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The role of a surfactant based additive on the production of recycled warm mix asphalts – Less is more

Joel R.M. Oliveira [a,*], Hugo M.R.D. Silva [a], Liliana P.F. Abreu [b], Juan A. Gonzalez-Leon [c]

[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
[c] CECA-Arkema France, Centre de Recherche Rhône-Alpes, 69493 Pierre-Bénite Cedex, France

HIGHLIGHTS

- ▶ The surfactant based additive used barely change the properties of the binder.
- ▶ Significant temperature reduction was obtained with very limited amount of additive.
- ▶ No detrimental influence of additive on the water sensitivity of studied mixtures.
- ▶ WMA mixtures have shown similar or slightly improved rut resistance performance.
- ▶ Stiffness and fatigue resistance performance was not affected by the additive.

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ABSTRACT

This study assesses the possibility of reducing the costs of warm mix asphalt (WMA) technology, by applying very small quantities of a surfactant based additive (in comparison to other types of WMA additives) to asphalt mixtures with high percentage of reclaimed materials. Using “less” additive, with “less” energy consumption, gas emissions and natural resources depletion, on the production of recycled mixtures with adequate performance, can be a “more” sustainable solution. Performance tests carried out on asphalt mixtures with 50% RAP, in comparison to a conventional mixture, showed a positive effect of the additive on the performance of the mixtures.

1. Introduction

Sustainable development is, presently, a much discussed topic. In fact, this subject embraces several areas, not only the environment, but also the economy, the security and the social issues. The need to make the asphalt paving technology more ecological, but keeping the mechanical and rheological properties of asphalt mixtures, has recently resulted in the development of the warm mix asphalt (WMA) concept.

WMA technology can significantly reduce the temperatures of mixing and application of the mixture comparatively to the traditional hot mix asphalt (HMA), by 20–30 °C [1]. This reduction of temperature is translated into a reduction on the consumption of energy on the manufacturing process. Moreover, the use of this technology leads to a decrease on the emissions of gases and odors from plants, and an improvement on the personnel working conditions [2–4]. 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 VOC; 10–30% in emissions of CO; 60–70% in emissions of NO_x and 20–25% in emissions of dust [1,5]. Another benefit associated to this technology is the possibility of extending the construction season and the time available for the application of the asphalt mixture during a certain day [6].

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 [6,7].

* 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), juan-a.gonzalez@arkema.com (J.A. Gonzalez-Leon).

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With respect to the selection of WMA additives, there is a wide range of options [4,6,8–10]. These additives used to be separated into two groups: foaming additives and organic additives [11,12]. On the present article, a different kind of additive was used, based on surface active agents (surfactants), especially developed for WMA applications. Other kinds of surfactants are already commonly used for road applications, such as anti-stripping agents and as asphalt emulsifiers [13–15]. The WMA surfactant additive used in this work does not affect significantly the mechanical/rheological properties of bitumen as has been previously observed with the use of other additives [5,6,11]. This additive acts at the interface between mineral aggregate and bitumen, in an analogous way to a common surfactant that places itself at the interface between water and oil [11,16].

Nowadays, WMA is a very important technology for the reduction of energy consumption and gas emissions during the production stage of asphalt mixtures, but it becomes significantly more important, when applied to recycled asphalt mixtures. In the road pavement industry, sustainability is often associated to pavement recycling, where part of the demolition waste (also known as reclaimed asphalt pavement – RAP) is reused and incorporated in the production of new asphalt mixtures. Recycling of asphalt mixtures is increasing due to higher costs of bitumen, scarcity of quality aggregates and environmental issues related to the disposal of aged asphalt mixtures [17–20]. Nevertheless, the amount of RAP used is usually limited, due to the reduction on the asphalt plant productivity and on the performance of the mixture.

Adequate performance of the recycled mixtures is a key issue in order to encourage their generalized use. Several studies have been carried out to assess the performance of recycled mixtures [21,22], but the use of WMA technology in the production of such mixtures is still in its early days. The present paper intends to contribute to the knowledge development in this area, by taking advantage of the particular properties of a surfactant based WMA additive, used in "less" amounts, to reduce the production temperature of recycled mixtures (with up to 50% RAP) and, consequently, improve the performance of the final mixture, making it "more" sustainable.

2. Materials and methods

2.1. Materials

The current paper presents the results of a series of tests carried out on a type of asphalt mixture that contains very hard binders, i.e., hot recycled asphalt mixture. Due to the properties of the binders that result from this type of mixture, namely their viscosity, 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 conclusions of a preliminary study, using a conventional asphalt concrete (AC) mixture.

In the preliminary study, a conventional 50/70 pen grade bitumen and a syenitic aggregate were used (which were imposed by the material availability on a construction site where the WMA technology was to be tested). In the main study (recycled mixture), the same type of bitumen was used, but the new aggregates used were of a different source (granitic) since the first aggregate was no longer available.

The RAP used in the main study was obtained from a National Road in Portugal and the material was milled off from a surface course that was presenting fatigue cracking, after 15 years in service. One of the objectives of this study was to assess the viability of using a high recycling rate (50%) in the production of new bituminous mixtures, without compromising the performance of the mixture, by using an additive that could reduce the production temperature of this type of mixture, without significantly increasing the costs of the mixture (by using the lower quantity of additive possible).

The moisture content could be an issue when producing WMA mixtures at lower temperatures [23–25]. In this work, this issue was assessed regarding the RAP material that may have been exposed to inadequate environmental conditions and is heated at lower mixing temperatures. Thus, two RAP samples were kept in an oven for 24 h at 110 °C, presenting an average moisture content of 0.8%. This value is considered low and was obtained because the RAP material was collected during summer and kept dry at the laboratory, corresponding to the moisture absorbed from the air. The RAP moisture was not considered to be relevant for the present study since the recycling rate used was 50%, i.e., the final moisture content in the mixture will not be higher than 0.4%, and other authors [24,25] showed that there is no significant influence of the aggregates moisture content in WMA mixtures for values up to 0.5%.

The RAP binder content was determined by the ignition method (EN 12697-39), being equal to 6.2%. The WMA additive used throughout the whole investigation was a surfactant based additive, which is described in more detail in the following section.

2.1.1. Surfactant based additive

The additive used in this work, as mentioned before, is a patented formulation of surfactant based molecules (ionic and non-ionic) that were specifically chosen for WMA applications. These formulations, as happens with other surfactants, are capable of changing the interfacial interactions between two different phases. In this case the additives interact at the mineral and bitumen interphase, changing the way the mineral interact between each other. A smaller amount of additive is required to cover the surface of the mineral aggregates than to actually change the properties of the whole volume of bitumen. This is the reason why such a small amount of chemical additive, between 0.3% and 0.6%, is required to produce WMA. At this small concentration of additive, even if it is a liquid with a lower viscosity than hot bitumen, the properties of the bitumen remain mainly unchanged. The viscosity and mechanical properties of the bitumen containing a chemical additive for WMA are not modified by its presence.

The additive used in this work is commercialized under the name of CECABASE® RT 945 by CECA [16]. This additive is actually made out of 27% by weight of renewable raw materials. It is liquid at room temperature and fully compatible with bitumen, which makes it easy to mix into the bitumen. The viscosity of this additive at room temperature (25 °C) is 0.63 Pa s. The amount of additive used in the present study was defined according to the properties of the final binder presented in Section 2.2.1.

2.1.2. Binders

The main bitumen used in the present study was a straight run 50/70 penetration grade bitumen. The two types of bitumen most commonly used in Portugal are the 35/50 pen and the 50/70 pen grade bitumens. The selection criterion was based on the use of a regular bitumen that could be used in the two types of mixture studied. Thus the 50/70 pen bitumen was chosen since it is softer than the 35/50 pen (which is important to reduce the viscosity of the RAP hard binder) and can still be used in the production of conventional asphalt mixtures.

In the preliminary study it was possible to observe that the additive would improve the workability of the mixture, while slightly softening the binder. Thus, it was concluded that this type of additive would be adequate to be used in asphalt mixtures where the binder is an aged bitumen (recycled mixtures), which is the main aim of the present article. In this type of asphalt mixtures, high production temperatures are usually applied, and a reduction on the temperature would mean a significant improvement on the working conditions, the energy consumption and the gas emissions during the production stage. Furthermore, it would result in a lower ageing effect on the final properties of the binder.

In the main study of this investigation, a recycled binder was extracted from a sample of RAP, by means of using a solvent, to separate the binder from the aggregates, followed by binder recovery using the rotary evaporator (according to EN 12697-3 standard). Then, it was characterized using penetration, softening point and dynamic viscosity tests, as explained in Section 2.2.1. The results of such tests are important to assess the properties of the final binder, which was obtained by interaction between the aged bitumen (RAP), the virgin bitumen and the WMA additive.

2.1.3. Aggregates

All aggregates used in this study are igneous rocks, while the filler is limestone. As previously mentioned, in the preliminary study, a syenitic aggregate was used while a granite aggregate was used in the main part of the study (both for the new aggregate and the RAP aggregate). The choice of aggregate type for the preliminary study was imposed by the aggregate availability on the region where a trial pavement section was built to test this type of technology [6].

Although each mixture was studied separately, in order to fulfil the requirements of the material specifications, they are both of the same type (AC14 surf) and should be used as a surface course mixture. All aggregates were characterized and their grading curves were analyzed in order to assess if they would meet the grading envelope of a surface course mixture, as can be observed in Fig. 1. For the remainder of this article, the conventional mixture evaluated in the preliminary study will be named "mixture A" while the recycled mixture will be named "mixture B". The RAP aggregates of mixture B were characterized after the determination of the binder content by the ignition oven test (EN 12697-39).

2.2. Methods

The methodologies used to obtain the results presented in Section 3 are described below. First, the binder content of each type of HMA mixture (conventional and recycled) was determined using the Marshall Mix Design Methodology.