandes).

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technology (Rubio et al., 2012) which intends to lower the production temperature, but keeping the mechanical and rheological properties of warm asphalt mixtures as close as possible to those of conventional mixtures (Zhao et al., 2012; Silva et al., 2010a) in order to increase their sustainability, which should be assessed by a Life Cycle Analysis similar to those available in the literature (Huang et al., 2009; Chiu et al., 2008; White et al., 2010).

WMA technology can reduce the temperatures of mixing and application of the mixture by 20–30 °C in comparison to the traditional Hot Mix Asphalt (HMA) (Prowell, 2007), which turns into a reduction on the energy consumption during the manufacturing process (Silva et al., 2009). Moreover, the use of this technology leads to a decrease on the emissions of gases and odors from asphalt plants, and an improvement on the personnel working conditions (Hurley and Prowell, 2005a, 2005b). With respect to gas emissions, there are studies that report reductions of about 30–40% in emissions of CO_2; 35% in emissions of SO_2; 50% in emissions of volatile organic compounds (VOC); 10–30% in emissions of CO; 60–70% in emissions of NO_x and 20–25% in emissions of dust (Prowell, 2007). Another benefit associated to this technology is the possibility of extending the construction season and the time available for compaction of the asphalt mixture during a certain day (Silva et al., 2010b).

WMA technologies can be classified by separating those that use water from those that use organic or synthetic additives to affect the temperature reduction. These methods are based on process engineering, aerogenous agents or special bitumen and additives (Silva et al., 2010b; EAPA, 2007).

With respect to the selection of WMA additives, there is a wide range of options (Xiao et al., 2009b; Silva et al., 2010b; Shang et al., 2011). These additives can be separated in two groups: foaming additives and organic additives (Silva et al., 2010a; Sheth, 2010). On the present article, the additive used comprises surface active agents (surfactants) and was especially developed for WMA applications (Gonzalez-Leon et al., 2009), although this type of agent is essentially used as anti-stripping agents and as asphalt emulsifiers (Al-Sabagh, 2002; DelRio-Prat et al., 2011; Xiao and Amirkhanian, 2010). This additive does not affect significantly the mechanical and rheological properties of bitumen, which occurs with the use of other additives (You et al., 2011; Morea et al., 2012; Xiao et al., 2012), and it acts at the interface between mineral aggregate and bitumen, in an analogous way to a surfactant, at the interface between water and bitumen (Sheth, 2010; Gonzalez-Leon et al., 2009).

The new combination of the mentioned types of technologies (asphalt rubber and surfactant based WMA additive), as presented in the current paper, results in a significant improvement on the production conditions of long-lasting asphalt mixtures, by reducing the temperature at which the mixtures are produced and compacted, improving the personnel working conditions, with the incorporation of very limited amounts of additive.

2. Materials and methods

2.1. Materials

The current paper presents the results of a series of tests carried out on asphalt mixtures that are produced with very hard binders, in this case, asphalt rubber (AR) mixtures, in comparison to conventional asphalt mixtures. Due to the high viscosity of the AR binder, high temperatures have to be used in their production stage to obtain an adequate workability. In order to reduce those temperatures a WMA additive was used, which was selected according to the results of a previous study (Silva et al., 2010b), in which different WMA additives were used to reduce the production temperature of a conventional asphalt mixture.

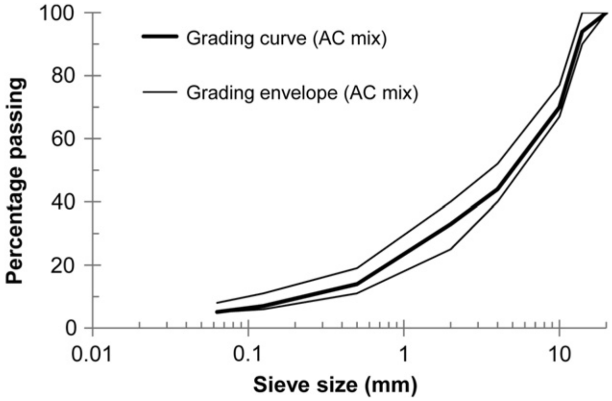

Fig. 1. Grading curve and grading envelope of the studied AC mixture.

The following sections describe the materials used throughout the whole investigation.

2.1.1. Aggregates

All aggregates used in this study are igneous rocks (granite), while the filler is limestone. Each mixture was studied separately in order to fulfil the requirements of the material specifications (Portuguese appendix of EN 13108-1), although they can both be used as a surface course mixture. All aggregates were characterized and their grading curves were analyzed in order to meet the grading envelope of a conventional dense asphalt concrete (AC 14) surface course mixture and a gap-graded asphalt rubber (AR 14) surface course mixture, as can be observed in Figs. 1 and 2.

2.1.2. Binders

The virgin bitumen used in the conventional asphalt concrete (AC) mixture is a straight run 50/70 penetration grade bitumen, since it is one of the most commonly used binders in Portugal. The asphalt rubber binder was produced by adding 21% (by weight of binder) of crumb rubber to the 50/70 pen bitumen, using an overhead stirrer with a blending speed of 500 rpm and a digestion time of 60 min at a temperature of 180 °C, in order to obtain a homogeneous binder. The rubber was obtained from used tires by the cryogenic grinding process and with a maximum nominal size of 0.6 mm.

2.1.3. Warm mix asphalt additive

In the study previously mentioned (Silva et al., 2010b) it was possible to observe that the selected additive would improve the

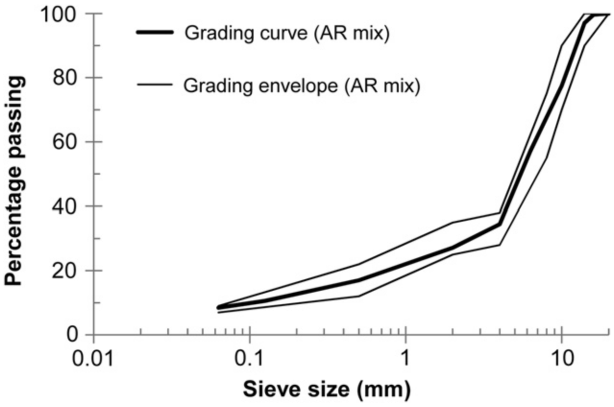

Fig. 2. Grading curve and grading envelope of the studied AR mixture.