Construction and Building Materials 135 (2017) 104–111

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Study of the porous asphalt performance with cellulosic fibres

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HIGHLIGHTS

- Porous asphalt presents a fine pellicle of bitumen in the aggregates coating.
- Cellulosic fibres avoid the binder drainage.
- The cellulosic fibres addition in porous asphalt is an eco-friendly solution.
- Porous asphalt with cellulosic fibres show good results to permanent deformation.

ARTICLE INFO

Article history:
Received 20 September 2016
Received in revised form 15 December 2016
Accepted 30 December 2016

Keywords:
Cellulosic fibres
Porous asphalt
Particle loss
Stiffness
Water sensitivity
Permeability
Wheel Tracking

ABSTRACT

The porous asphalt (PA) use in road pavements surface layers is one of the most common solutions worldwide to address the climate changes impact like heavy rain. The aim of this study is to evaluate the performance of these mixtures with the cellulosic fibres addition, known for their adherence capacity between the aggregates and the binder. These will help to prevent the binder loss by drainage, which is one of the main problems of porous asphalt, since the fine aggregates content is reduced. Comparing to the conventional porous asphalt the cellulosic fibres addition improved performance to permanent deformation.

1. Introduction

The cities growth, relating to population and infrastructures, has been leading to a progressive soil waterproofing [1]. This, associated with extreme climate changes, increases the floods and droughts associated risks, since it reduces the most favourable area for water infiltration [2,3]. This occurrence affects the urbanization hydrologic factors by increasing the surface runoff, the water quality deterioration and concentration of pollutants, reducing groundwater recharge [4–9]. The porous asphalt use in surface layers of road pavement is one of the solutions used worldwide to decrease the caused effects.

The porous asphalt can be applied both in conventional pavements with impermeable base layer, and also in permeable pavements with a fully constituted structure by porous layers [10–13].

In addition to the effects associated to surface runoff improvement, the application of these mixtures allows the decrease of the urban heat island effect, reduce the tires noise, the surface runoff and, consequently, the spray effect and aquaplaning, leading to a safer driving [14–16]. Noise reduction is also improved by the increase of porous asphalt air voids content with the help of the aggregates optimized sieve line [17,18]. Their disadvantages are, on the one hand, the load capacity reduction, mainly in permeable pavements, and on the other hand, periodic maintenance due to clogging, concerns that still are an investigation object [19–24].

The porous asphalt first generations were produced with high binder percentages to allow a better connection between the aggregates, emerging however, its hardening problem due to the mastic low amount [17]. Thus, nowadays, there are used polymer modified bitumen with differentiating characteristics, such as elasticity, aging resistance and plastic deformations, good adhesiveness with the aggregates and the low thermal susceptibility [25–27].

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http://dx.doi.org/10.1016/j.conbuildmat.2016.12.222
0950-0618/

The problems related to environmental issues have motivated the research about eco-friendly materials. This fact combined with the relatively high binder percentage and with the need to improve the mixtures durability has led to the additives incorporation like the fibres, not only in asphalt mixtures but also in stone matrix asphalt and asphalt concrete. A wide variety of fibre types has been used in asphalt mixtures, including cellulose, mineral, synthetic polymer, glass fibres, newsprint, carpet fibres and recycled tire fibres [28–36]. Cellulosic fibres are the most commonly used additives [37–42]. The current study uses cellulosic fibres to improve porous asphalt performance. These fibres present a set of important advantages, such as wide availability at relatively low cost, recycling ability, biodegradability, non-hazardous nature, zero carbon footprint, and interesting physical and mechanical properties (low density and well-balanced stiffness, toughness and strength) [43,44]. One of the main objectives of cellulosic fibres is to stop binder drainage preventing its loss during storage and transport [45].

Thus, this research objective is to evaluate the porous asphalt performance incorporated with cellulosic fibres compared to porous asphalt without cellulosic fibres, named conventional. The mix design was initially performed for the four mixtures studied and the percentage influence of the fibres to be used. Subsequently, the performance was evaluated through laboratory tests of indirect tensile stiffness modulus, water sensitivity, permeability and permanent deformation. With this solution it is intended to develop resilience and adaptation better practices to the increase of extreme climate changes and respond to the sustainability current demands, through the eco-friendly materials use.

2. Materials and methods

The study began with the used materials characterization in the porous asphalt production. Then, it was performed the mix design study through the Cantabro test. Finally, the performance tests described in methods were performed.

The surface layer solution proposed in this article consists of a double porous layer in order to improve surface runoff and reduce the clogging problem [21,25]. Thus, in practice, it is first applied layer with coarse aggregate, which increases the air voids content, then the layer with fine aggregate that offers greater comfort to the wearer, reduces noise and at the same time has drainage capacity [25]. These two mixtures were produced without cellulosic fibres (PA01 with fine aggregate and PA02 with coarse aggregate) and with cellulosic fibres (PA1 with fine aggregate and PA2 with coarse aggregate).

2.1. Materials

This paper presents the four porous asphalt mixtures study composed of granitic origin natural aggregates, fillers, polymer modified bitumen and cellulosic fibres as an additive.

2.1.1. Additive

The cellulosic fibres used are granules made of natural cellulose fibres with bitumen mixture, traded with the name of Viatop Premium by JRS, J. Rettenmaier & Söhne. Viatop Premium is a pelletized blend of 90% by weight of ARBOCEL ZZ 8/1 and 10% by 50/70 bitumen weight. These fibres may be used as additives in bituminous mixtures, in order to improve their characteristics, increasing its durability and performance. The fibres bituminous coating guarantees a quick and complete dispersion in the mixture having a stabilizing effect due to a dense three-dimensional fibre network. Since the porous asphalt has a structure with few fines and, consequently, a smaller contact surface between the coarse aggregates, the use of cellulosic fibres aims to increase the amount of mixture bitumen without checking drainage. These allow, on the one hand, the bituminous binder retention and, on the other hand, help the aggregates coating, meaning the formation of a bituminous layer with constant thickness. Thus, cellulosic fibres avoid the mastic efficacy loss. The detailed characterization is presented in Table 1.

Table 1
Cellulosic fibres Viatop Premium characteristics.

Granulated characteristics	
Aspect	Cylindrical granules
Fibres content	87 to 93%
Granules average length	2 to 8 mm
Granules average diameter	5 ± 1 mm
Bulk density	440 to 520 g/l
Particle size distribution, # <4,5 mm	max. 10%
Bitumen characteristics included in the granulated	
Penetration (EN 1426) a 25 °C	50/70 (0.1 mm)
Softening point (EN 1427)	46/54 °C
Fibres characteristics	
Basic composition	Technical cellulose fibre
Cellulose content	80 ± 5%
pH value (5 g/100 ml)	7.5 ± 1.0
Fibre average length	1100 μm
Fibre average diameter	45 μm
Particle density	480 kg/m^3

2.1.2. Binder

The binder used in the porous asphalt production was PMB 45/80 Polymer Modified Bitumen, traded with the name of Elaster BM-3b, by CEPSA Portuguesa Petróleos, SA, indicated for porous asphalt and stone mastic asphalt use. This modified bitumen was obtained by a chemical reaction between a hydrocarbon binder and an elastomeric polymer, according to EN 14023 standard. The range of temperatures recommended for the mixing is between 155 to 165 °C and the compacting is between 150 to 160 °C.

The bitumen characterization was based on the penetration test (EN 1426), with measured penetration value of 53 dmm, the softening point test (EN 1427), with measured value of 63.2 °C, and elastic recovery (EN 13398) with a result higher than 70%.

2.1.3. Particle size distribution determination

This investigation was developed with natural aggregates of granitic origin due to these materials abundance in the central region of Portugal. The used granites were of different fractions (stone dust, 5/10 gravel and 5/15 gravel). In addition, all mixtures

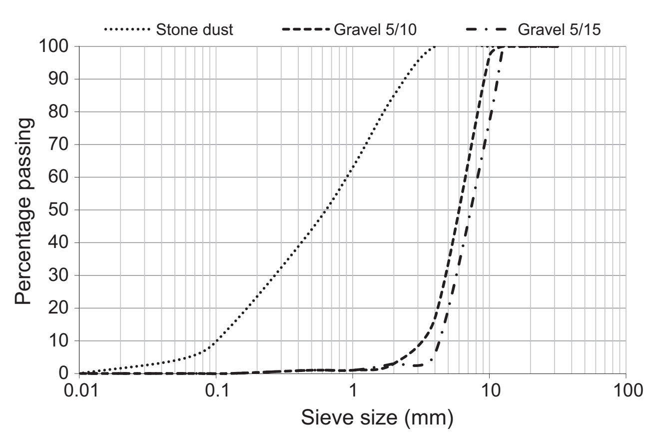

Fig. 1. Aggregates grading curves.