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RESISTANCE TO PERMANENT DEFORMATION IN BINDER CONTENT AND FILM THICKNESS VIEWPOINT

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1. Introduction

Wheel tracking tests are usually used to verify a permanent deformation resistance of asphalts. The application of the standard EN 13108-1 for asphalt concrete allows using another test method (triaxial compression test) to verify permanent deformation resistance. A triaxial test is able to eliminate disadvantages of wheel tracking tests, particularly the different stress distribution in a test sample in comparison with a pavement.

Resistance to permanent deformation is one of the properties that are necessary to test in type testing. In general it is known higher bitumen content negatively influenced permanent deformation resistance. But measured test results presented in following part of paper point out differences in mixtures however the bitumen contents were relatively the same.

2. Permanent deformation

The permanent deformation with cracking and potholes is the most often distress on asphalt pavement. It represents accumulation of small amounts of deformation that occurs each time a load is applied. Especially with AADT increasing, heavy axle load forms stresses in asphalt layers and forms rutting characterized by downward and lateral movement of mixture. Permanent deformation (rutting) in asphalt layers develops in three stages (Fig.1):

- *primary (initial) stage* is part of deformation, where asphalt mixture is formed and compacted by traffic (densification, volume reduction).
- *secondary (middle) stage*, it is considered to be representative of deformation behavior for the greater part of lifetime of pavement and constant rate rutting. Traffic load (horizontal and vertical) cause shear stresses in asphalts. There is a displacement of asphalt mixture and flow rutting due to shear stress.
- *tertiary (last) stage*, is characterized by accelerating rutting, excessive rapid plastic deformations considering number of load. It is typical characteristic of asphalts unsuitable from permanent deformation point of view.

Permanent deformation is condition of pavement failure caused accumulation of permanent deformations by repeated axle load.

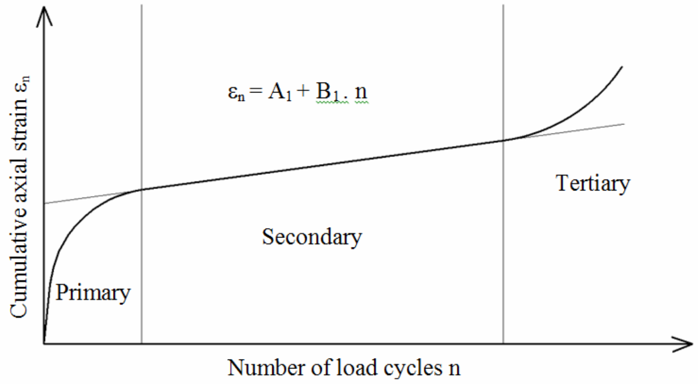

Fig. 1 The creep curve of asphalt mixtures

3. Test method

Test method B of EN 12697-25 [1] determines resistance to permanent deformation of a cylindrical specimen of asphalts. The specimen in triaxial chamber is subjected to a confining pressure and cyclic axial stress – have sinusoidal or block-pulse loading (Fig.2). The requirements on values of pressures, frequencies and test temperatures are defined in standard EN 13108-20 type testing (Tab.1).

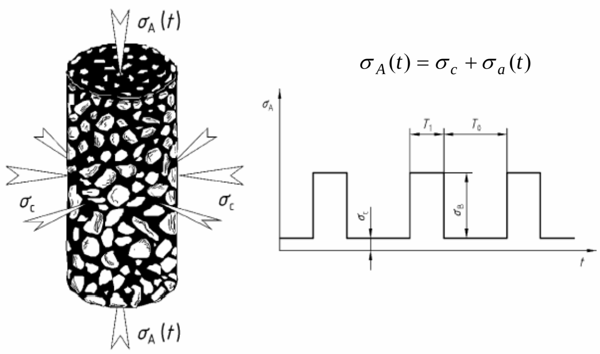

Fig. 2 The principle of sample loading by block-pulse cyclic impulses

Tab.1.The test conditions for wearing course [4]

Layer	Test temperature	Confining stress	Axial stress	Frequency	Cyclic axial pressure form
wearing course	50 ^{0}C	150 kPa	300 kPa	3 Hz	have sinusoidal
				1 s / 1 s	block-pulse

During the test the changes in height of specimen are measured at specified numbers of load applications. And the cumulative axial strain ε_n (permanent deformation) of test specimen is determined as a function of number of load applications:

$$\varepsilon_n = 100.(h_0 - h_n)/h_0 , \quad (1)$$

where: ε_n – is total axial deformation of test sample after n-loading cycles, [%],
h_0 - is average height after preloading of sample, [mm],
h_n - is average height after n loading cycles, [mm].

The results are represented in a creep curve as given in Fig.1. Resistance of permanent deformation of tested mixture is characterized with parameter f_c. The creep rate f_c is determined in the (quasi) linear part of creep curve (stage 2) as the slope expressed in microstrain/loading cycle:

$$f_c = B_1 \,.\, 10^4 , \quad (2)$$

where: B_1 is slope of least square linear fit of the creep curve between 3 000 and 10 000 load applications.

4. Experimental measurement

Tested mixtures were asphalt concrete AC 11 with SBS polymer modified bitumen PmB 45/80-75 from batch plants. All mixtures fulfilled requirements defined in EN 13108-1 and complementary Slovak criteria. Aggregate gradation and bitumen content of tested mixtures are in Tab.2.

Tab.2. Aggregate gradation and asphalt content of tested mixtures

Sieve size in mm	Gradation of AC 11 mixtures								
	Passing in %								
	1	2	3	4	5	6	7	8	Limits
16	100	100	100	100	100	100	100	100	100
11,2	96,8	98,2	97	97,4	97,3	97	95,5	95,6	90-100
4	46,7	52,7	46,8	48,2	55	50,6	49,8	49,7	45-67
2	32,2	34,6	33,5	33	35,9	33	33	33,5	25-50
0,50	13	15,3	16	16,1	17,4	15,8	15,9	17,1	10-33
0,063	6,5	6,8	7,9	7,5	7,1	7,2	7	8,2	4-11
Bitumen content in %	5,74	5,66	5,7	5,7	5,7	5,7	5,7	5,7	min. 5,4

From previous experimental measurement [7] the assumption of better results of resistance to permanent deformation of modified bitumen was verified and confirmed as can be seen in Fig.3.

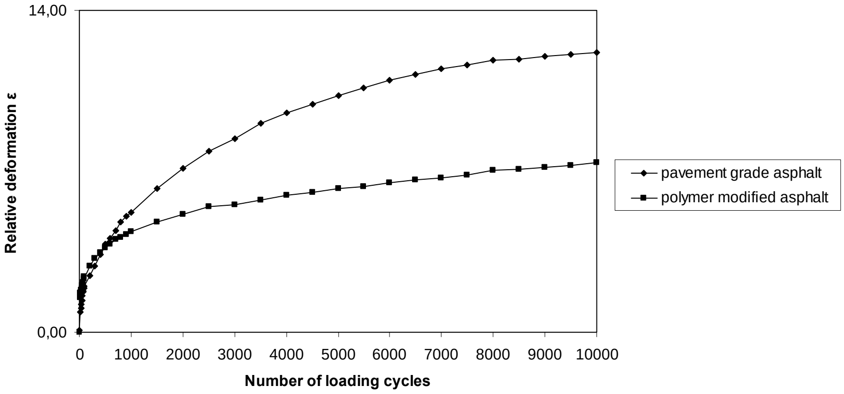

Fig.3 The creep curve of AC11 with different binder type and same content [7]

Achieved results of creep rate f_c of tested mixtures asphalt concrete AC11 [6] are displayed in Fig.4. The values of parameter *fc* are within the range 0,05 and 0,16 and belong the category $f_{cmax\ 0,2}$ defined in EN 13108-1. Tested mixtures of asphalt concrete AC 11 were with same type of PmB bitumen and with more or less same bitumen content (5,66 % to 5,74 %) even though different results of f_c were obtained.

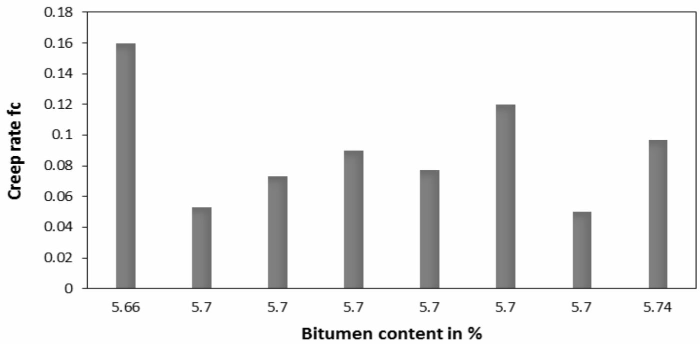

Fig.4 Results of creep rate of tested AC11 mixtures

During detailed investigation there were small differences in aggregate gradation. Changes in gradation make change of aggregate surface area and the mixture needs different bitumen content to coat aggregate particles, to bind them to each other and to make stiff material.

Generally the surface area of aggregates is determined empirically using surface area factors and gradation of aggregate [5]. In Slovakia the aggregate surface area ε is calculated by multiplying the total mass of specified fraction expressed as a percentage passing each sieve size by appropriate factor and adding the resultants together [2]:

$$\varepsilon = 0{,}01.(0{,}174.G+0{,}40.g+2{,}30.S+15{,}33.s+140.f), \tag{3}$$

where: G - aggregate proportion retained by sieve 8 mm in % of mass, g - aggregate proportion retained by sieve 4 mm in % of mass, S - aggregate proportion retained by sieve 0,25 mm in % of mass, s - aggregate proportion retained by sieve 0,063 mm in % of mass, f - percentage passing sieve 0,063 mm.

The aggregate surface is important since it affects the amount of bitumen needed to coat the aggregate. Asphalts that have high surface area and low bitumen content are undesirable because these mixes will have a thin bitumen film on aggregate and will probably not have enough durability. Theoretical bitumen film thickness is calculated from surface area and bitumen content according [5]:

$$T = \frac{b}{100 - b} \cdot \frac{1}{\rho_b} \cdot \frac{1}{SA}, \tag{4}$$

where: T - is bitumen film thickness, [mm],
ρ_b - density of bitumen, [kg/m^3],
SA – aggregate surface area, SA = ε according [2], [m^2/kg],
b - bitumen content, [%].

Calculated surface area and theoretical bitumen film thickness of tested mixtures are showed in Tab.3. Comparison of reached results of permanent deformation resistance with calculated film thickness is shown in following Fig.5.

Tab.3. Aggregate surface area and calculated bitumen film thickness of tested mixtures

	Mixtures AC 11							
	1	2	3	4	5	6	7	8
Surface area in m^2/kg	10,779	11,423	12,787	12,354	12,076	11,986	11,722	13,346
Theoretical bitumen film thickness in micron	5,649	5,252	4,727	4,893	5,005	5,043	5,157	4,529

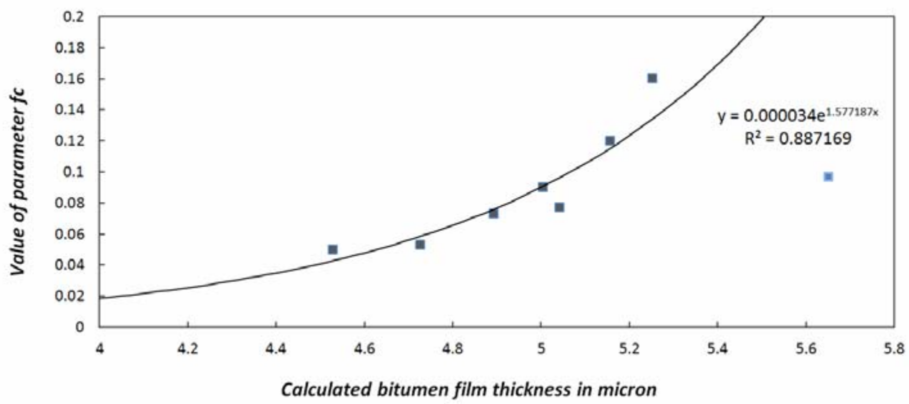

Fig.5 Relation between theoretical bitumen film thickness and results of permanent deformation resistance of AC11

From measuring of resistance to permanent deformation it is can be observe relation between aggregate surface area and bitumen film thickness and permanent deformation exist. With higher bitumen content the film thickness increases and the aggregate particles are not enough close to interlock themselves and make strength structure and resistance to permanent deformation of mixture decreases. Exception results of mixture 1 that has greater bitumen film thickness. But it has less surface area and coarse aggregate skeleton that better resistances to rutting. On the other side no adequate bitumen thickness can cause deficiency of cohesion between aggregate and forms dry mixture. There is a faster bitumen oxidation and ageing of bitumen. Through thin bitumen film the water penetrates to aggregate and makes bitumen stripping.

5. Conclusions

The evaluation of the asphalt mixtures resistance to permanent deformation by cyclic triaxial test is a part of functional performance design of asphalt concrete. This method better simulates the real stress and tenseness in pavement layers and allows displaying differences in resistance of asphalt mixtures to permanent deformation according bitumen content. An eight mixtures of asphalt concrete (AC11) were tested to a resistance to permanent deformation. And it was observed the bitumen film thickness (in relation to surface area and bitumen content) effects resistance results. With increasing bitumen film thickness insufficient interlocking of aggregate causes the mixture isn´t stiff and has assumption to plastic deformation and to form rutting under traffic loading.

References

[1] STN EN 12697-25 Bituminous mixtures. Test methods for hot mix asphalt. Cyclic compression test.
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[6] Bežilla, T.: Asphalts resistance to permanent deformation, Doctoral thesis, 2010.
[7] Bežilla, T., Remišová, E., Komačka, J.: Investigation asphalt influence on resistance to permanent deformation, XVIII Russian–Slovak-Polish seminar “Theoretical Foundation of Civil Engineering”, Moscow-Archangelsk, 01.-05.07.2009.

ODOLNOSŤ PROTI TRVALÝM DEFORMÁCIÁM Z POHĽADU OBSAHU A HRÚBKY FILMU SPOJIVA

Summary

Predkladaný príspevok je venovaný skúšobnej metóde na stanovenia odolnosti zmesí typu asflaltový betón proti trvalým deformáciám (STN EN 12697-25 metóda B) podľa funkčného prístupu pri návrhu zmesi. Cyklická tlaková skúška určuje odolnosť valcového skúšobného telesa pomocou charakteristík dotvarovania (rýchlosť dotvarovania f_c). V príspevku sú výsledky experimentálnych meraní 8 zmesí typu AC11 a analyzovaná závislosť z pohľadu obsahu a hrúbky filmu spojiva.