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Usage of foamed bitumen in asphalt mixtures

Petr Hyzl[a*], Ondrej Dasek[a] and Dusan Stehlik[a]

[a]*Institute of Road Structures, Brno University of Technology, Brno, Czech Republic*

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ABSTRACT

This paper focuses on the application of foamed bitumen technology in the production of asphalt mixtures. This technology replaces the common asphalt binder with foamed bitumen for production of asphalt mixtures. Given the foaming, it is possible to produce asphalt mixture at a lower working temperature. This “eco-friendly” technology has been increasingly used by the asphalt mixture producers in Europe because of reducing the energy demands of the asphalt mixture productions. In this paper, first the technology of the foamed bitumen production is explained and then the results of laboratory research are presented, in which selected empirical and functional parameters of two types of asphalt mixtures of the asphalt concrete type (AC) are compared. These mixtures were produced in two versions, one of them containing the common asphalt binder and the other one the foamed bitumen. While comparing the samples, attention was paid especially to the comparison of the stiffness modulus of the laboratory-produced asphalt mixtures according to EN 12697-26 and to their low-temperature characteristics according to EN 12697-46.

1. Introduction

Manufacture of standard asphalt mixtures is performed at relatively high temperatures, which vary depending on the used bituminous binder, ranging from 140 to 180 °C (Stewart et al., 2018; Pérez-Jiménez et al. 2013; Ameri et al., 2016; Wang et al., 2016; Eghbali et al., 2019, Wagoner et al. 2005; Motamedi et al., 2020; Pour et al. 2018, Braham et al. 2010). Such working temperatures are often associated with high energy demand and production of greenhouse gases, which can have negative impacts for the environment. At this point it is important to mention the Kyoto protocol, in which many countries committed to reduce greenhouse gas emissions. Given these binding agreements, the environment protection provides motivation to search for new technologies of asphalt mixture manufacture. One of the current trends seen in the area of manufacturing and overlaying of asphalt mixtures is the issue of the possibility to lower the working temperatures. There are several ways how to lower the asphalt mixture working temperature and create a so-called “hot asphalt mixture”. There are relatively well-known experiences from using low-viscosity bituminous binders or using organic or other chemical additives, which lower the viscosity of the bituminous binder. The technology of foamed bitumen, however, is currently still not very wide-spread. It is a technology where the bituminous binder, prior to coating the heated aggregate, is foamed by adding small amount of water into the hot bituminous

* Corresponding author.
E-mail addresses: hyzl.p@fce.vutbr.cz (P. Hyzl)

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binder. The water temperature is high so the water state changes from liquid to gas. This leads to increased volume of the bituminous binder and for a brief period also lowers its viscosity. This expansion allows better coating of the aggregate and the residual moisture allows better compaction of the asphalt mixture. Usage of the foamed device allows decreasing the working temperature by 20 to 40 °C. The process of foamed asphalt manufacture is depicted in Fig. 1.

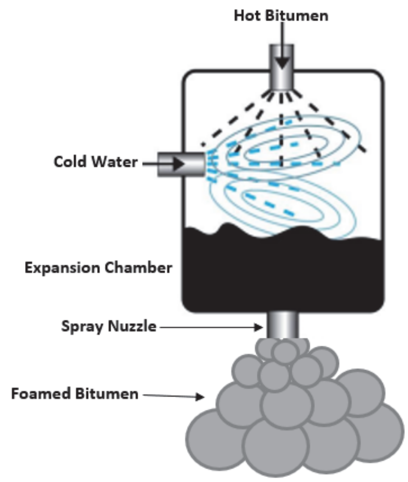

Fig. 1. Method of foamed asphalt manufacturing

Dosage of cold water (temperature 15 to 25 °C) required for ideal foaming of the bitumen usually ranges between 2 and 4 % of the asphalt mass. Two parameters of the foamed asphalt are monitored in terms of its quality:

- expansion ratio (ER)
- half-life ($\tau1/2$)

The first parameter of asphalt foam quality is the expansion ratio. This value expresses the ratio between maximum volume reached by the asphalt foam and the volume of the original bituminous binder. High-quality asphalt foam should have an expansion ratio of 8 to 15. The second parameter in terms of foamed asphalt quality is the half-life. This value is defined as the time it takes for the foam to reach 50% of its maximum achieved volume.

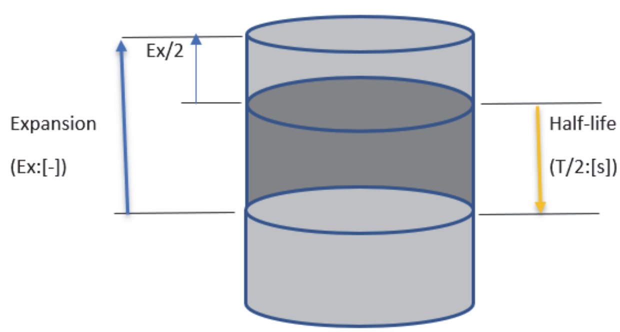

Fig. 2. Relationship between expansion ratio and half-life

In general, the longer the half-life, the higher the quality and stability of the asphalt foam. Fig. 2 shows the schematic of relation between ER and $\tau1/2$. Half-life is expressed in seconds and usually reaches values between 10 and 15 seconds. Half-life of high-quality asphalt foam should reach values above 15 seconds. Increasing the amount of water added increases the expansion ratio and decreases the half-life. Both of the above mentioned parameters depend on the type and origin of the bituminous binder, the temperature of the hot bituminous binder, the amount of compressed air added and the pressure at which the water is injected into the hot bituminous binder. Based on the expansion ratio, half-life and the ratio of injected water one can determine the so-called foam index (FI), which expresses the suitability of the asphalt foam for mixing with aggregate or RAP. Half-life is indirectly proportional to the expansion ratio (Venclikova, 2018; Marquardt, 2014; EAPA, 2014). The aim of the laboratory work of this research was to compare selected functional parameters of two types of asphalt mixtures of the asphalt concrete (AC) type. In particular, it was the AC 11 and AC 16 mixture, which were prepared in accordance with the EN 13 108-1 (2016) standard in two variants: (a) with standard bituminous binder 50/70 and (b) with foamed bituminous binder 50/70. All variants were manufactured in accordance with (Venclikova 2018) in a plant, where immediately after the manufacturing the test samples were also created for subsequent laboratory tests. This research phase involved comparing the parameters at equivalent working temperatures and only the effect of the usage of foamed asphalt on the selected parameters was evaluated.

2. Methods and Materials

The following comparisons were made between the test samples:

a) Comparison of stiffness modulus in accordance with the EN 12697-26 Bituminous mixtures - Test methods for hot mix asphalt - Part 26: stiffness, method 2PB-TR (EN 12697-26; 2012).
b) Comparison of low-temperature characteristics in accordance with the EN 12697-46 Bituminous mixtures – Test methods for hot mix asphalt – Part 46: Low temperature cracking and properties by uniaxial tension tests, method TSRST (EN 12697-46, 2012).

The tested asphalt mixtures were of the concrete (AC) type. In particular it was the AC 11 and AC 16 mixture with maximum aggregate particle size of 11 mm or 16 mm, respectively. Always two variants were created – one without using the foam asphalt technology and one with using the foam asphalt technology (labeled as Foam). Granularity of the tested mixtures is provided in Table 1.

Table 1. Sieve size distribution

Sieve size distribution		Sieve passage (%)			
		AC11	**AC11 Foam**	**AC16**	**AC16 Foam**
Sieve size (mm)	22.4	100.0	100.0	100.0	100.0
	16	100.0	100.0	97.1	97.3
	11.2	97.6	98.3	69.7	73.0
	8	74.8	78.8	60.6	62.1
	4	45.7	44.3	38.9	38.9
	2	32.3	32.4	26.7	28.2
	0.125	9.8	9.7	6.8	7.8
	0.063	7.3	7.2	5.0	5.7

Dosage of bitumen 50/70 in case of the AC11 and AC11 Foam was 5.9%, for the mixture AC 16 and AC 16 Foam 4.5 %. The value of binder penetration, determined in accordance with the EN 1426 (2015) was 63 p.u. Value of binder softening point, determined in accordance with the EN 1427 (2015) was 51.2°C.

3. Results

Comparison of the asphalt mixture stiffness is provided in Table 2 and graphically evaluated in Fig. 3.

Table 2. Results of stiffness modulus determination in accordance with the EN 12697-26 (2012).

		E-modulus (MPa) at 15°C and load frequency:				
		5 Hz	10 Hz	15 Hz	20 Hz	25 Hz
Asphalt mixture	AC11	7599	8418	8885	9268	9735
	AC11 Foam	7842	8567	9006	9376	9746
	AC16	9800	10514	10934	11143	11791
	AC16 Foam	8840	9600	10043	10406	10857

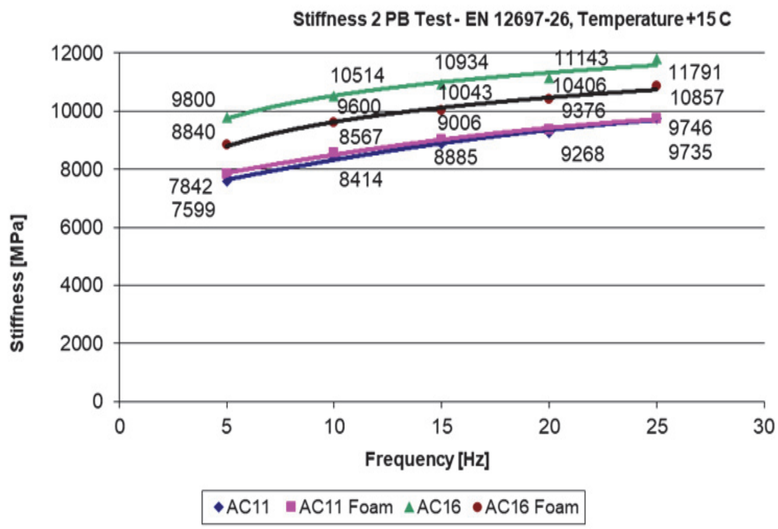

Fig. 3. Graphical representation of the results from stiffness modulus determination in accordance with the EN 12697-26 (2012)

Results of the low-temperature properties are given in Table 3.

Table 3. Results of low-temperature parameters in accordance with the EN 12697-46 (2012)

		Low-temperature parameters (EN 12697-46)		
		Max. power (kN)	**Maximum tension upon cracking (MPa)**	**Sample temperature upon cracking (°C)**
Asphalt mixture	**AC11**	10,37	4,15	-19,07
	AC11 Foam	9,01	3,58	-17,80
	AC16	7,32	2,95	-15,07
	AC16 Foam	8,35	3,38	-17,00

4. Conclusions

The results of stiffness modulus determined in accordance with the EN 12697-26 [5] show that the stiffness of the AC11 and AC11 Foam mixtures is almost identical and in case of the coarse mixture AC16 and AC16 Foam the stiffness modulus values were very similar. When looking at the results of low-temperature parameters determined in accordance with the EN 12697-46 [6] one can see that the values of the individual mixtures and their variants with and without foamed asphalt are again very similar. Given the above comparison of selected functional characteristics of the individual variants of the tested asphalt mixtures it can be concluded that using the foamed asphalt technology did not lead to any undesired changes in the tested parameters. Such positive results mean that future research will concentrate on the comparison of the identical variants, but the foamed asphalt variants will be manufactured at a working temperature 20°C lower.

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