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# Variation In Surface Permeability Of Interlock Concrete Pavements -Insights From Ernakulam District

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***Abstract***: *Traditional methods of pavements using bituminous mixes have to be provided with drainage infrastructure as well, in heavy rainfall regions. Providing similar surfaces even for low-volume rural roads is often done without providing drains, considering space constraints. This impacts the draining of rainwater, causing flash floods. Low Impact Development (LID) techniques are a proven and effective alternative, which ensure easy construction and maintenance, while also reducing stormwater runoff. 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 surface permeability of sample stretches that cover various sites in the district of Ernakulam in Kerala to assess the impact of age and traffic density.*
***Keywords***: *Permeable Pavement, Rainfall, geography, Grain size, Low volume roads*

## 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 regard 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 environmental sustainability. Development has led to reduced permeable land area, impacting groundwater replenishment and freshwater 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. Kerala has an extensive road network as shown in Table 1, totalling over 2.36 lakh kilometres, representing a growth of over 58 percent from 1.52 lakh km in 2010-11. 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 |

### Objectives Of The Study

The PICP aids in the faster removal of rainwater. The observed rainfall intensity in the region should be less than the permeability of the surface so that flooding does not happen. As the sediment load on PICP surface increases, the permeability reduces. This happens with the age of pavements and the nature of traffic. The location may also have an impact on the sediment load and permeability. The study aims to capture the variations in the permeability coefficient based on these three factors as observed at the site.

### Previous Studies On Permeability

Benjamin et al. (2003) conducted a comprehensive six-year study to evaluate the long-term effectiveness of permeable pavement as a substitute for traditional impervious asphalt pavement. The study was conducted in a parking space, aimed to assess signs of wear, structural durability, precipitation infiltration capacity, and the impact on infiltrated water quality. Surface runoff was minimal, but rainwater infiltration was high. Water samples that infiltrated through the permeable pavement showed significantly lower levels of zinc, copper, and motor oil pollutants compared to runoff from asphalt pavement.

Nimmo et al. (2004) considered pore space, which is the part of the soil's volume that is not taken up or separated by solid material, as fluid pathways, which exhibit complex and winding routes, featuring varying degrees of constriction and are typically characterized by high levels of interconnectedness. These concepts are best understood, measured, and applied in relation to the fluids that fill and flow through the pore spaces. The amount of pore space in soil plays a crucial role in various soil processes. When soil is disturbed during activities like digging or repacking, it can impact the hydraulic conductivity (k). Research suggests that while intergranular pores are rarely completely closed off, macropores may fully close, rendering them ineffective. Miklas et al. (2007) conducted a comprehensive review of permeable pavement systems (PPS) in the context of both traditional and modern urban drainage. The study focused on the detailed design, maintenance, and water quality control aspects of PPS.

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 an increasing frequency of flooding events in urban catchments. Low 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..

A six-lane highway in Nanjing was studied by Zhu et al. (2019). Three different pavement structures - permeable pavement, Permeable road and drainage surface - were simulated to study their impact on diminishing surface runoff and reducing urban stormwater under varying rainfall conditions. Of the three, the permeable road was effective in reducing the runoff coefficient and flood peak.

Kayhanian et al. (2019) recommended the use of Full Depth Permeable Pavement (FDPP) for effectively managing stormwater runoff. FDPP must maintain specific characteristics throughout the life of the pavements: (1) have adequate subgrade reservoir capacity to capture runoff volume, (2) surface pavement remain highly permeable and unclogged, (3) allow minimum permeability of subgrade soil to infiltrate the captured runoff, and (4) assure no adverse impact on underground water.

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 the concrete test section performed well in infiltrating the stormwater. The study concluded that a fully permeable pavement design could be used for freeways.

**Factors Promoting Use Of Pavers**

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.

**Need For Study Based On 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, work is being 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 the 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, following the devastating floods and the COVID pandemic. Urgent maintenance works were the focus during the period and this may have contributed to 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 are being upgraded to 4/6 lanes as per IRC standards. A very few stretches of state highways and Major District Roads, especially at junctions, have been provided with Interlock Paver blocks, as shown in Figure 1. A major chunk of the Interlock paver tile work over the past years has been done on arterial roads, internal circulation paths, and Yards. Most of these works have been arranged by the respective local government agencies for rural and residential lanes. Figure 2 shows a steady increase of such works done by Local Government Institutions. The total number of Interlock Paver tile works done on the various road categories is listed in Table 2. It shows a steady increase barring post-COVID restrictions.

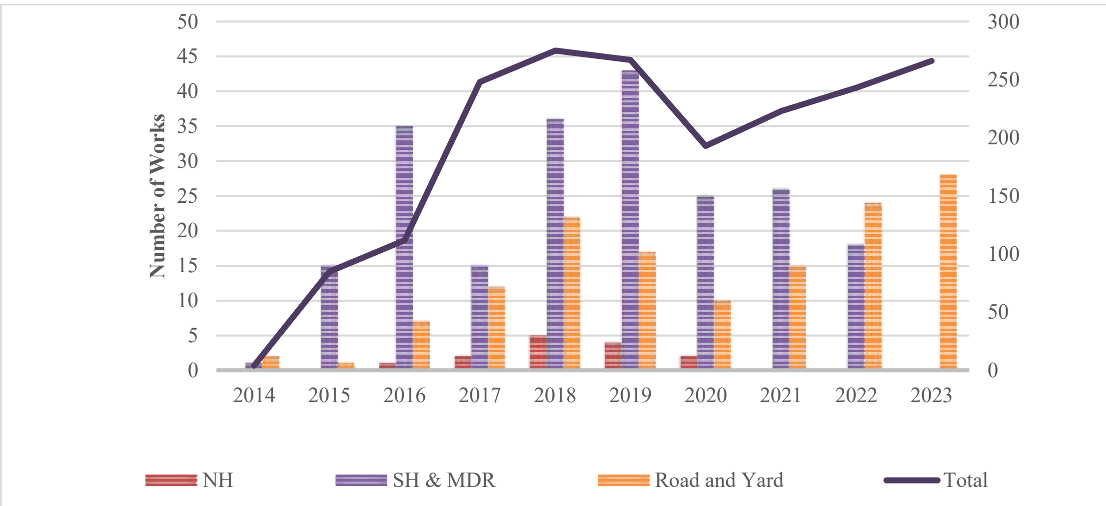


**Figure 1 Interlock Pavers in Roads of varying Traffic-PWD**

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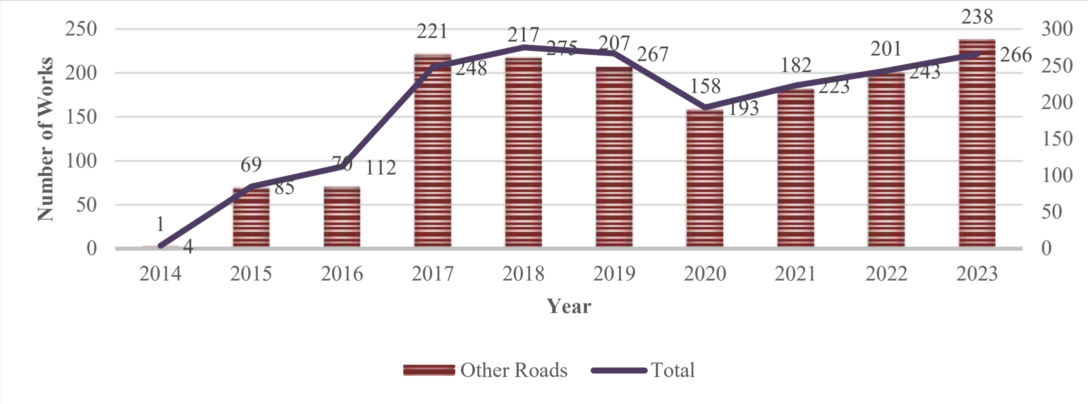


**Figure 2 Interlock Pavers in Roads of Low Traffic**

**Table 2 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, 2024)

Kerala is a coastal state but is also blessed with hills, forests, and abundant rivers, contributing to the geological diversity of the region. Heavy rainfall is experienced for nine months of the year. The pre-monsoon season occurs in the months of March, April, and May, while the South West monsoon, which causes the majority of precipitation, happens in the four months of June, July, August, and September. It is followed by North East Monsoons in October and November. These seasons recorded normal rainfall of 367 mm, 2004 mm and 322 mm respectively. Figure 3 shows the rainfall variation in Months of March to November in the previous 5 years (2018-2022). Kerala recorded the highest annual rainfall of 3,610.2 mm in 60 years in 2021 and the maximum daily rainfall in Ernakulam during the flood year of 2018 was recorded from August 15 to 17, averaging an intensity of 5.44 mm/hr.

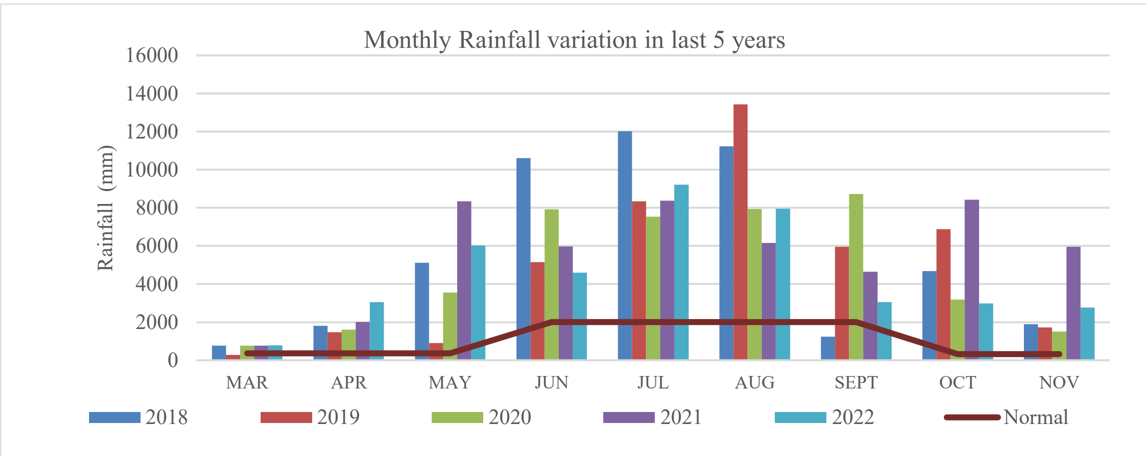


**Figure 3 Variation of Rainfall from 2018-2022**

Coastal areas have borne the brunt of heavy rains, but the hill districts have also suffered damage to road infrastructure. Construction of resilient roadways is being promoted as the solution to recurring damage and loss of connectivity. According to the State Economic Review 2023, a total of 28775 kilometres of roads have been provided with a concrete or interlock surface. Around 1.11 lakh kilometres of roads under LSGD are provided with a bituminous surface, while 56952 km are earthen roads. A district-wise analysis of the roads provided with interlock Paver tiles during the period from 2014 is shown in Table 3

**Table 3 Interlock Paver works 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 |
| Ernakulam | | 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 |
| Thiruvananthapuram | 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. Ernakulam has the highest number of works using interlock tiles at nearly 33%, followed by Thiruvananthapuram at 29% as shown in Figure 4

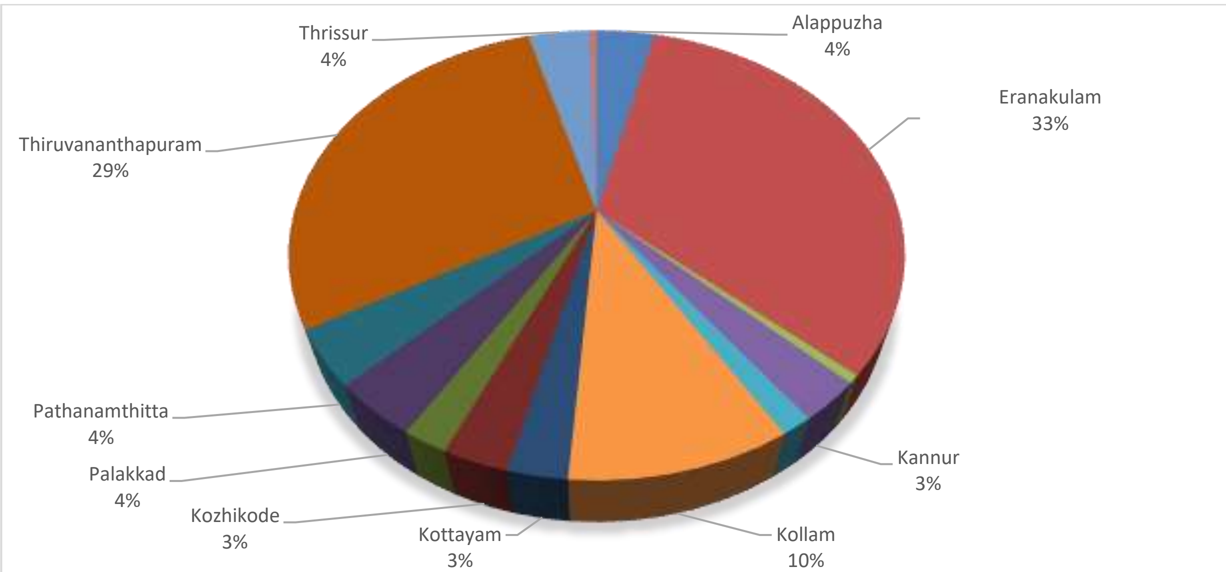


**Figure 4 District-wise variation in cumulative works**

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

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.

As most of the roads have already matured subgrades that are heavily compacted, with reduced percolation, the surface layers of PICP play a crucial role in infiltration. Hence, this study is focused on the sediment load from the surface of PICP at various sample stretches within Ernakulam District.

## STUDY METHODOLOGY

The roads that have been constructed using permeable interlock concrete paver tiles across the state of Kerala is assessed and the study region is selected with sufficient samples that offer a broad combination of various land use, terrain and age of pavements.

The surface sediment is collected from sites, and the surface temperature is recorded. Grain size distribution and moisture content are then assessed in the laboratory for each sample.

Based on particle size distribution, the coefficient of permeability is found using established empirical relations, the most common being Hazen's formula ($k = C \times D_{10}^2$), where $D_{10}$ is the effective grain size (particle size in cm such that 10% of the particles are finer) and C is a constant, often taken as 100. Other formulas exist, and the choice depends on the soil type and the level of accuracy required, as these are approximations rather than precise measurements. Permeability corrections for temperature account for changes in a fluid's viscosity and, in some materials, structural changes that affect permeability. The primary method involves adjusting permeability based on the fluid's dynamic viscosity, as an inverse relationship exists (lower viscosity leads to higher permeability). Corrections typically involve multiplying the measured permeability by the ratio of viscosities at a reference temperature and the test temperature.

Correction Factor = (Viscosity at Reference Temp) / (Viscosity at Test Temp)

The coefficient of permeability (K) at a different temperature (T) can be adjusted using a formula that accounts for the viscosity at both the test temperature and the standard temperature: $K27 = K_t \times (\eta_t/\eta 27)$, where $\eta$ is the viscosity of the fluid as per IS 5529 (Part 1) : 2013

The infiltration capacity of pavement is dependent on the permeability of the surface rather than the sublayers of PICP.

Hence, surface permeability is assessed and corrected for temperature. In case of granular soils initial moisture content has less influence compared to other factors like compaction of subsequent layers.

Also, a soil may have very high permeability, but if it is already saturated from a previous rain, its current infiltration rate will be very low. Conversely, a dry, sandy soil with high permeability will have a very high initial infiltration rate, which will slow as the soil approaches saturation.

Thus, the dry season, from February to March, was chosen for the field studies.

The hydraulic conductivities were calculated by HydroSieve by Devlin (2015) and are based on the generalized formula:

$$K = \frac{\rho g}{\mu} C\varphi(n) d_e^2$$

where K is hydraulic conductivity (cm/s), r is fluid density (g/mL), g is acceleration due to gravity (cm/s2), m is dynamic viscosity (poise, or g/cm s), C is a constant related to porous medium characteristics, j(n) is a function of porosity, and de is the effective grain diameter (cm). Both the density and viscosity terms are temperature sensitive and are calculated as a function of the fluid temperature.

The rainfall data for the state was collected from secondary sources and the observed average rainfall intensity in the study area was tabulated to ascertain the average annual rainfall and monthly variations. This also helped to identify the dry spell during which the study could be conducted.

### Study area

The various sites are spread over the District of Ernakulam and are represented in Figure 5. It may be noted that the district has both hilly as well as coastal and low-lying regions with varying groundwater levels.

Table 4 shows the list of sites where studies have been conducted with details of location and category.


**Figure 5 Geographical representation of the test sites (based on Google Earth image)**

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https://theaspd.com/index.php

**Table 4 Details of Sample Location and Category**

| Hilly Region | | | | | Coastal/Lowland | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Sample Designation* | *Years* | *category* | *Latitude* | *Longitude* | *Sample Designation* | *Years* | *category* | *Latitude* | *Longitude* |
| M-2 | 4 | MDR | 9.9290 | 76.3745 | R-6 | 6 | Residential | 10.1470 | 76.2325 |
| M-11 | 9 | MDR | 9.9899 | 76.4011 | H-2 | 5 | NH | 10.1505 | 76.2230 |
| M-12 | 9 | MDR | 10.0800 | 76.4710 | H-5 | 6 | NH | 10.1818 | 76.2046 |
| M-13 | 9 | MDR | 10.0755 | 76.4779 | R-2 | 5 | Residential | 10.1433 | 76.2149 |
| M-14 | 9 | MDR | 10.0466 | 76.5317 | R-7 | 6 | Residential | 9.8531 | 76.3844 |
| H-4 | 5 | SH | 10.0307 | 76.3759 | R-8 | 6 | Residential | 9.8554 | 76.3840 |
| H-9 | 7 | SH | 10.1041 | 76.3551 | R-9 | 6 | Residential | 9.8978 | 76.3674 |
| M-8 | 6 | MDR | 10.1125 | 76.4178 | H-3 | 5 | SH | 9.9095 | 76.3657 |
| M-6 | 5 | MDR | 10.1212 | 76.5677 | R-3 | 5 | Residential | 10.0203 | 76.2991 |
| M-9 | 7 | Industrial | 10.1782 | 76.5304 | H-1 | 4 | SH | 10.0039 | 76.3053 |
| M-3 | 5 | Industrial | 10.1772 | 76.5360 | M-7 | 5 | MDR | 9.9708 | 76.3174 |
| R-11 | 8 | Residential | 10.2037 | 76.4999 | R-10 | 7 | Residential | 9.9721 | 76.3181 |
| R-12 | 8 | Residential | 10.2038 | 76.4655 | R-1 | 3 | Residential | 9.9603 | 76.3032 |
| M-4 | 5 | Industrial | 10.1731 | 76.4348 | R-4 | 5 | Residential | 9.9565 | 76.3000 |
| M-5 | 5 | Industrial | 10.1613 | 76.3855 | H-8 | 6 | SH | 9.9010 | 76.2952 |
| M-10 | 9 | Industrial | 10.0805 | 76.3233 | H-6 | 6 | NH | 9.9402 | 76.3311 |
| M-1 | 3 | Industrial | 9.9590 | 76.3649 | H-7 | 6 | NH | 9.9383 | 76.3497 |
| M-2 | 4 | MDR | 9.9290 | 76.3745 | | | | | |

## RESULTS AND DISCUSSIONS

Laboratory studies on the sample were conducted in the School of Engineering laboratory. Grain size distribution, initial moisture content, and temperature were used in the HydroSieve Excel program, which yielded the results shown in Table 5.

**Table 5 Physical Properties of Sediment collected from PICP Surface across the District**

| *Sample Designation* | *$D_{10}$ (mm)* | *$D_{20}$* | *$D_{50}$* | *$D_{60}$* | *Uniformity Coeff* | *Porosity (n)* | *D (geom. mean)* | *k( cm/s)* | *Terrain* |
|---|---|---|---|---|---|---|---|---|---|
| R-6 | 0.059 | 0.162 | 0.386 | 0.495 | 8.33 | 0.31 | 0.247 | 0.00152 | Coastal |
| H-2 | 0.052 | 0.152 | 0.425 | 0.537 | 10.35 | 0.29 | 0.236 | 0.00087 | Coastal |
| H-5 | 0.065 | 0.164 | 0.365 | 0.475 | 7.32 | 0.32 | 0.236 | 0.00198 | Coastal |
| R-2 | 0.056 | 0.157 | 0.291 | 0.372 | 6.59 | 0.33 | 0.181 | 0.00158 | Coastal |
| R-7 | 0.185 | 0.265 | 0.833 | 1.309 | 7.09 | 0.32 | 0.684 | 0.0143 | Coastal |
| R-8 | 0.069 | 0.169 | 0.339 | 0.435 | 6.3 | 0.33 | 0.227 | 0.00244 | Coastal |
| R-9 | 0.142 | 0.196 | 0.399 | 0.507 | 3.57 | 0.39 | 0.366 | 0.0181 | Coastal |
| H-3 | 0.152 | 0.232 | 0.534 | 0.692 | 4.55 | 0.36 | 0.408 | 0.017 | Coastal |
| R-3 | 0.013 | 0.284 | 0.855 | 1.129 | 6.7 | 0.33 | 0.61 | 0.0106 | Coastal |
| H-1 | 0.051 | 0.152 | 0.37 | 0.494 | 9.67 | 0.3 | 0.228 | 0.00065 | Coastal |
| M-7 | 0.046 | 0.121 | 0.277 | 0.352 | 7.73 | 0.32 | 0.16 | 0.00065 | Coastal |
| R-10 | 0.144 | 0.217 | 0.501 | 0.634 | 4.4 | 0.37 | 0.396 | 0.012 | Coastal |
| R-1 | 0.069 | 0.182 | 0.405 | 0.509 | 7.32 | 0.32 | 0.269 | 0.00159 | Coastal |
| R-4 | 0.042 | 0.111 | 0.304 | 0.422 | 9.96 | 0.29 | 0.171 | 0.00044 | Coastal |
| H-8 | 0.144 | 0.206 | 0.424 | 0.515 | 3.57 | 0.39 | 0.31 | 0.0153 | Coastal |
| H-6 | 0.078 | 0.185 | 0.374 | 0.463 | 5.95 | 0.34 | 0.248 | 0.00262 | Coastal |
| H-7 | 0.124 | 0.194 | 0.368 | 0.446 | 3.58 | 0.39 | 0.261 | 0.0121 | Coastal |
| R-5 | 0.04 | 0.092 | 0.261 | 0.311 | 7.76 | 0.32 | 0.135 | 0.00059 | Coastal |
| M-2 | 0.088 | 0.214 | 0.559 | 0.754 | 8.6 | 0.31 | 0.362 | 0.00274 | Hilly |
| M-11 | 0.047 | 0.112 | 0.29 | 0.39 | 8.26 | 0.31 | 0.166 | 0.0008 | Hilly |
| M-12 | 0.073 | 0.195 | 0.519 | 0.684 | 9.36 | 0.3 | 0.326 | 0.00175 | Hilly |
| M-13 | 0.041 | 0.093 | 0.324 | 0.448 | 10.97 | 0.29 | 0.162 | 0.00045 | Hilly |
| M-14 | 0.126 | 0.233 | 0.536 | 0.667 | 5.29 | 0.35 | 0.358 | 0.00912 | Hilly |
| H-4 | 0.06 | 0.163 | 0.313 | 0.4 | 6.65 | 0.33 | 0.196 | 0.00076 | Hilly |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| H-9 | 0.073 | 0.196 | 0.572 | 0.88 | 11.99 | 0.28 | 0.369 | 0.0011 | Hilly |
| M-8 | 0.169 | 0.222 | 0.52 | 0.665 | 5.24 | 0.35 | 0.373 | 0.00807 | Hilly |
| M-6 | 0.072 | 0.173 | 0.366 | 0.475 | 6.56 | 0.33 | 0.258 | 0.00223 | Hilly |
| M-9 | 0.063 | 0.17 | 0.403 | 0.53 | 8.38 | 0.33 | 0.266 | 0.00118 | Hilly |
| M-3 | 0.07 | 0.189 | 0.544 | 0.745 | 10.7 | 0.29 | 0.342 | 0.0012 | Hilly |
| R-11 | 0.133 | 0.209 | 0.491 | 0.624 | 4.7 | 0.36 | 0.374 | 0.0117 | Hilly |
| R-12 | 0.131 | 0.236 | 0.632 | 0.86 | 6.58 | 0.33 | 0.426 | 0.00907 | Hilly |
| M-4 | 0.069 | 0.181 | 0.428 | 0.534 | 7.74 | 0.32 | 0.272 | 0.00209 | Hilly |
| M-5 | 0.051 | 0.134 | 0.299 | 0.398 | 7.76 | 0.32 | 0.178 | 0.00125 | Hilly |
| M-10 | 0.078 | 0.193 | 0.447 | 0.546 | 6.95 | 0.32 | 0.287 | 0.00289 | Hilly |
| M-1 | 0.126 | 0.24 | 0.544 | 0.693 | 5.51 | 0.35 | 0.362 | 0.00823 | Hilly |

The physical properties of the surface dust, based on particle size distribution of the dust collected, give an indication of the surface permeability. The nature of sediment load varies in the hilly coastal regions, as shown in Table 6. Kaloal et al. (2025) had recently reported that the infiltration rate of water through the ground depends on, among other factors, temperature, soil moisture and porosity.

**Table 6 Variation of Sediment Properties based on Terrain**

| *Terrain* | *$D_{10}$ (mm)* | *$D_{20}$* | *$D_{50}$* | *$D_{60}$* | *Uniformity Coeff* | *Porosity (n)* | *D (geom. mean)* | *k( cm/s)* |
|---|---|---|---|---|---|---|---|---|
| Coastal | 0.0851 | 0.18006 | 0.42839 | 0.56094 | 6.708 | 0.33444 | 0.2985 | 0.006352 |
| Hilly | 0.0865 | 0.18547 | 0.45806 | 0.60547 | 7.72 | 0.32177 | 0.2987 | 0.003802 |

It is seen that the coefficient of permeability is higher in coastal areas. And is inversely proportional to the D60, ie, the effective particle size corresponding to 60% by weight passing the sieves.
The infiltration rate is also affected by the surface permeability, which is in turn affected by clogging. Various studies have reported that the clogging increases with the age of the pavement. Thus, the Permeability Coefficient must reduce with age.

**Table 7 Variation of Sediment Properties Based on Age of Pavement**

| Age (Years) | *$D_{10}$ (mm)* | *$D_{20}$* | *$D_{50}$* | *$D_{60}$* | *Uniformity Coeff* | *Porosity (n)* | *D (geom. mean)* | *k( cm/s)* |
|---|---|---|---|---|---|---|---|---|
| <4 | 0.0825 | 0.222 | 0.5915 | 0.77125 | 7.3975 | 0.3225 | 0.403 | 0.00569 |
| 5 | 0.0875 | 0.173 | 0.3983 | 0.50817 | 6.6458 | 0.33417 | 0.263 | 0.00572 |
| 6 | 0.0994 | 0.189 | 0.4499 | 0.60656 | 6.4744 | 0.33667 | 0.322 | 0.00698 |
| 7 | 0.0763 | 0.1897 | 0.4453 | 0.58233 | 7.6433 | 0.32667 | 0.292 | 0.00218 |
| > 7 | 0.071 | 0.165 | 0.424 | 0.57157 | 8.7771 | 0.31143 | 0.273 | 0.00259 |

It is observed that with the increase in age of the pavement, the physical properties of the sediment change, and the coefficient of permeability also reduces considerably after approximately 7 years. This is still higher than the maximum rainfall intensity recorded in previous years.
The nature of traffic also influences the compaction of lower layers, which affects the overall infiltration rates of the pavement system.

**Table 8 Variation Of Sediment Properties Based on Traffic Density**

| Category | *$D_{10}$ (mm)* | *$D_{20}$* | *$D_{50}$* | *$D_{60}$* | *Uniformity Coeff* | *Porosity (n)* | *D (geom. mean)* | *k( cm/s)* |
|---|---|---|---|---|---|---|---|---|
| Highways | 0.0887 | 0.1827 | 0.4161 | 0.54467 | 7.07 | 0.333333 | 0.277 | 0.005821 |
| MDR | 0.0799 | 0.1764 | 0.4326 | 0.56293 | 7.789 | 0.320714 | 0.277 | 0.003047 |
| Residential | 0.0922 | 0.1907 | 0.4811 | 0.64527 | 6.544 | 0.334545 | 0.347 | 0.007486 |

## CONCLUSIONS

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. The general trend is consistent with the sustainability goals envisioned for the state, aimed at mitigating the effects of climate change.

This study shows that the surface permeability of PICP is higher in coastal regions of the district. After 6 years, the pavement system has reduced permeability and hence maintenance actions are required. Pavements that cater to higher traffic loads, such as MDRs and highways, tend to have lower permeability compared to residential, low-traffic roads. Hence, PICPS are more effective on low-volume roads.

Approximately 84% of the entire state road network is under the control of local government institutions and caters to low-volume roads. 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. 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 to check spelling and synonyms. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

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