Construction and Building Materials 147 (2017) 478–487

Contents lists available at ScienceDirect

Construction and Building Materials

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

Comparison of low-temperature cracks intensity on pavements with high modulus asphalt concrete and conventional asphalt concrete bases

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HIGHLIGHTS

- High modulus (HMAC) and conventional asphalt (AC) concretes were compared.
- We considered low-temperature cracking of pavements being in normal service.
- The statistical method based on the ordered logistic regression model was used.
- Pavements with HMAC belongs to group of cracked pavements with 2.45 times higher odds.

ARTICLE INFO

Article history:
Received 24 March 2016
Received in revised form 21 February 2017
Accepted 24 April 2017

Keywords:
High modulus asphalt concrete
Low-temperature cracking
Logistic regression model
Field investigations

ABSTRACT

High modulus asphalt concrete (HMAC) base courses provide very good resistance to rutting and fatigue but they can increase the risk of low-temperature cracking as compared with conventional asphalt concrete (AC). The article presents the comparison of these two road materials in terms of low-temperature cracking. The statistical method based on the ordered logistic regression model was used. The analysis was based on results of field investigations, that was carried out on 80 selected road sections being in normal service in Poland. The intensity of low-temperature cracking was an analysed parameter. The results of the analysis indicated evident effect of asphalt base type on intensity of low-temperature cracking. Besides the effect of mixture type, the method included influence of climatic condition and pavement age on low-temperature cracking. The essence of the analysis was to compare the probabilities of being of pavement in the group with a given cracks intensity. It was revealed that pavements with high modulus asphalt bases had 2.45 times higher odds of being in the group of cracked pavements than pavements with conventional asphalt concrete bases.

1. Introduction

1.1. Background

High modulus asphalt concrete (designated in literature as HMAC, HiMA or EME) was developed in France in 1980s [1]. As compared to conventional asphalt concrete (AC) it contains harder grade bitumen and more dense structure what results in higher stiffness modulus. Pavements with HMAC base provided very good resistance to rutting and fatigue. Usage of HMAC base in pavement structure allows to reduce the thickness of the asphalt layers up to 25% [1–3] in comparison to pavement structure with typical asphalt concretes, while the fatigue life remains unchanged, what can result in significant savings during pavement construction. Good performance encouraged other countries to implement HMAC technology on their own road network.

In certain countries the technology of HMAC was implemented with the full compliance with French standards [4–6], in others with some modifications [7,8]. However modifications of French standards could lead to excessive premature distresses of pavement. Premature distresses appeared on trials sections in UK and were precisely described in research [9,10]. In Poland [11] as well as in the Baltic countries [12,13] the HMAC technology was implemented with some changes as compared to French standards. The most important modifications introduced for HMAC mixes in Poland are: more closed structure (2–4% voids, while in France is up to 6%), lower stiffness modulus (14,000 MPa in 10 °C, while in France 14,000 MPa in 15 °C) and softer bitumen (20/30 pen. instead of 10/15 or 15/25 pen.). Moreover, bitumen modified by SBS polymers: PMB 25–55/60 and 10–40/65, and multigrade bitumen were also used in Poland. The minimum bitumen content

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http://dx.doi.org/10.1016/j.conbuildmat.2017.04.179
0950-0618/

equals 5,0% and it is slightly lower than it is recommended in French standards.

The main reason of changes in terms of French standards was the fact, that the climate in France is milder than in Poland what results in lower winter temperatures in Poland. Nevertheless the problem with low-temperature cracking occurred on sections constructed with HMAC base courses [14], which led to discussion between experts whether the usage of mixes of such high modulus, made from hard grade bitumen, is justified in Poland. Low-temperature cracks are one of the major distress observed in Poland even in pavements with conventional AC bases made from 35/50 and 50/70 penetration grade neat bitumen. Therefore, usage of harder 20/30 neat bitumen could strongly increase the risk of occurrence of thermal cracking. Up till now no reasonable and cost-effective solutions to reduce the risk of thermal cracking were introduced. The most interesting and promising are either the usage of modified or highly modified bitumen [15], or usage of other additives [16]. But it is worth to consider whether the typical maintenance of cracks or improvement of the bitumen or mixture properties is better way to deal with this problem. Taking into consideration all this facts it was necessary to compare the performance of pavements with HMAC bases to pavements with conventional AC bases.

Grade of bitumen and stiffness of asphalt mix are very important but not the only factors, that influence the probability of occurrence of thermal cracks in a pavement. Among others, the most well-known influential factors are: climatic conditions, pavement age, chemical composition and properties of asphalt binder, mixture composition and its mechanical properties, and the quality of construction of pavement structure. Consideration of all these factors on the one hand would increase the accuracy and reliability of the analysis, but on the other hand would complicate or even make the analysis impossible. Nevertheless, data as pavement age, climatic conditions and structure are relatively easier to collect as compared to collection data on binders, asphalt mixtures and layers mechanical properties for particular road sections.

1.2. Objectives and scope

The Department of Highway Engineering at the Gdansk University of Technology was granted a research project from the General Directorate for National Roads and Motorways to investigate the advantages and disadvantages of the HMAC technology used in Poland, with particular interest in low-temperature cracking and in resistance to permanent deformations. The paper present the part of results of the wide research program [17]. The analysis presented in the paper concerns comparison of the intensity of low-temperature cracking on pavement with HMAC and conventional AC base. The objective was to find how much the probability of occurrence of low-temperature cracks will increase when the high modulus asphalt concrete is used in pavement structure instead of conventional asphalt concrete. For this purpose the method based on ordered logistic regression model was used to compare the properties of two road materials. Parameters of the model were determined on the basis of the results of field investigations carried out on 80 test sections. Further the parameters of the model were analysed and interpreted in order to draw conclusions from field investigation.

2. Field investigation

In many cases investigations of new road materials like HMAC are based on laboratory test results compared with data acquired from especially constructed trial sections e.g. [18,19] or compared with set of data after improvement of a specific element, like type of bitumen e.g. [20–23]. Such methods and their results, which are available in literature, have following limitations: the number of test section is very limited and located in one region, also the length of the sections is relatively short, trial test sections are constructed under strong supervision and high quality, most often deviating from the typical contract conditions, only single factors (like bitumen properties) are taken into account. Often, there are not available direct comparisons of high modulus asphalt concrete to conventional asphalt concrete.

The purpose of the presented new method of field investigations was to fill these gaps. The field investigation was conducted on 80 road sections, 33 of them were constructed with HMAC and 47 with conventional AC. They were located throughout whole Poland. All those sections were constructed under normal contract conditions and have been in normal service and maintenance. The type of structure is the same in all of cases: asphalt layers are laid directly on the subbase made from unbounded crushed stone. Foundation and capping layer varies but the risk of reflected cracks from cement treated layers in foundation is minimalized because crushed stone in subbase is used in all cases. Thickness of asphalt layers varies in different sections from 11 to 31 cm and thickness of subbase varies from 15 to 25 cm. Each of section separately is characterized by the same pavement structure, age, the asphalt mix parameters and the contractor who executed pavement works. 50 sections were located on motorways or expressways, 28 on major nationals roads, and the remaining 2 on major province roads. Age of sections tested in 2014 varied from 1 to 12 years. All road sections were heavily loaded by commercial vehicles. Sections were located in three different climatic regions of Poland. Climatic regions were assumed on the basis of the maximum depth of frost penetration, used for pavement design, in accordance with the Polish standard PN-81/B-03020. The following regions show in Fig. 1 are included:

A – the coldest – maximum depth of frost penetration equals h_z = 1,2 or 1,4 m,
B – the medium – maximum depth of frost penetration equals h_z = 1,0 m,
C – the warmest – maximum depth of frost penetration equals h_z = 0,8 m.

The total length of selected road sections was around 503 km for pavements with HMAC and 800 km for pavements with AC. The length of particular sections ranged from 1 km to 63 km. Localizations of investigated sections are presented in Fig. 1.

The field investigation consisted of visual assessment of pavement distresses including cracks, ruts, roughness and surface condition and it was conducted in accordance with the Polish standardized method SOSN *Evaluation of pavement condition system* [24], supplemented if necessary by the *American Distress Identification Manual* [25]. The condition of the top of wearing course was observed and it was next rated in relation to what was the material used in the base course underneath, either HMAC or AC. However for the analysis presented in this article, solely information about low-temperature cracks is presented. Cracks which originated from other causes than low-temperature, like fatigue cracks or cracks which occurred near bridges, culverts, manholes etc. were excluded from the analysis. The low-temperature cracks were identify as single transverse cracks that were visible on the surface of each investigated section. The possibility of occurrence of reflective cracks from cement treated layers was excluded due to the fact that subbase layers directly under the asphalt layers were made from unbound aggregate.

The theory of development of low-temperature cracking assumed that crack is initiated in the point where the thermal stress are higher than tension strength of asphalt mix [26,27].