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DOI: 10.2478/rjti-2024-0021

ROMANIAN JOURNAL
OF TRANSPORT INFRASTRUCTURE

PARAMETERS AND CHARACTERISTICS FOR CHOOSING THE TYPE OF ASPHALT MIXTURE FOR THE ROAD WEARING COURSE

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Abstract

The pavement is the reinforced part of the road or street on which vehicular traffic travels. Pavement for road consist of different road layers, the choice of their composition (order of layers) and characteristics (thickness, quality) depending mainly on the traffic as well as other factors: climatic conditions, nature of the soil in the foundation, local materials, gradients, working technologies.

The choice of wearing course is one of the most important stages in the design of a road structure, both for a road being rehabilitated and for a new road. The performance of the asphalt mixture, which is used as wearing course, is very important.

In the present study the following types of tests were considered in order to highlight the characteristics of the types of asphalt mixtures and types of bitumen used: resistance to permanent deformation (wheel tracking) in accordance with SR EN 12697-22, resistance to fatigue is determined according to SR EN 12697-24, Annex A (Two – point bending test on trapezoidal shaped specimens) and Annex E (Indirect tensile test on cylindrical shaped specimens), triaxial cyclic compression test according to SR EN 12697-25 and indirect tensile test on cylindrical shaped specimens (IT – CY) was carried out in accordance with SR EN 12697-26, Annex C.

1. INTRODUCTION

The pavement is the reinforced part of the road or street on which vehicular traffic travels. Pavement for road consist of different road layers, the choice of their composition (order of layers) and characteristics (thickness, quality) depending mainly on the traffic as well as other factors: climatic conditions, nature of the soil in the foundation, local materials, gradients, working technologies.

Among the layers of a road structure, the wearing course is the one which, located on the surface, must be able to withstand the direct action of traffic (tangential action of vehicle wheels) and climate, transmits vertical loads to the other layers, has adequate roughness, ensure good drainage of rainwater and be waterproof. It is made of bituminous and macadam layers (in the case of flexible and mixed road structures), plain cement concrete or reinforced cement concrete (in the case of rigid road structures) (Figure 1.).

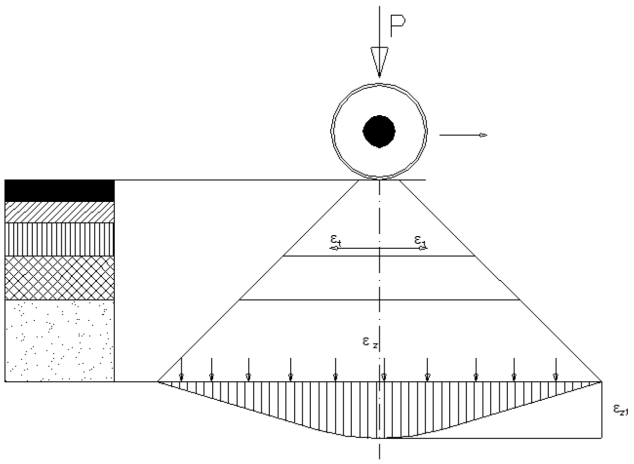

Figura 1. Deformations in the road structure under standard loading

Asphalt cracking causes are multiple and depend primarily on the structural characteristics of road materials. The causes are: cracking because of aging, reflective cracking, fatigue cracking, fatigue from a wrong mixture design and other causes [1].

The physico-mechanical properties of asphalt mixtures depend on temperature. If the temperature of the asphalt mix increases, the viscosity of the bitumen decreases, leading to a reduction in the strength of the asphalt mixture [2].

Asphalt mixture is described by the types and properties of aggregates in the asphalt mixture, as well as the percentage and type of bitumen [3].

Fatigue occurs and develops because of repeated tensile strains coming from traffic loads that determine the pavement layer tensile stress. Permanent deformations occur because of repeated traffic loads superimposed to high temperature [4].

The main condition to ensure a high-performance asphalt mixture is the selection of both the grading curve and the bitumen (percentage and type) [5], [6], [7], [8].

Stiffness modulus is one of the most important parameters for the mechanical characterisation of asphalt mixtures. At the same time, it is an input parameter in the design process of flexible road structures.

In the field of civil engineering, transportation infrastructure is one of the important fields, and flexible pavements are still the most used technological solutions in every road network around the world [9].

Among the materials component of a flexible pavement, the asphalt mixture is considered to be the most important material to be characterized accurately [10].

Failure to meet the standard values for the parameters could lead to improper mechanical behaviour, causing typical fatigue or temperature degradation, which would inevitably lead to a reduced service life of pavement. For this reason, it is crucial to correctly characterise the mechanical behaviour of asphalt mixtures from a performance-based perspective [11], [12], [13].

Thus, it will be established the fatigue behavior of this asphalt mixtures taking into account the climate conditions and the mixture recipe. Because of the climate conditions of our country, which are characterized by both high values of temperature during the summer and low values during the winter, the asphalt mixture must be designed to have a good behavior at both high temperatures and low temperatures [14].

The conventional approach adopted is the experimental one: this allows an accurate assessment of the mechanical performance of the asphalt mixes investigated, but is time-consuming and often very expensive laboratory tests. In addition, this approach has other disadvantages, such as the need to repeat the experimental study when any compositional variable of the mix under investigation changes, with the resulting impact on time and cost [15], [16], [17], [18], [19], [20].

This article presented to the research and laboratory studies carried out within the Road Laboratory of the Technical University of Civil Engineering of Bucharest on asphalt mixtures used in the wearing course.

2. TYPES OF ASPHALT MIXTURES USED AS PAVEMENT WEARING COURSE

According to the norms in force, the asphalt mixtures for the wearing course can be, depending on the technical class of the road or the technical category of the street, MAS 16 - stabilized asphalt mixture, MADr 16 draining asphalt mixture, asphalt concrete with screening, with modified bitumen BA 16m, with additivated bitumen BA 16A or with plain bitumen BA 16, asphalt concrete with crushed gravel with additivated bitumen BAPC 16A or with plain bitumen BAPC 16 and anti-rutting asphalt concrete rich in gravel BAA 16, with crushed gravel BAAPC 16 or with lime BAAPCV 16.

Obviously, the more traffic the road structure has to carry, the higher the characteristics of the road layers.

For example, if you want a road or a street:

- a surface with improved characteristics (i.e. increased skid resistance, reduced rolling noise, improved visibility in wet weather, faster water drainage and reduced aquaplaning);

- with a durable and stable wearing course (i.e. a bituminous surface resistant to fatigue, ageing and rutting);
- as well as reduced maintenance costs by reducing the duration of temporary disruption of road traffic for repairs and by the execution of thinner layers which imply operativity and efficiency (min. 3 cm or 3.5 cm, depending on the maximum size of aggregate used), the use of stabilized asphalt mixture, MAS, is recommended. It is known that this type of mix requires a higher percentage of bitumen (D50/70) because of the presence of fiber but it also has a stony mineral skeleton with a high content of chipping, in which stone-stone contacts are made, leading to a perfect interlocking of the aggregates.

When the wearing course must present an increased resistance to permanent deformation and stripping, BAA anti-rut asphalt mixtures will be used for both reinforcement or rehabilitation works and new works: heavy vehicle traffic lanes, parking areas, frequent acceleration and deceleration areas. These mixtures are characterized by a strong mineral skeleton, the absence of natural sand, low bitumen content and, under certain conditions, the use of hydrated lime (to improve the adhesion of bitumen to natural aggregates and increase the resistance of wearing courses to rutting and stripping). A characteristic of these asphalt mixtures is the use of D 60/80 type non-paraffinized bitumen for cold areas and D 40/60 type bitumen for hot areas, in view of the increase in heavy traffic.

In certain situations, on roads or streets with heavy or very heavy traffic or for special technically and economically justified works (ring roads, intersections, public squares, crossings, residential areas), a wearing course made of MADr asphalt drainage mixtures, characterized by a high voids volume (20-24%) and a discontinuous grain size composition, may be used. This bituminous drainage surfacing is designed to rapidly remove water from the road surface, improve visibility in wet weather and reduce hydroplaning. It will be applied on an impermeable substrate, as it is necessary to evacuate precipitation water rapidly to avoid degradation of the road surface. The bitumen used shall be of type D 70/100 or D 50/70, pure, additivated or modified.

Also, in order to increase resistance to permanent deformation at high temperatures and resistance to cracking at low temperatures, bituminous surfacings made with polymer-modified bitumen are used. The roadworks on which this wearing course is used are those with heavy and very heavy traffic as well as special, technically and economically justified roadworks (heavy vehicle traffic lanes, parking areas, frequent acceleration and deceleration areas etc.).

A comparison between the grading of the asphalt mixtures used in the present study, as wearing course, is shown in Figure 2.

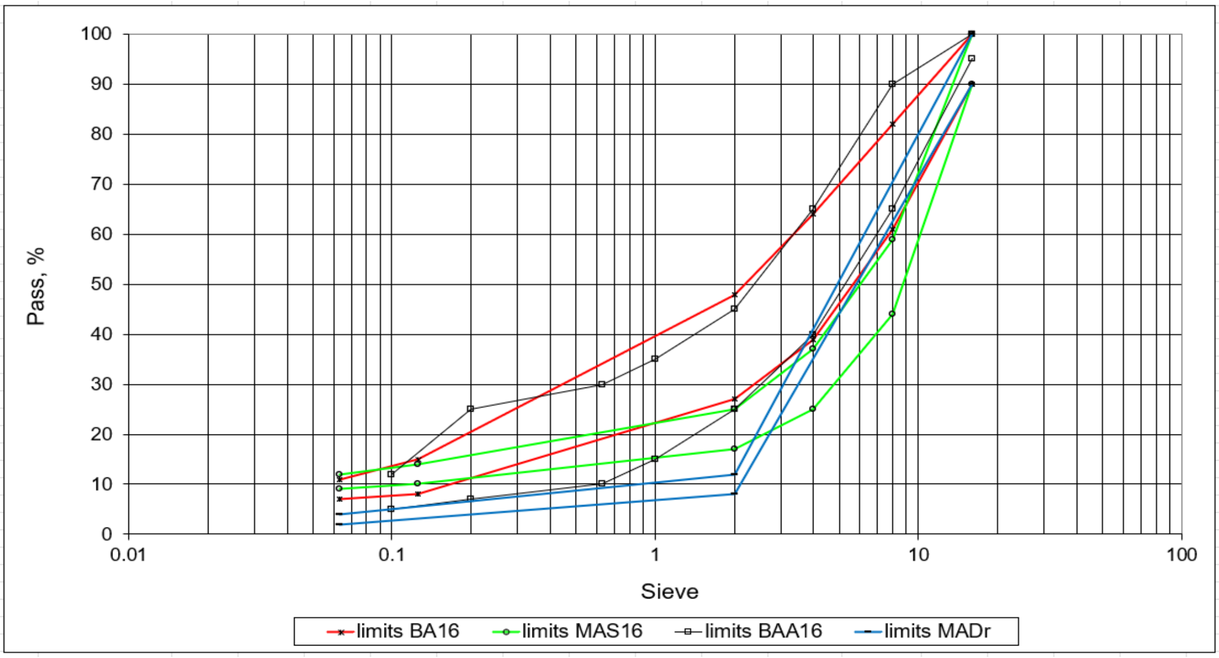

Figure 2. Grading zones of asphalt mixtures used in wearing courses

3. MATERIALS USED AND SPECIFIC LABORATORY TESTS

Among these asphalt mixtures presented above, the present paper focuses on the analysis of the characteristics of BA 16 - 1, BA 16 - 2 asphalt concret (low bitumen and low filer content, has superior roughness qualities to BA 16 -1 asphalt concrete) and BAA16 anti-rutting asphalt concrete and MAS 16 stabilized asphalt mixtures with different types of bitumen.

Table 1 shows the characteristics of the bitumens used in this study.

Tabel 1 Used bitumen characteristics

Characteristics	A	B	C	D
Penetration, 25^{o}C, 1/100 mm	65	63	100	90
Soft point, IB, ^{o}C	50.5	48.5	46	51.5
Ductility, 25^{o}C, cm	> 100	> 100	> 100	90
Inflamability point, ^{o}C	350	350	351	299

The choice of the types of experimental tests for determining the characteristics of asphalt mixtures used in wearing courses results taking into account the main degradations encountered in a flexible pavement, degradations that occur under the effect of loads given by increasingly heavy and intense traffic and the stresses due to variations in environmental factors (temperature and humidity). These degradations are rutting and fatigue cracking of asphalt mixes and they are two important aspects to be taken into account when designing an asphalt mixture recipe in the laboratory.

The effects of rutting on traffic comfort and safety make it necessary to design road structures in such a way that the characteristics of the surface layer do not fall below certain limits, throughout the entire designed life of the pavement.

The effects of fatigue can be found in fatigue cracking of the asphalt layer, different from the thermal cracking that occurs due to thermal shrinkage. As loads continue to pass, the tensile deformation at the base of the asphalt layer leads to the initiation of a crack, which will propagate in the layer with increasing of traffic, eventually leading to failure.

The technical specialist has at his disposal a whole range of specific laboratory tests such as: gyrocompactor, Marshall press, fatigue tests on four-point on prismatic specimens, two-point on trapezoidal specimens, cylindrical specimens - indirect tensile, permanent deformation tests on cylindrical specimens, Wheel Tracking rutting depth tests etc. which ultimately lead to the establishment of an optimum mix in terms of creep and fatigue behavior.

The resistance to permanent deformation in the wearing course is measured by:

- the dynamic creep of the asphalt mixture by repeated uniaxial testing of a cylindrical asphalt sample;

- the rate of permanent deformation recorded on an asphalt slab at a given number of passes of a tire with well-defined characteristics.

Rutting can occur, depending on the traffic and bituminous materials, when the temperature is at least 35^{o}C. Laboratory studies show that for a bituminous mixture at a temperature of 60^{o}C, a rut depth 5 times greater than the maximum rut depth is produced.

The main parameters that directly influence the level of the traffic lanes can be grouped into four groups:

a) traffic;
b) geometric characteristics and the localities through which the road passes;
c) climatic type;
d) materials used.

The fatigue resistance is defined by the number of loads, N_{adm} that the asphalt mixture can withstand before failure.

Factors influencing fatigue resistance are the following:

a) mode of compaction;
b) asphalt mixture variables;
c) environmental variables;
d) test conditions.

In the U.T.C.B. Roads Laboratory, laboratory studies were carried out for the design of asphalt mixtures of BA 16 and MAS 16 type and the determination of the physical and mechanical characteristics in temperature regimes: 23°C, 40°C and 50°C by triaxial cyclic compression test (Figure 3). The permanent deformation for a given level of traffic stress was also determined.

Specific laboratory studies were also carried out to determine the stiffness and fatigue behavior of asphalt mixtures (BA16 - 1, BA16 - 2, BAA16, MAS16) on two types of tests: two-point bending test on trapezoidal specimens and indirect tensile test on cylindrical shaped specimens (Figures 4 and 5).

Figure 3. Triaxial cyclic compression test

Triaxial cyclic compression test determines the resistance to permanent deformation of a cylindrical specimen of bituminous mixture. The specimen is either prepared in the laboratory or cored from the road. A cylindrical test specimen, maintained at elevated conditioning temperature, is placed between two plan parallel loading platens. The specimen is subjected to a confining pressure, σ_c, on which a cyclic axial pressure $\sigma_a(t)$ is superposed.

During the test the change in height of the specimen is measured at specified numbers of load applications. From this, the cumulative axial strain, εn, (permanent deformation) of the test specimen is determined as a function of the number of load applications. The results are represented in a creep curve. From this, the creep characteristics of the specimen are computed.

The axial loading system shall consist of two steel loading platens between which the specimen is placed. The static confining pressure and the axial cyclic pressure shall be applied by means of a servo-hydraulic, pneumatic, electro-magnetic or other suitable system, able to generate the required pressures with an accuracy of at least ± 2,0 % [24].

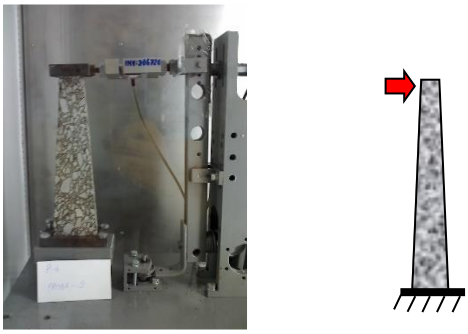

Figure 4. Two-point bending test on trapezoidal specimens (fatigue)

Two-point bending test on trapezoidal specimens (fatigue) characterises the behaviour of bituminous mixtures under fatigue loading with controlled displacement by two-point bending using trapezoidal shaped specimens. The method can be used for bituminous mixtures with a maximum aggregate size of up to 20 mm on specimens prepared in a laboratory or obtained from road layers with a thickness of at least 40 mm. For mixtures with an upper size D between 20 mm and 40 mm, the test can be performed using the same principle but with adapted specimen sizes. For a given frequency of sinusoidal displacement, the method shall be carried out on several elements tested in a ventilated atmosphere at a controlled temperature.

The specimen i shall be moved sinusoidally at its head at the imposed displacement amplitude ± 5 μm until the failure criterion has been reached. Between 100 cycles and 500 cycles, the reaction forces shall be recorded to ± 2 % and the average reaction force calculated. The displacement z_i shall be measured and ε_i calculated for this element test [24].

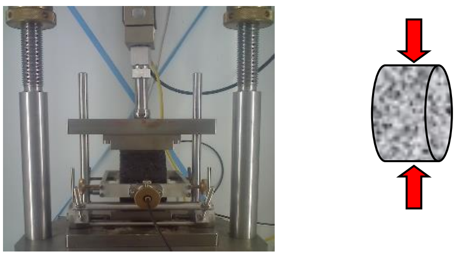

Figure 5. Indirect tensile test on cylindrical shaped specimens (fatigue)

Indirect tensile test on cylindrical shaped specimens (fatigue) characterises the behaviour of bituminous mixtures under repeated load fatigue testing with a constant load mode using an indirect tensile load. A cylindrical specimen manufactured in a laboratory or cored from a road layer can be used in this test. A cylinder-shaped test specimen shall be exposed to repeated compressive loads with a haversine load signal through the vertical diametrical plane. This loading develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane, which causes the specimen to fail by splitting along the central part of the vertical diameter. The resulting horizontal deformation of the specimen shall be measured and an assumed Poisson's ratio used to calculate the tensile strain at the centre of the specimen [24].

4. RESULTS

The results to be presented in the following figures are selective, by types of tests performed: triaxial cyclic compression test - resistance to permanent deformation (Figure 6. and Figure 7.), stiffness (Figure 8.), rutting (Figure 9. and Figure 10.), fatigue on trapezoidal specimens (Figure 11. and Figure 12.), and fatigue on cylindrical specimens (Figure 13. and Figure 14.).

Figure 6. and Figure 7. show the results of the resistance to permanent deformation (triaxial cyclic compression test) according to SR EN 12697-25, for MAS 16 stabilized asphalt mixture, BA 16 - 1 asphalt concrete and BA 16 - 2 asphalt concrete, using bitumen type A.

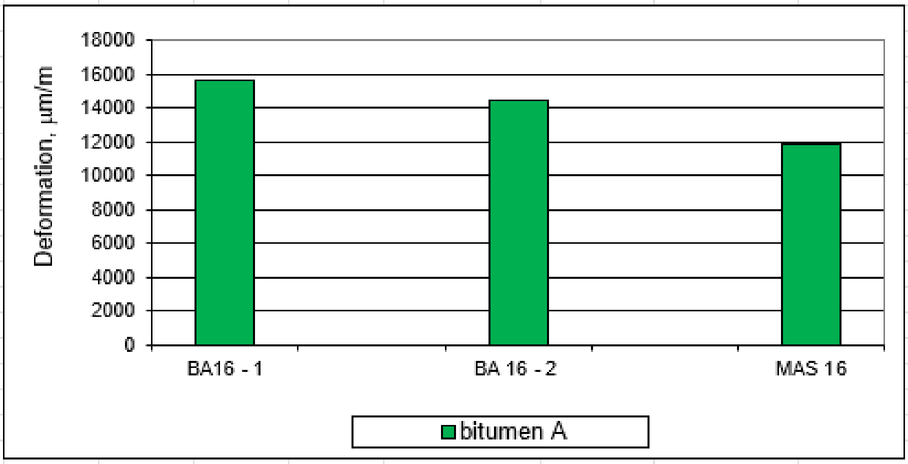

Figure 6. Deformation versus asphalt mixture type at 50°C, 300 KPa and 10000 pulses

The permanent deformation is lower in the case of MAS 16 stabilized mixture with 18% - 24% in the case of asphalt concrete BA 16 - 1, respectively BA 16 -2.

The creep rate is lower for MAS 16 stabilized mixture by 30% - 45% than for asphalt concrete BA 16 - 1 and BA 16 -2, respectively.

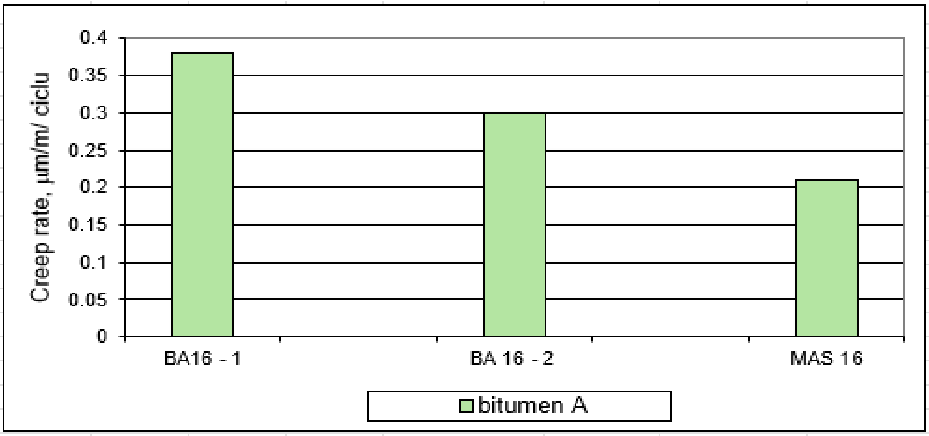

Figure 7. Creep rate versus asphalt mixture type, at 50°C, 300 KPa and 10000 pulses

Figure 8. shows the stiffness moduli for MAS 16 stabilized asphalt mixture, BA 16 - 1 asphalt concrete and BA 16 - 2 asphalt concrete, applied horizontal tension of 250 MPa, temperature 15°C, bitumen A and bitumen D. The indirect tensile test on cylindrical shaped specimens (IT – CY) was carried out in accordance with SR EN 12697-26, Annex C.

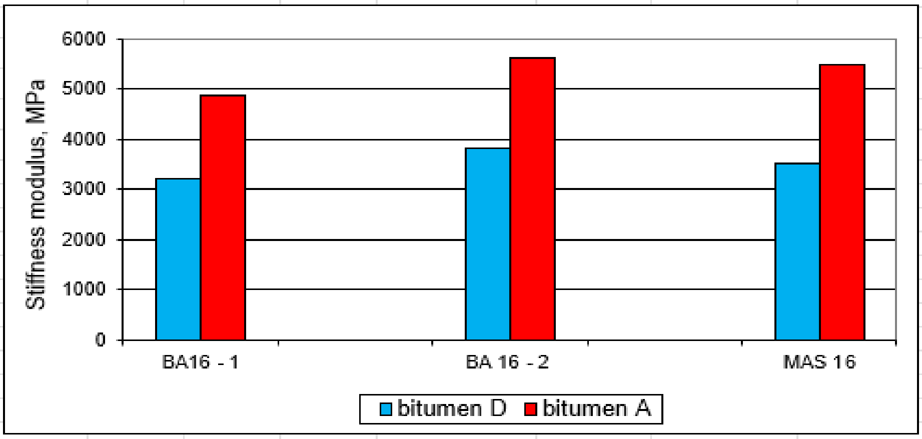

Figure 8. Stiffness moduli for asphalt mixtures BA16, BAR16, MASF16, 250 MPa horizontal applied tension, temperature 20°C

The stiffness modulus is 11% higher in the case of MAS 16 stabilized mixture than in the case of asphalt concrete BA 16 - 1 and 2% lower than in the case of asphalt concrete BA 16 -2.

Figure 9. and Figure 10. show the results of resistance to permanent deformation (wheel tracking) in accordance with SR EN 12697-22, for MAS 16 stabilized asphalt mixture, BA 16 - 1 asphalt concrete and BA 16 - 2 asphalt concrete, using bitumen type A.

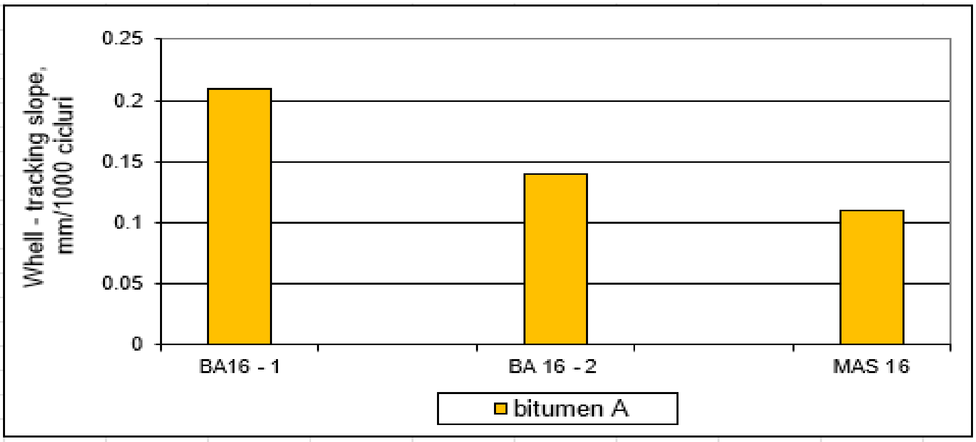

Figure 9. Wheel - tracking slope versus asphalt mixture type at 60°C

The wheel – tracking slope is lower in the case of MAS 16 stabilized mixture by 21% - 48% than in the case of asphalt concrete BA 16 - 2 and BA 16 -1, respectively.

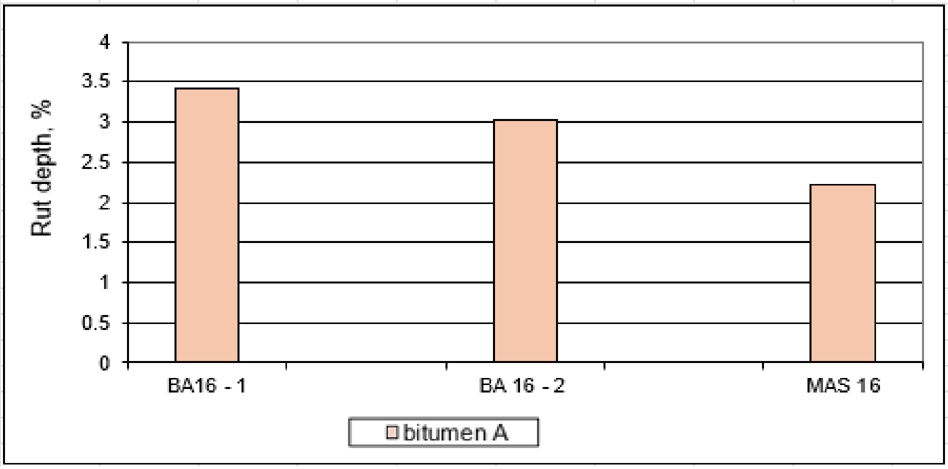

Figure 10. Rut depth versus asphalt mixture type at 60°C

The rut depth is lower for the stabilized mix MAS 16 by 26% - 35% than for asphalt concrete BA 16 - 2 and BA 16 -1, respectively.

Resistance to fatigue is determined according to SR EN 12697-24, Annex A (Two – point bending test on trapezoidal shaped specimens) and Annex E (Indirect tensile test on cylindrical shaped specimens).

Figure 11. shows the variation of the phase angle as a function of the number of cycles for BAA 16 asphalt antirutting mixture, bitumen A, B, C and D, frequency 10 Hz and temperature 23^{o}C.

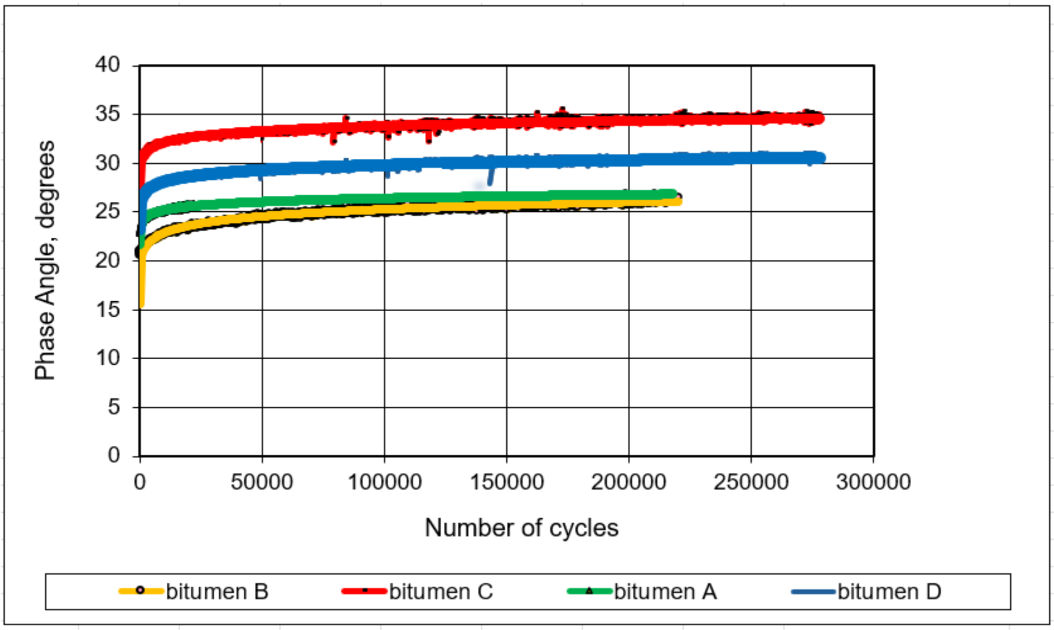

Figure 11. Phase angle versus number of cycles: influence of bitumen type, asphalt anti-rutting mixture, frequency 10 Hz, temperature 23°C, trapezoidal samples

Figure 12. shows the variation of the phase angle as a function of the number of cycles for asphalt concrete BA 16 -1, asphalt concrete BA 16 -2 and asphalt mixture MAS 16, bitumen A, frequency 10 Hz, temperature 15°C.

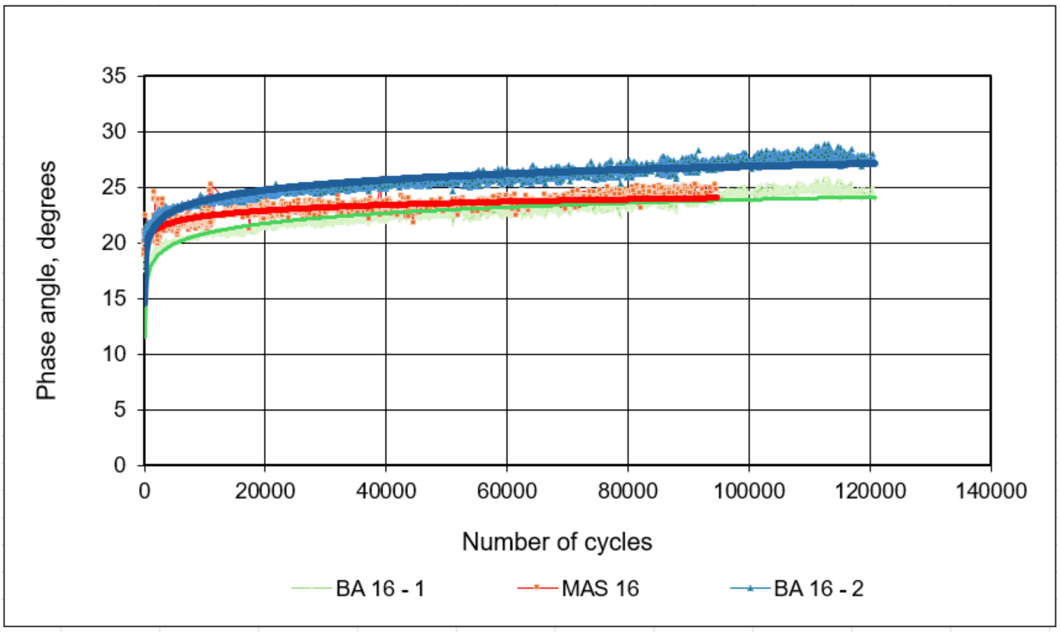

Figure 12. Phase angle versus number of cycles: influence of mix type, bitumen A, frequency 10 Hz, temperature 15°C, trapezoidal specimens

The fatigue resistance versus bitumen type (bitumen A, bitumen D) for asphalt concrete BA16 - 1, horizontal tension 300 MPa and temperature 15°C is presented in Figure 13.

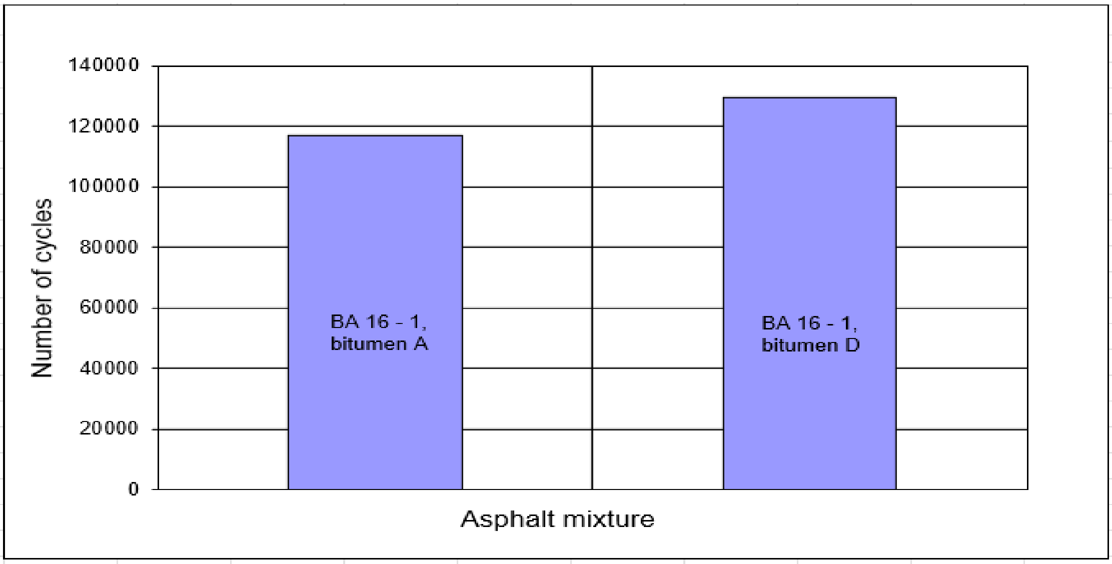

Figure 13. Fatigue resistance versus BA16 - 1 asphalt mixture for 2 bitumen type (bitumen A, bitumen D), temperature 20°C, cylindrical specimens

The fatigue resistance as a function of asphalt mixture type for bitumen A, horizontal tension 300 MPa and temperature 15°C is presented in Figure 14.

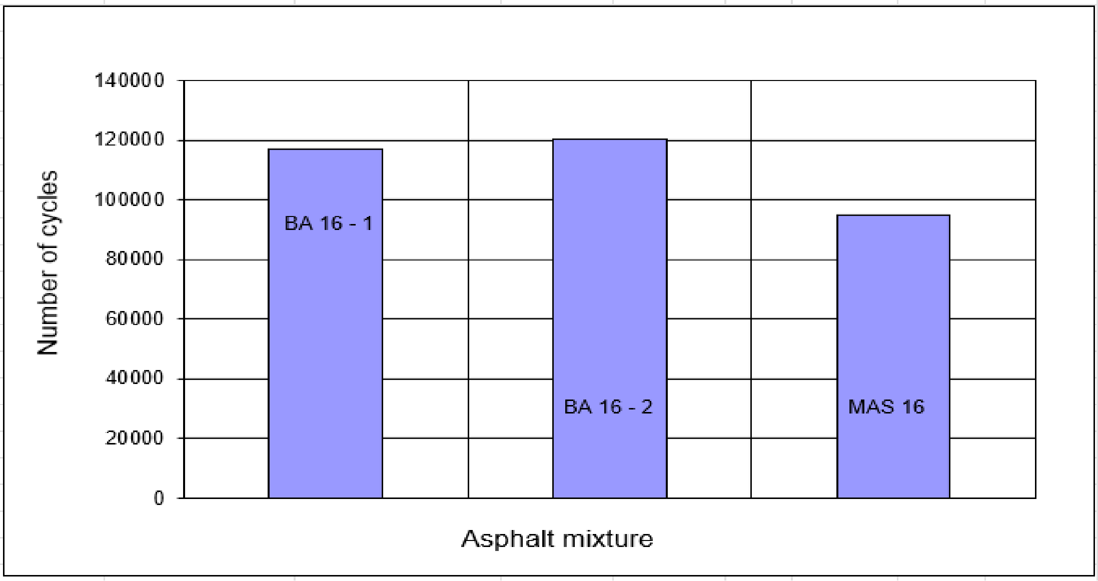

Figure 14. Fatigue resistance versus asphalt mixture type for bitumen A, temperature 15°C, cylindrical specimens

Table 3. shows the characteristics of the asphalt mixtures considered in this work, as determined by dynamic tests.

Table 3. Characteristics of asphalt mixtures determined by dynamic tests

Characteristic	**Type Mixture**	**Laboratory results**	**The old SR 174/2009**	**The actual in force norm AND 605/2016+A**	**SR EN 13108-1**
Resistance to permanent deformations (triaxial cyclic compression test) - deformation at 50 ºC, 300KPa and 10000 pulses, µm/m - creep rate at 50 ºC, 300KPa and 10000 pulses, µm/m/cycle	BA 16 - 2	15610	max. 30000 (1800 pulses) max. 3 (1800 pulses)	max 30000 max 2	-
		0.38			f_{cmax}0,4
	BA 16 - 2	14439			-
		0.30			f_{cmax}0,4
	MAS 16	11860		max 20000 max 1	-
		0.21			f_{cmax}0.4
Stiffness modulus at 20ºC, MPa	BA 16 - 1	4875	min.4500 (at 15ºC)	min 4000 (20ºC)	S_{min} 4500 S_{max} NR
	BA 16 - 2	5621			S_{min} 5500 S_{max} NR
	MAS 16	5489		min 4200 (20ºC)	S_{min} 4500 S_{max} NR
Resistance to permanent deformations, 60 ºC (wheel - tracking) - wheel - tracking slope, mm/1000 cycles - rut depth, % of the initial sample thickness	BA 16 - 1	0,21	max 1.0 max 9	max 0,5 max 7	WTS_{AIRmax}0,30
		3,42			PRD_{AIRmax} 4
	BA 16 - 2	0,14			WTS_{AIRmax}0,15
		3,02			PRD_{AIRmax} 4
	MAS 16	0,11	max 0.6 max 7	max 0,3 max 5	WTS_{AIRmax}0,15
		2,23			PRD_{AIRmax} 3

5. CONCLUSIONS

From the study of the permanent deformation behavior of asphalt mixtures used in wearing courses, the following conclusions can be drawn:

- the value of permanent deformation is influenced by the type of mix under the same loading and temperature conditions: the stabilized asphalt mixture MAS16 shows lower values of permanent deformation than the classic asphalt mix BA16;

- the permanent deformation is strongly influenced by the temperature value: the higher the temperature, the greater the permanent deformation; temperature influences the behaviour of stabilized asphalt mixtures more than that of conventional asphalt mixtures; it follows that particular care must be taken when determining the recipe of the stabilized asphalt mixture, which has a somewhat higher percentage of bitumen than a conventional asphalt mixture;

- stabilized asphalt has a better triaxial cyclic compression test behaviour than conventional asphalt;
- the type of bitumen contributes to determining the permanent deformation of the mixtures studied: a bitumen with a higher consistency and better behaviour at high and low temperatures, will lead to asphalt mixtures with lower values of permanent deformation than bitumens of low consistency under the same loading and temperature conditions.
- the phase angle, φ has lower values for asphalt mixtures made with 50/70 penetration bitumen, indicating a more pronounced elastic character compared to asphalt mixtures made with 80/100 penetration bitumen;
- 50/70 penetration bitumen leads faster to breaking than softer 80/100 penetration bitumen, so the number of fatigue cycles is lower; BA16 - 2 asphalt mixtures show the best fatigue behavior compared to MAS16 and BA16 - 1 asphalt mixtures.

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