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ScienceDirect

Procedia Engineering 172 (2017) 239 – 246

Procedia Engineering

www.elsevier.com/locate/procedia

Modern Building Materials, Structures and Techniques, MBMST 2016

The influence of binding agents on stiffness of mineral-cement-emulsion mixtures

Bohdan Dołżycki*, Mariusz Jaczewski, Cezary Szydłowski

Gdansk University of Technology, Narutowicza 11/12, 80-233 Gdańsk, Poland

Abstract

This paper attempts to determine the behavior of mineral-cement-emulsion mixture (MCE) under load, whether is it similar to asphalt mixtures (viscoelastic behavior) or to cement treated materials (elastic behavior). To answer this question nine mineral-cement-emulsion mixtures with different combinations of cement and emulsion content were tested in laboratory using Simple Performance Test (SPT). For each mixture stiffness moduli and phase angles were assessed for three different temperatures (4, 20 and 40 deg. C) and 9 load frequencies. Conducted tests revealed complex behavior of mineral-cement-emulsion mixes, which is intermediate between elastic and viscoelastic. Opposite combinations of cement and emulsion content showed either more elastic or more viscoelastic behavior. This article presents stiffness moduli and phase angles determined for all 9 mixtures and analysis of this results. The increase of cement content leaded to more elastic behavior (higher values of stiffness moduli and lower values of phase angles) and increase of emulsion content leaded to more viscoelastic behavior (lower values of stiffness moduli and higher values of phase angles). Nonetheless mineral-cement-emulsions mixtures showed more viscoelastic behavior, as their properties change significantly with the change of temperature, but their behavior is not as viscous as in asphalt concrete, as their maximum phase angle is much lower than typical for asphalt concrete.

Peer-review under responsibility of the organizing committee of MBMST 2016

Keywords: viscoelastic materials, mineral-cement-emulsion mixtures, stiffness modulus, phase angle.

* Corresponding author. Tel.: +48 58 348 61 28; fax: +48 58 347 10 97.
E-mail address: bohdan.dolzycki@wilis.pg.gda.pl

Peer-review under responsibility of the organizing committee of MBMST 2016
doi:10.1016/j.proeng.2017.02.103

1. Introduction

Deep cold in-place recycling is one of the most commonly used type of recycling of existing old flexible pavements. Different types of binding agents and their combinations are used for cold in-place recycling. In Poland the two most commonly used technologies are mineral-cement-emulsion mixtures (MCE) and mixtures with combination of foamed bitumen and cement. This two type of mixtures are described with details by Dołżycki [1], Kukiełka [2] and Iwański et al. [3].

The two main binding agents used in mineral-cement-emulsion mixtures are cement and emulsion. The reclaimed asphalt pavement used in MCE mixtures, which usually originates from old, low quality and highly deteriorated roads, has low durability. On the other hand, the requirements stated for the mixture, especially in the case of strength are very high. All this results in high amount of binding agents added to the mixture, especially cement. This approach is used in Poland [4] and neighboring countries, like Germany [5].

The properties of MCE mixture strongly depend on the proportions and interactions between the two used binding agents (Theyse et al. [6], Bocci et al. [7]). The addition of emulsion influences the increase of viscous behavior (the pavement acts more as a flexible pavement), the increase of internal integrity, decreases the risk of shrinkage cracking, increases the resistance to water and frost action and increases the fatigue life of the pavement. The excessive amount of emulsion results in decreasing the stiffness modulus of MCE mixture. The addition of cement influences the increase of stiffness modulus, tension strength and the resistance to water and frost action. Additionally it allows to achieve quite high beginning strength of MCE mixture, what is desirable for optimum usage of reconstructed pavement for the purpose of technological traffic. It also fastens the dissolution of asphaltic emulsion. On the other hand, the addition of cement increases the shrinkage of embedded mixture, what can result in shrinkage cracks of MCE layer and in the consequences in reflective cracking of asphalt layers of pavement. This problem was described by Chomicz-Kowalska et al [8], Uzarowski et al [9].

The properties of the MCE mixture are resultant of the combination of two binding agents, which are responsible for two different types of chemical bonds. Asphaltic emulsion generates asphaltic bonds, which are responsible for flexible behavior of the embedded layer. Cement generates hydraulic bonds, which are responsible for the stiffness of the layer. The behavior of the MCE layer is decided by the dominating type of bond. Asphaltic bonds should be dominating in designed MCE mixtures, as they are responsible for decreasing the risk of shrinkage cracking. On the other hand, hydraulic bonds, which are responsible for the resistance to the weather conditions, shouldn't be completely omitted.

The main aim of this study was to evaluate the influence of particular binding agents on the stiffness modulus of the MCE mixtures and the formulation of the limit of hydraulic bonds.

2. Materials

The stiffness of MCE mixtures depends on gradation of mineral mixture, the amount and type of bitumen in reclaimed asphalt pavement and on the combination of the used binding agents. To assess the influence of used binding agents the MCE mixture was designed according to Polish recommendation [4]. Single grading curve was designed on the basis of reclaimed asphalt pavement, continuously graded 0/31,5 mixture and 0/2 fine aggregate. The proportions of used aggregates are presented in Table 1 and the grading curve is presented on Figure 1. Designations of MCE mixtures were chosen as follows: "C" indicates the amount of cement and "E" indicates the amount of asphaltic emulsion. For example MCE mixture with 2% of cement and 4% of asphaltic emulsion is designated as C2E4. The tests were conducted for 9 combinations of binding agents: 2%, 4% and 6% of each binding agent. Used combinations and mixtures designation are presented in Table 2.

Table 1. The composition of used MCE mixtures.

Mineral mixture		
C2	C4	C6