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Development And Performance Evaluation Of Pervious Interlocking Concrete Pavers

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Abstract: Urbanization has lead to the creation of many impervious structures like roads, buildings and many more, which lead to excessive stormwater runoff, urban flooding, groundwater depletion. Another major issue is that the industries are dumping the byproducts like fly ash ,silica fume in river and land mass which depletes the quality of our environment. This project aims to design, develop, and evaluate Pervious Interlocking Concrete Pavers (PICPs) as a sustainable pavement solution for urban stormwater management. Impervious surfaces have led to significant surface runoff, causing flooding, erosion and reduced groundwater recharge. Pervious pavers allow rainwater to infiltrate through their joints and structure, reducing runoff volume and improving water quality through filtration. The project involves selection of suitable aggregate size, cement content, and water-cement ratio to achieve desired compressive strength while maintaining adequate permeability. Laboratory tests including compressive strength, split tensile strength, permeability, abrasion resistance were conducted to assess mechanical and hydrological performance. Mix 4, incorporating OPC, fly ash, silica fume, polypropylene fibres , and superplasticizer with a w/b ratio of 0.4, achieved an optimal 28-day compressive strength of 18 MPa with an infiltration rate of 4.5 cm/min and water absorption of 19.7%. The findings confirm PICPs as a cost-effective, eco-friendly paving solution suitable for pathways, parking areas, and low-traffic roads, supporting sustainable urban development and groundwater recharge. Index Terms: Pervious Interlocking Concrete Pavers (PICPs), Stormwater Management, Permeability, Compressive Strength, Sustainable Pavement, Recycled Aggregates.

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I. INTRODUCTION

Rapid urbanization and infrastructure development have significantly transformed the natural landscape, leading to an increase in impervious surfaces such as roads, parking lots and pavements. These surfaces restrict the natural infiltration of rainwater into the ground, resulting in excessive surface runoff, urban flooding, erosion and depletion of groundwater levels. Managing stormwater in a sustainable and eco-friendly manner has therefore become a major challenge for modern cities. Pervious Interlocking Concrete Pavers (PICPs) are specially designed paving units that allow water to pass through the joints or through the paver body into an underlying aggregate layer, enabling on-site infiltration, storage, and groundwater recharge. Unlike traditional impervious pavements, PICPs manage stormwater at the source by reducing runoff and filtering pollutants such as sediments, heavy metals, and hydrocarbons. They form an essential component of Sustainable Urban Drainage Systems (SUDS) and Low Impact Development (LID) strategies. PICPs are widely adopted in parking areas, walkways, driveways and low-traffic roadways and are increasingly being integrated into green infrastructure initiatives worldwide. They not only mitigate stormwater problems but also contribute to urban heat reduction, improved air quality, and enhanced sustainability of the built environment. Furthermore, their ability to be reused, replaced, or recycled makes them an environmentally responsible choice in modern pavement design. The development and performance evaluation of pervious interlocking concrete pavers involve studying their mechanical strength, permeability, durability, and clogging resistance, along with optimizing material composition and geometric design. Research in this area focuses on balancing permeability with strength by adjusting aggregate gradation, cement content and admixture use to achieve both hydraulic efficiency and structural integrity.

II. LITERATURE REVIEW

Yasir Abduljaleel et al. (2025) utilized a sophisticated coupling of PCSWMM modeling and Python-based data analysis to evaluate PICP performance in Renton, Washington. Their study highlights a critical challenge: while urbanization and climate change are expected to drive a 43% increase in runoff, PICP systems can mitigate this by reducing runoff between 24% and 75%. However, they emphasize that long-term efficiency is contingent on maintenance, noting that infiltration rates naturally decline from 15.2 to 11.6 mm/min as partial clogging occurs over time.

Laura Moretti et al. (2025) demonstrated that the optimal base thickness for PICPs must be highly specialized, ranging from 100 mm for urban walkways to 1760 mm for heavy industrial applications, depending on the underlying soil and load requirements. Beyond water management, their work confirms that these systems serve as a vital tool in mitigating the Urban Heat Island (UHI) effect.

Rael Ernani Wojahn et al. (2024) found that a strategic combination of fine sand and coarse aggregates maximizes water flow while simultaneously reducing pollutants like ammonia nitrogen and turbidity.

Tamimi et al. (2023) observed that substituting natural stone with 100% Recycled Concrete Aggregate (RCA) can reduce compressive and tensile strength. They identified a sustainable remedy: the inclusion of natural fibers (such as date palm leaves) and fine aggregates can bridge internal micro-cracks and restore structural ductility.

Arjun Siva Rathan R.T. et al. (2021) established that a blend of 80% (12 mm) and 20% (6 mm) aggregates creates the ideal balance between mechanical durability and the void space necessary for permeability.

Cacciuttolo et al. (2023) confirmed that PICP systems in Chile could successfully manage a 100-year return period rainfall event without reaching saturation.They demonstrated the PICPs capability in flood mitigation.

Nguyen et al. (2022) in Australia challenged the common misconception that these systems clog rapidly, suggesting a confident, conservative design infiltration rate of 400 mm/h which supports the long term reliability of the system.

III. MATERIALS AND METHODOLOGY

A. Material Selection

The raw materials used in PICP production are Ordinary Portland Cement (OPC 53), Fly Ash, Silica Fume, Polypropylene Fibres , Polycarboxylate Superplasticizer, Recycled Coarse Aggregate (6–12 mm), and water. OPC 53 provides high early strength and quick setting properties. Fly ash enhances workability, reduces heat of hydration, and improves long-term durability. Silica fume, being an ultrafine pozzolanic material, enhances bond strength and reduces permeability. Polypropylene fibres of 12 mm length and 20–40 µm diameter were incorporated at 0.1–0.15% by volume to improve crack resistance. Recycled aggregates were used to improve sustainability and minimise environmental impact.

B. Mix Proportioning

Five mixes were designed with varying proportions of cementitious materials, water, fibers and superplasticizer. The no-fines pervious mix design eliminates fine aggregate for maximising interconnected voids while SCMs enhance paste durability and polypropylene fibres improve crack resistance. The details of the mix proportions are given in Table 1.

Table 1: Mix Proportion of PICP Specimens

Mix	Cement	Fly ash	Silica fume	Coarse aggregate	Polypropylene fibre	Super plasticiser	W/B
$CFSP_2SP_5$	1600	0	0	4000	0.20%	0.3	0.4
$CF_5S_5P_2SP_5$	1440	80	80	4000	0.20%	0.3	0.4
$CF_{10}S_{10}P_2SP_5$	1280	160	160	4000	0.20%	0.3	0.4
$CF_{15}S_{15}P_2SP_5$	1120	240	240	4000	0.20%	0.3	0.4
$CF_{20}S_{20}P_2SP_5$	960	320	320	4000	0.20%	0.3	0.4

C. Casting and Curing

Moulds were cleaned and coated with a release agent. The concrete mix was prepared by hand compacting for achieving the uniform consistency. Each layer was compacted using tamping rods to remove entrapped air.specimens were demoulded after 24 hours and curing was performed by immersing the interlock at 27 ± 2°C as per IS 516 (Part 5/Sec 1): 2020 for a minimum of 28 days.

D. Performance Evaluation Tests

Performance was evaluated through compressive strength test on 20 cm × 20 cm × 6 cm paver specimens at 7, 14, and 28 days using a Compression Testing Machine (CTM), permeability/infiltration test using a rubber tube setup to measure water infiltration rate,slump cone test to assess fresh concrete workability, sieve analysis on 12 mm, 10 mm, and 6.3 mm sieves, Los Angeles abrasion test, water absorption test, aggregate impact value test, flakiness index and elongation index tests as per relevant IS standards.

IV. RESULTS AND DISCUSSIONS

A. Abrasion Test

The PICP specimens exhibited 27% mass loss under the abrasion test, which falls within the typical 20–35% range reported for pervious concrete systems designed primarily for stormwater infiltration. This range value indicates that the aggregates are very strong and can withstand loads .

Table 2: Abrasion Test Results

Description	Value
Initial Weight (W_1)	5000 g
Weight Retained After Test (W_2)	3650 g
Loss in Weight (W_1-W_2)	1350 g
Abrasion Value	27%

B. Water Absorption Test on Aggregate

The coarse aggregate of size 6-12 mm exhibited 0.93% average water absorption, well within the <1.5% limit for crushed aggregates as per IS 2386. This low absorption characteristic ensures precise control of the 0.40 w/b ratio and consistent paste coating of aggregates.

Table 3: Water Absorption Test on Aggregate

Sample No.	Dry Weight W_1 (kg)	Wet Weight W_2 (kg)	Water Absorption (%)
1	1.985	2.005	1.01
2	2.012	2.030	0.89
3	1.998	2.016	0.90
Average	—	—	0.93

C. Aggregate Impact Value

The coarse aggregate exhibited an Aggregate Impact Value (AIV) of 22% as per IS 2386 (Part 4), indicating moderately strong aggregate suitable for light to medium traffic pervious concrete paver applications. This value classifies the aggregate as 'moderately strong' per IRC:SP:62-2014 guidelines, so it is suitable for pedestrian pathways and light vehicular parking areas.

Table 4: Aggregate Impact Value

Sample No.	Original Weight W_1 (g)	Weight Passing 2.36 mm W_2 (g)	Impact Value (%)
1	500	110	22

D. Flakiness Index and Elongation Index

The flakiness index of 13% confirms excellent particle shape quality of the 6–12 mm coarse aggregate, exceeding IS 383 requirements (<15% for crushed aggregate). The elongation index of 17%, combined with the flakiness index of 13%, confirms superior particle shape quality (combined indices <30%). The predominantly cubical/angular particle morphology enhances paste retention, compaction uniformity, and load transfer efficiency, contributing to the target 18–22% porosity and 12–18 MPa compressive strength.

Table 5: Flakiness and Elongation Index

Test	Size Fraction (mm)	Total Sample Weight (g)	Flaky/Elongated Weight (g)	Index (%)
Flakiness	12.5–10 & 10–6.3	1000	130	13
Elongation	12.5–10 & 10–6.3	1000	170	17

E. Slump Cone Test

The average slump value of 3.67 cm confirms optimal low-workability characteristics of the pervious concrete mix, ideal for interlocking concrete paver production. This controlled workability ensures aggregate interlock preservation, uniform paste distribution, and void structure integrity during vibration compaction.

Table 6: Slump Cone Test Values

Trial No.	Height of Cone (mm)	Height of Slump (mm)	Slump Value (cm)
1	300	295	5
2	300	298	2
3	300	296	4
Average	—	—	3.67

F. Compressive Strength

The 28-day compressive strength of Mix $CF_{15}S_{15}P_2SP_5$ achieved 18 MPa, confirming superior structural performance for the pervious interlocking concrete paver, meeting premium light vehicular grade capacity per IS 15658 specifications. The progressive strength development over 7, 14, and 28 days for all the five mixes is presented in Table 7. Mix $CF_{15}S_{15}P_2SP_5$ with polypropylene fibres and superplasticizer consistently outperformed Mix $CFSP_2SP_5$, Mix $CF_5S_5P_2SP_5$, Mix $CF_{10}S_{10}P_2SP_5$ and Mix $CF_{20}S_{20}P_2SP_5$ due to better paste-aggregate bonding and the pozzolanic reactions of silica fume and fly ash.

Table 7: Compressive Strength (MPa)

Mix	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
$CFSP_2SP_5$	5.75	9	10.25
$CF_5S_5P_2SP_5$	6.75	10.35	11.25
$CF_{10}S_{10}P_2SP_5$	8.85	12.5	14.75
$CF_{15}S_{15}P_2SP_5$	11.75	16	18
$CF_{20}S_{20}P_2SP_5$	10	14.25	16.25

G. Water Absorption of Interlock

The water absorption of Mix 3 at 19.7% confirms optimal interconnected porosity in the pervious interlocking concrete paver, achieving the ideal balance between 18 MPa compressive strength and superior stormwater infiltration capacity per IS 15658 standards. The absorption performance ensures reliable hydraulic functionality with excellent durability for pedestrian/light vehicular applications.

Table 8: Water Absorption of Interlock

Mix	Dry Weight (kg)	Saturated Weight (kg)	Weight Gain (kg)	Absorption (%)
$CFSP_2SP_5$	4.730	6.223	1.503	31.77
$CF_5S_5P_2SP_5$	4.730	5.918	1.188	25.11
$CF_{10}S_{10}P_2SP_5$	4.730	5.920	1.19	25.15
$CF_{15}S_{15}P_2SP_5$	4.730	5.662	0.932	19.7
$CF_{20}S_{20}P_2SP_5$	4.730	5.900	1.170	24.7

H. Permeability Test

The infiltration rate of $CF_{15}S_{15}P_2SP_5$ was calculated as 4.5 cm/min, confirming superior surface permeability of the pervious interlocking concrete paver. This result achieves perfect synchronisation between 19.7% interconnected porosity.The infiltration rate was calculated by first calculating the Plan Area and converting Volume to Cubic centimeters. Then determine the equivalent depth and then calculate final infiltration rate(cm/min).

Table 7: Infiltration rate of Interlock

MIX	Volume of water (L)	Infiltration rate(cm/min)
$CFSP_2SP_5$	0.9	2.25
$CF_5S_5P_2SP_5$	1.08	2.7
$CF_{10}S_{10}P_2SP_5$	1.44	3.6
$CF_{15}S_{15}P_2SP_5$	1.8	4.5
$CF_{20}S_{20}P_2SP_5$	2.16	5.4

V. CONCLUSIONS

The study on Pervious Interlocking Concrete Pavers (PICP) proves that it is a sustainable alternative to conventional pavements. The key conclusions are:

1. Mix $CF_{15}S_{15}P_2SP_5$, incorporating OPC 53, fly ash, silica fume, polypropylene fibres, and polycarboxylate superplasticizer with a w/b ratio of 0.4, achieved the highest 28-day compressive strength of 18 MPa, which satisfies IS 15658 requirements for light vehicular traffic applications.
2. The infiltration rate of 4.5 cm/min and water absorption of 19.7% confirm optimal interconnected porosity, making Mix $CF_{15}S_{15}P_2SP_5$ highly suitable for stormwater management applications.
3. The aggregate characteristics flakiness index 13%, elongation index 17%, AIV 22% and water absorption 0.93% confirm premium material quality, providing the foundation for consistent PICP production.
4. The use of supplementary cementitious materials (SCMs) such as fly ash and silica fume improved compressive strength, enabled efficient utilisation of industrial by-products and contributed to sustainable construction.
5. PICPs offer sufficient load-bearing capacity for light to medium traffic and they areeasy to maintain due to their modular interlocking design, and support groundwater recharge, flood reduction, and reduction of the urban heat island effect.

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