Construction and Building Materials 172 (2018) 166–175

Contents lists available at ScienceDirect

Construction and Building Materials

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

A laboratory study of high-performance cold mix asphalt mixtures reinforced with natural and synthetic fibres

Hayder Kamil Shanbara [a,c,*], Felicite Ruddock [b], William Atherton [b]

[a] Department of Civil Engineering, Faculty of Engineering and Technology, Liverpool John Moores University, Henry Cotton Building, Liverpool L3 2ET, UK
[b] Department of Civil Engineering, Faculty of Engineering and Technology, Liverpool John Moores University, Peter Jost Centre, Liverpool L3 3AF, UK
[c] Civil Engineering Department, College of Engineering, Al Muthanna University, Sammawa, Iraq

HIGHLIGHTS

- Novel cold mix asphalt mixtures reinforced using natural fibres.
- Significant improvement in mechanical properties of the reinforced CMA is revealed.
- Mechanical properties of the reinforced CMA are comparable to the HMA.

ARTICLE INFO

Article history:
Received 1 December 2017
Received in revised form 26 March 2018
Accepted 27 March 2018

Keywords:
Cold mix asphalt
Emulsion
Mechanical properties
Natural fibre
Reinforcing
Surface course
Synthetic fibre

ABSTRACT

This research aims to examine the impact of using natural and synthetic fibres as reinforcing materials, on the mechanical properties and water susceptibility of cold mix asphalt (CMA) including indirect tensile stiffness and resistance to rutting, cracking and moisture damage. Four different types of fibres were used: glass as a synthetic fibre, and hemp, jute and coir as natural fibres. Various samples of CMA, with and without fibres, were fabricated and tested. Traditional hot mix asphalt (HMA) was also used for comparison. The results indicate a significant improvement in the indirect tensile stiffness modulus, for all fibre-reinforced CMA mixtures, over different curing times. The improved tensile behaviour represents a substantial contribution towards slowing crack propagation in bituminous mixtures, while scanning electron microscopy analysis confirmed the fibre shape and surface roughness characteristics. The improved performance of the reinforced mixtures with both natural and synthetic fibres, facilitated a substantially lower permanent deformation than traditional hot and cold mixtures at two different temperatures (45 °C and 60 °C). When using glass and hemp fibres as reinforcing materials, there was a significant improvement in CMA in terms of water sensitivity. Resistance to surface cracking was also improved when fibres were incorporated. Based on the test results, 0.35% fibre content by mass of dry aggregate and 14 mm fibre length are recommended to achieve the optimum performance output for indirect tensile stiffness.

1. Introduction

Asphalt mixes are composite materials that mainly consist of asphalt as a binder, aggregate and voids. They have generally been used as a material for constructing flexible road pavements because of the good adhesion that exists between binder and aggregates [1]. However, due to increasing traffic volume in terms of traffic load repetitions, high and low temperatures and water sensitivity, various types of distresses can appear on the surface of flexible pavements, such as rutting (permanent deformation), segregation and cracking. The perfect flexible pavement design should be durable, strong and resistant to permanent deformation and cracking, thus resisting these types of failures, or at least delaying future pavement deterioration. Although bituminous mixtures with additives such as polymers, crumb rubber and natural rubber have previously been used in an attempt to overcome deterioration, permanent deformation and fatigue cracking problems still exist. These problems occur because the tensile and shear strength of bituminous layers are weak [2]. Reinforcing bituminous mixtures is one of the methods used to improve their tensile strength and engineering properties, especially when conventional mixes do not meet traffic, environmental and pavement structure requirements, as mentioned in [3,4].

* Corresponding author at: Department of Civil Engineering, Faculty of Engineering and Technology, Liverpool John Moores University, Henry Cotton Building, Liverpool L3 2ET, UK.
E-mail address: H.K.Shanbara@2014.ljmu.ac.uk (H.K. Shanbara).

https://doi.org/10.1016/j.conbuildmat.2018.03.252
0950-0618/© 2018 Elsevier Ltd. All rights reserved.

Fibre reinforcement improves fatigue life and retards future rutting by increasing resistance to cracking and permanent deformation. Different types of fibres are used to enhance the engineering properties of bituminous mixes to achieve this [5]. These fibres have desirable properties and are used to reinforce other materials which also require such properties [6–10]. There is a better chance of improving the tensile strength and cohesion of asphalt mixtures by using fibres which have high tensile strength, as compared to asphalt mixtures alone [11]. The essential roles of these fibres as reinforcing materials, are to increase the tensile strength of the resulting mixtures and provide more strain resistance to fatigue cracking and permanent deformation [5]. Draining-down of asphalt concrete mixtures is prevented by using fibres, rather than polymers, during the paving and transportation of materials, therefore, fibres are specifically recommended [12,13]. In addition, fibres improve the viscosity of asphalt mixtures [10], resistance to rutting [14–16], stiffness modulus [17], moisture susceptibility [10] and retard reflection cracking for pavements [18,19].

Currently, synthetic and natural fibres are used as reinforcing materials in Hot Mix Asphalt (HMA). Synthetic fibres such as carbon, polymer and glass, have high tensile strength in comparison to bituminous mixtures, therefore, using such fibres to reinforce asphalt mixtures has the potential to help develop resistance to rutting and creep compliance [20], moisture susceptibility [21], stiffness modulus [22] and freeze–thaw resistance [23]. Natural fibres (plant based), which are annual renewable sources, are also used to reinforce the polymer matrix. The natural framework component of these fibres are cellulose, hemicelluloses, lignin, pectin and wax [24]. These components provide certain benefits such as high strength, acceptable thermal properties and enhanced energy recovery [20].

The overall objective of this study is the laboratory investigation of the performance of a range of natural and synthetic, fibre-reinforced Cold Mix Asphalt (CMA) mixtures. These mixtures are also compared with traditional cold and hot mix asphalt mixtures, and with CMA mixtures containing synthetic fibres as a reinforcing material.

2. Cold mix asphalt (CMA) reinforcement

CMA is an emulsified asphalt mixture that can be produced at ambient temperatures and is used in roadway construction. To date, it has been considered as an inferior mixture, in comparison to HMA, because of low early stiffness, a long curing time needed to reach its final strength and higher air voids content. Therefore, it is necessary to find a method to improve the performance of such mixtures, extending service life and reducing mixture difficulties, so that it can be used in the place of HMA, in any situation and under a range of environmental conditions. The addition of fibres to bituminous mixtures as a reinforcing material, may constitute an interesting method to achieve this goal.

Reinforcement can be defined as incorporating materials which have specific properties, within other materials that lack said properties [25]. The primary purpose of fibres as a reinforcing material, is to provide additional tensile and shear strength in the resulting mixtures and then to develop an appropriate amount of strain resistance during the rutting and fatigue process of the mixture [5]. Fibres in bituminous mixtures also have the ability to decrease the drain-down of those mixtures [26], at the same time increasing ductility due to enhancement of their mechanical properties [27]. Fibre reinforcing bituminous mixtures work as a crack barrier by carrying tensile stresses to prevent the formation and propagation of cracks [28]. Ferrotti et al. [29] conducted research on the experimental characterisation of a high-performance CMA mixture reinforced with three different synthetic fibres; cellulose, gals-cellulose and nylon-polyester-cellulose. Different curing times of 1, 7, 14 and 28 days were investigated under two conditions, wet and dry. The testing procedures included Marshall, indirect tensile, abrasion and compactability. Within 7 days curing time, mixtures containing 0.15% cellulose fibre, were found to have a better performance than the conventional mixture at 28 days curing. Based on literatures [1,2,5,8,11,12], fatigue life and property of asphalt mixtures can be enhanced by fibre addition.

3. Materials and experimental program

3.1. CMA mixtures

CMA mixtures consist of both coarse and fine crushed granite aggregates, traditional mineral filler (limestone) and cationic, slow-setting, bituminous emulsion (C50B3). An aggregate blend gradation of 14 mm, close-graded surface coarse, was used in accordance with BS EN 933-1 [30], as shown in Fig. 1. The cationic slow-setting emulsion was used as a binding agent for the aggregates. It is a cold asphalt binder (CAB 50) based on a 40/60 penetration grade bitumen, the bitumen residual content being 50%. A traditional binder consisting of 100/150 penetration grade bitumen, with a softening point of 43.5 °C, was used for the conventional hot mix asphalt mixture.

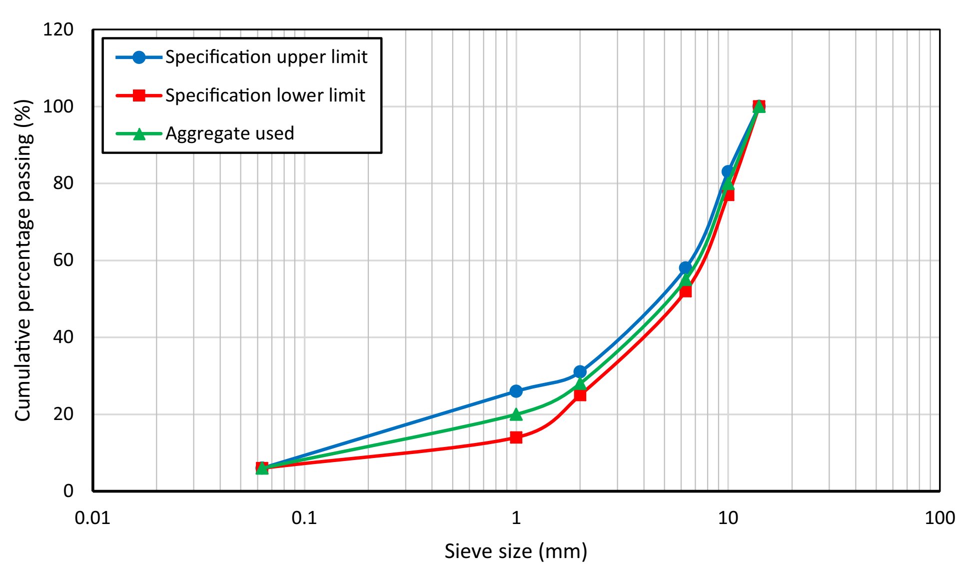

Fig. 1. 14 mm close graded surface course.