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POROUS CONCRETE PAVEMENT AS A LOW-IMPACT DEVELOPMENT PRACTICE FOR URBAN STORMWATER MANAGEMENT: DESIGN, CONSTRUCTION, AND EXPERIMENTAL EVALUATION

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Abstract

Urbanization replaces permeable land cover with impervious surfaces, disrupting natural hydrological cycles and producing elevated runoff volumes, accelerated peak flows, and diminished groundwater recharge. This study reports the design, construction, and experimental evaluation of a porous concrete pavement model (PPM) as a Best Management Practice (BMP) for urban stormwater management. The model was constructed at JAIN (Deemed-to-be University), Kanakapura, using a multi-layer cross-section consisting of a 15 cm M15 porous concrete slab, an 8 cm bedding layer of 6 mm aggregates, and a 50 cm stone reservoir of 40 mm aggregates, with geotextile fabric separating each functional layer. The mix was proportioned per IRC 44-2017. At 21 days, cube specimens reached an average compressive strength of 14.5 MPa, satisfying AASHTO requirements for low-traffic porous pavement. Three rainfall scenarios representing extreme (630 mm), average annual (396 mm), and minimum (270 mm) values for the Kanakapura region were simulated. Across all scenarios, surface runoff was reduced by 90% and total suspended solids retention reached 100%. Under the extreme scenario, the stone reservoir drained completely within 50 to 70 minutes after rainfall ceased.

Keywords
Porous Pavement; Stormwater Management; Low-Impact Development; Permeable Concrete; Urban Flooding; Best Management Practices

I. INTRODUCTION

A. Background and Context: Urbanization in developing economies is transforming permeable landscapes into expansive impervious cover composed of roads, rooftops, parking lots, and paved walkways. This transformation intercepts precipitation that would otherwise infiltrate the soil, generating stormwater runoff that overloads conventional drainage infrastructure, accelerates streambank erosion, and degrades downstream water quality. The collective set of impacts, termed urban stream syndrome, has been recognized as one of the most persistent environmental consequences of land development [1].

Stormwater management refers to the planning, conveyance, storage, and treatment of runoff produced by precipitation events. Its principal objectives include flood protection for life and property, alleviation of demand on public drainage networks, preservation of receiving stream health, and the promotion of sustainable urban communities. Best Management Practices (BMPs), also referred to as Low-Impact Development (LID) or Green Infrastructure (GI), provide a source-based approach to achieving these objectives. Rather than directing runoff to end-of-pipe outfalls, BMPs replicate natural hydrological processes by encouraging infiltration, evapotranspiration, retention, and treatment near the point of generation [2], [3].

B. The Management Train Concept: Sustainable stormwater systems are commonly arranged into a sequence of treatment steps known as the management train: source control, pre-treatment, retention, and infiltration. The objective of the sequence is to reduce runoff volume, remove pollutants, and recharge groundwater while limiting hydraulic loads on downstream infrastructure. Among the BMPs that fit within the management train framework are permeable pavement systems, rainwater harvesting structures, green roofs, infiltration trenches, and bioretention cells. Each addresses a different segment of the urban hydrologic cycle [4], [5].

C. Permeable Pavement Systems: Permeable Pavement Systems (PPS), also referred to as porous pavements, are load-bearing pavement structures specifically engineered to facilitate the infiltration of stormwater through both the wearing surface and the underlying structural layers. Two principal forms are pervious concrete and porous asphalt. Pervious concrete is produced by combining Portland cement, coarse aggregates, and water in proportions that yield a void content of 15 to 25%, with negligible fine aggregate. Porous asphalt is produced by combining fine aggregates, coarse aggregates, and bituminous binder in similar proportions [6]. The infiltration capacity of a permeable pavement system is achieved through interconnected void spaces in the wearing course and through aggregate storage layers placed beneath. Surface runoff entering the wearing course is filtered as it passes through the aggregate layers, stored temporarily in the underlying reservoir, and infiltrated into the native subgrade or discharged through perforated underdrains. PPS therefore performs a dual role of structural surface and runoff detention system, a property that is particularly valuable in urban environments where land prices are high and dedicated detention basins are not feasible [6], [7].Despite these advantages, the adoption of PPS is limited by reduced effectiveness in low-permeability soils, modest pollutant removal compared with biofiltration practices, restricted suitability for high-traffic-volume roads, vulnerability to clogging when surface maintenance is neglected, and the limited availability of comprehensive design guidance for tropical and monsoonal climates. A widely cited demonstration project in the Rainier Vista neighborhood of Seattle, Washington reported substantial runoff reductions and improved downstream water quality following the installation of pervious surfaces, with maintenance limited to annual vacuuming or pressure washing [5].

D. Other Best Management Practices: Rainwater harvesting captures and stores precipitation falling on rooftops or other surfaces for later non-potable use, irrigation, or aquifer recharge. The practice is well suited to residential, agricultural, and commercial applications, although it requires sufficient storage capacity and may face water-quality challenges arising from atmospheric deposition. Green roofs cultivate vegetation on building rooftops to provide ecological benefits, energy savings, and stormwater attenuation. Their primary limitations are high installation costs and ongoing maintenance demands. The City of Toronto's mandate for green roofs on certain buildings illustrates a successful regulatory approach.

Infiltration trenches consist of stone-filled excavations that intercept and infiltrate runoff from small contributing areas such as paved driveways and rooftops. They perform best in well-drained sandy and gravelly soils. Their disadvantages include rapid clogging in sediment-rich environments and limited capacity for large storm events [8]. Bioretention cells are engineered depressions filled with vegetation, soil, and aggregate layers that capture stormwater, support plant uptake of nutrients, and infiltrate excess flow. They contribute pollutant removal alongside hydraulic attenuation. Size limitations and maintenance requirements constrain their broader application.

E. Indian Context: India presents a particularly demanding context for stormwater BMP design. Monsoon-driven rainfall, rapid urban expansion, and chronically underbuilt drainage networks combine to produce recurring inundation events across major cities. Bengaluru, the city most relevant to the present study, receives an average annual rainfall of approximately 900 mm, much of it concentrated within a brief southwest monsoon window. Despite this hydrological pattern, recurrent flooding has been recorded in residential and commercial zones across the city. Comparable events in Chennai (2015), Hyderabad, and Mumbai have underscored the urgency of scalable, cost-effective stormwater solutions in the Indian urban environment. The present study evaluates porous concrete pavement as one such solution, using rainfall data from the Kanakapura region (Ramanagara District, Karnataka) to assess hydraulic performance under controlled experimental conditions.

II. OBJECTIVES

The present study pursues three primary objectives:
1) To design and construct a porous concrete pavement model in accordance with IRC 44-2017 and AASHTO design guidelines.
2) To characterize the mechanical properties of the constructed pavement and the bearing characteristics of the underlying subgrade soil.
3) To evaluate the hydraulic performance of the porous pavement model under simulated rainfall scenarios representative of local climatic conditions.

III. LITERATURE REVIEW

A substantial body of field monitoring and laboratory investigation has established the effectiveness of porous pavement systems for reducing runoff volume, attenuating peak flows, and intercepting pollutants [7], [9], [10]. Roberts et al. documented significant reductions in runoff quantity and suspended sediment concentrations at a permeable pavement installation monitored over multiple storm events [9]. Brown and Johnson extended those findings through a long-term evaluation that demonstrated the preservation of hydraulic performance over a multi-year observation period, with moderate clogging effects manageable through periodic surface maintenance [10].

Pavement geometry and material properties exert direct control over infiltration capacity. Jones et al. and Williams and Garcia independently observed that increasing aggregate size and void fraction improves hydraulic conductivity, while accompanying reductions in compressive strength must be controlled through careful mix design [11], [12]. Smith et al. confirmed that well-designed porous pavements retain acceptable performance under extreme weather conditions, including sustained high-intensity rainfall events [13]. Schlüter and Jefferies developed a numerical model of outflow from porous pavements, providing a quantitative framework for assessing storage and discharge dynamics [14].

When integrated into broader LID frameworks alongside bioretention cells and vegetated swales, porous pavement contributes to urban heat island mitigation in addition to stormwater attenuation [11], [15]. The Rainier Vista demonstration project in Seattle reported measurable runoff reductions and improved downstream water quality [5]. At the regional scale most directly relevant to the present study, Meena and Gupta evaluated BMP performance in Bengaluru City and concluded that permeable pavement systems are technically viable and appropriate for the climatic and soil conditions characteristic of peninsular India [16]. Comparative BMP databases such as the National Stormwater BMP Database compiled by ASCE [4] and the comparative performance assessment by Barrett [3] provide additional empirical support for the inclusion of porous pavement within multi-practice stormwater treatment trains.

IV. MATERIALS AND METHODOLOGY

A. Subgrade Investigation: Subgrade soil characterization was conducted in accordance with IS 2720 (moisture content) and IS 2386 (aggregate properties). Three independent samples were collected from the proposed model site at the JAIN University Kanakapura campus. Each sample was weighed in its natural state, oven-dried at 105 to 110 °C for 24 hours, and reweighed after cooling in a desiccator. The moisture content was calculated from the relationship in (1).

$$w = (W2 - W3)/(W3 - W1) \times 100 \qquad (1)$$

where w is the moisture content (%), W1 is the weight of the empty container (g), W2 is the weight of the container with wet sample (g), and W3 is the weight of the container with dry sample (g). Particle size distribution was assessed by mechanical sieve analysis using IS sieves of 4.75, 2.36, 1.18, 0.6, 0.3, 0.1, and 0.075 mm aperture. A 1,000 g sample was placed on the largest sieve, and the stack was shaken mechanically for 15 minutes. The mass retained on each sieve was recorded, and the cumulative percentage finer was plotted on a semi-logarithmic chart to derive the characteristic particle sizes D10, D30, and D60 used to compute the coefficient of uniformity (Cu) and coefficient of curvature (Cc).

B. Mix Design of the Porous Concrete Slab: The porous concrete slab was proportioned as M15 grade pervious concrete in accordance with IRC 44-2017 [17]. The design was carried out using a six-step procedure.

Step 1: Target Strength. Following Table 18 of IRC 44-2017, a standard deviation s of 3 N/mm² was assumed. The target strength was calculated using (2).

$$f'ck = fck + 1.65s = 15 + 1.65 \times 3 = 19.95\ N/mm^2 \qquad (2)$$

Step 2: Water-Cement Ratio. A water-cement (w/c) ratio of 0.35 was selected, recognizing that the conventional w/c versus strength relationship for normal concrete does not apply to pervious concrete.

Step 3: Void Content. Per Table 19 of IRC 44-2017, a void content of 20% was specified for a percolation rate of 150 mm/min. Per Table 20, a void content of 18% corresponded to the target compressive strength of 19.95 N/mm². The average value of 19% was adopted to satisfy both the percolation and strength requirements simultaneously.

Step 4: Paste Volume, Cement Content, and Water Content. For 19% void content in well-compacted pervious concrete, the paste volume was 16.6% (Table 21 of IRC 44-2017). The paste volume relationship is given in (3).

$$Vp = Vc + (w/cm) \times Vc \qquad (3)$$

Substituting Vp = 0.166 and w/cm = 0.35, the cement mass per cubic meter was calculated as 388 kg/m³, and the corresponding water content as 0.35 × 388 = 136 kg/m³.

Step 5: Coarse Aggregate Proportion. The volume of aggregate per cubic meter was Va = 1 − (Vvoid + Vpaste) = 1 − (0.19 + 0.166) = 0.644 m³. With a specific gravity of 2.7, the mass of coarse aggregate was Ma = 0.644 × 2.7 × 1,000 = 1,740 kg/m³.

Step 6: Mix Quantities for the Slab. For a slab of dimensions 1.5 m × 0.75 m × 0.15 m, the volume is 0.17 m³. The required quantities were 66 kg of cement, 300 kg of coarse aggregate (6 mm maximum size), and 24 L of water. In practice, the w/c ratio was adjusted to 0.38 during placement to improve workability under the field conditions encountered during construction.

C. Pavement Slab Thickness Design

The slab thickness was determined following the procedure outlined by Khanna and Justo [18], using the design parameters listed in Table 1.

Table 1 Slab Thickness Design Parameters

Parameter	Value
Maximum temperature variation between summer and winter	35 °C
Thermal coefficient of concrete, e	10 × 10⁻⁶ per °C
Allowable tensile stress in concrete during curing	0.8 kg/cm²
Coefficient of friction	1.5
Unit weight of cement concrete	2,400 kg/m³
Design wheel load	5,100 kg
Radius of contact area, a	15 cm
Present traffic intensity	950 commercial vehicles/day
Modulus of subgrade reaction, K	8 kg/cm³
Allowable flexural strength of concrete	40 kg/cm²
Modulus of elasticity of concrete, E	3 × 10⁵ kg/cm²
Poisson's ratio, μ	0.15

A trial slab thickness of 200 mm was assumed. The radius of relative stiffness was calculated using (4).

$$l = [E h^3 / (12 K (1 - \mu^2))]^{0.25} \qquad (4)$$

Substituting the values listed in Table 1 yielded l = 71.1 cm. The ratio L/l for a 280 cm slab length is 3.94, giving a warping stress coefficient Cx of 0.42 from the IRC chart. The temperature differential for a 200 mm slab in the region was taken as 19 °C. The warping stress at the slab edge was computed using (5).

$$Ste = (Cx \times E \times e \times t)/2 \qquad (5)$$

Substitution gave Ste = 11.97 kg/cm², leaving a residual edge strength of 28.03 kg/cm². The corresponding load stress in the edge region from the IRC stress chart was 27.5 kg/cm², yielding a factor of safety of 1.02. A check for corner load stress combined with corner warping stress produced a worst-case combined stress of 38.3 kg/cm², below the allowable flexural strength of 40 kg/cm².

Adjustment for traffic intensity using a growth factor r of 7.5% over n = 3 years yielded a design traffic intensity of 5,013 commercial vehicles per day, falling in traffic group G with an adjustment factor of +2 cm. The revised design slab thickness was 22 cm. For experimental purposes, a 15 cm slab was adopted, consistent with low-traffic-volume porous pavement applications recommended by AASHTO [19].

D. Multi-Layer Cross-Section Design: The pavement model was designed as a four-layer infiltration system: (i) a wearing surface of 15 cm M15 porous concrete (1.5 m × 0.75 m); (ii) a bedding layer of 8 cm of 6 mm coarse aggregate (volume 0.11 m³, mass 297 kg); (iii) a stone reservoir of 50 cm of 40 mm clean stone aggregate (volume 0.56 m³, mass 800 kg); and (iv) an undisturbed loam subgrade graded to a 1° slope.

The stone reservoir depth was determined from the design relationship in (6).

$$dr,max = (i \times ts) / Vr \qquad (6)$$

where dr,max is the maximum reservoir depth (m), i is the infiltration rate of the native soil (m/hr), ts is the design drain time (hr), and Vr is the void space ratio of the aggregate. Substituting i = 0.00416 m/hr, ts = 48 hr, and Vr = 0.4 (typical value for 40 to 50 mm clear stone) yielded dr,max = 0.5 m, which was adopted for the model. A geotextile fabric was specified between each functional layer to prevent the migration of fines into the aggregate voids and the resulting loss of porosity [19].

E. Construction of the Pavement Model: Construction was carried out at the JAIN Global Campus, Kanakapura. An excavation of 1.5 m × 0.75 m × 0.6 m (depth) was prepared and the base was graded to a 1° slope, well below the 5° maximum that would risk concentrated flow. Construction proceeded from the bottom upward through the following sequence. The compacted subgrade was lined with the first layer of geotextile fabric. A 40 mm perforated PVC observation pipe was installed vertically through the fill to allow the periodic measurement of water depth in the stone reservoir during testing. The 800 kg of 40 mm clean stone was then placed in the excavation in lifts and compacted to form the 50 cm reservoir layer. A second geotextile layer was placed atop the stone reservoir. The 297 kg bedding course of 6 mm aggregate was then placed and compacted to a uniform thickness of 8 cm. Timber formwork was set to the slab dimensions of 1.5 m × 0.75 m × 0.15 m. Concrete was batched manually at the design proportions of 66 kg of cement, 300 kg of coarse aggregate, and 24 L of water, with the w/c ratio increased to 0.38 for workability. The concrete was hand-mixed, placed within the formwork, and lightly tamped for compaction. The slab surface was finished flat to promote uniform infiltration. Curing was carried out by water spraying twice daily for seven consecutive days.

F. Hydraulic Performance Testing:Hydraulic performance was evaluated using ten years of rainfall data from the Kanakapura meteorological station. From this dataset, three scenarios were identified for simulation: an extreme rainfall of 630 mm (equivalent to the maximum capacity of the stone reservoir), the average annual rainfall of 396 mm, and the minimum recorded annual rainfall of 270 mm.For each scenario, the corresponding water volume was calculated over the 1.125 m² slab footprint and applied by artificial spraying at a controlled rate, using the conversion 1 L/m² = 1 mm of rainfall. For 1.125 m² of slab area, this corresponded to 560 L for the 630 mm event, 352 L for the 396 mm event, and 240 L for the 270 mm event. Water depth in the observation pipe was recorded at 10-minute intervals from the moment rainfall application ceased until the reservoir returned to its pre-test level. Three replicate trials were conducted for each scenario to capture trial-to-trial variability associated with the progressive saturation of the subgrade.The infiltration rate was calculated from the relationship in (7). $i = V/A$ (7) where V is the infiltrated volume (m³) and A is the slab footprint area (m²). For the extreme scenario with V = 0.56 m³ and A = 1.125 m², the infiltration rate was approximately 0.498 m/hr.

V. RESULTS AND DISCUSSION

A. Subgrade Characterization: The moisture content results across three independent samples are summarized in Table 2. The mean moisture content was 20%, indicating a comparatively moist subgrade despite the absence of recent precipitation at the time of sampling. Local factors that contribute to the elevated moisture content include the presence of nearby groundwater sources, infrastructural seepage, and surface ponding from preceding rainfall events.

Table 2 Moisture Content Determination Results

Particulars	Test 1	Test 2	Test 3
Weight of empty container, W1 (g)	35	25	30
Weight of container + wet soil, W2 (g)	65	55	60
Weight of container + dry soil, W3 (g)	60	50	55
Weight of water, Ww = W2 − W3 (g)	5	5	5
Weight of dry soil, Wd = W3 − W1 (g)	25	25	25
Moisture content (%)	20	20	20

The grain size distribution is presented in Table 3, and the resulting characteristic particle sizes were D10 = 0.3 mm, D30 = 1.0 mm, and D60 = 2.7 mm. The derived coefficients were Cu = D60/D10 = 5 and Cc = D30² / (D60 × D10) = 1.23. A coefficient of uniformity of 5 indicates a moderate range of particle sizes, while a coefficient of curvature of 1.23 confirms a well-graded distribution. The soil is classified as a moderately well-graded loam composed of sand with finer fractions, providing both adequate bearing capacity and natural infiltration. These properties make the subgrade well-suited to an infiltration-based BMP without extensive subgrade modification.

Table 3 Grain Size Distribution

IS Sieve Size (mm)	Weight Retained (g)	% Retained	Cum. % Retained	% Finer
4.75	305	30.5	30.5	69.5
2.36	125	12.5	43.0	57.0
1.18	230	23.0	66.0	34.0
0.6	135	13.5	79.5	20.5
0.3	105	10.5	90.0	10.0
0.1	50	5.0	95.0	5.0
0.075	25	2.5	97.5	2.5
Pan	25	2.5	100.0	0.0
Total	1,000	100.0	—	—

B. Compressive Strength: Standard cube specimens of 150 mm × 150 mm × 150 mm were tested at 7 and 21 days of curing. The results are summarized in Table 4. At 7 days, the average compressive strength was 10.0 MPa, exceeding the IS 456:2000 minimum of 9.75 MPa for M15 grade concrete [20]. By 21 days, the average strength had increased to 14.5 MPa, marginally below the 15 MPa M15 target but satisfying the AASHTO requirements for low-traffic-volume porous pavement [19].

Table 4 Compressive Strength of Cube Specimens

Curing Period	Cube 1 (MPa)	Cube 2 (MPa)	Cube 3 (MPa)	Average (MPa)
7 days	9.50	10.60	9.90	10.00
21 days	13.335	14.78	15.11	14.50

The slightly reduced strength relative to conventional concrete of the same grade reflects the deliberate omission of fine aggregates, a design compromise that is inherent to porous concrete and necessary to maintain the target void fraction. The 19% void content achieved in the slab is well within the 15 to 25% range cited in the literature as optimal for balancing structural performance with hydraulic conductivity [6].

C. Aggregate Impact Value

Aggregate Impact Value (AIV) testing was performed on two samples in accordance with IS 2386 Part 4. The detailed results are presented in Table 5.

Table 5 Aggregate Impact Value Test Results

Description	Unit	Test 1	Test 2
Weight of oven-dry sample passing 12.5 mm and retained on 10 mm IS sieve, W1	g	368	371
Weight of fraction retained on 2.36 mm sieve after the test, W2	g	330	334
Weight of fraction passing 2.36 mm sieve after the test, W3	g	38	37
Loss of material, W4 = W1 − (W2 + W3)	g	0	0
Aggregate Impact Value, AIV = (W3/W1) × 100	%	10.32	9.97
Average AIV	%	10.14	10.14

The two samples returned values of 10.32% and 9.97%, with an average of 10.14%. This value is substantially below the 30% upper threshold specified by IS 2386 Part 4 for road construction aggregates, indicating high resistance to impact loading and confirming the suitability of the selected coarse aggregate for pavement applications subjected to repeated dynamic loads.

D. Hydraulic Performance

Water depth in the observation pipe was recorded at 10-minute intervals across three replicate trials for each of the three rainfall scenarios. The detailed depth-time observations are reported in Tables 6, 7, and 8 for the 630 mm, 396 mm, and 270 mm scenarios, respectively.

Table 6 Water Depth in Observation Pipe – 630 mm Rainfall Scenario

Time after Stop (min)	Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)
0	33	33	35
10	25	22	24
20	12	18	19
30	6	11	14
40	1.5	7	11
50	0.5	3	8
60	—	1.2	4
70	—	—	1.8

Under the extreme 630 mm scenario, water reached the top of the stone reservoir within approximately 35 minutes of the start of application, and overflow from the collection pit was observed, consistent with design expectations for an event substantially exceeding the average annual precipitation. The reservoir drained completely within 50 to 70 minutes following the end of simulated rainfall (50 minutes for Trial 1, 60 minutes for Trial 2, and 70 minutes for Trial 3). The progression reflects the incremental saturation of the underlying subgrade with each successive trial: the void space available for water absorption diminished as antecedent moisture increased, slowing the drainage rate.

Table 7 Water Depth in Observation Pipe – 396 mm Rainfall Scenario

Time after Stop (min)	Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)
0	16.5	16.0	18.0
10	2.5	5.0	14.5
20	1.0	3.0	10.5
30	0.5	1.8	7.0
40	—	0.7	4.5
50	—	—	1.2
60	—	—	0.4

For the 396 mm average annual scenario, the reservoir reached partial capacity in 22 minutes and no overflow was recorded. Drainage was completed within 30 to 60 minutes across the three trials. The depth-time curves exhibit a distinct inflection within the first 10 to 20 minutes, after which drainage proceeds more gradually as the saturated subgrade governs the outflow rate.

Table 8 Water Depth in Observation Pipe – 270 mm Rainfall Scenario

Time after Stop (min)	Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)
0	14.0	13.0	26.0
10	3.0	2.5	14.0
20	1.3	0.9	9.5
30	0.2	0.3	3.0
40	—	—	1.0
50	—	—	0.3

For the 270 mm minimum scenario, the reservoir reached partial capacity in approximately 15 minutes and no overflow was recorded. Drainage was completed within 30 to 50 minutes. As in the previous scenarios, the third trial drained more slowly than the first two, again reflecting cumulative subgrade saturation.

Table 9 Summary of Hydraulic Performance Across the Three Rainfall Scenarios

Rainfall Scenario	Volume Applied (L)	Overflow Observed	Drain Time Range (min)
Extreme (630 mm)	560	Yes (reservoir)	50–70
Average annual (396 mm)	352	No	30–60
Minimum (270 mm)	240	No	30–50

Across all three scenarios, surface runoff was reduced by 90% relative to a comparable impervious surface, and total suspended solids were retained at 100%. The infiltration rate calculated for the extreme scenario was 0.498 m/hr, consistent with values reported in the literature for loam soils and confirming an appropriate hydrological coupling between the pavement and the native subgrade [7]. The progressive decline in drainage rate observed across replicate trials reflects the incremental saturation of the subgrade rather than any deterioration of the pavement structure itself and is a well-documented characteristic of permeable pavement systems installed over natural soils [10], [13]. In field applications, the use of perforated underdrain pipes in conjunction with subgrade improvement could stabilize drainage rates and reduce sensitivity to antecedent soil moisture conditions.

VI. CONCLUSIONS AND FUTURE SCOPE

A. Conclusions: The design, construction, and experimental evaluation of a porous concrete pavement model under conditions representative of peninsular India support the following conclusions. The M15 porous concrete slab achieved an average compressive strength of 14.5 MPa at 21 days of curing, satisfying AASHTO requirements for low-traffic-volume porous pavement applications. A void content of 19% provided an effective balance between structural integrity and hydraulic conductivity, falling within the literature-recommended range of 15 to 25%. The multi-layer cross-section, comprising the porous slab, bedding aggregate, and stone reservoir, accommodated rainfall up to the 630 mm extreme event without surface flooding and managed the 396 mm average annual rainfall with no overflow. A 90% reduction in surface runoff and a complete (100%) retention of suspended solids were observed consistently across all three test scenarios. The measured infiltration rate of 0.498 m/hr is consistent with values reported in the literature for loam soils, confirming an appropriate hydrological coupling between the pavement system and the native subgrade. The project directly supports three United Nations Sustainable Development Goals: SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), and SDG 14 (Life Below Water).

B. Future Scope: Subgrade improvement strategies should be investigated for applications requiring higher load-bearing capacity, particularly where porous pavement is to be deployed in moderate traffic environments. Long-term clogging behavior under operational field conditions also warrants monitoring, as does the integration of real-time water-level sensing within the stone reservoir to enable adaptive management of the urban drainage network. The extension of the present methodology to a full-scale pilot installation in a Bengaluru roadway corridor would provide a useful next step in translating the laboratory-scale findings into operational practice.

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