



BEHAVIOUR TO PERMANENT DEFORMATIONS OF SOME ASPHALT MIXTURES IN WEARING COURSES

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Abstract

The asphalt mixture must be both flexible at low temperatures to prevent cracking and sufficiently rigid at high temperatures to prevent permanent deformation. Permanent deformations of flexible pavements are mainly due to creep of asphalt mixtures. Permanent deformations occur due to repeated traffic loads superimposed with high temperature. Determining the resistance of asphalt mixtures to permanent deformation is very important, as it characterises the limit of the elastic range and helps to achieve quality asphalt mixtures. Like the fatigue phenomenon, the permanent deformation phenomenon also plays an important role in the design of road pavements. The present paper aims to highlight the laboratory results on the permanent deformation resistance of asphalt mixtures used in wearing courses (BBA 16 - airport asphalt mix, SMA 16 – stone mastic asphalt and MAMR 16 - asphalt mix which meets the requirements of a wearing course asphalt mix but which has been designed to have a higher modulus of rigidity than those normally used for wearing courses). The results of the laboratory tests are presented in the form of tables and graphs.

Keywords: asphalt mixture, permanent deformations, road, flexible pavements

1 Introduction

The asphalt mix produced must be both flexible at low temperatures to prevent cracking and sufficiently rigid at high temperatures to prevent permanent deformation. Permanent deformations of flexible road pavements are mainly due to the creep of bituminous mixtures. Determining the resistance of bituminous mixtures to permanent deformation is very important as it characterises the limit of the elastic range and helps to achieve quality bituminous mixtures. Improper design mix of aggregate, filler and bitumen causes permanent creep deformations. Creep can be both static and cyclic creep. In 1994 Sousa and Weissman observed that static creep tends to generate intergranular blockages in the bituminous mixture skeleton compared to cyclic creep which does not allow these types of blockages to occur. Due to the cyclic nature of traffic, the behaviour of bituminous mixtures under cyclic loading is very important. Modified bitumens give bituminous mixtures greater resistance to permanent deformation [1]. According to Di Benedetto and Corte, the increase in permanent deformation after a cycle is practically negligible and is SMA by the reversible deformation, which is much higher [2]. After a number of cycles the permanent deformation can also be measured, therefore the cyclic behaviour and the number of passes are important parameters for permanent deformations. In conclusion permanent deformations are due to plastic deformations of the mineral skeleton and viscous deformations such as binder flow.

Various efforts have been undertaken to establish test methodologies and evaluation parameters that can effectively measure the permanent deformation resistance of asphalt mixtures [3-6]. Zhang et al. [7] studied the permanent deformation resistance of six types of asphalt mixtures and observed that dynamic creep is strongly correlated with dynamic modulus results. Witczak et al. conducted a comprehensive study on dynamic modulus. Test results show that there is a high correlation between permanent deformation and dynamic modulus of asphalt pavement [8]. The complexity of permanent deformation development is due to several factors such as binder type, binder content, mixture type, loading level, temperature, etc [3, 6, 8-11].

2 Materials and recipe

In this paper, the aim was to determine the permanent deformations for an airport asphalt mixture compared to other types of asphalt mixes and the differences obtained for the permanent deformations of the designed asphalt mixture BBA 16 considering the compaction mode. In order to achieve the goal, three wearing course asphalt mixtures were chosen: asphalt mixture for airport (BBA16), stone mastics asphalt (SMA16) and asphalt mix which meets the requirements of a wearing course asphalt mix but which has been designed to have a higher modulus of rigidity than those normally used for wearing courses (MAMR 16) with two of binders (a modified one, especially for airports and a original one).The materials (aggregates, fibre and bitumen) used to prepare the asphalt mixtures and the asphalt mixtures recipes are presented in Table 1.

Table 1 Types of bituminous mixtures used and related materials

Type of mixture	Source/ type	Aggregate			Filer	Fiber	Bitumen
		8/16	4/8	0/4			
BBA 16	Source/ type		Revărsarea		Holcim		45/80 Fr A 50/70
	%	29	23	37	11	-	5.3
MAMR 16	Source/ type		Revărsarea		Holcim		45/80 Fr A 50/70
	%	35	29	25	11	-	4.12
SMA 16	Source/ type		Turcoaia		Holcim	Topcel	45/80 Fr A 50/70
	%	45	25	13	11	0.3	5.7

3 Laboratory studies

The cylindrical specimens were made using the impact compactor – SR EN 12697-30 (Marshall compactor - 50 blows/ face for BBA 16 and MAMR 16, respectively 75 blows/ face for SMA 16) and the Gyrocompactor – SR EN 12697-31. The conditions under which the tests were carried out are in accordance with SR EN 12697-25: temperature 50°C, axial loading 300 kPa, frequency 1s/1s (block type) and different values of lateral pressure, Figure 1. According to the Romanian norms (AND 605/2016) for the determination of the physical-mechanical characteristics of bituminous mixtures, the creep test is performed for 10000 pulsations.

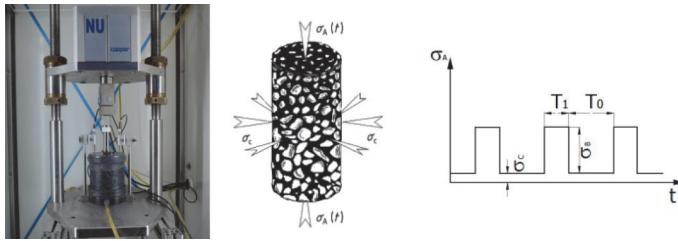


Figure 1 Apparatus for triaxial cyclic compression testing and type of loading

The representation of the creep curves for BBA 16 asphalt mixture function of the number of pulses applied, for different lateral pressures is shown in Figure 2 and the creep modulus is shown in Figure 3.

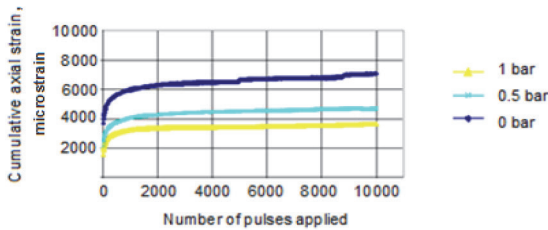


Figure 2 Creep curve for BBA 16 asphalt mixture, for various lateral pressures

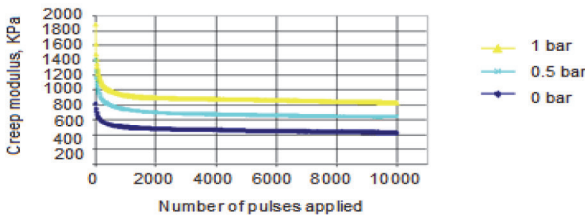


Figure 3 Creep modulus for asphalt mixture BBA 16, for various lateral pressures

Method I and method II for calculation of creep parameters of samples compacted with Marshall Impact and samples compacted with Gyrocompactor are shown in the Table 2, Table 3, Table 4 and Table 5.

Table 2 Method I for calculation of creep parameters on samples compacted with Marshall Impact, 1 bar, 300 KPa [11]

Type of mixture	Parameters and equation in stage II Method I ($\epsilon_n = A_1 + B_1 n$)		Creep speed $f_c = B_1$	Creep module $E_n = \sigma / \epsilon_n$, kPa		
	A ₁	B ₁		initially	1000	10000
BBA 16 45/80 Fr A	4905	0.0213	0.0213	1650	687	587
BBA 16 50/70	11551.5	0.224	0.224	427	265	218
MAMR16 45/80 Fr A	6260.4	0.0208	0.0208	741	503	464
MAMR16 50/70	11307	0.0615	0.0615	418	291	252
SMA16 45/80 Fr A	5882.5	0.0425	0.0425	1025	558	476
SMA16 50/70	12837	0.2835	0.2835	512	266	192

Table 3 Method I for calculation of creep parameters on samples compacted with Gyrocompactor, 300 KPa

Type of mixture	Parameters and equation in stage II Method I ($\epsilon_n = A_1 + B_1 n$)		Creep speed $f_c = B_1$	Creep module $E_n = \sigma / \epsilon_n$, kPa		
	A ₁	B ₁		A ₁	B ₁	10000
BBA 16 45/80 Fr A, 1 bar	3435	0.019	0.019	1886	928	828
BBA 16 45/80 Fr A, 0.5 bar	4310	0.037	0.037	1412	738	641
BBA 16 45/80 Fr A, 0 bar	6661	0.041	0.041	817	500	424

Table 4 Method II for calculation of creep parameters on samples compacted with Marshall Impact, 300 KPa, 1 bar [11]

Type of mixture	Parameters and equation in stage II Method II ($\log \epsilon_n = \log A + \log B n$)		Permanent deformation ϵ_{1000}^{\cdot} $\epsilon_{1000, \text{calc}} = A_{1000}^B$	Permanent deformation ϵ_{10000}^{\cdot} $\epsilon_{10000, \text{calc}} = A_{10000}^B$
	A	B		
BBA 16 45/80 Fr A	4028	0.026	4821	5118
BBA 16 50/70	2775	0.174	9231	13792
MAMR16 45/80 Fr A	5188	0.0239	6119	6465
MAMR16 50/70	8357.95	0.038	10867	11860
SMA16 45/80 Fr A	3955.49	0.0505	5607	6298
SMA16 50/70	4339.1	0.139	11334	15610

Table 5 Method II for calculating creep parameters on samples compacted with Gyrocompactor, 300 kPa

Type of mixture	Parameters and equation in stage II Method II ($\log \epsilon_n = \log A + \log B n$)		Permanent deformation ϵ_{1000}^{\cdot} $\epsilon_{1000, \text{calc}} = A_{1000}^B$	Permanent deformation ϵ_{10000}^{\cdot} $\epsilon_{10000, \text{calc}} = A_{10000}^B$
	A	B		
BBA 16 45/80 Fr A, 1 bar	2750	0.030	3383	3625
BBA 16 45/80 Fr A, 0.5 bar	3239	0.040	4269	4680
BBA 16 45/80 Fr A, 0 bar	4758	0.043	6404	7071

Variation of creep modulus as a function of lateral pressure, BBA 16 asphalt mixture, samples compacted with Gyrocompactor is presented in Figure 4. Variation of creep modulus on samples compacted with Marshall Impact as a function of creep modulus on samples compacted with Gyrocompactor, 1 bar is presented in Figure 5.

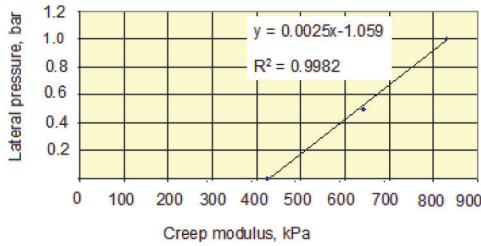


Figure 4 Variation of creep modulus as a function of lateral pressure, BBA 16 asphalt mixture, samples compacted with Gyrocompactor

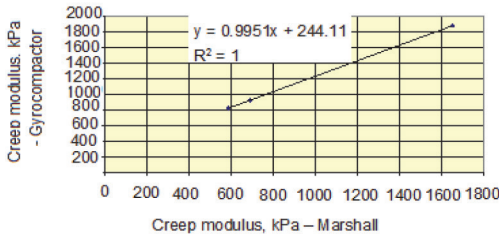


Figure 5 Variation of creep modulus on samples compacted with Marshall Impact compactor as a function of creep modulus on samples compacted with Gyrocompactor, 1bar

Variation of permanent deformation as a function of lateral pressure on samples compacted with Gyrocompactor is presented in Figure 6 and variation of permanent deformation on samples compacted with Marshall Impact as a function of permanent deformation on samples compacted with Gyrocompactor, 1 bar is presented in Figure 7.

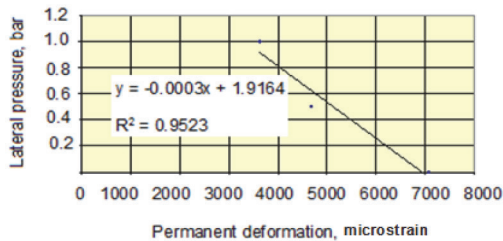


Figure 6 Variation of permanent deformation as a function of lateral pressure on samples compacted with Gyrocompactor

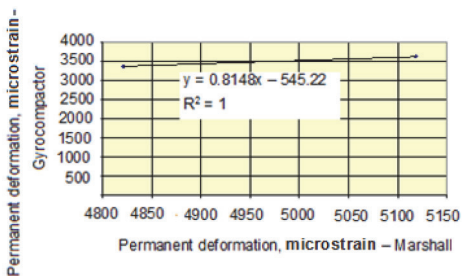


Figure 7 Variation of permanent deformation on samples compacted with Marshall Impact as a function of permanent deformation on samples compacted with Gyrocompactor, 1 bar

4 Conclusions

For all three types of bituminous mixtures, the permanent deformations are higher for the original 50/70 bitumen than for the specially modified 45/80 Fr.A airport bitumen (between 50 and 65%). The creep modulus is approximately 40 - 75 % lower when using original 50/70 bitumen than when using specially modified 45/80 Fr.A. airport bitumen.

Permanent deformations after 10 000 pulsations are about 17-25 % lower for BBA 16 asphalt mixture than for MAMR 16 asphalt mixture and SMA 16 asphalt mixture for 45/80 Fr A modified airport bitumen. Permanent deformations after 10000 pulsations are about 14-25% lower for MAMR16 asphalt mixture compared to BBA 16 asphalt mixture and SMA 16 asphalt mixture for the 50/70 original bitumen.

The creep modulus is higher for both the initial number of cycles and at 1000 and 10000 pulses for BBA 16 asphalt mixture than for MAMR 16 asphalt mixture and SMA 16 asphalt mixture, respectively. When using the specially modified 45/80 Fr.A airport bitumen, the creep rate is approximately equal for BBA 16 and MAMR 16 asphalt mixtures and approximately 50% higher for SMA 16 asphalt mixture.

When using the original 50/70 bitumen, the flow rate for MAMR 16 asphalt mixture is about 73% lower than that for BBA 16 asphalt mixture and about 79% lower than that for SMA 16 asphalt mixture.

For BBA 16 airport asphalt mixture and 45/80 Fr.A airport special modified bitumen it is observed that for a lateral friction of 1 bar the creep modulus is 20-25 % higher than the creep modulus obtained with a lateral friction of 0.5 bar and 46-57 % higher than the creep modulus obtained without lateral friction. The creep rate for 1 bar side friction is 49% lower than for 0.5 bar side friction and 54% lower without side friction. Permanent deformation for 10000 cycles is about 23% lower for BBA 16 airport asphalt mix with 1 bar side friction than for airport asphalt mix with 0.5 bar side friction and 49% lower than for airport asphalt mix without side friction.

The compaction mode has an influence on the permanent deformations. For Marshall Impact the permanent deformations are 29% higher than for Gyrocompactor. The creep modulus is 13 - 30% higher for Gyrocompactor than for Marshall Impact compactor. The creep rate is 11% lower for Gyrocompactor than for Marshall Impact.

Considering the two methods used to process the creep results, we can say that the first method is simpler, but has the disadvantage of a poor representation of the creep curve, because there is no portion on the curve with constant slope. The second method has an advantage due to the representation, in which a linear portion of the curve can be observed.

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