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Foamed bitumen: an alternative way of producing asphalt mixtures

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Abstract

With the constant need to improve and make the production of asphalt mixtures more sustainable, new production techniques have been developed, the implementation of which implies the correct knowledge of their performance. One of the most promising asphalt production techniques is the use of foamed bitumen. However, it is essential to understand how this binder will behave when subjected to the expansion process. The loss of volume of the foamed bitumen could be translated by a decay curve, which allows to determine the ideal temperature and water content added to the bitumen in order to assure adequate conditions to the mix the bitumen with the aggregates. On the present study, a conventional 160/220 pen grade bitumen was tested by using different temperatures and water contents, and it was concluded that the optimum temperature for the production of foamed bitumen (with the studied bitumen) is 150ºC, which corresponds to a viscosity of 0.1 Pa.s. The water content mostly influence the half-life of the bitumen foam, resulting in quicker volume reductions for higher water contents.

Keywords: Warm mix asphalt; foamed bitumen; asphalt mixtures; bitumen foaming characteristics.

1. Introduction

The asphalt pavement industry has been more concerned with the environment in the last years. The need to mitigate the negative impact of the road construction on the environment has resulted in a high number of new techniques that reduce the adverse effects of the production of asphalt mixtures.

The asphalt mixtures comprise about 95% of mineral aggregates and 5% of bitumen. Due to its viscoelastic nature, bitumen presents a liquid form when heated up to temperatures around 150ºC and a solid form at ambient temperatures. Thus, the production of asphalt mixtures has traditionally been made using high temperatures to be able to work with the bitumen. These temperatures are even higher when the mixtures incorporate reclaimed asphalt materials. The need to mitigate the influence of the production in the ageing of bitumen results in the use of different heating temperatures of the aggregates and reclaimed materials [1,2].

The utilization of high temperatures to the production and application of new asphalt mixtures also cause a high level of GHG emissions. For that reason, the industry has been developing techniques to reduce the production temperatures of the mixtures. This type of mixtures are normally classified as half-warm or warm mix asphalts. The classification of half-warm mixtures is given to mixtures produced between 70 and 100ºC, and the warm mixtures are produced between 100 and 140ºC [3].

A significant number of advantages can be associated to the use of warm mix asphalt (WMA) in a global perspective, i.e., without differentiating between the techniques applied. The reduction of production temperature reduces the gas emissions and the energy

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consumption, while improving the working conditions [4]. Associated to those main advantages, others can be mentioned, namely, the cost reduction associated to the lower energy consumption, the increase on the transport distances due to the lower compaction temperatures [5], and could also extend the paving windows [6], with the mixtures being applied in conditions worse than those of hot mix asphalts (HMA).

WMA mixtures can be produced by different techniques, using organic or chemical additives or foaming processes [7]. The latter can be obtained by water-containing technologies or by water-based technologies [6]. Water-containing technologies are obtained by incorporating additives which include water in their composition, while, in the water-based technologies, the water is injected into the hot bitumen in small quantities and immediately added to the aggregates in the asphalt mixing chamber [4]. This process is normally more technically complex and requires a relatively large financial investment for plant modifications.

To the production of foamed bitumen by direct injection of water, the air and the water are injected in the bitumen as show in Fig. 1.

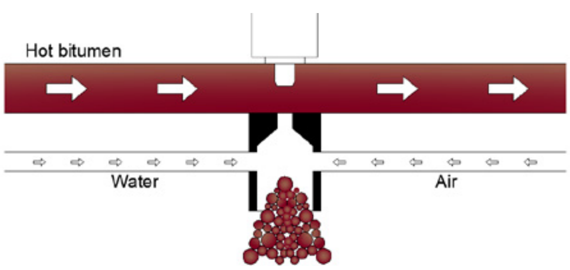

Fig. 1. Schematic procedure of producing foamed bitumen (adapted from [11]).

Jenkins [8] mentioned that the foamed bitumen process is analogous to a baker beating an egg, which is viscous, into foam of low viscosity before mixing it with flour. The beaten egg increases in volume, which is necessary in order to evenly distribute it among the flour and produce a mix of acceptable quality and consistency. Similarly, the foamed bitumen increases in volume, facilitating a good bitumen distribution over the aggregates.

The two basic characteristics of foamed bitumen are the maximum expansion ratio (ERmax) and the half-life (HL). The expansion ratio (ER) is the ratio between the volume of the bitumen in a specific time and the initial volume; the ERmax is the maximum value of the ER, immediately after injection. The HL is the time measured between the moment that the foamed bitumen reaches its maximum volume and the moment it reaches half of that value. Jenkins [8] also mentions the foam index (FI) as a characteristic that should be used to choose the ideal conditions for the expansion process. The FI is obtained by applying a theoretical expression to the decay curve, and calculating the area of the graph between the decay curve and a lower limit associated with the adequate viscosity of the bitumen to be mixed with the aggregates. In terms of the decay curve (DC), this is the representation of the evolution of the ER as a function of the elapsed time.

The expansion characteristics of the bitumen is influenced by different parameters. Some studies mention that a softer bitumen, combined with high temperatures, have better results than a harder bitumen [9]. However, other study mentions that the viscosity is one of the most important parameters, i.e., different bitumen foamed at equiviscous temperatures will have identical characteristics [10].

For the present study, only one bitumen was analysed, but with different water contents and temperatures, in order to understand the influence of that type of variables on the bitumen decay curve.

2. Materials and Methods

The material used in this study was essentially a 160/220 pen grade bitumen. This bitumen has been chosen taking into account the literature review that mentions that softer bitumens have generally better foaming results.

To the production of foamed bitumen, a Wirtgen WLB 10 S machine was used. This equipment has been developed to a laboratory scale with the objective of making the analysis of FB characteristics in small scale possible, but it is similar to the equipments used in normal scale [11]. In order to reduce the number of variable under study, the air pressure was maintained with the default value (5.5 bar; 550 kPa), the temperature of all components of the machine were adjusted to the same temperature of the bitumen and a nozzle with 2 mm of diameter (capable of injecting 50 g of bitumen per second) was selected.

2.1. Basic characteristics

Regarding the basic characteristics of the bitumen, penetration (EN 1426) [12], softening point (EN 1427) [13] and dynamic viscosity (EN 13302) [14] tests were carried out. To complete the analysis of the bitumen,