INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING,
MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

Assessing the Potential Use of Porous Asphalt Pavements under Timor-Leste's Climatic Conditions

Fernando da Costa Fernandes, Alexandre Marques, Aquino Vilde Acácio da Cruz, Nelia Ximenes Belo

Department of Civil Engineering, Faculty of Engineering, Polytechnic Institute of Timor-Leste

DOI: https://doi.org/10.51583/IJLTEMAS.2026.150600069

Received: 15 June 2026; Accepted: 20 June 2026; Published: 06 July 2026

ABSTRACT

Timor-Leste's tropical climate, characterized by high temperatures, strong solar radiation, and seasonal heavy rainfall, poses significant challenges to conventional asphalt pavements, including rutting, moisture damage, and accelerated aging. Porous asphalt pavements, widely adopted in tropical and subtropical regions, offer enhanced drainage capacity and potential environmental benefits. This study evaluates the applicability of porous asphalt under Timor-Leste's climatic conditions through a narrative literature review of evidence reported in comparable tropical environments. The analysis highlights the hydraulic and thermal advantages of porous asphalt, such as improved stormwater management, reduced hydroplaning risk, and potential mitigation of urban heat accumulation. However, concerns regarding durability, clogging, maintenance requirements, and economic feasibility remain critical. Findings suggest that porous asphalt could contribute to climate-resilient infrastructure in Timor-Leste, but local validation through laboratory testing, pilot-scale field studies, and life-cycle cost assessments is essential before large-scale implementation.

Keywords: porous asphalt, tropical climate, pavement engineering, drainage, Timor-Leste

INTRODUCTION

Road infrastructure plays a fundamental role in supporting economic growth and social development in Timor-Leste. With increasing urbanization, the demand for durable and sustainable pavement systems has become more pressing. However, the country's tropical climate presents significant challenges for conventional asphalt pavements. Elevated temperatures accelerate asphalt binder aging and rutting, while intense rainfall exacerbates moisture-induced deterioration and surface water accumulation.

Porous asphalt pavements have emerged as promising alternative technology to address these challenges. Unlike conventional dense-graded asphalt mixtures, porous asphalt is characterized by interconnected air voids that enable rapid infiltration of rainwater through the pavement structure, thereby enhancing stormwater management and improving driving safety during rainfall events (Ahmad et al., 2017; Zhou et al., 2025).

In addition to hydraulic benefits, porous asphalt has been associated with environmental advantages such as reduced splash and spray, improved surface drainage, and potential mitigation of pavement surface temperatures (Joumblat et al., 2026). These attributes are particularly relevant for tropical regions where high temperatures and heavy rainfall are prevalent.

Nevertheless, concerns remain regarding durability, susceptibility to clogging, maintenance requirements, and economic feasibility. Assessing the suitability of porous asphalt under Timor-Leste's climatic conditions is therefore a critical preliminary step toward determining its potential role in future road infrastructure development.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

METHODOLOGICAL FOCUS

This study employed a narrative literature review to evaluate the potential applicability of porous asphalt pavements under the climatic conditions of Timor-Leste. Relevant publications were systematically identified using major scientific databases, including Scopus, ScienceDirect, and Google Scholar. The selection process prioritized peer

The review focused on key performance dimensions, namely hydraulic behavior, durability, thermal response, maintenance requirements, and economic feasibility. In addition, supplementary sources describing the climatic characteristics of Timor-Leste were consulted to provide contextual relevance.

By synthesizing findings from diverse tropical environments, the methodology aimed to establish a comparative framework for assessing the suitability of porous asphalt in Timor-Leste. This approach allowed for the identification of potential benefits, limitations, and research gaps, thereby informing future laboratory investigations and pilot.

FINDINGS AND DISCUSSION

Climate Characteristics of Timor-Leste

Timor-Leste is located in Southeast Asia and experiences a tropical monsoon climate characterized by relatively high temperatures throughout the year and distinct wet and dry seasons (Molyneux et al., 2012). Average annual air temperatures generally range from 25°C to 35°C in lowland regions, while pavement surface temperatures may substantially exceed ambient temperatures during periods of intense solar radiation (Bacon et al., 2016).

Table 1. Climatic Comparison of Timor-Leste and Tropical Countries with Porous Asphalt Applications

Country	Climate Type	Average Temperature (°C)	Annual Rainfall (mm)	Porous Asphalt Applications	Main References
Timor-Leste	Tropical Monsoon	25–35	1,000–2,500	Limited documented implementation	Weather Atlas (2025); Timor-Leste Climate and Weather (2024)
Malaysia	Tropical Rainforest	24–34	2,000–3,000	Urban roads and parking areas	Shahnewaz et al. (2021)
Indonesia	Tropical Monsoon	24–33	1,500–3,500	Urban roads and permeable pavement systems	Chen & Yang (2020)
Thailand	Tropical Savanna	24–35	1,200–2,500	Drainage-oriented pavement applications	Chen & Yang (2020)
Singapore	Equatorial Tropical	25–33	2,200–2,800	Urban stormwater management systems	Chen & Yang (2020)
Northern Brazil	Tropical Wet-Dry	24–34	1,500–3,000	Sustainable pavement projects	Joumblat et al. (2026)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

The wet season typically extends from November to April, with annual rainfall varying between 1,000 and 2,500 mm depending on geographical location and elevation (Climate & Weather, 2024; Kalma & Franks, 2003). These climatic conditions impose significant challenges for pavement infrastructure. Elevated temperatures accelerate asphalt binder oxidation and rutting, while heavy rainfall intensifies moisture-induced damage and surface water accumulation.

Urban areas are particularly vulnerable to localized heat build-up, as conventional asphalt surfaces with low albedo absorb and retain solar energy, thereby contributing to urban heat island effects (Ximenes et al., 2026). Comparative analyses indicate that Timor-Leste's climate shares similarities with other tropical countries where porous asphalt has been successfully implemented, such as Malaysia, Indonesia, and Singapore (Watson, 2011).

However, as shown in table 1, documented applications in Timor-Leste remain limited. This suggests that while climatic suitability is evident, further exploration and localized validation are required to determine the feasibility of porous asphalt under the country's specific environmental and infrastructural conditions.

Porous Asphalt Performance in Tropical Regions

Porous asphalt pavements have been widely investigated in tropical and subtropical regions, with studies from Malaysia, Indonesia, Thailand, Singapore, and Brazil demonstrating significant hydraulic and environmental benefits (Chen & Yang, 2020). A key advantage lies in their drainage capacity: the interconnected pore structure enables rapid infiltration of rainwater, thereby reducing surface runoff, minimizing water accumulation, and lowering hydroplaning risks during intense rainfall events (Jiang et al., 2022). These properties are particularly relevant in tropical climates characterized by short-duration, high-intensity storms.

Beyond hydraulic performance, porous asphalt has shown potential thermal benefits. Research indicates that porous pavement systems can reduce surface temperatures through evaporative cooling and diminished heat storage, contributing to mitigation of localized urban heat accumulation (Joumblat et al., 2026). Such thermal properties are especially valuable in regions with persistent high solar radiation.

Nevertheless, porous asphalt typically exhibits lower mechanical strength than dense-graded asphalt mixtures due to its high air-void content. To address this limitation, researchers have explored modifications such as polymer-modified binders, fibers, and additives to enhance resistance to ravelling, cracking, and aging (Shahnewaz et al., 2021).

Clogging represents another critical challenge. Fine particles transported by traffic and runoff may obstruct the pore network over time, reducing permeability and drainage efficiency. Regular maintenance practices, including vacuum sweeping and surface cleaning, are therefore essential to sustain long-term functionality (Chen & Yang, 2020).

Table 2. Climatic Factors and Expected Porous Asphalt Performance in Timor-Leste

Climatic Factor	Timor-Leste Condition	Expected Impact on Porous Asphalt
High temperature	25–35°C	Increased binder aging and ravelling risk
Intense rainfall	Seasonal monsoon rainfall	Improved drainage performance and reduced runoff
Long dry season	May–October	Reduced moisture-related deterioration
Dust accumulation	Common during dry season	Increased clogging potential

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

High solar radiation	Strong year-round exposure	Potential reduction in pavement surface temperatures

Referring to table 2, evidence from tropical countries underscores that successful implementation depends not only on climatic suitability but also on construction quality, material selection, and institutional capacity for maintenance. These factors highlight the need for localized validation before porous asphalt can be adopted at scale in Timor-Leste.

Potential Benefits and Limitations for Timor-Leste

Potential Benefits

The implementation of porous asphalt pavements in Timor-Leste could deliver notable environmental and functional advantages. A primary benefit is enhanced drainage capacity, as the interconnected pore structure enables rapid infiltration of rainwater, thereby reducing surface water accumulation during heavy rainfall and improving driving safety by lowering hydroplaning risks (Chen & Yang, 2020).

Porous asphalt may also strengthen stormwater management by reducing runoff and promoting groundwater recharge (Chiranjeevi & Shankar, 2025; Glick et al., 2013). These benefits are particularly relevant in urban areas where conventional drainage systems often face capacity constraints during periods of intense precipitation. By decreasing runoff volumes and peak flow rates, porous asphalt supports more sustainable urban water management practices (Jayakaran et al., 2019; Lin et al., 2026).

Thermal performance represents another advantage. Previous studies indicate that porous pavements can reduce surface temperatures through evaporative cooling and improved heat dissipation mechanisms (Joumblat et al., 2026). Considering Timor-Leste's high solar radiation and elevated temperatures, these properties may contribute to mitigating localized heat accumulation and enhancing thermal comfort in urban environments.

Limitations

Despite its potential advantages, several limitations should be carefully considered before the large-scale implementation of porous asphalt pavements in Timor-Leste. One key concern is durability, as the high air-void content that enhances permeability can also reduce mechanical strength compared with conventional dense-graded asphalt mixtures (Caro et al., 2010). In addition, under tropical climatic conditions, elevated temperatures may accelerate asphalt binder aging and increase the susceptibility to ravelling and surface deterioration (Saha Chowdhury et al., 2022). Furthermore, the applicability of porous asphalt in Timor-Leste remains largely unverified due to the absence of local field performance data, while variations in traffic loading, construction practices, maintenance capacity, and locally available materials may affect pavement performance and limit the transferability of findings from other tropical contexts.

Another major challenge is clogging, where fine particles from traffic, wind, and stormwater runoff gradually obstruct the interconnected pore structure, reducing permeability and drainage efficiency over time (Sha et al., 2021). As a result, regular maintenance interventions such as vacuum sweeping and surface cleaning are necessary to sustain long-term functionality and hydraulic performance of porous asphalt pavements (Uddin et al., 2025).

Economic Considerations

Economic feasibility is equally important. Porous asphalt generally requires higher initial construction costs than conventional pavements due to specialized aggregate gradations, higher-quality materials, stricter

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

construction controls, and periodic maintenance operations aimed at preventing clogging. However, the higher initial investment may be partially compensated for by several long-term benefits. Improved drainage performance can reduce the need for extensive stormwater infrastructure, while enhanced road safety during rainfall events may contribute to lower accident-related costs (Ji et al., 2020).

Nevertheless, the economic viability of porous asphalt under Timor-Leste's specific conditions remains uncertain. Future research should therefore incorporate comprehensive life-cycle cost analyses (LCCA) and cost-benefit assessments comparing porous asphalt with conventional alternatives, as also reflected in table 3.. Such studies would provide robust evidence to support infrastructure planning and investment decisions in the country.

Table 3. Comparative Assessment of Conventional and Porous Asphalt in Timor-Leste

Parameter	**Conventional Asphalt**	**Porous Asphalt**	**Implications for Timor-Leste**
Drainage Performance	Limited surface drainage	High infiltration and drainage capacity	Advantages during seasonal heavy rainfall
Hydroplaning Risk	Relatively higher	Reduced due to rapid water removal	Improved road safety during storm events
Surface Temperature	Higher heat absorption and storage	Potential evaporative cooling effect	May contribute to reducing localized heat accumulation
Initial Construction Cost	Lower	Higher	May require greater initial investment
Maintenance Requirement	Relatively low	Regular cleaning required to prevent clogging	Maintenance planning is essential
Durability	Generally higher structural integrity	Potential ravelling and clogging issues	Requires careful material selection and design
Stormwater Management	Limited runoff control	Enhanced runoff reduction and infiltration	Supports sustainable urban drainage
Suitability for Urban Flood Mitigation	Moderate	High	Particularly relevant for urban areas
Environmental Benefits	Limited	Improved water management and thermal performance	Supports climate-resilient infrastructure

Research Gaps and Future Research

Although the available literature indicates that porous asphalt pavements have demonstrated satisfactory hydraulic and environmental performance in several tropical countries, significant knowledge gaps remain regarding their applicability under the specific conditions of Timor-Leste.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

First, there is a lack of field performance data for porous asphalt pavements in Timor-Leste. Most existing evidence comes from countries such as Malaysia, Indonesia, Thailand, Singapore, and Brazil. Variations in traffic loading, construction practices, maintenance capacity, and locally available materials may affect pavement performance and limit the direct applicability of these findings.

Second, quantitative assessments of rainfall-runoff relationships, infiltration capacity, and drainage efficiency under Timor-Leste's climatic conditions remain unavailable. Given the country's seasonal monsoon climate and occurrence of high-intensity rainfall events, site-specific hydraulic evaluations are required.

Third, the long-term durability of porous asphalt under local environmental conditions has not yet been investigated. Laboratory studies should evaluate resistance to ravelling, moisture damage, rutting, and aging using locally sourced aggregates and asphalt binders.

Fourth, the economic feasibility of porous asphalt implementation remains uncertain. Future studies should compare the life-cycle costs of porous asphalt and conventional asphalt pavements, including construction, maintenance, rehabilitation, and operational costs.

Finally, pilot-scale field projects are recommended to monitor pavement performance under actual traffic and environmental conditions. Such projects would provide valuable information for future pavement design guidelines and infrastructure planning in Timor-Leste.

Although the available literature suggests that porous asphalt may offer several environmental and hydraulic advantages under tropical climatic conditions, significant research gaps remain regarding its applicability in Timor-Leste. To support future decision-making and large-scale implementation, a structured research framework is proposed, as presented in Table 3.

Table 3. Recommended Future Research Framework for Porous Asphalt in Timor-Leste

Research Area	**Objective**	**Suggested Method**	**Expected Output**
Hydraulic Performance	Evaluate infiltration and drainage capacity	Permeability and infiltration tests	Infiltration rate (mm/h), drainage efficiency (%)
Mechanical Performance	Assess durability and structural resistance	Marshall Stability, ITS, Cantabro Loss tests	Stability (kN), tensile strength (MPa), Cantabro loss (%)
Thermal Performance	Evaluate temperature reduction potential	Surface temperature monitoring using infrared sensors or thermocouples	Surface temperature reduction (°C)
Material Characterization	Assess suitability of local materials	Aggregate and binder laboratory testing	Aggregate properties, binder characteristics
Field Validation	Verify real-world pavement performance	Pilot road sections and field monitoring	Long-term permeability, distress development, maintenance requirements

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

Economic Assessment	Determine cost-effectiveness	Life-Cycle Cost Analysis (LCCA) and Cost-Benefit Analysis (CBA)	Life-cycle cost, benefit-cost ratio

As shown in Table 3, future studies should prioritize laboratory testing and field validation using locally available materials and climatic data. Attention should be given to hydraulic performance during the wet season, durability under high temperatures, and long-term maintenance requirements. In addition, economic evaluations are necessary to determine whether the environmental and operational benefits of porous asphalt can justify its higher initial construction costs.

CONCLUSION

This study has examined the potential applicability of porous asphalt pavements under the climatic conditions of Timor-Leste by synthesizing findings from tropical and subtropical regions. The review highlights several potential benefits, including improved drainage capacity, enhanced stormwater management, and possible thermal advantages that may mitigate localized heat accumulation. These characteristics suggest that porous asphalt could contribute to safer, more sustainable, and climate-resilient road infrastructure in the country.

At the same time, notable limitations must be acknowledged. Reduced mechanical strength, susceptibility to ravelling, clogging of pore networks, and higher maintenance requirements represent significant challenges. Furthermore, the absence of localized empirical data in Timor-Leste underscores the need for laboratory investigations, pilot-scale field trials, and comprehensive life-cycle cost analyses to validate performance under local conditions.

Overall, while international studies indicate the potential of porous asphalt in tropical climates, its application in Timor-Leste will require rigorous scientific validation, thorough economic feasibility assessments, and adequate institutional capacity for construction and maintenance. Addressing these gaps will strengthen the basis for evidence-based policymaking and strategic infrastructure planning, enabling porous asphalt to serve as a viable option for sustainable and climate-resilient development in Timor-Leste.

REFERENCE

1. Ahmad, K. A., Abdullah, M. E., Abdul Hassan, N., Daura, H. A., & Ambak, K. (2017). A review of using porous asphalt pavement as an alternative to conventional pavement in stormwater treatment. World Journal of Engineering, 14(5), 355–362.
2. Bacon, S. A., Mau, R., Neto, F. M., Williams, R. L., & Turner, N. C. (2016). Effect of climate warming on maize production in Timor-Leste: Interaction with nitrogen supply. Crop & Pasture Science, 67(2), 156–166.
3. Caro, S., Masad, E., Bhasin, A., Little, D., & Sanchez-Silva, M. (2010). Probabilistic modeling of the effect of air voids on the mechanical performance of asphalt mixtures subjected to moisture diffusion. Asphalt Paving Technol, 79, 221–248.
4. Chen, J.-S., & Yang, C.-H. (2020). Porous asphalt concrete: A review of design, construction, performance and maintenance. International Journal of Pavement Research and Technology, 13, 601–612.
5. Chiranjeevi, G., & Shankar, S. (2025). Influence of Aggregate Gradation and Pore Structure on Porous Asphalt Mixture Permeability and Resilient Modulus. Journal of Rehabilitation in Civil Engineering. https://doi.org/10.22075/jrce.2024.33599.2027
6. Climate, T.-L. & Weather. (2024). Climate and weather characteristics of Timor-Leste.
7. Glick, S., Shuler, S., & Guggemos, A. A. (2013). Life Cycle Analysis for Sustainable Development: A Case Study of Parking Lot Pavements. International Journal of Construction Education and Research, 9(3), 226–236. https://doi.org/10.1080/15578771.2012.714443

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

8. Jayakaran, A. D., Knappenberger, T., Stark, J. D., & Hinman, C. (2019). Remediation of Stormwater Pollutants by Porous Asphalt Pavement. Water, 11(3), 520. https://doi.org/10.3390/w11030520
9. Ji, T., Xiao, L., & Chen, F. (2020). Parametric Analysis of the Drainage Performance of Porous Asphalt Pavement Based on a 3D FEM Method. Scopus, 32(12). https://doi.org/10.1061/(ASCE)MT.1943-5533.0003468
10. Jiang, J., Leng, Z., Yang, B., Lu, G., Tan, Z., Han, M., & Dong, Z. (2022). Penetration mechanism of the emulsion-based rejuvenator in damaged porous asphalt mixture: Microstructure characterization and 3D reconstruction. Materials & Design, 221, 111014. https://doi.org/10.1016/j.matdes.2022.111014
11. Joumblat, R., Al-Smaily, A. M., Melo Neto, O. M., Youssef, A. M., & Soliman, M. R. (2026). Cooling and hydrological performance of porous asphalt pavements: A state-of-the-art review for urban climate resilience. Sustainability, 18(8), 3836.
12. Kalma, J. D., & Franks, S. W. (2003). Rainfall in arid and semi-arid regions. In Understanding water in a dry environment (pp. 31–80). CRC Press.
13. Lin, L., Cheng, X., Hu, X., & Pan, P. (2026). Purification performance of zeolite-modified porous asphalt mixtures for pavement runoff treatment. Case Studies in Construction Materials, 24, 05824. https://doi.org/10.1016/j.cscm.2026.e05824
14. Molyneux, N., Cruz, G. R., Williams, R. L., Andersen, R., & Turner, N. C. (2012). Climate change and population growth in Timor Leste: Implications for food security. Ambio, 41(8), 823–840.
15. Saha Chowdhury, P., Mullapudi, R. S., & Reddy, M. A. (2022). An Investigation on the Effect of Aging on Chemical and Mechanical Properties of Asphalt Binders. Scopus, 34(10). https://doi.org/10.1061/(ASCE)MT.1943-5533.0004396
16. Sha, A., Liu, Z., Jiang, W., Qi, L., Hu, L., Jiao, W., & Barbieri, D. M. (2021). Advances and development trends in eco-friendly pavements. Journal of Road Engineering, 1, 1–42. https://doi.org/10.1016/j.jreng.2021.12.002
17. Shahnewaz, S. M., Masri, K. A., & Ghani, N. A. A. A. (2021). Porous asphalt modification using different types of additives: A review. Construction, 1(1), 44–53.
18. Uddin, M. A., Shahabuddin, M., Jameel, M., Rahman, M., Hosen, M. A., Alanazi, F., AbdelMongy, M., & El-kady, M. S. (2025). Sustainable construction practices in urban areas: Innovative materials, technologies, and policies to address environmental challenges. Energy and Buildings, 341, 115831. https://doi.org/10.1016/j.enbuild.2025.115831
19. Watson, C. J. (2011). Sustainable Urban Design Practices that Mitigate Urban Heat Islands and Reduce Energy Consumption.
20. Ximenes, M., Pratas, J. A., Azevedo, J. M., & Ribeiro, J. (2026). Evaluating the concentration, distribution, and contamination of toxic metals in the urban soil of Dili, Timor-Leste. Geology, Ecology, and Landscapes, 10(2), 520–541.
21. Zhou, Y., Cheng, Z., Zheng, X., Wang, T., Wu, X., Yu, X., & Xie, S. (2025). A holistic exploration of porous asphalt mixtures: From durability and permeability to low-temperature and functional properties. Heliyon, 11(2).