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ESTABLISHING OF WEARING COURSE ASPHALT MIXTURE STIFFNESS

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Abstract

Stiffness is a fundamental characteristic of an asphalt mixture and is used as an indicator of mixture performance in designing of asphalt mixture. Studying of asphalt mixture stiffness is a challenge based on dependence of stiffness on temperature, time and frequency of loading. In laboratory, the stiffness of asphalt mixture can be determined on few test, each test having different conditions imposed by European standards. In Roads Laboratory of Technical University of Civil Engineering Bucharest can be conducted the following tests on asphalt mixtures from wearing course: 4 point bending test (on prismatic samples), 2 point bending test (on trapezoidal samples) and indirect tensile test (on cylindrical samples).
The paper purpose is to establish the value of asphalt mixture stiffness which has to take into account in pavement design by means of laboratory tests. The results obtained are based on a study on various types of asphalt mixture designed with gyratory compactor with different types of bitumen, at three testing temperature. It will be made an attempt to realize a link between these 3 tests, in order to achieve close values for asphalt mixture's stiffness.

Keywords: asphalt mixture, stiffness, indirect tensile test, two points bending test, four points bending test

1 Introduction

The studies concerning the complex modulus of the asphalt mixtures have been started since 1960 thanks to the informations that this characteristic may provide with respect to asphalt mixtures behaviour.
As it is known, the complex modulus characterise the relationship between stress and strain when the asphalt mixture is subjected to a sinusoidal waveform load depending on time. In case of a liniar viscoelastic material, the complex modulus is characterised by norm and phase angle. The norm of complex modulus is an indicator of material stiffness and is characterised by the two components, the elastic one and the viscous one.
The stiffness modulus of asphalt mixture is a fundamental property that gives informations about how much the materials deforms under a given load and is closely related with the fatigue cracking and permanent deformation because of time temperature dependence. The stiffness modulus of asphalt mixture is useful for: evaluation of asphalt mixture quality, asphalt mix design, pavement design, analysis of asphalt mixture damage.
This paper contains a case study obtained from testing of several asphalt mixture recipes in wich the influence of several factors on stiffness values was observed: the used test type, the load level and the applied frequency, the test temperature, the laboratory compaction mode.

2 About the used materials and the asphalt mixture recipes

This study was carried out in Roads Laboratory of Faculty of Railways, Roads and Bridges (Technical University of Civil Engineering of Bucharest) on five types of asphalt mixtures designed according to romanian norms: a classic asphalt mixture, BA16 type, a high modulus asphalt mixture, MAMR16 type and an asphalt mixture with fiber, MASF16 type. The materials (aggregates, fiber and bitumen) used to prepare the asphalt mixtures and the asphalt mixtures recipes are presented in Table 1.

3 About the used laboratory tests and testing conditions

In order to establishing the stiffness modulus of asphalt mixture in laboratory it was used the three stipulated tests in European Norm SR EN 13108-20:

- test applying Indirect Tension to cylindrical specimens IT-CY, according to SR EN 12697-26 Annex C. In this test the applied load (force) is constant in time. The loading time is (124 ± 4) ms and the measured stiffness modulus is the mean of five pulses of applied load.
- Four Point Bending test on prismatic specimens 4PB-PR, according to SR EN 12697-26 Annex B. In this test the specimen is subjected to four-point periodic bending with free rotation and (horizontal) translation at all load and reaction points. The strain amplitude, constant in time, is maximum (50 ± 3) microdef and the initial stiffness modulus shall be determined as the modulus for a load cycle between the 45th and the 100th load repetition.
- Two Point Bending test on trapezoidal specimens 2PB-TR, according to SR EN 12697-26 Annex A. In this test the the strain amplitude is constant and less or equal to (50 ± 3) microdef. The stiffness modulus is determined for 30s to 2 min.

The samples were tested according to the program presented in Table 2.

Table 1 The used asphalt mixtures materials and the recipes of the used asphalt mixtures

Asphalt Mixture	Source /type and %	Crushed Rock			Filler	Fiber by Mixture	Bitumen by Mixture
		8/16	4/8	0/4			
MAMR16	Source / type	Revarsarea			Limestone Holcim	-	OMV 25/55-65 PMB STAR FALT
	%	35	29	25	11	-	4.12
BA16	Source / type	Dealu Plesa			Limestone Holcim	-	D 50/70 Arpechim Romania
	%	25	22	45	8	-	6.1
MASF16a	Source / type	Carpat Agregate			Limestone Holcim	Viatop	OMV 50/70 + additive (0.5%Adeten 05)
	%	52	18	17	13	0.5	6.0
MASF16m-1	Source / type	Carpat Agregate			Limestone Holcim	Viatop	D 45/80-65 PMB Lotos Polonia + additive (Adeten 03)
	%	53	18	17	12	0.5	5.9
MASF16m-2	Source / type	Turcoaia			Limestone Holcim	Topcel	OMV 25/55-65 PMB STAR FALT
	%	45	25	13	11	0.3	5.7

Table 2 Testing program

Type of test	Temperature [°C]	Frequency or loading time
IT-CY	0; 10; 15; 20; 40	124ms
4PB-PR	0; 10; 15; 20; 40	8; 10; 15; 20; 25; 30 Hz
2PB-TR	0; 10; 15; 20; 40	8; 10; 15; 20; 25; 30 Hz

Frequencies and temperatures contain values among European Standard Specifications SR EN 13108-20 (bold values) and of Romanian Standard SR174 (italic values).

4 About the dimensions and the compaction mode of samples

The samples were compacted in laboratory depending on type of tests. Thus, for IT-CY test, were manufactured cylindrical samples with ϕ=100mm and h≈63mm as following: at gyrocompactor (GC), (air voids≅3.5%); at Marshall hammer for 50 and 75 blows/side (MC-50, MC-75); cored from slabs compacted with roller compactor (RC). For 4PB-PR test were manufactured prismatic samples with L=405mm, l=50mm, h=50mm by cutting from slabs compacted with roller compactor (RC). For 2PB-TR test were manufactured trapezoidal samples with H=250mm, B=70mm, b=25mm, e=25mm by cutting from slabs compacted with roller compactor (RC).

5 Obtained experimental results

Following the laboratory studies conducted by the program from Section 3 on samples made according to Section 4 of the types of asphalt mixtures listed in Section 2, it has achieved experimental results plotted in figures 1 - 10. It has in view to highlight the values of stiffness modulus of asphalt mixtures according to:

- type of compaction in the laboratory of samples by IT-CY test on cylindrical samples at a temperature of 15oC (Fig. 1);
- the load applied to prismatic samples tested at the 4PB-PR test at a temperature of 15oC and frequency of 8Hz (Fig. 2);
- frequency of loading applied prismatic samples tested at the 4PB-PR test at a temperature of 15oC (Fig. 3) and 20°C (Fig. 4) and trapezoidal samples tested at 2PB-TR test at a temperature of 15°C (Fig. 5);
- test temperature of cylindrical samples tested at IT-CY (Fig. 6), prismatic samples tested at the 4PB-PR test at a frequency of 8Hz (Fig. 7) and 10Hz (Fig. 8) and trapezoidal samples tested at 2PB-TR test at a frequency of 10Hz (Fig. 9);
- type of laboratory test (Fig. 10).

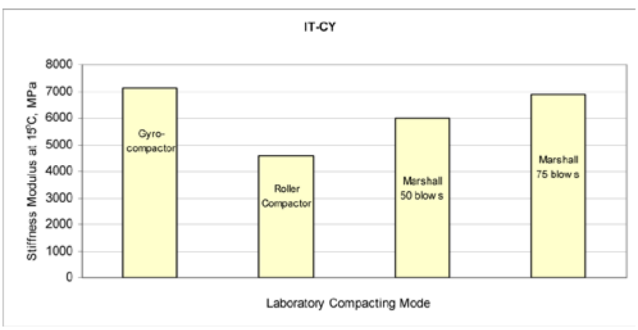

Figure 1 Compaction mode influence on stiffness modulus (MAMR16, IT-CY)

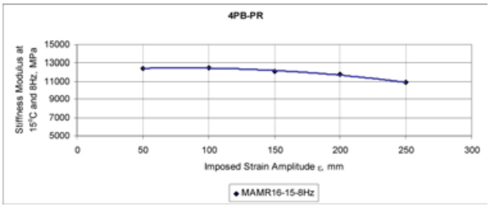

Figure 2 Load level influence on stiffness modulus (MAMR16,IT-CY,15°C, 8Hz)

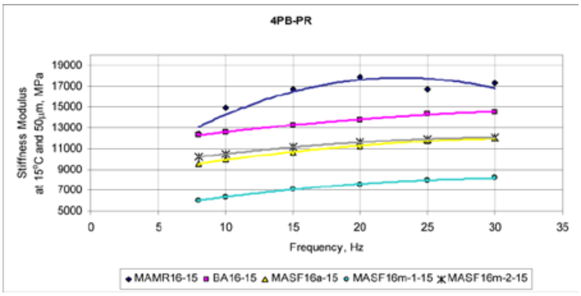

Figure 3 Testing frequency influence on stiffness modulus (4PB-PR, 15°C)

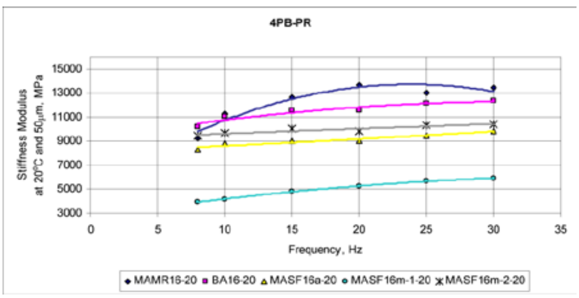

Figure 4 Testing frequency influence on stiffness modulus (4PB-PR, 20°C)

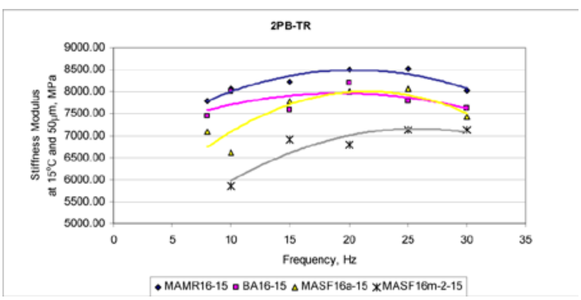

Figure 5 Testing frequency influence on stiffness modulus (2PB-TR, 15°C)

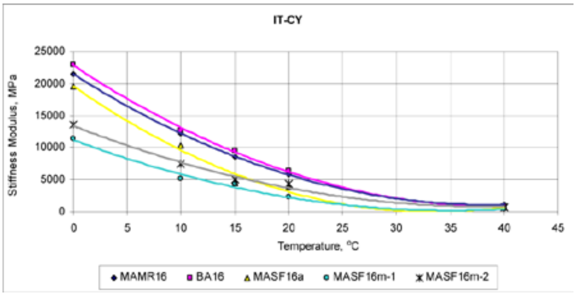

Figure 6 Testing temperature influence on stiffness modulus (IT-CY)

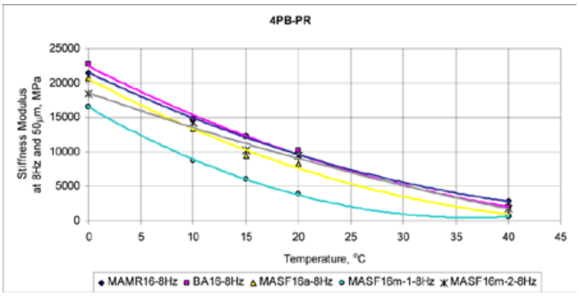

Figure 7 Testing temperature influence on stiffness modulus (4PB-PR, 8Hz)

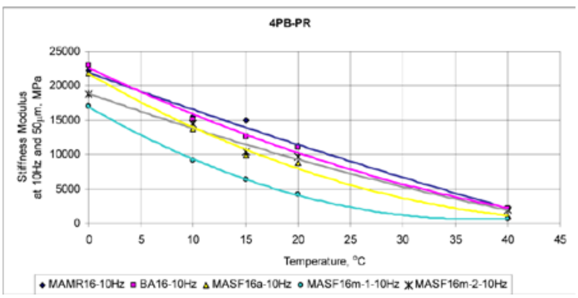

Figure 8 Testing temperature influence on stiffness modulus (4PB-PR, 10Hz)

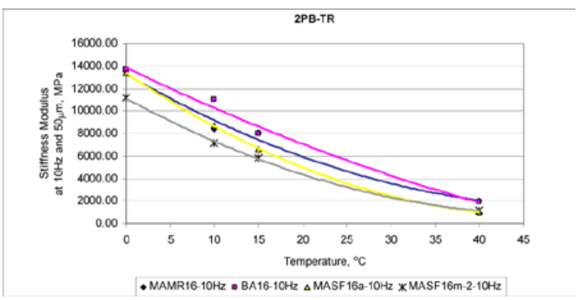

Figure 9 Testing temperature influence on stiffness modulus (PB-TR, 10Hz)

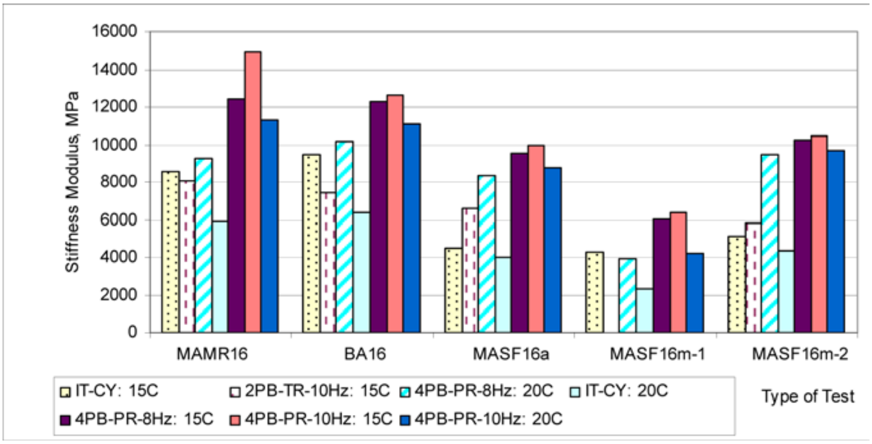

Figure 10 Type of test influence on stiffness modulus values

6 Conclusions

The conclusions that result from this study are presented below. The values of stiffness modulus depend on compaction mode, strain level of test, frequency of test, temperature and type of test, as results from the above graphics.
In order to determine the asphalt mix stiffness in Romanian norms the compaction mode is established according to the type of asphalt mixture. It is known that laboratory compaction method should reproduce as closely as in situ compaction. As seen in Fig. 1, it can obtain different values of the stiffness modulus depending on the type of compaction used: closely values for the stiffness modulus at GC and MC-75; an increase of ≈16% stiffness modulus value for GC compared to MC-50; an increase of ≈36% stiffness modulus value for GC compared with the RC. To establish the correlation between modes of compaction of laboratory and field more studies are needed further, depending on the type of asphalt mixture.
The higher the load the smaller the stiffness modulus value: an ≈80% increase of strain amplitude lead to a ≈12% drop of the value of stiffness modulus (Fig. 2).
As expected, the stiffness modulus generally increases with frequency and decreases with temperature applied, regardless of the type of test laboratory for all asphalt mixtures tested. Thus, the 4PB-PR test found an increase of ≈7...17% of the value of stiffness modulus for an increase of frequency by 50% (between 10 and 20Hz), high percentage registering for MAMR16 and small percentage for BA16. By comparing the graphs from Fig. 3 and Fig. 4, a parallelism of the curves for the same type of mixture is oberved. The studied asphalt mixtures present the same susceptibility to load level variation for the both temperatures of 15°C and 20°C. The trend is similar for 2PB-TR test (Fig. 5): an increase of ≈3...7% of stiffness modulus for a frequency increase by 50% (between 10 and 20Hz), this time the high percent is registering for MASF16a.
Concerning the temperature (Fig. 6 to 9), there is a decrease on average by 93% of the stiffness modulus when the temperature increases by 100% (from 0°C to 40°C), regardless of type of test, test frequency and asphalt mix type tested.
In an attempt to establish a link between types of tests available to determine the asphalt mix stiffness modulus it was plotted the Fig. 10. It is point out that to obtain close values between tests, IT-CY test should be done at 15°C temperature, 4PB-PR test must be conducted at 20°C temperature and at 8 Hz frequency and 2PB-TR test should be conducted at 15°C temperature and 10 Hz.

Asphalt mixtures are therefore more or less susceptible to load frequency variation depending on the type of test or compaction mode but have the same susceptibility to temperature. This aspect should be taken into account in considering stiffness modulus values needed in asphalt pavement design.

References

[1] Romanescu, C, Răcănel, C, Burlacu, A: Laboratory results obtained from indirect tension test on asphalt mixtures, Buletinul Stiintific U.T.C.B. no.3, 2007

[2] Răcănel, C, Romanescu, C, Dicu, M, Burlacu, A, Surlea, C: Fatigue lines for asphalt mixtures used in wearing course, RILEM Advanced Testing and Characterisation of Bituminous Materials RHODES, pg 795-805, 2009

[3] SR EN 12697-31/2006, Bituminous mixtures – Test methods for hot mix asphalt –Part 31: Specimen preparation by gyratory compactor

[4] SR EN 12697-30/2006. Bituminous mixtures – Test methods for hot mix asphalt –Part 30: Specimen preparation, impact compactor

[5] SR EN 12697/33 -2003. Bituminous mixtures – Test methods for hot mix asphalt – Part 33: Specimen prepared by roller compactor

[6] SR EN 12697/26 -2005. Bituminous mixtures – Test methods for hot mix asphalt – Part 26: Stiffness

[7] SR EN 13108/20 -2005. Bituminous mixtures – Material specifications – Part 20: Type testing

[8] SR EN 174-2002. Road works.Hot bituminous rolled pavements. Quality requirements