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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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TESTING AND INTERPRETATION OF THE PERMEABILITY OF ASPHALT MIXES

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Abstract

The effect of water in and between asphalt pavement layers has been noticed and tested since the 1960-s, and the idea that asphalt pavements are not impermeable has been shortly proven. However, similarly to various countries, road pavements in Hungary are still considered impermeable on the level of national regulations regarding design and certification. Despite a high number of literature in this matter, and the existence of a European Norm and proven methods and equipment to measure permeability of asphalt pavements in the laboratory and in-situ as well, there is typically little or no requirement referring to the testing and required values that indicate the presence and flow of water either in the mix, or the pavement structural design stage, or regarding the requirements for built layers. Although the effect of water can be severe over time, affecting the performance of the layers and the pavement structure. The paper presents field study showing the effect of water on the state of in-service layers, the standard European method and equipment to test permeability of asphalt layers, and laboratory permeability tests conducted on core samples and laboratory samples. After a high number of permeability tests, void content vas determined for tested specimens. The effect of asphalt mix void content on the permeability are shown, depicting that void contents otherwise acceptable by current standards and also international practice may lead to, in fact, permeable layers.

Keywords: asphalt permeability, pavement moisture, air void content

1 Introduction

The presence of water in road pavement layers is evident in case of granular layers such as subgrades and subbase layers, however its presence in and between bound layers, especially asphalt layers as presented in this paper, despite having been tested and published both in the field and in laboratory since the 1960-s, still strikes as a novelty to a wider professional community.

There are several cases of water-inflicted damage in asphalt layers in international and national literature as well [1, 2]. Several case studies have also depicted clear relations between the compaction rate and interlayer bonding of asphalt layers and the presence and movement of water within and between asphalt layers, respectively since even the 1970-s [3, 4]. In spite of such findings, in Hungary, similarly to most countries, there are poor or no specifications at all, with regard to permeability of asphalt layers, besides the specifications regarding air void content of the built layer. As, besides of research, professional consultancy regarding pavement rehabilitation and construction, asphalt mix testing and design being main field of the Asphalt unit at the Tracks Laboratory, Budapest University of Technology and Economics, the authors have encountered several cases of water permeability issues within asphalt layers and asphalt pavements. The manager of a highway in Hungary contacted the Laboratory to

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analyse the possible causes of pavement failures, accompanied by symptoms relatable to water movement. Based on international literature, issues have been investigated and a permeability testing device has been also acquired conform the relevant European standard [5]. The paper presents main findings using simple tests and computer tomography and attempts to point out further research goals to assess such problems.

2 Test plan

Ground-penetrating radar (GPR) measurements have been taken on the selected highway section to assess sections with high chance of water presence. A total of 5 sections have been selected. According to the test plan core samples have been taken in all lanes and the emergency lane as well (two samples each lane), thus a total of 30 samples have been taken. Almost all samples showed the presence of water at first sight as parts of the samples were wet after several hours or being on the surface, showing a relatively higher void content – filled with bore water as seen on Fig. 1 as example.

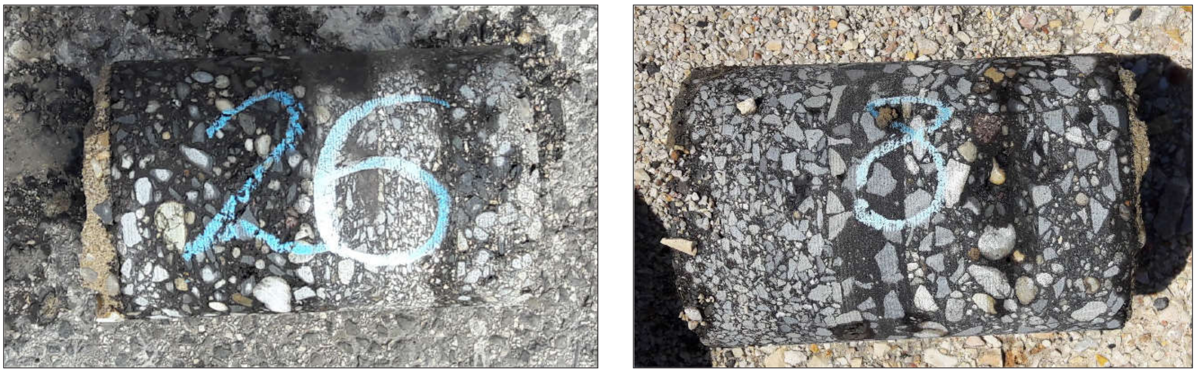

Figure 1 Examples of wet core samples

According to the international literature permeability of asphalt pavements is strongly relatable to air void content (rate of compaction) of the layers, accordingly the test plan consisted of not only permeability measurements but air void content determination as well, for all samples. As a novelty – in Hungary – computer tomography (CT) has also been applied as an experimental technique. CT results will be analysed in the future.

3 Asphalt permeability tests

Several known test methods of permeability of laboratory asphalt samples as well as in-service layers are available. The results of field tests are convincing, in these cases the permeability of pavement cracks is also taken into account besides the material permeability of the pavement layers. Moreover, in this case the permeability of the whole pavement is tested i.e. the water capable to reach the subgrade is inferred [6-8]. Laboratory tests according to the according European Norm [5] consist of a water column having constant height in a cone making the permeation of the water through the sample possible. Fig. 2 shows the test compilation of the two standard methods, the vertical permeability where the water permeates into and out of the sample on the horizontal planes, and the horizontal permeability measurement, whereas water permeates into the sample on the horizontal plane, but permeates out on the vertical cylinder.

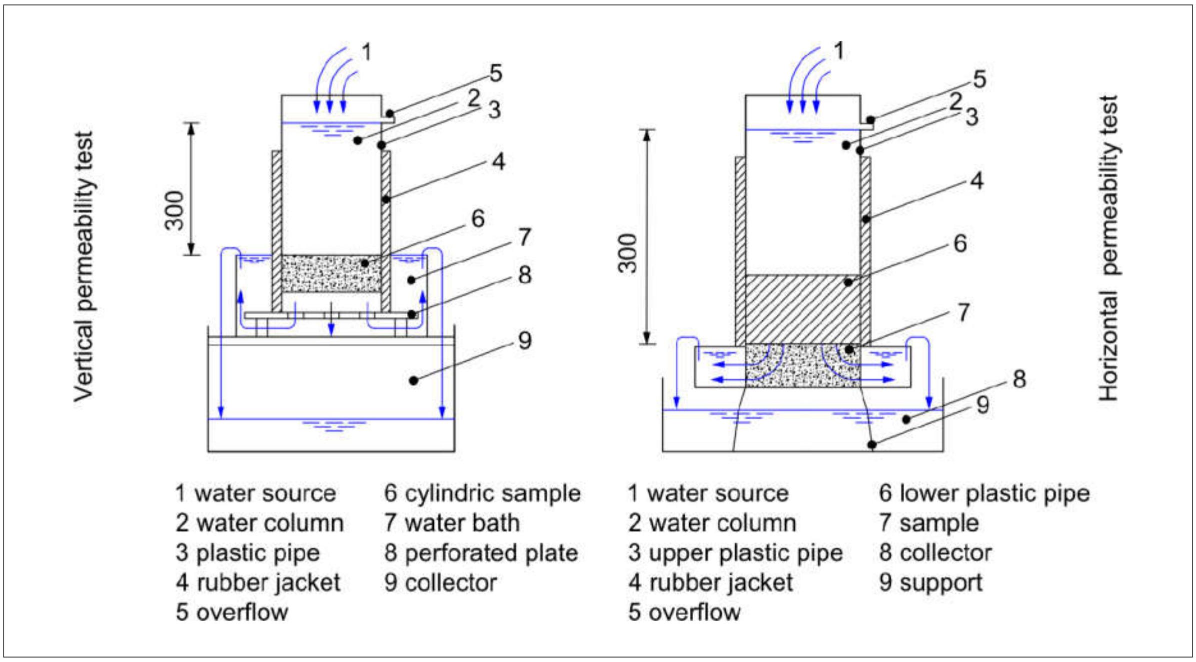

Figure 2 Test method of horizontal (right) and vertical permeability (left)

In both cases, water column is kept at constant height resulting in a constant water pressure, and the mass of water exfiltrating the sample is measured, by time. Permeability is given as seen in Eq. (1) and Eq. (2).

$$k_v = \frac{4 \times \frac{m}{t} \times 10^{-6} \times l}{h \times \pi \times D^2} \tag{1}$$

$$k_h = \frac{\frac{m}{t} \times 10^{-6} \times l}{(H + P + 0,5l) \times (\pi \times D \times l)} \tag{2}$$

Where:

k_v and k_h – vertical and horizontal permeability [m/s];
m – the mass of the permeated water [g];
t – the test time [s];
l – thickness of the sample [m];
H+P – height of the water column + the height of the sample [m];
D – specimen diametre [m];
h – height of water column [m].

Air void content of the samples has been determined using the standard EN 12697-8. The test method is assumed to be commonly known and will not be presented.

4 Test results

As shown by various previous findings, there is a reliable connection between air void content and permeability. However the permeability of the asphalt samples is not only affected by void content, maximal particle size, sample dimensions and naturally method of measurement also affect the movement of water (if any) [9] [10]. There are also research suggesting correlation between normalised particle size and permeability. To understand the foreword presented values of permeability the values given in Table 1. should be assessed [11].

Table 1 Suggested permeability categories for asphalt materials

Cat.	Permeability [m/s]	Air void content [%]	Description
A1	0,01-0,1	2,5-3,7	very low permeability
A2	0,1-1	3,7-5,6	low permeability
B	1-10	5,6-8,5	medium permeability
C	10-100	8,5-13	high permeability
D	100-1000	13-20	almost permeable
E	1000-10000	>20	permeable (drain asphalt)

Regarding newly built layers, of the parameters obviously affecting permeability as well, only air void content of mixes and layers must meet criteria, as seen in Table 2.

Table 2 Air voids for design, tolerance, reduced quality and rejected cases

Asphalt mix		Wearing courses			Binder courses			Base courses	
		SMA 8	SMA 11	AC11 AC16	AC11	AC16	AC22	AC16	AC22 AC32
Design	V_{MIN}	2,0%		2,5%	3,0%			3,0%	
	V_{MAX}	4,0%	4,5%	4,5%	4,5%	5,0%	5,5%	5,0%	6,0%
Tolerance,	V_{TOL}	V_{max} +3,0%							
Reduced,	V_{RED}	V_{TOL} +2,0%							
Rejected,	V_{REJ}	9,0%	9,5%	9,5%	9,5%	10,0%	10,5%	10,0%	11,0%

Design and threshold values are determined on technological basis, layers having the presented air void content are assumed to be waterproof. Construction tolerance is +3%, although a given layer may be accepted within an additional +2% air void content at a discount price. A given pavement layer is rejected at the air void contents given in the last row.
As previous research has shown, correlation between air void content and permeability shows a third-degree polynomial relation in the form of $K = A \cdot \exp(B \cdot V)$. Parameters A and B have been determined using Solver, for air void-permeability of samples, for each particle size separately. Coefficient of determination was found high for all separate cases, from 0,85 to even 0,98, as shown by Fig. 3., 4. and 5. Parameters and regression coefficients are shown in Table 2.

Table 3 Coefficient of determination in the analysed cases

	Vertical permeability			Horisontal permeability		
	A	B	R^2	A	B	R^2
SMA8 (n=11)	$4{,}37 \times 10^{-8}$	0,59	0,86	$4{,}24 \times 10^{-8}$	0,58	0,90
AC11 (n=9)	$1{,}42 \times 10^{-7}$	0,45	0,97	$1{,}15 \times 10^{-7}$	0,42	0,98
AC22 (n=24)	$1{,}74 \times 10^{-7}$	0,41	0,91	$1{,}47 \times 10^{-7}$	0,37	0,85

As seen, tight correlation is found between permeability and air void content, taken into account the aggregate particle size as well. Result are based on 11, 9 and 24 sample results, respectively, as some samples got damaged at processing or boring.

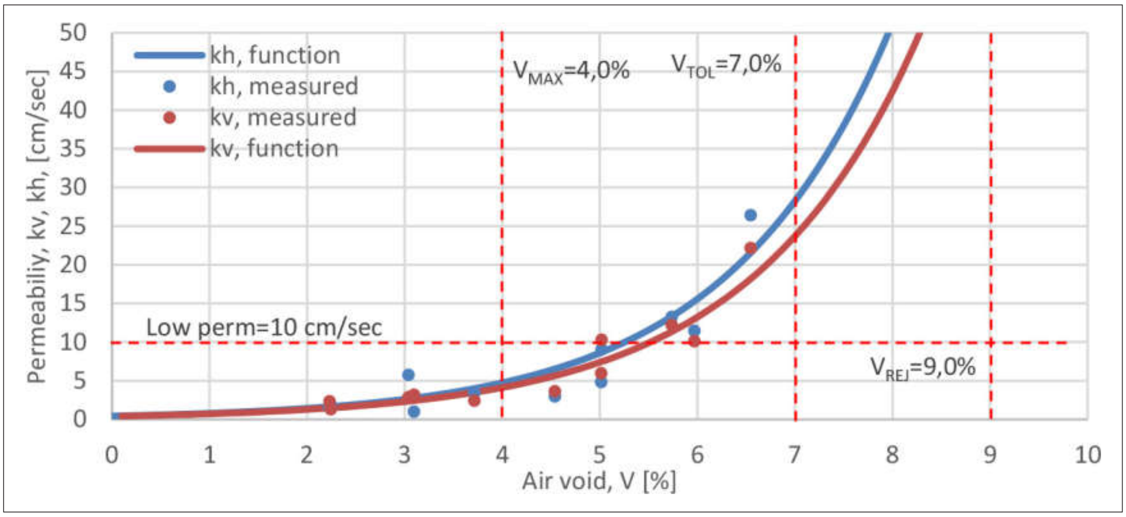

Figure 3 Measured and calculated permeability, SMA8 layer

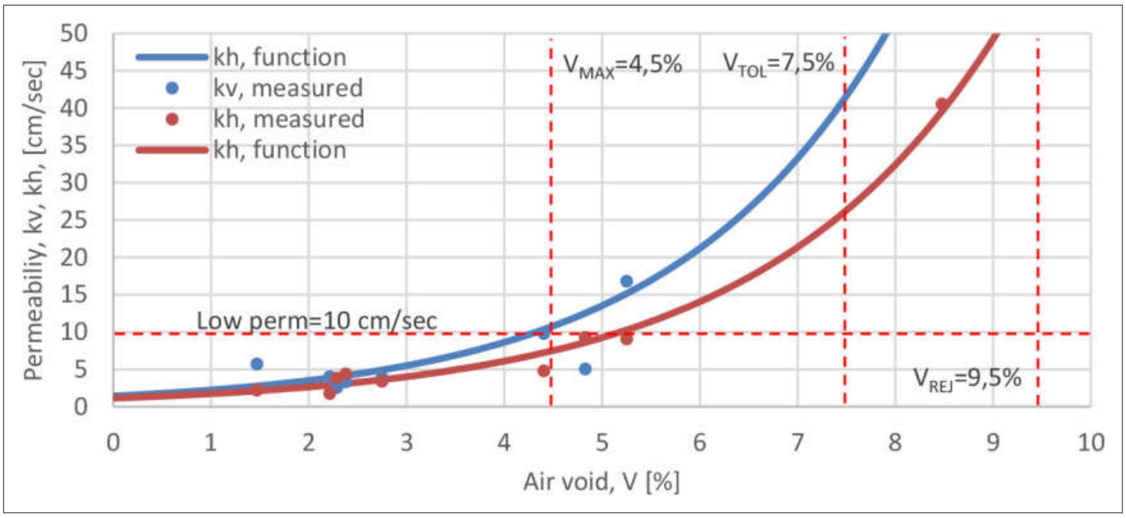

Figure 4 Measured and calculated permeability, AC11 layer

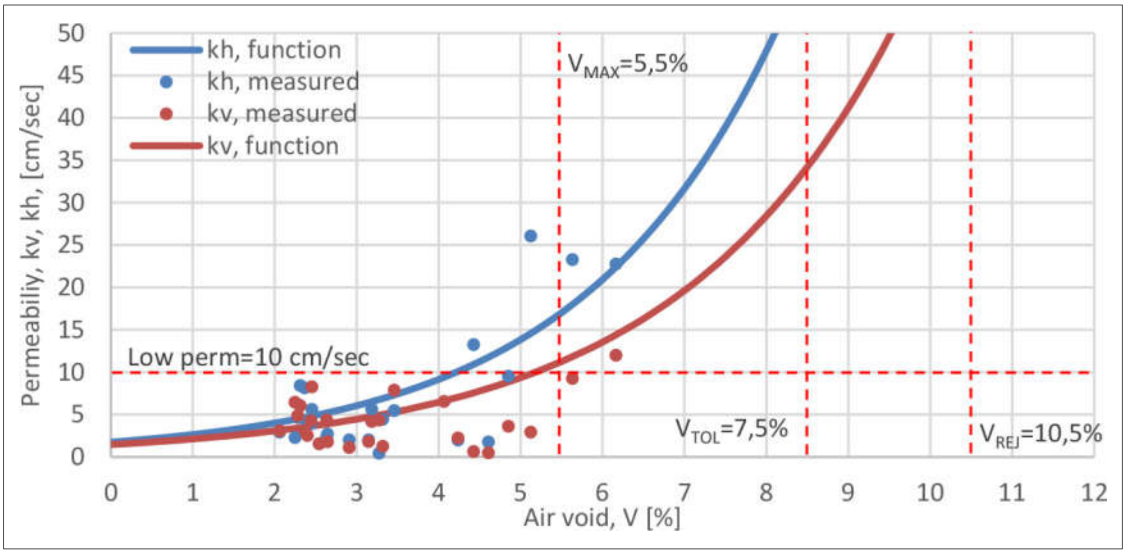

Figure 5 Measured and calculated permeability, AC22 layer

As seen, according to current regulations in light of permeability, allowed air void contents of the analysed mixes, based on core sample test results, may exceed very low permeability limit and lead to a low-permeability layer.

5 Conclusions

Analyse shave been conducted on a highway, having pavement failures that suspect the presence and movement of water within and between pavement layers. Samples taken from sections determined using GPR for water detection have been tested with a straightforward method according to the European Standards.
Test results of the core samples show a clear relation between the air void content and the horizontal and vertical permeability of the samples, which coincide with results published in international literature.
Results show that horizontal permeability is always higher than the vertical permeability, which shows a difference in the test method, and indicates that the two methods should be distinguished. It can also be seen, that in case of mixes having smaller particle sizes, given air void contents result in higher permeability both ways than in cases of bigger particle sizes. This, also, indicates, that results must be given considering the gradation as well, not only the air void content.
As seen based on the air void content-permeability relations, asphalt layers with acceptable air void content may be in fat, permeable, which may lead to a variety of pavement failure types and deterioration of lower layers as well. Using the methods and based on the results presented in this paper, a well-established relation may be determined between permeability and air void content, leading to the possibility of incorporating the waterproofness of the layers in the standards, which is now poorly addressed. To do this the precision of the test measurement must be determined as well, which is currently unknown.

References

[1] TRL, The Movement of Water in Roads, London, 2006.

[2] Reid, J., Crabb, G., Temporal, J., Clark, M.: A study of water movement in road pavements, London: TRL, 2006.

[3] Dawson, A.: Water movement in road pavements, University of Nottingham: Proceedings of the Second Symposium on Unbound Aggregates in Roads, pp. 7-12, 1985.

[4] Morris, P., Gray, W.: Moisture conditions under roads in the Australian environment, Australian Road Research Board: Research Report ARR No. 69, 1976.

[5] EN 12697-19, “Bituminous mixtures. Test methods for hot mix asphalt. Permeability of specimen,” European Standard, 2012.

[6] Ridgeway, H.: Infiltration of Water Through the Pavement Surface, Washington: Transportation Research Record, 1976.

[7] B. &. M. Cooley Jr., “NCAT Report 01-03 – Developing Critical Field Permeability and Pavement Density Values for Coarse-Graded Superpave Pavements,” Journal of the Transportation Research Board, DOI: http://dx.doi.org/10.3141/1761-06, 2014.

[8] Cooley, L.: Permeability of Superpave Mixtures: Evaluation of Field Permeameters, Auburn University: National Centre for Asphalt Technology, 1999.

[9] Ariza, P., Bjorn, B.: Evaluation of Water Flow Through Pavement Systems, NCHRP, 2002.

[10] COST 351, Water in Road Structures. Movement, Drainage and Effects, Nottingham: Springer, 2008.

[11] Waters, T.: “A study of water infiltration through asphalt road surface materials,” International symposium on subdrainage in roadway pavements and subgrades, 1998.

[12] Mohiuddin, A.: "Permeability and moisture damage characteristics of asphalt pavements," 2013.

[13] Mostafa, A., Amir abd, E.H., Bekheet, W., Abd El Halim, A.O., Easa, S.: "Reducing susceptibility of flexible pavements to moisture induced damage through superior compaction technology," Proc., Canadian Society for Civil Engineering, 6th Transportation Specialty Conference, 2005.

[14] Rueda, E.J., Caro, S., Caceido, B.: "Influence of relative humidity and saturation degree in the mechanical properties of Hot Mix Asphalt (HMA) materials," Construction and Building Materials 153., pp. 807-815, 2017.

[15] Lubloy, E., Balazs, G.L., Barsi, A.: "CT analysis of core samples from fire-damaged concrete structures," Magazine of Concrete Research 69(15), pp. 802-810, 2017.

[16] Lubloy, E., Ambrus, D., Kapitany, K., Barsi, A.: "Air void distribution of asphalts determined by computed tomography," Periodica Polytechnica. Civil Engineering, 59 (4), p. 503, 2015.

[17] EN 12697-8, "Bituminous mixtures. Test methods for hot mix asphalt. Determination of void characteristics of bituminous specimens," European Standard, 2003.