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Road and Rail Infrastructure II

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Road and Rail Infrastructure II

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COMPARISON OF LOW–TEMPERATURE BITUMINOUS MIXTURES SELECTED PROPERTIES

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Abstract

Nowadays the theme of reducing energy needs for bituminous mixtures production is topical. In this case is one of the solutions to use low temperature bituminous mixtures. This modern technology ensures the similar or higher quality parameters in one hand with lower processing temperature, compared to conventional mixtures produced by the hot process. This article is based on controlled study approach and deals with properties experimental verification of low temperature bituminous mixtures focusing on fatigue, crack propagation, Young´s modulus and complex modulus.

Keywords: low temperature asphalt mixtures, Young's modulus, complex modulus, fatigue, crack propagation

1 Introduction

The theme of reducing energy needs for bituminous mixtures production is very topical. In this case is one of the solutions to use low temperature bituminous mixtures. Technology of these mixtures is divided into the technology of adding organic additives and waxes or chemical additives and reagents. Other possibility is foamed asphalt. The function of additives is based on lowering asphalt viscosity and can be add into asphalt binder or bituminous mixtures. The lower viscosity enable to lower temperature needs for production and processing. The level of reducing temperature depends on the additive type. The asphalt binder modification with low–viscosity additive improves its properties. For low temperature bituminous mixtures is an advantage ensuring equal or higher quality parameters as well at lower temperatures, compared to conventional mixtures produced by the hot process. Generally can be concluded increase the resistance of bituminous mixtures to traffic loads, increase bearability and extend the life time of which implies improve road safety.

2 Properties experimental verification

In the experimental part were designed specific types of asphalt mixtures specifically asphalt concrete (ACL 16, ACP 16 and ACP 22 in accordance with [9]) with the binder 50/70 modified by FT additive (organic intermixture) and as well modified by IT additive (chemical intermixture). The asphalt mixtures with binder without additives were chosen as a reference. An experimental properties verification of the strength and deformation characteristics of the asphalt mixtures was carried out tests for resistance to fatigue, crack propagation, a determination of Young's modulus and Complex modulus of asphalt mixtures. From the test results evaluation can assess the impact of the additives on the durability asphalt mixture against the applied load and assess the appropriateness of the use of additives for a particular asphalt mixtures.

3 Young's modulus

Values of the Young's modulus characterize the resistance of asphalt mixtures to the applied load, depending on the stress and strain. With the Young's modulus increase decrease the asphalt mixture strain and increase the resistance against the traffic load. The test could be processed by several test methods on different test specimens. In the study was used IT-CY method (indirect tensile test) using a cylindrical specimen with dimensions of 101.6 x 62.5 mm according to [4] and [7]. Test temperatures were chosen 0, 15, 27 and 40 ° C. With the temperature increase the value of asphalt mixture Young's modulus decrease. As can be seen from values mentioned table subsequently use of FT additives results in an increased Young's modulus which contribute to better resistance against load. The percentage increase at 0°C is 6.5% at 15°C 18% at 27°C 30% and at 40°C 35% (compared with reference asphalt mixture).

Table 1 Table 1. Young's modulus (IT-CY method):

Bituminous mixture	Temperature [°C]	S_m [MPa]	Increase S_m [%]
ACP 22 50/70	0	21499	0
ACP 22 50/70 + 3% FT		22894	6,5
ACP 22 50/70	15	9318	0
ACP 22 50/70 + 3% FT		10978	17,8
ACP 22 50/70	27	3049	0
ACP 22 50/70 + 3% FT		3957	29,8
ACP 22 50/70	40	865	0
ACP 22 50/70 + 3% FT		1167	34,9

4 Complex modulus

Part of the research project was focused on asphalt mixture complex modulus comparison. Measurement of complex modulus was chosen because it is a viscoelastic characteristic and therefore reflects time aspect of load.
Measurements were made by 4PB-PR method according to [4] and [7] in the temperature range from -10°C to 40°C and a frequency range 0.1 ~ 60Hz. These measurements were then with the help of Time–Temperature Superposition (TTS) principle [2] shifted into one master curve. To achieve a comprehensive quality of the master curve in the frequency range was chosen logarithmically growing range of frequencies. Applying the TTS principle was obtained information on the material characteristics of the larger interval of frequency than which could be ever measured with test equipment [1]. The reference temperature was chosen to 30°C. Comparison of real and imaginary components of complex modules and phase angles are shown in Fig. 1 and Fig. 2.

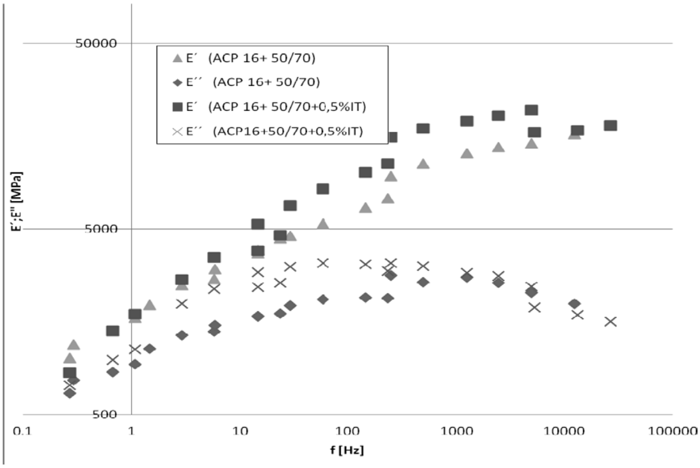

Figure 1 Real and imaginary part of complex modulus

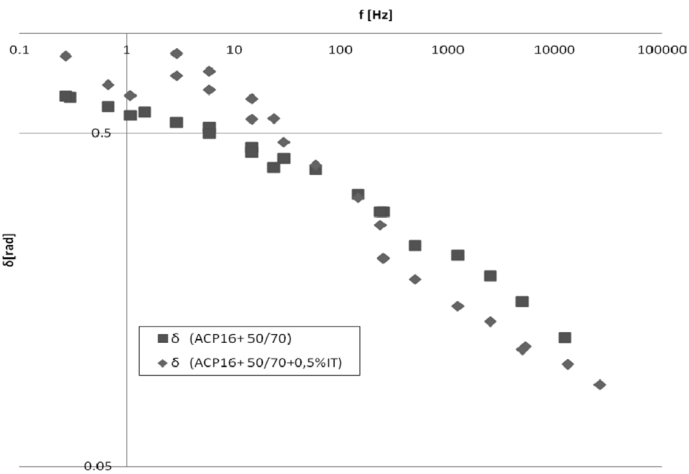

Figure 2 Phase angle

From these results it can be concluded some differences between regular asphalt mixture ACP 16+ 50/70 and ACP16+ 50/760 with IT additive. Asphalt mixtures with addition of IT have a considerably higher value of real and imaginary components of complex modules in the middle frequency range. If we consider the chosen reference temperature of 30 ° C as the temperature of pavement, this difference should result in a smaller deformation caused by vehicles at common speed. In this area of frequency have the asphalt mixtures similar values of phase angle, this property indicates that the same part of the deformation in the material remains preserved as plastic deformation.

Complex modules in the lower and higher frequency range are comparable for both mixtures. The phase angle of asphalt mixtures without the addition has a lower value in the lower frequency range and higher values in the higher frequency domain. Mixture with the addition of IT is likely to have higher initial deformation (consequent compaction of asphalt mixture) and a lower increase in permanent deformation (in the form of rutting) over a lifetime.

5 Fatigue

The fatigue test method defines asphalt mixture resistance against cycling load. The test specimens are exposed to repetitive compression stress causing a fracture in the perpendicular plane.

Table 2 Table 2. Fatigue characteristics

					Fatigue characteristics		
Asphalt mixture	**T [°C]**	**δx [kPa]**	**Sm [MPa]**	**δ [δstrain]**	**k**	**n**	**δ [δstrain]**
ACP 22 50/70	15	800	9318	0,16570	75,512	1,635	0,17271
		900		0,18641			0,17076
		1000		0,20713			0,21695
ACP 22 50/70 + 3 % FT		800	10978	0,14065	0,291	4,7681	0,14204
		900		0,15823			0,15496
		1000		0,17581			0,17776

Test according to [3] and [6] can be implemented on different test specimens. In this article are presented values measured on cylindrical specimens with dimensions of 101.6 x 40 mm. During the test is measured vertical deformation of the specimen until failure. Than is determining the tensile strain in the middle of specimen and based on the relation of strain and number of load cycles is computed fatigue life. Mentioned dependence is expressed in logarithmic scale using the S-N curve also known as Wöhler's diagram (Fig. 3), where the slope of the S-N curve refers to fatigue life of the asphalt mixture. When the derivation of the S-N curve is higher than the material has better resistance to fatigue. Experimental properties of asphalt mixtures ACP 22 have been verified. Adding FT additives into binder leads to extend the lifetime of the asphalt mixture and increase its resistance to the applied load.

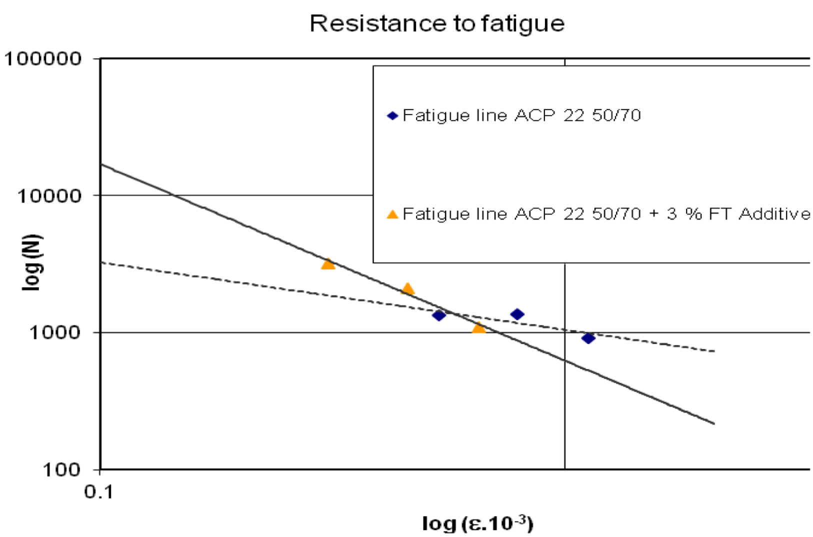

Figure 3 Resistance to fatigue of the asphalt mixtures

6 Crack propagation

Resistance of asphalt mixtures to crack propagation is determined on the half–cylindrical specimen with the groove in the middle Fig. 4. The specimen is loaded by bending in three points. Bend specimen is than caused by a constant increment of deformation (5 mm per minute). The load is continuously increased to a peak value of Fmax, which directly relates to the resistance to fracture of the specimen K_{lc}. In our case we used half–cylindrical specimens with a diameter of 101.6 mm and 50 mm thick. The test temperature was chosen 5°C. Adding ingredients IT (IterFlow) was increased resistance to asphalt crack propagation as can be seen from table:

Table 3 Table 3. Asphalt mixture crack propagation resistance:

Asphalt mixture	ε_{max} [%]	F_{max} kN]	K_{lc} [N/mm$^{3/2}$]	Increase of K_{lc}[%]
ACP 16+ 50/70	1,86	5,70	37,11	0
ACP 16+ 50/70 + 0,5 % IT	1,66	6,05	39,34	6,0

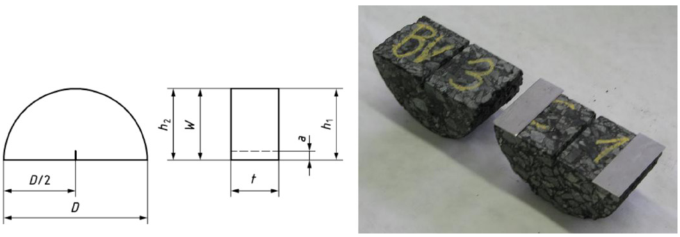

Figure 4 Half–cylindrical specimen

7 Conclusion

The positive influence of used additives (which lowers production temperature and lay down temperature) was proved by several test procedures. With the modification of asphalt binder by IT and FT can be achieved better properties of asphalt binder and asphalt mixes. In the article were taken in consideration Asphalt mixes used in asphalt base layers and their properties with respect to Young's modulus, Complex modulus, Fatigue and Crack propagation were taken in consideration in this article. The additives has better influence to asphalt mixes stiffness (Higher value of Young's modulus and Complex Modulus), also resistance against cycling load (fatigue) and crack propagation. With the achieving desired, respectively increasing the quality parameters of asphalt mixes with one hand with choice of appropriate technological processes and other important factors affecting the asphalt mixes production and further performance, we can ensure a safer, more convenient and economical driving a motor vehicle.

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