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COMPARISON OF STANDARDS AND REQUIREMENTS FOR POROUS ASPHALT MIXTURES

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Abstract

Porous asphalt is a bituminous material prepared in such a manner that it has a very high content of interconnected voids that allow passage of water and air in order to provide the compacted mixture with better drainage and noise reducing characteristic. The analysis of available regulations and scientific literature shows that the national standards of porous asphalt mixtures differ in type of granulometric envelopes, the type of bitumen and its content in the mixture and the limits of the air voids content in the mixture. In this paper, standards used for porous asphalt in Croatia are compared with the US, Australian and Dutch standards for this type of asphalt. In addition, samples prepared based on HRN EN 13108-7 and HRN EN 12697-17 requirements were tested and results were compared using Croatian and other available standards. This paper also investigates the effects of ambient temperature on abrasion loss of porous asphalt. The abrasion loss results are compared to the other standards.

Keywords: porous asphalt, Cantabro test, abrasion loss

1 Introduction

Porous asphalt pavement is a type of porous pavement structure designed to allow rainfall and runoff to flow into and through the pavement structure. The main difference compared to the standard asphalt mixture is a higher proportion of coarse aggregate and a higher content of air voids in the mixture. The total amount of bitumen in the porous asphalt mixture is equal or slightly higher than the amount of bitumen in dense asphalt mixtures with the same maximum size of aggregate. The main characteristics of porous asphalt pavement are high permeability and reduced traffic noise [1]. Common applications of porous asphalt pavements are parking lots, sidewalks and pathways [2]. In addition, in the Netherlands porous asphalt is also used for pavements for heavy wheel loads. In 2009 about 80 % of total surface of the Dutch motorways was covered with porous asphalt [3]. Porous asphalt pavement is not recommended at intersections due to the possibility of oil and fuel leaking from the vehicles and infiltrating into porous asphalt air voids [4]. Some advantages of porous asphalt pavements are: maintaining a high skid resistance, noise reduction, providing a storm-water management system that promote infiltration, reducing the dangers of aquaplaning and reducing a glare at night during wet weather [5, 6, 7]. The main disadvantages are: the need for early preventive maintenance, clogging of air voids, shorter expected service life compared to dense asphalt pavements and higher total project cost [2, 6, 8].

This study was prepared with the aim to compare standards used for porous asphalt mixture in Croatia with other countries (the USA, the Netherlands and Australia). Test results for porous asphalt mixtures are presented in the paper, with emphasis on Cantabro test - abrasion loss of porous asphalt specimen. In addition, the aim was to investigate the effect of ambient temperature on abrasion loss of porous asphalt specimens according to national standard HRN EN 12697-17 and to compare obtained results with limit values of foreign standards.

2 Standards and guidelines

The porous asphalt mixture in Croatia is defined in standard HRN EN 13108-7 [9]. The limit values for porous asphalt mixture are defined in Croatian technical requirements for asphalt pavements [10]. The guidelines applied in different countries and the review of past research related to Cantabro test are presented below.

2.1 Porous asphalt requirements in Croatia, USA and Australia

Croatian technical requirements for asphalt pavements [10] defines properties and requirements for construction products and usability of asphalt layers in road construction, reconstruction and maintenance. Depending on the aggregate gradations, three types of porous asphalt mixtures are used in Croatia (PA 8, PA 11 and PA 16). In Croatia, depending on the traffic load, conventional bitumen 50/70 or polymer-modified bitumen 40/100-65, 45/85-65 and 45/80-55 is used. The porous asphalt mixture can be classified in two categories M1 and M2, and must satisfy the required technical properties (air voids content, indirect tensile strength ratio ITSR, and abrasion resistance). These parameters are listed in Table 1.
In the USA, properties and requirements for porous asphalt mixtures are defined in the Standard Practice for Open-Graded friction Course (OGFC) Mix Design [11]. Limit values and characteristics of mixtures in the USA are presented in table 1. The draindown potential can be decreased by adding fiber stabilizers (cellulose fiber or mineral fiber) in porous asphalt mixture [10]. For some mixtures that use polymer-modified bitumen or asphalt rubber, fiber additives may not be required to control draindown or to obtain good performance. The Cantabro test has been used in Europe for many years, but it is optional in the USA and it has seen very little use in the USA [11]. The operating temperature should be 25 ± 5 °C and the machine operates at 300 rotations. Abrasion loss values are shown in Table 1. In the Netherlands [3,6], the standard wearing course is performed as single layer PA 16 with air voids content of 20 %. It can also be performed as two layered, combining PA 8 and PA 16. The porous asphalt mixture PA+ is also used. PA+ contains 5.2 % bitumen 70/100 and drainage inhibitors that increase the pavement lifespan. In Australia [4], a porous asphalt mixture is grouped as Type I and Type II depending on indicative traffic volume (commercial vehicles per lane per day). The requirements for the mixture are presented in Table 1.
The porous asphalt mixture in the USA and Australia has a higher bitumen content compared to Croatia. The use of additives is recommended in cases where no polymer-modified bitumen is used. The maximum air voids content in the USA and Australia is not defined. In Croatia the maximum air voids content amounts to 26 % for M2 or 28 % for M1. The minimum air voids content in Croatia and in the USA is lower compared to Australia, where the minimum air voids content in the mixture amounts to 20-25 %.

Table 1 Comparison of requirements for a porous asphalt mixture by country

	Croatia		The USA	Australia	
Standard	**HRN EN 13108-7: Bituminous mixtures – Material specifications – Part 7: Porous Asphalt [8], Hrvatske ceste: Croatian technical requirements for asphalt pavements [10]**		**D7064/ D7064M-08: Standard Practice for Open-Graded friction Course (OGFC) Mix Design [11]**	**STANDARDS AUSTRALIA (1995). Hot Mix Asphalt. AS 2150 (Standards Association of Australia) [4]**	
Types of Porous asphalt mixture	M1	M2		Type II	Type I
Minimum bitumen content (%)	3% polymer modified bitumen	3% conventional bitumen	6-6.5% conventional bitumen, 5.5.-10% modified bitumen	4.5-6.5% conventional/ modified bitumen	3.5-5.5% conventional/ modified bitumen
Minimum air voids content (%(V/V))	18%	16%	18%	20-25%	20%
Maximum air voids content (%(V/V))	28%	26%	not specified	not specified	not specified
ITSR (%)	80%		80%	80%	80%
Maximum value of abrasion loss, PL, %(m/m)	30% 30% (aged specimens)		20% (unaged specimens)	20% (unaged specimens)	25% (unaged specimens)
			30% (aged specimens)	35% (aged specimens)	
Fillers and additives	The use of own filler or Portland cement as an added filler is not allowed.		Cellulose or mineral fiber 0.2-0.5% by mixture mass	Cellulose or mineral fiber 0.2-0.5% by mixture mass. Fillers: Portland cement, hydrated lime, fly-ash, ect.	

2.2 Cantabro test

Abrasion loss is tested in laboratory and the test is called Cantabro test. The test evaluates the resistance of porous asphalt specimens to abrasion loss due to abrasion and impact forces. Cantabro test is a quick and simple test so it is used in many countries. For instance, it is used in Japan [12] to determine the resistance of abrasion loss of porous asphalt in winter conditions. Test method for determining the abrasion loss of porous asphalt specimens in Croatia is specified in HRN EN 12697-17 [13].

This standard [13] specifies a test method for porous asphalt specimens in the Los Angeles machine (without steel balls). Cantabro test is applied to laboratory compacted cylindrical specimens where the upper sieve size does not exceed 22.4 mm. During the test, the ambient temperature should be measured near the Los Angeles machine. Ambient temperature usually used for this test is between 15°C and 25°C and the temperatures above 35°C are not suitable for this test [13]. At least five specimens are required and they should have a mass of (1.0±0.2) kg. Bulk density and air voids content are determined by the standard HRN EN 12679-6 and HRN EN 12697-8. Specimens should be kept at the ambient temperature for at least 4 hours before testing. Then the specimen is placed into the drum of the Los Angeles machine which operates at the speed of 3,1 rad/s up to 3,5 rad/s (30 to 33 rpm) for a total of 300 rotations. The mass of specimen should be determined before and after placing it inside of the Los Angeles machine. The mass difference gives the value of abrasion loss. Specimens before and after the Cantabro test are shown in Figure 1.

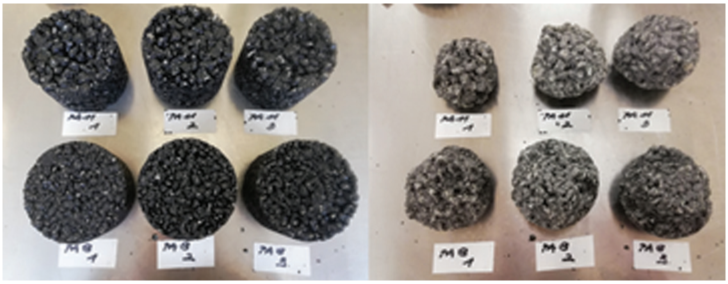

Figure 1 Specimens before and after Cantabro test

Recent studies related to Cantabro test show the influence of ambient temperature and bitumen content in the porous asphalt mixture. The authors [14] considered the effects of ambient temperatures on abrasion loss and temperature change of porous asphalt according to the standard EN 12697-17 and Standard Specification for Road Works in Malaysia. The test was performed in the Netherlands (the average laboratory temperature was 24 °C) and Malaysia (the average laboratory temperature was 30 °C). It was concluded that the abrasion loss in the mixture decreases with an increase in the ICT (initial conditioning temperature) and with an increase of the bitumen content. In this study [14], specimens are prepared with granite aggregate (two different aggregate gradations) and two different type of bitumen (conventional bitumen 60/70 and modified bitumen PG76) with 4.0 to 5.5 % bitumen content. Type of bitumen that is used in mixture are marked according to AASHTO standard. Also, modified bitumen PG76 is referred to SMA that has softening point min. 60 and penetration at 25°C is specified in ASTM D5. According to the authors, [14] the type of bitumen, bitumen content, ICT and surface temperature of specimens have a significant impact on the Cantabro test results. Porous asphalt specimens, which contain modified bitumen, showed better results than those specimens that contain conventional bitumen. It was also concluded that an increase in ambient temperature leads to an increase in the surface temperature of the specimen and to an increase of the temperature inside the drum of the Los Angeles machine. In the paper, the authors [2] studied a porous asphalt mixture with different bitumen contents (5-7.5 %) on the unaged and aged specimens. It was concluded that samples containing 6 % of bitumen obtained the best results, taking into account air voids content, abrasion loss, aging characteristics and drain-down potential.

3 Laboratory testing

Cylindrical specimens were prepared in a standard Marshall mold. Two tests were conducted and six specimens were made for each. The ambient temperature for the first test was 23.2°C-25.4°C (on average 24.3°C) and for the second test temperature was not precisely determined at the time, but it was continuously above 30°C and below 35°C. In this study, the temperature of 30°C will be assumed. Figure 2 (left) shows the aggregate gradations PA8 for three specimens of porous asphalt mixture type M1 with aggregate designation AG1. The other three specimens were prepared as porous asphalt mixture type M1 with aggregate designation AG1 and aggregate gradations PA11 shown in Figure 2 (right). Porous asphalt specimens contain 3.0-4.0 % of polymer modified bitumen 45/80-65. The specimens were kept at the ambient temperature for at least 4 h before testing.

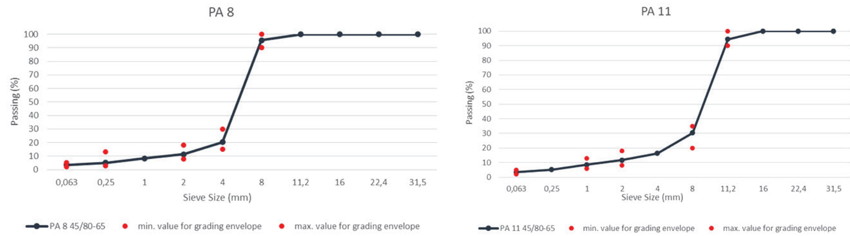

Figure 2 Aggregate gradations PA8 (left) and PA11 (right) adopted in this study

The diameter and height of the specimens were measured and these data were used to obtain density and air voids content of porous asphalt. The specimens were weighed before and after placing inside the drum of the Los Angeles machine.

4 Results and discussion

The specimens presented in Table 2 and Table 3 are marked as PA8 1-3 and PA11 1-3, and for every specimen the dimensions, density and air voids content are shown. These parameters are determined according to previously mentioned standards for ambient temperature of 30°C and for temperature between 23.2- 25.4°C. The tables show the mean height, mean diameter and volume of specimens. The bitumen content ranges from 3 to 4 %. The ρ_{MV} value represents the asphalt mixture bulk density obtained by the volumetric method. Bulk density ρ_{bdry} is obtained from measured dimensions of dry specimen. VMA stands for the calculated air voids content in aggregate, V_m for the calculated air voids content in the specimen, and VFB for the air voids content filled with bitumen. The air voids content in the specimens ranges from 25.0 % to 28.9 %. These values meet the minimum air voids content, which is 18 % according to the Croatian technical requirements for asphalt pavements [10]. However, six out of nine specimens do not meet the maximum air voids content of 28 %. The percentage of air voids filled with bitumen is lower when PA8 aggregates are used in the porous asphalt mixture.

Table 2 PA mixture characteristics (ambient temperature of 30 °C)

SPECIMEN	PA8-1	PA8-2	PA8-3	PA11-1	PA11-2	PA11-3
h (mm)	69,8	70,0	69,8	68,9	68,4	68,2
d (mm)	101,5	101,6	101,7	101,6	101,6	101,6
V (mm^3)	565347,57	567253,86	566488,61	558423,58	554257,44	553037,51
bitumen content (%)	3,0	3,5	4,0	3,0	3,5	4,0
ρ_{MV} (g/mm^3)	2,600	2,580	2,560	2,600	2,580	2,560
ρ_{bdry} (g/mm^3)	1,848	1,856	1,869	1,865	1,897	1,914
V_M (%)	28,9	28,1	27,0	28,3	26,5	25,2
VMA (%)	34,3	34,4	34,3	33,7	32,9	32,7
VFB (%)	15,7	18,4	21,3	16,2	19,7	22,8

Table 3 PA mixture characteristics (ambient temperature of 23.2 to 25.4°C)

SPECIMEN	PA8-1	PA8-2	PA8-3	PA11-1	PA11-2	PA11-3
h (mm)	69,5	69,8	69,7	68,9	68,0	68,0
d (mm)	101,6	101,6	101,6	101,6	101,5	101,5
V (mm^3)	563256,03	566093,60	565282,86	557895,98	549743,34	549873,18
bitumen content (%)	3,0	3,5	4,0	3,0	3,5	4,0
ρ_{MV} (g/mm^3)	2,600	2,580	2,560	2,600	2,580	2,560
ρ_{bdry} (g/mm^3)	1,852	1,856	1,868	1,863	1,908	1,919
V_M (%)	28,8	28,1	27,0	28,4	26,1	25,0
VMA (%)	34,2	34,4	34,3	33,8	32,6	32,5
VFB (%)	15,8	18,4	21,3	16,1	20,0	23,0

Table 4. shows the results obtained according to standard HRN EN 12697-17 at the ambient temperatures of 30°C and 23.2°C-25.4°C.

Table 4 Test results according to standard HRN EN 12697-17

			Temp. 30 °C			
SPECIMEN	**PA8-1**	**PA8-2**	**PA8-3**	**PA11-1**	**PA11-2**	**PA11-3**
mass before (g)	1044,7	1052,8	1058,6	1041,5	1051,5	1058,3
mass after (g)	485,5	653,3	796,4	485,4	662	818,9
abrasion loss (%)	53,5	37,9	24,8	53,4	37	22,6
			Temp. 23,2°C - 25,4°C			
SPECIMEN	PA8-1	PA8-2	PA8-3	PA11-1	PA11-2	PA11-3
mass before (g)	1043,1	1050,8	1056,2	1039,1	1048,8	1055,3
mass after (g)	498,7	667,7	651,9	328,2	565,4	680,9
abrasion loss (%)	52,2	36,5	38,3	68,4	46,1	35,5

Data from Table 4 are shown in Figure 3. In addition, abrasion loss values and abrasion loss limits from different countries are presented in Figure 3. Specimens PA8-3 and PA11-3 meet the limit value for abrasion loss and the lowest value is shown for ambient temperature of 30°C (24.8 % for PA8-3 and 22.6 % for PA11-3). In addition, these specimens have the highest bitumen content (4 %) and lower air voids content compared to the other specimens. According to the Croatian technical requirements for asphalt pavements [10] abrasion loss should not exceed 30 %. Specimens tested in the ambient temperature of 23.2°C-25.4°C do not meet the limit value for abrasion loss. Also, presented results do not meet the other guidelines shown in Table 1.

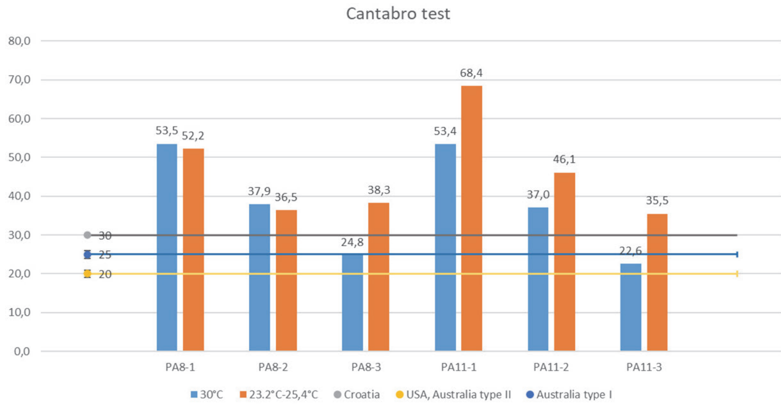

Figure 3 Abrasion loss – results

According to Colonna [15], at temperature of 30 °C, interpolation yields a maximum abrasion loss of 16 %. Abrasion loss in this test amounts between 22.6 % to 53.5 % and does not meet the results recommended by Colonna [15]. Also, abrasion loss values for ambient temperature 25°C do not meet the value of 20 % recommended by Colonna [15]. For ambient temperature 23.2°C-25.4°C abrasion loss amounts between 35.5 % and 68.4 %. For the specimen PA11-1, the abrasion loss at lower temperature is 15 % higher than the abrasion loss at higher temperature. The smallest difference in the result is observed in the specimen PA8-1 and the difference is 1.3 %. For PA11-1 and PA11-3 at ambient temperature of 23.2°C- 25.4°C, the difference in results is 32.9 %. This is also the greatest difference in the results at the given temperature. At ambient temperature of 30°C, for the specimen PA11-1 abrasion loss is 30.8 % higher than the abrasion loss for the specimen PA11-3. Generally, specimens PA8-1 and PA11-1 have the highest abrasion loss values. These specimens have a lower bitumen content (3 %) and a higher air voids content compared to other specimens. Air voids content for specimen PA8-1 for different ambient temperature amounts to 28.9 % and 28.8 %. For PA11-1 air voids content amounts to 28.3 % and 28.4 %. Four specimens (PA8-3, PA11-1, PA11-2 and PA11-3) show lower abrasion loss at higher ambient temperature and two specimens (PA8-1 and PA8-2) show higher abrasion loss.

5 Conclusions

According to the standard HRN EN 12697-17, Cantabro test is used to evaluate bonding properties between aggregate and bitumen. During the test, the specimens are exposed to abrasive force between the surface of the specimen and the walls of the Los Angeles machine. Two tests were conducted at ambient temperatures of 23.2°C-25.4°C and 30°C on cylindrical porous asphalt specimens. It can be concluded from the results that the ambient temperature affected the abrasion loss value. In addition, abrasion loss value is affected by bitumen content and air voids content. Specimens with higher bitumen content have lower abrasion loss value. Comparison of results with other analyzed guidelines shows the need to design a porous asphalt mixture with a higher bitumen content and lower air voids content. This indicates the need to repeat the testing with new parameters in order to determine whether the abrasion loss value shall be within the permited value.

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