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Warm mix asphalt: Chemical additives' effects on bitumen properties and limestone aggregates mixture compactibility

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Abstract

Asphalt industries consume large amounts of fuels and emit pollutant gases into the atmosphere. Warm mix asphalt is the most recognized way to minimize these negative impacts, which have given rise to numerous issues related to their performance and the materials used. In this study, the basic and rheological properties of three different bituminous binders, modified with two different chemical additives, were evaluated, determining their behaviour and susceptibility to modification. The results showed that, although chemical additives do not affect the binder by reducing its viscosity, they act on the mixture, allowing to improve its compactability and, consequently, reduce the required production and compaction temperatures.

Keywords: Warm mix asphalt; Bitumen; Chemical additives; Behaviour; Additive-binder interaction; Road pavements

1. Introduction

Over the last few years asphalt industry has been looking for new strategies to improve energy performance, reducing costs, but simultaneously guaranteeing the quality of bituminous mixtures [1]. Bituminous mixtures produced at lower temperatures, designated as warm mix asphalt are one of the strategies most explored and evaluated for a long time; according to Kristjansdottir [2] these technologies emerged, led by Professor Ladis Csanyi of the University of Iowa, in 1956, who developed a bituminous mixture introducing foam, taking the first step on foaming technologies. According to the EAPA [3], there are several techniques and products that reduce production and compaction temperatures, ensuring the full coating of the aggregates, and thus the workability and compactability of the bituminous mixture. The most common division separates the warm technologies into chemical additives, organic additives and foaming techniques. Organic additives are usually waxes and fatty amides such as Sasobit®, Asphaltan B and Licomont Bs 100. These products, at temperatures above bitumen's melting point, are able to reduce its viscosity. Chemical additives are often emulsifiers and surfactants, such as Cecabase®, Rediset® and Evotherm. These products are designed to improve the coating of aggregates, acting to reduce the internal friction between the aggregate and binder [4]. Finally, the foaming techniques can be separated into injection foaming nozzles and minerals, both following the same base line: the introduction of small amounts of water into the hot bitumen

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that causes the expansion of the bitumen and the formation of a large quantity of foam, reducing the bitumen viscosity to achieve proper coating of the aggregates [5].

Among these numerous types of technologies and products able to reduce the production and compaction temperatures of bituminous mixtures, the chemical additives have been showing to be most economic and simple to use. González-León et al. [6] performed a study about two fundamental issues that have huge importance, their impact in environment and their effect on workability of mixture; through a chromatographic analysis it was possible to verify a decrease in volatile organic compound (VOC) emissions with the reduction in manufacturing temperature; regarding the workability evaluation, a gyratory compactor was used and the results showed that chemical additive allows to decrease the compaction temperature by 40 °C and improve the compactability of mixture, even with substantial quantities of reclaimed asphalt pavement (RAP). Also Several authors, such as Morea et al. [7], Pérez-Martínez et al. [8] and Adbulla et al. [9], have been proving that the performance of bituminous mixtures modified with chemical additives is similar or, in some parameters, superior to the conventional one. The first authors, Morea et al. [7], verified that the incorporation of chemical additives improve the elastic response of bitumens, a fact observed through a frequency sweep test at low frequencies. Additionally, these additives allowed to reduce the accumulated strain in the end of creep test compared to unmodified bitumen. Pérez-Martínez et al. [8] found that chemical additives, if applied through wet process provide better results, producing mixtures at lower temperatures but ensuring comparable or even superior mechanical behaviour to conventional mixtures, as also Adbulla et al. [9] proved. These authors through rheological tests showed that bitumens modified with chemical additives presented a decrease in $G^*/\sin(\delta)$ values that suggest an improvement of fatigue resistance at medium temperatures. Moreover, these modified bitumens exhibited higher values of surface free energy which could mean better adhesion between the mixture components and, consequently, higher resistance to water action.

The present research about additive–binder interaction was aimed at searching for the effects of chemical additives on the rheological properties of bitumen, evaluating the compatibility between different additives and binders. Since the literature, namely Oliveira et al. [10], indicates that these additives do not change the bitumen properties, including its viscosity, in fact they seem to act at microscopic interface between aggregates and bitumen, reducing friction between these, this study aims to demonstrate that the performance of binders in the bituminous mixtures will not be affected, but that the bitumen–aggregate interaction will be improved. For this purpose, a hard bitumen, conventional bitumen and crumb rubber modified bitumen were characterized before and after the application of additives. In the second phase of the study, one of the chemical additives studied was selected to be tested on the mixture, proving the capability of this product to reduce the production and compaction temperatures of bituminous mixtures.

2. Materials and methods

Next subchapters show the materials selected for this study and the methodology that was used.

2.1. Materials

Bitumens, additives and mineral aggregates will be described in the next subchapters.

2.1.1. Bitumens

For this study three different types of asphalt binder were selected: a hard bitumen with a penetration of 10/20 0.1 mm; a conventional bitumen with a penetration grade of 35/50 and crumb rubber modified bitumen, produced with conventional bitumen of penetration grade 35/50. The selection of such different bitumens aimed to verify the action field of the warm additives evaluated. These bitumens were evaluated in order to understand their behaviour and susceptibility to modification. To simplify the analysis of results, the bitumens were designated as B10/20, B35/50 and CRMB35/50, respectively. Their reference values are shown in Table 1.

2.1.2. Additives

The additives Cecabase® and Rediset®, both chemical, were used. According to their producers these additives are surfactant products that act at the microscopic interface between the aggregates and bitumen, reducing the internal frictional forces and ensuring the workability and compactability of the bituminous mixture produced and compacted at lower temperatures [3]. Fig. 1 shows the aspect of both additives.

Cecabase® (Fig. 1a) is a surface active agent that can be directly applied into the hot binder. Its standard dosage is between 0.2 and 0.5% based on binder weight. This agent, according to its producer, can lower the manufacturing temperatures by approximately 50 °C [11]. This additive is a liquid with a density of about 8.30 lbs/gal and a flash point of 199 °C. According to González-León and Luca [12] this additive helps to avoid a strong adhesion between and aggregates, acting as a lubricant during the mixing, laying and compacting processes. As indicated above, the literature indicates that chemical additives do not affect the properties of bitumen; Silva et al. [13] evaluated the performance of Cecabase® and Sasobit®, verifying that there are no affinity problems with aggregates and only Sasobit® effects the viscosity of bitumen. Regarding the performance of warm mixtures with this additive, Goh et al. [14] performed a study using different additive contents and several tests, such as dynamic modulus, tensile strength, fatigue, flow and rutting. The results showed that the addition of Cecabase® slowed the ageing of mixture, causing the increase in rutting depth, but the remaining

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