CETRA^{2026} 27-30 May 2026, Bol, Island Brač, Croatia
9th International Conference on Road and Rail Infrastructure

CONSTRUCTION AND FIELD PERFORMANCE MONITORING OF EXPERIMENTAL PERMEABLE ASPHALT PAVEMENT WITH WARM MIX ASPHALT IN A PARKING AREA

Ieva Jakubėnaitė[1], Audrius Vaitkus[1], Judita Škulteckė[1], Ovidijus Šernas[2]
[1]Vilnius Gediminas Technical University, Faculty of Environmental Engineering, Department of Roads, Lithuania
[2]Vilnius Gediminas Technical University, Road Research Institute, Lithuania

Abstract

In Lithuania, the amount of precipitation during the summer season of 2025 reached an average of 275.6 mm, which is more than 20% higher than the standard climate normal (SCN) of the 1991-2020 summer season of 229 mm. The increase in rainfall and the frequency of extreme precipitation events are important challenges to road infrastructure, particularly in urban areas where drainage systems are inadequate or deteriorating. To address these issues of surface water drainage and accumulation on road surfaces, permeable pavement technologies are being explored as sustainable solutions to improve stormwater management and reduce surface runoff. This study presents the construction and field performance monitoring of experimental permeable asphalt pavement sections incorporating warm mix asphalt in a real parking area in Vilnius County, Lithuania. Warm mix asphalt contributes to climate change mitigation by reducing production temperatures and reducing energy consumption and emissions. During the construction phase, detailed monitoring was performed to evaluate the quality of layer compaction and the uniformity of the mixing of the warm mix asphalt. Three test sections with different drainage characteristics were constructed: impermeable pavement, semi-permeable porous asphalt pavement with warm mix asphalt, and fully permeable porous asphalt pavement with warm mix asphalt. Field and laboratory studies were aimed at assessing the hydraulic and physical performance of pavement structures, including air void content, density, and vertical and horizontal water permeability. The results provide valuable information on the feasibility of applying permeable porous asphalt pavement with warm mix asphalt under Lithuanian conditions and support the optimization of design parameters for sustainable, climate-resilient road and parking infrastructure.

Keywords: permeable pavement, warm mix asphalt, permeability, sustainable pavement

1 Introduction

In recent years, climate change has led to notable changes in precipitation patterns across many European regions, including Lithuania, with increases in both total precipitation and the frequency of extreme rainfall events [1–3]. In Lithuania, the amount of precipitation during 2023 was more than 3% higher than the standard climate normal (SCN) of the 1991–2020 period. In 2024, precipitation was approximately 10% lower than the SCN, and in 2025, it was 3% lower than the SCN but 7% higher than in 2024 [4]. These changes present increasing challenges for roads and urban infrastructure, particularly in urbanized areas where existing surface water drainage systems are often aged or unsuitable for higher rainfall or extreme precipitation volumes.

DOI: https://doi.org/10.5592/CO/CETRA.2026.1892

Moreover, these changes increase the risk of local flooding and negatively impact traffic safety and pavement longevity [5]. In view of this, increasing attention is being focused on permeable pavement technologies that allow precipitation to infiltrate through the pavement construction, reducing surface runoff, peak flows, and the load on urban stormwater systems. At the same time, the road construction sector needs to reduce energy consumption and greenhouse gas emissions. Using warm mix asphalt technologies, it is possible to reduce the temperatures of mixtures produced and laid, fuel consumption, and improve working conditions during construction [6–10]. A combination of permeable pavement with warm mix asphalt can help solve rainwater management and climate change mitigation challenges. Despite growing interest in permeable pavement with warm mix asphalt technologies, Lithuania needs more research under real operating conditions to determine their suitability and performance in local climate conditions. Field performance is important, as it allows assessment of the quality of construction and the hydraulic and physical properties of permeable asphalt pavement.

The aim of this study is to investigate the installation and the primary physical and hydraulic performance: air void content, density, vertical and horizontal water permeability, of experimental permeable asphalt pavement with warm mix asphalt in a real parking in the Vilnius region. The studies determine the possibility of installing this technology and help develop sustainable, climate-resilient road and parking lot solutions. This study is the first field-scale implementation and performance monitoring of permeable porous asphalt pavement with warm mix asphalt under Lithuanian climatic conditions, where freeze–thaw cycles, high seasonal precipitation variability, and cold compaction conditions create additional challenges not addressed in previous studies.

2 Materials and methods

2.1 Site description

The experimental parking area of porous asphalt (PA 11) with warm mix asphalt and surface-base asphalt concrete (AC 16 PD) in this study is located in Vilnius County, Lithuania (figure 1). The parking area is 245 m^2 and is separated into three different drainage characteristics which were constructed: impermeable pavement, semi-permeable porous asphalt pavement with warm mix asphalt and fully permeable porous asphalt pavement with warm mix asphalt. The experimental parking area was constructed in the first two weeks of November 2025. The paving temperature range for PA 11_F and PA 11_S was approximately 135–143°C.

Figure 1 The test site location in Vilnius County

Table 1 Actual aggregate particle size distribution of asphalt mixture samples

Sieve size [mm]	Passing [%]					
	PA 11_F_1	PA 11_F_2	PA 11_S_1	PA 11_S_2	AC 16 PD_1	AC 16 PD_2
16	100	100	100	100	100	100
11.2	89	88	89	91	89	86
8	10	9	9	11	76	73
5.6	5	5	5	6	63	63
2	5	4	4	5	43	43
1	4	4	4	5	35	35
0.5	4	4	4	5	28	28
0.25	4	4	4	5	18	18
0.125	4	4	4	5	10	10
0.063	3.7	3.6	3.5	4.1	6.5	6.4

The impermeable pavement structure consisted of an 8 cm layer of AC 16 PD, a 20 cm base layer of crushed dolomite stone (fraction 0-32), and a 30 cm frost-resistant protection layer. The semi-permeable porous asphalt pavement with warm mix asphalt (PA 11_S) comprised an 8 cm layer of PA 11 with warm mix asphalt, a 20 cm base layer of crushed dolomite stone (fraction 0-32), a 30 cm frost-resistant protection layer, and geogrid and geotextile materials. The fully permeable porous asphalt pavement with warm mix asphalt (PA 11_F) included an 8 cm layer of PA 11 with warm mix asphalt, a 20 cm base layer of crushed dolomite stone (fraction 5-32), and a 30 cm frost-resistant protection layer. The optimal bitumen content for asphalt mixtures was selected in accordance with the TRA ASPHALT 25 requirements. For the PA 11 mixture, the specified optimal content is 6.00%. However, lower bitumen content of 4.90% (PA 11_F) and 5.10% (PA 11_S) was tested in the laboratory. For the AC 16 PD, the optimal bitumen content is 5.20%, but a higher value (5.80%) was tested in the laboratory. Polymer-modified bitumen PMB 45/80-65 was used in PA 11_F and PA 11_S, while bitumen 70/100 was used in AC 16 PD. PA 11_F and PA 11_S mixtures were designed by adding dolomite fractions: 8–11, 5–8, 2–5, 0–2, mineral filler, cellulose and Stardope® Warm-Mix 2G. AC 16 PD was designed by adding dolomite fractions (11–16, 8–11, 5–8, 2–5), sand fraction (0–2), mineral filler and adhesive additive. The actual aggregate particle size distribution of the asphalt mixture samples is given in table 1.

2.2 Test methods

The following physical and hydraulic properties were determined in the laboratory and in the field. In the laboratory samples of PA 11_F, PA 11_S and AC 16 PD were tested to determine:
- air void content according to standard EN 12697-8
- maximum density according to standard EN 12697-5
- bulk density according to standard EN 12697-6
- vertical and horizontal water permeability according to standard EN 12697-19.

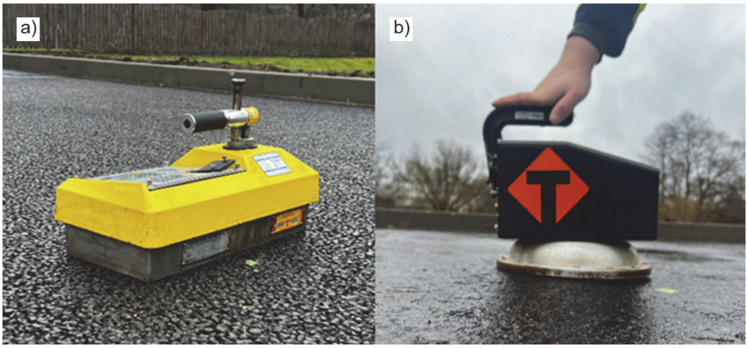

Figure 2 Equipment for measuring density: a) Nuclear density gauge, b) Non-Nuclear density gauge

In the field, density measurements were conducted using a Nuclear density gauge – Troxler Model 4640-B (figure 2a) in accordance with AASHTO T 355 and a Non-Nuclear density gauge – PQI 380 (figure 2b) in accordance with ASTM D7113. Before the measurements, both devices were configured using integrated calibration and field deviation functions. Reference bulk density values were determined based on the average stabilized values. The bulk density values of 2.236 Mg/m^3 were accepted for the PA 11_F and PA 11_S mixtures, and 2.473 Mg/m^3 for the AC 16 PD. These values were then used as reference density for further field measurements.

3 Results and discussion

3.1 Air voids content

The air void content ranged from 2.5% to 26.2%. The impermeable mixture AC 16 PD had the lowest air void content (2.5%), while the permeable mixtures demonstrated significantly higher values: 26.2% for PA 11_F and 25% for PA 11_S. Both permeable mixtures comply with the technical requirements TRA ASPHALT 25 (24–28%). The amount of air voids achieved confirms that the required interconnected pore structure has successfully formed in warm mix permeable asphalt mixtures. Considering that production and laying were carried out at lower temperatures (135–143°C) and under late-season conditions, the results indicate that the warm mix asphalt technology did not negatively affect the formation of an interconnected pore structure. This confirms that reduced production temperatures are compatible with the structural requirements necessary for effective hydraulic performance. The bulk density ranged from 1.880 Mg/m^3 (PA 11_F) to 2.423 Mg/m^3 (AC 16 PD), while the maximum density ranged from 2.485 Mg/m^3 (AC 16 PD) to 2.547 Mg/m^3 (PA 11_F). The difference between the PA 11_F and PA 11_S samples was 0.010 Mg/m^3 in bulk density and 0.026 Mg/m^3 in maximum density. The small variation between the permeable mixtures indicates consistent production and sufficient compaction under field conditions. The results confirm that the reduced production temperature did not negatively affect the structural integrity or density quality of the mixture.

3.2 Horizontal and vertical water permeability

The average vertical water permeability of the mixtures tested was in the range $0.0015 \cdot 10^{-3} \sim 1.7123 \cdot 10^{-3}$ m/s. The highest values of the average vertical permeability were obtained for the samples PA 11_S – $1.7123 \cdot 10^{-3}$ m/s, PA 11_F – $1.4674 \cdot 10^{-3}$ m/s, and the lowest values of the average vertical permeability were obtained during the test for the sample AC 16 PD with a value of $0.0015 \cdot 10^{-3}$ m/s. The difference between PA 11_F and PA 11_S samples – $0.2449 \cdot 10^{-3}$ m/s.

The highest variation of the samples was found for the PA 11_S sample, which varied from $1.3561 \cdot 10^{-3}$ m/s to $1.9904 \cdot 10^{-3}$ m/s, while the lowest variation was observed for the PA 11_S mixture, which varied from $1.2671 \cdot 10^{-3}$ m/s to $1.7453 \cdot 10^{-3}$ m/s.

The average horizontal water permeability of the mixtures tested was in the range of $0.0002 \cdot 10^{-3} \sim 0.0015 \cdot 10^{-3}$ m/s. The highest values of the average horizontal water permeability were given for the samples PA 11_S – $0.0015 \cdot 10^{-3}$ m/s, PA 11_F – $0.0014 \cdot 10^{-3}$ m/s, and the lowest values of the average horizontal permeability were obtained during the test for the sample AC 16 PD with a value of $0.0002 \cdot 10^{-3}$ m/s. According to the literature, the minimal water permeability should be more than $1.0 \cdot 10^{-3}$ m/s [11], whereas other guidelines indicate that the minimal water permeability is $0.5 \cdot 10^{-3}$ m/s [12]. The slightly higher permeability of PA 11_S compared to PA 11_F may be influenced by differences in aggregate gradation, which affect pore size distribution and air void connectivity in permeable porous asphalt with warm mix asphalt mixtures. Slight differences in the pavement laying temperature during transportation, when the mixtures were transported in different trucks, may also have affected the viscosity of the binder and the suitability of the mixture for use, thus affecting the preservation of the interconnected air void structure. Nevertheless, both mixtures exhibited hydraulic properties suitable for rainfall management in car parks and low-traffic urban infrastructure.

3.3 Density measurement by Nuclear and Non-Nuclear methods

The difference between the density values measured for the PA 11_F and PA 11_S mixtures was 0.0240 Mg/m^3 when using the Nuclear method and 0.0132 Mg/m^3 when using the Non-Nuclear method. A comparison of the density measurements obtained using both methods showed that for the permeable asphalt mixtures PA 11_F and PA 11_S, the Non-Nuclear method recorded slightly higher density values than the Nuclear method, with differences of 0.073 Mg/m^3 and 0.062 Mg/m^3, respectively. In contrast, for the AC 16 PD mixture, the Nuclear method showed significantly higher density values than the Non-Nuclear method, with a difference of about 0.250 Mg/m^3. The results show that both methods are applicable for controlling the density of porous asphalt mixtures in field conditions. The consistency of the measurements confirms proper compaction and validates the reliability of the field quality control procedures used during construction.

4 Conclusion

The field implementation demonstrated that permeable porous asphalt pavement with warm mix asphalt can be successfully constructed under late-season Lithuanian climatic conditions at reduced paving temperatures 135–143°C. The achieved bulk densities of 1.880 Mg/m^3 (PA 11_F) and 1.890 Mg/m^3 (PA 11_S) confirm adequate compaction despite reduced production temperatures. The permeable mixtures achieved air void contents 26.2% (PA 11_F) and 25.0% (PA 11_S), fully complying with the TRA ASPHALT 25 requirement (24–28%). These values confirm the successful formation of a stable and interconnected pore structure necessary for hydraulic functionality. The measured average vertical water permeability values of $1.4674 \cdot 10^{-3}$ m/s (PA 11_F) and $1.7123 \cdot 10^{-3}$ m/s (PA 11_S) significantly exceeded the minimum recommended thresholds of $0.5 \cdot 10^{-3}$ m/s and $1.0 \cdot 10^{-3}$ m/s reported in the literature. This confirms sufficient infiltration capacity for stormwater management in parking areas and low-traffic urban infrastructure. Density measurements performed using Nuclear and Non-Nuclear methods showed small differences for permeable mixtures (0.073 Mg/m^3 for PA 11_F and 0.062 Mg/m^3 for PA 11_S), confirming the reliability of both techniques for field quality control. Larger discrepancies were observed for AC 16 PD (approximately 0.250 Mg/m^3), indicating mixture-dependent sensitivity of the measurement methods.

The combined structural and hydraulic performance results demonstrate that permeable porous asphalt with warm mix asphalt satisfies both functional and sustainability-related objectives under Lithuanian climatic conditions, providing a validated baseline for long-term monitoring of hydraulic stability, clogging resistance, and freeze-thaw durability.

References

[1] Laino, E., Iglesias, G.: Extreme weather events and environmental contamination under climate change: A comparative review of ten European coastal cities, Current Opinion in Environmental Science & Health, 45 (2025), 100606, DOI: 10.1016/j.coesh.2025.100606

[2] Laino, E., Iglesias, G.: Extreme climate change hazards and impacts on European coastal cities: A review, Renewable and Sustainable Energy Reviews, 184 (2023), 113587, DOI: 10.1016/j.rser.2023.113587

[3] Moradian, S., Iglesias, G., Broderick, C., Olbert, I.A.: Assessing the impacts of climate change on precipitation through a hybrid method of machine learning and discrete wavelet transform techniques, case study: Cork, Ireland, Journal of Hydrology Regional Studies, 49 (2023), pp. 101523–101523, DOI: 10.1016/j.ejrh.2023.101523

[4] Lietuvos hidrometeorologijos tarnyba (Meteo.lt), https://www.meteo.lt, 26.01.2026.

[5] Jakubėnaitė, I., Vaitkus, A., Škultecké, J., Šernas, O.: Performance of Laboratory Designed Permeable Asphalt Mixtures, The Baltic Journal of Road and Bridge Engineering, 19 (2024) 2, pp. 131–151, DOI: 10.7250/bjrbe.2024-19.639

[6] Cheraghian, G. et al.: Warm mix asphalt technology: An up-to-date review, Journal of Cleaner Production, 268 (2020), 122128, DOI: 10.1016/j.jclepro.2020.122128

[7] Zaumanis, M.: Warm Mix Asphalt (Chapter), Climate Change, Energy, Sustainability and Pavements, pp. 309–334, 2014., DOI: 10.1007/978-3-662-44719-2_10

[8] Behnood, A.: A review of the warm mix asphalt (WMA) technologies: Effects on thermo-mechanical and rheological properties, Journal of Cleaner Production, 259 (2020), 120817, DOI: 10.1016/j.jclepro.2020.120817

[9] Rubio, M.C., Martínez, G., Baena, L., Moreno, F.: Warm mix asphalt: an overview, Journal of Cleaner Production, 24 (2012), pp. 76–84, DOI: 10.1016/j.jclepro.2011.11.053

[10] Vaitkus, A., Čygas, D., Laurinavičius, A., Vorobjovas, V., Perveneckas, Z.: Influence of warm mix asphalt technology on asphalt physical and mechanical properties, Construction and Building Materials, 112 (2016), pp. 800–806, DOI: 10.1016/j.conbuildmat.2016.02.212

[11] Aboufoul, M., Garcia, A.: Factors affecting hydraulic conductivity of asphalt mixture, Materials and Structures, 50 (2016) 2, DOI: 10.1617/s11527-016-0982-6

[12] Eisenberg, B., Lindow, K.C., Smith, D.R.: Permeable Pavements, 2015., DOI: 10.1061/9780784413784