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Adoption of Sustainable practices for Roads: A case study of the trend in Kerala over past years

Emey Varkey [1@], Benny Mathews Abraham [2] and Sreedevi B G[3]
1 Research Scholar, Department of Civil Engineering, Cochin University of Science and Technology, Kalamassery, Kochi, 682022, India. email: emeyvarkey@gmail.com
2 Professor & HoD, AISAT & Former Professor, CUSAT, Kochi- 682022. e-mail:bennymabraham@gmail.com
3Former Director, National Transport Planning and Research Centre, Email:bgsreedevi@yahoo.com

ABSTRACT
Traditional pavements using bituminous mixes perform well only when provided with drainage infrastructure, especially in heavy rainfall regions. Providing similar surfaces for low volume rural roads is often done without providing drains, considering space constraints. This impacts draining of rainwater, causing flash floods. Low Impact Development (LID) techniques, like use of interlock cement paver blocks, have proven to be a viable and effective alternative by reducing stormwater runoff and ensuring ease of construction and maintenance. Several case studies have focused on residential roads, parking lots, and other low volume roads as potential areas for the provision of permeable pavements. This paper aims to assess the yearly trend in increased use of this construction in the current road scenario in Kerala.
Keywords: *Permeable Pavement, Runoff, infiltration, Low volume roads, climate, flood*

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I. INTRODUCTION

In recent times, there has been a growing focus on "sustainability" in the field of development science, leading planners to reevaluate how urban areas can be reformed or redeveloped or revitalised. "Sustainability" is a term considered in this regards as both a means and an end to achieve urban development, prompting initiatives to address issues such as urban sprawl, congestion, and decline in the pursuit of "urban sustainability."

The foundation of sustainable development lies in economic, social, and environmental sustainability, with a focus on ensuring environmental sustainability. There is global concern about the limited natural resources, which restrict production and pose a long-term threat to economic growth due to environmental destabilization and pollution. Development has led to reduced permeable land area, impacting groundwater replenishment and fresh water sources.

Kerala is a state in India, located between the northern latitudes of 8°17'30"N to 12°47'40"N, and the eastern longitudes of 74°27'47"E to 77°37'12"E. The state has a vast coastline. As of 2023, Kerala has an extensive road network totalling over 2.36 lakh kilometres, representing a growth of over 58 percent from 1.52 lakh km in 2010-11. The different categories of roads in Kerala are presented in Table 1. Around 24% of the total network is unpaved, and these areas remain under the jurisdiction of local self-government institutions. Of these low traffic volume roads, 60% have been provided with bituminous surfacing while 12 % are surfaced using concrete or paver blocks.

Table 1 Composition of Roads in Kerala - 2023

Agency	Surfaced	Unsurfaced	Total
PWD(SHs & MDRs)	29573	-	29573
National Highway	1781	-	1781
LSGI	139821	56952	196773
Others			7516
Total	171175	56952	235643

1. Permeable Pavements: The Benefits

Permeable surfaces are designed to enhance drainage capacity and improve the microclimate by increasing water evaporation. They can be constructed using regional and recycled materials, such as building rubble. Permeable pavements reduce the speed of runoff water and prevent the infiltration of pollutants.

These systems effectively decrease the amount of storm water runoff and have been proven to fully capture the storm water generated by rainfall of up to 7 mm intensity. This reduction in storm water volume helps minimize the negative effects of urban areas on surface water systems. Besides lowering outflow volumes, these systems also delay and lessen peak flows.

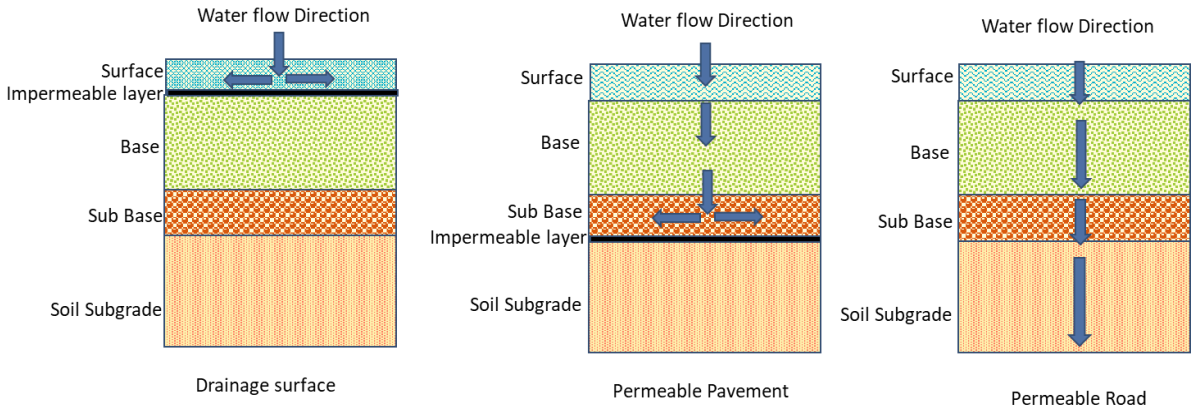

Figure 1 Different kinds of permeable pavements

Permeable surfaces serve a dual purpose by providing support and acting as drainage media. Acting as a filter and storage unit, they facilitate the soaking of rainwater to the underground system as shown in Figure 1. It happens through the surface first, then flow to the underlying layer. Here temporary storage occurs, before percolating into the ground or flowing to the existing drainage system. It's important to note that such surfaces should always be accompanied by a drainage system or an infiltration basin.

II. Recent Studies on Permeability

The composition of pervious concrete facilitates water purification by filtering out suspended particles as water passes through the material. Research indicates that pervious concrete is capable of removing 94.3% of phosphorus from water through adsorption while in use (Radlinska et al., 2012). Additionally, the top layer of pervious concrete has lower porosity compared to the deeper sections. This low value indicates that over a period, pervious surface lose infiltration capacity.

Clogging, caused by the accumulation of sediment and debris, obstructs the natural permeability of pervious pavements, leading to a reduction in their ability to effectively manage stormwater. This sedimentation occurs relatively quickly, necessitating regular maintenance to ensure optimal performance. Wuguang et al. (2016) developed a clogging simulator using a sustainable permeability test which showed a very high correlation.

Giuseppe et al. (2016) studied the inadequacy of traditional urban drainage systems, leading to increasing frequency of flooding events in urban catchmentsLow Impact Development (LID) techniques reduce stormwater runoff and increase urban infiltration and evapotranspiration.

Wuguang et al. (2016) conducted a study on the reasons for clogging by creating a clogging simulator that assesses the long-term permeability of pavements using porous concrete blocks. Their proposed sustainable permeability test method was used to evaluate various types of porous concrete block pavers, revealing a strong correlation between the coefficient of permeability pre and post test. The study found that increased vibration frequency led to the easy clogging of pores.

Sidewalks of urban areas have been paved using permeable which aids in control of stormwater runoffs. This also decreases the discharge of pollutants to water bodies. Meysam et al. (2017) performed laboratory experiments to evaluate how the permeable pavements that are subjected to sediment loadings are effective in removing pollutants and suspended solids. This study revealed that the permeable pavement became choked in 7 hydrological years, with a 20% reduction in three hydraulic years. The model indicated a horizontal to vertical hydraulic conductivity of 3.5. The study also found 100% sediment retention over its entire lifespan. With annual cleaning and maintenance, permeable pavements retain hydraulic functions throughout their lifespan. Removal of particulate pollutants also continues effectively.

Porous pavements facilitate greater water infiltration and evaporation compared to both pavers and asphalt. Fini et al. (2017) discovered that permeable pavement led to a significant decrease in evaporative cooling from the soil, while impermeable pavements caused significant soil warming. At a depth of 20cm, the soil temperatures under concrete pavers and asphalt were 4°C and 5°C warmer, respectively, compared to the temperatures under porous pavements and unpaved soils. The use of porous pavements can help to increase

evaporation from paved soil surfaces. This increased evaporation can play a role in reducing the urban heat island effect caused due to increased human activities compared to adjoining rural areas. By allowing water to seep through the pavement and evaporate, porous pavements can help to cool the immediate environment and mitigate the heat island effect. This can have positive impacts on urban temperatures and overall environmental comfort in urban areas..

In a study conducted by Saadeh et al. in 2019, the researchers examined the impact of traffic on fully permeable pavements featuring both asphaltic and concrete surfaces. The study utilized the mechanistic-empirical approach credited to the California Pavement Research Center (UCPRC) to develop a new design method. This approach aimed to provide a comprehensive understanding of how different pavement materials and designs interact with the effects of traffic, with the ultimate goal of improving the overall performance and longevity of permeable pavements. Both the asphalt section and concrete test section performed well in infiltrating the stormwater. The study concluded that a fully permeable pavement design could be used for freeways.

II.1. Service Life and Quality of permeable pavements

David et al. (2014) after various laboratory tests and simulation models, suggested using fully permeable shoulder retrofit as a stormwater management strategy for highways, based on life cycle cost analysis. This research resulted in creating catalogue-type design tables for shoulder retrofit on highways, yards or parking spaces with slow moving traffic.

Anush et al. (2016) conducted a comprehensive review of studies focusing on serviceability, mechanical and hydrological properties of pervious concrete. The research has documented the stormwater purification efficiency of pervious concrete and also evaluated techniques to enhance the hydraulic efficiency of pavements using pervious concrete. The analysis of life cycle costs has indicated favourable outcomes for pervious concrete, making its a promising sustainable material for future roadways.

Thus, the best management alternative to providing traditional drains is providing shoulder retrofits with Full dept permeable pavement. Furthermore, a life-cycle cost analysis comparing FDPP to conventional stormwater BMPs for highway shoulders demonstrates cost-effectiveness.

II.2. The effects on flood mitigation

Reports of ongoing studies have emerged from different regions of India, including the Hatkeshwar area of Ahmedabad, Karanjade Node, Panvel, and Guwahati. These studies suggest the use of Paver tiles as a potential option for flood control measures.

II.3. Factors Promoting Use of Pavers in Kerala

The availability of paver blocks is a key factor that encourages the use of paved roads. Another benefit is the government's acceptance through a regulatory framework. The Industries department has categorized block-making as an MSME sector with incentives to ensure a steady supply. The regulatory framework has been adjusted to allow the use of paver tiles in the local self-government department's projects. The notification regarding the same was released vide DB3/5215/2013/CELSGD dated 04.04.2022.

III. Exploring the Latest Trends in Construction

The existing bituminous roads in various states of distress are often provided with a layer of gravel, typically consisting of 20mm chipping stones and bedding sand, before laying the paver tiles. Now works have been carried out, after the removal of the top sealing coat. Efforts have been made to pulverize it and lay it again.

Use of Interlock Paver tiles in the various works across Kerala, undertaken by the Government departments, showed a steady increase over past 10 years. Table 2 shows the number of works that were arranged over a period of last 10 years. The table shows a decline in the works arranged after 2018 after the devastating floods coupled with COVID pandemic. Urgent maintenance works were the focus during the period and this may have contributed for the decrease in works arranged during the period.

In Kerala, road infrastructure is mainly catered to by the Public Works Department and the Local self Government Department. The National Highways in the state being upgraded to 4/6 lanes as per IRC standards. A very few stretches of state highways and Major District Roads, especially in Junctions have been provided with Interlock Paver blocks and represented in Figure 2. Major chunk of the Interlock paver tile works over past years have been done on arterial roads or internal circulation paths and Yards. Most of these works have been arranged by the respective local government agencies for rural and residential lanes. Figure 3 shows a steady increase of such works done by Local Government Institutions. Total number of Interlock Paver tile works done on the various road categories is listed in Table 3. It shows a steady increase barring post Covid restrictions.

Table 2 Trend of Government works using Interlock Paver Blocks

Year	PWD All	LSGD	Total
2014	3	1	4
2015	16	69	85
2016	42	70	112
2017	27	221	248
2018	58	217	275
2019	60	207	267
2020	35	158	193
2021	41	182	223
2022	42	201	243
2023	28	238	266
2024 *	11	53	64
	363	1617	1980

***(till February)**

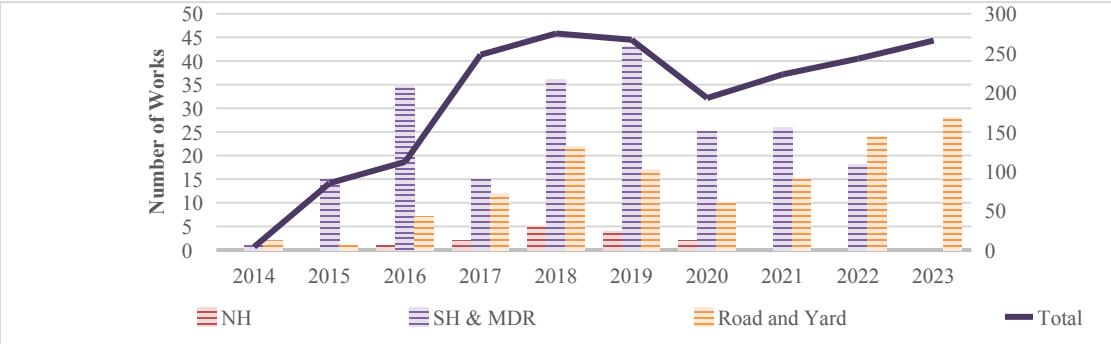

Figure 2 Interlock Pavers in Roads of varying Traffic-PWD

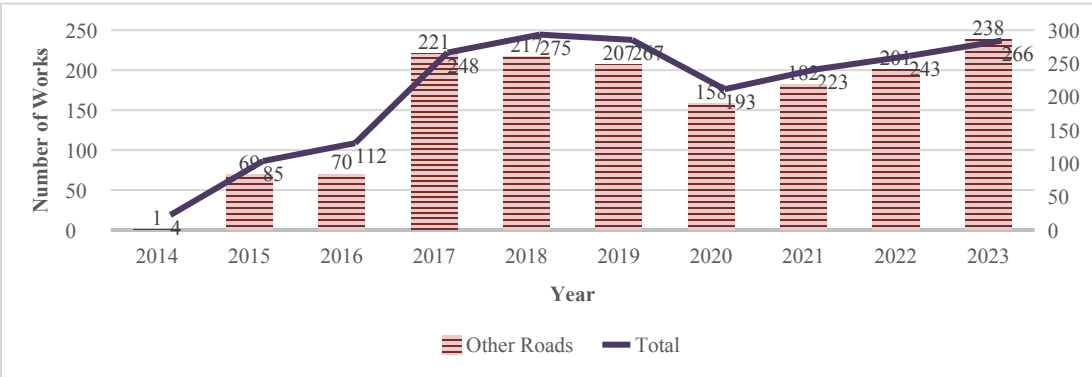

Figure 3 Interlock Pavers in Roads of Low Traffic

Table 3 Trend in Interlock Paver Roads

Year	NH	SH & MDR	Road &Yard	Other Roads	Total
2014		1	2	1	4
2015		15	1	69	85
2016	1	35	7	70	112
2017	2	15	12	221	248
2018	5	36	22	217	275
2019	4	43	17	207	267
2020	2	25	10	158	193

2021		26	15	182	223
2022		18	24	201	243
2023			28	238	266
2024*		1	10	53	64
Total	14	215	134	1617	1980

***(till Feb)**

As per the state Economic Review- 2023, a total length of 28775 kilometres of roads have been provided with Concrete/Interlock surface. Around 1.11 lakh kilometres of roads under LSGD are provided with a bituminous surface, while 56952 km are earthern roads. A district-wise analysis of the roads provided with interlock Paver tiles during the period from 2014 is shown in Table 4

Table 4 Interlock Paver works arranged in various districts

District	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Alappuzha			2	7	12	10	12	8	7	11	4
Eranakulam		55	64	85	53	103	68	58	86	71	7
Idukki			2	1	1	2	2	1		2	
Kannur		1		5	8	2	6	4	9	16	6
Kasargod	1	3	2	2	2	3	3	3	4	3	2
Kollam		7	4	11	36	41	26	18	19	30	3
Kottayam	1		5	12	4	9	4	3	2	10	2
Kozhikode			5	7	8	10	2	2	9	12	3
Malappuram				3	9	6		1	5	11	5
Palakkad				5	6	12	10	22	9	11	3
Pathanamthitta			1	4	23	20	7	16	4	1	3
Thiruvanantha puram	2	18	26	100	104	44	37	82	72	66	22
Thrissur		1	1	5	9	5	14	5	17	19	1
Wayanad				1			2			3	3
Total	4	85	112	248	275	267	193	223	243	266	64

Year on year the increase in the use of Paver tiles is evident from the above table, even after accounting for the post-COVID recession. Table 5 indicates that Ernakulam has the highest number of works using interlock tiles at nearly 33%, followed by Thiruvananthapuram at 29%. The same is evident from Figure 4 as well.

Table 5 District wise Cumulative Works over last 10 years

District	Works	Percent
Alappuzha	73	3.7
Eranakulam	650	32.8
Idukki	11	0.6
Kannur	57	2.9
Kasargod	28	1.4
Kollam	195	9.8
Kottayam	52	2.6
Kozhikode	58	2.9
Malappuram	40	2.0
Palakkad	78	3.9
Pathanamthitta	79	4.0
Thiruvananthapuram	573	28.9
Thrissur	77	3.9
Wayanad	9	0.5
Total	1980	100

The hill districts of Idukki and Wayanad have the least such works. This is also representative of the overall road coverage in these districts.

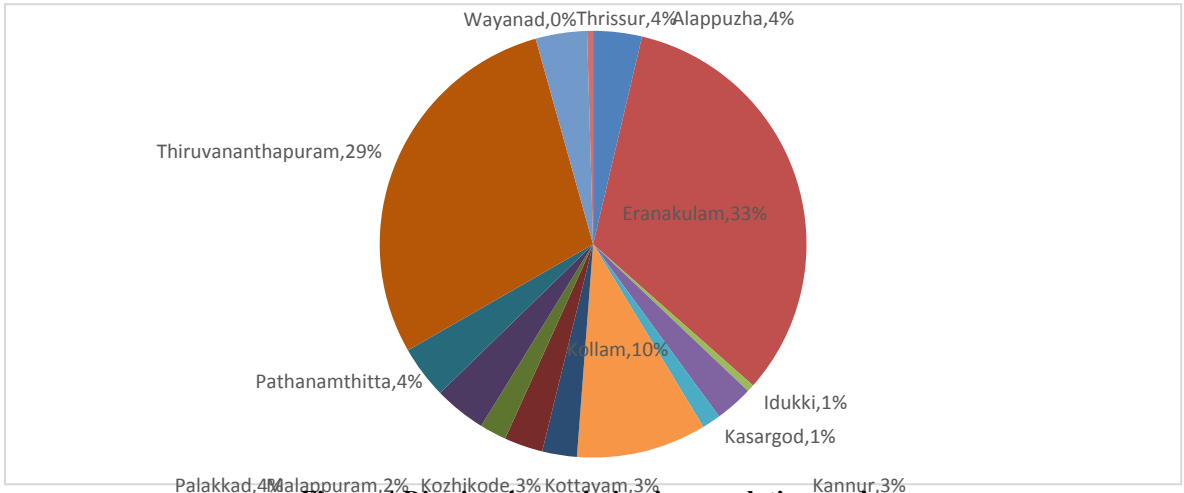

Figure 4 Districtwise variation in cumulative works

Thiruvananthapuram is the administrative capital of Kerala and Ernakulam is known as the Commercial capital of Kerala. Both these districts have shown consistent increases in the number of similar works arranged. This trend is represented in Figure 5 that shows the works arranged for low volume traffic roads catered to by the local self government department.

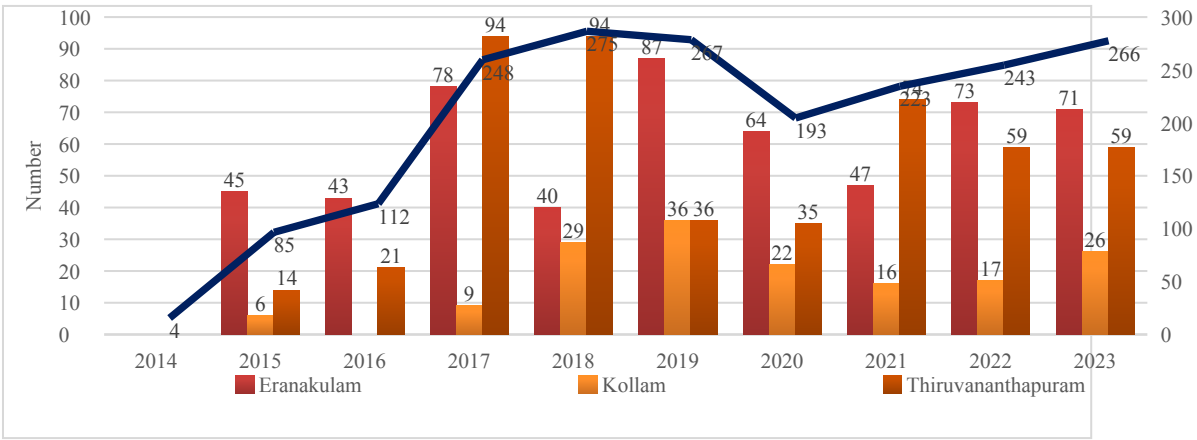

Figure 5 Annual variation in 3 districts- Low Volume Roads

IV. CONCLUSIONS

Permeable pavements offer sustainable benefits such as improving groundwater reserves, enhancing water body quality, reducing urban temperatures, allowing recyclable materials, and lowering lifecycle costs compared to traditional drainage systems.

Using permeable surfaces is a sustainable way to mitigate soil sealing that occurs when a Bituminous surface is used, as soil functions are not hindered. General trend is consistent with the sustainability goals envisaged for the state, to mitigate climate change effects.

84 % of the entire state road network is under local government institutions. Out of all these, around 80% of the surfaced roads have been provided with a Bituminous surface. Reversing this ratio in favor of interlocking paver blocks will contribute to improved percolation surfaces. Ultimately this should help alleviate sudden floods due to rainfall.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Grammarly in order to check spelling and synonyms After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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