© July 2026 | IJIRT | Volume 13 Issue 2 | ISSN: 2349-6002

Performance Evaluation of Interlocking Concrete Paver Block Pavements under Repeated Traffic Loading

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***Abstract*—Interlocking Concrete Paver Blocks (ICPBs) are increasingly used in urban transport infrastructure because of their durability, modular construction, and ease of maintenance. Bus stops and parking areas experience heavy static loads, repeated braking and acceleration forces, and high contact stresses that often cause rutting and premature failure in conventional pavements. This study evaluates the suitability of ICPBs by reviewing their mechanical properties, rutting resistance, load distribution, and maintenance performance. The influence of block shape, thickness, laying pattern, jointing sand, and edge restraints on pavement performance is also examined. Findings from laboratory and field studies indicate that properly designed ICPB pavements effectively distribute traffic loads, reduce subgrade stresses, and provide better resistance to permanent deformation than conventional pavement systems. Their modular nature enables quick replacement of damaged blocks, reducing maintenance time, traffic disruption, and life-cycle costs. Additional benefits include improved permeability, lower urban heat effects, and easier access to underground utilities. The study concludes that ICPBs offer a durable, rut-resistant, and maintenance-efficient alternative for bus stops and parking areas when designed and constructed according to established engineering standards.**

***Index Terms*—Interlocking concrete paver blocks, bus stops, parking areas, rutting resistance, compressive strength, pavement maintenance**

I. INTRODUCTION

Rapid urbanization and economic growth have resulted in a substantial increase in vehicle ownership throughout developing countries, leading to higher traffic volumes and greater loading intensity on transportation infrastructure. Bus stops, bus bays, parking areas, industrial yards, container terminals, and commercial vehicle parking facilities experience particularly severe loading conditions due to repeated vehicle braking, acceleration, turning movements, and prolonged stationary loading. These loading conditions generate high contact stresses that accelerate pavement deterioration and increase maintenance requirements.

Conventional flexible pavements constructed using bituminous materials are highly susceptible to permanent deformation under repeated wheel loads. Rutting, shoving, bleeding, fatigue cracking, and pothole formation are common modes of failure that reduce ride quality, compromise safety, and increase maintenance costs. Although rigid concrete pavements provide greater structural capacity, they require higher initial construction costs, longer curing periods, and more complex repair procedures. Consequently, highway engineers and urban planners continue to seek alternative pavement systems capable of combining structural strength, economic efficiency, ease of maintenance, and environmental sustainability.

Interlocking Concrete Paver Blocks (ICPBs) have emerged as one of the most promising pavement technologies for heavy-duty urban applications. The pavement consists of precast concrete blocks placed over a compacted bedding sand layer and confined using edge restraints. Under traffic loading, adjacent blocks transfer loads through mechanical interlocking and frictional resistance between joints, thereby distributing stresses over a larger pavement area and reducing localized deformation. Unlike monolithic pavement systems, ICPBs permit individual block replacement without disturbing surrounding pavement layers, making maintenance operations significantly faster and more economical.

The structural performance of ICPBs depends upon several engineering parameters, including concrete compressive strength, block geometry, block thickness, laying pattern, bedding sand quality, joint filling, base course stiffness, subgrade strength, and edge restraint effectiveness. Previous studies have demonstrated that herringbone laying patterns provide superior resistance against horizontal movement generated by vehicle braking and turning actions. Proper compaction of bedding sand and adequate joint filling further improve load transfer efficiency and minimize differential settlement.

Apart from mechanical advantages, Interlocking Concrete Paver Blocks offer significant environmental benefits. The modular construction process minimizes material wastage during installation and maintenance. Damaged blocks can be reused or recycled, thereby reducing construction debris and conserving natural resources. Permeable interlocking pavements additionally facilitate groundwater recharge, reduce stormwater runoff, and mitigate urban heat island effects. These characteristics make ICPBs an important component of sustainable urban infrastructure development.

In India, increasing urban traffic congestion and frequent maintenance of bus stops and parking areas have emphasized the need for durable pavement alternatives capable of withstanding repeated heavy loading with minimal service interruption. Several municipalities have already adopted interlocking pavements for footpaths, residential roads, parking lots, and commercial developments. However, relatively limited research has specifically investigated the structural behaviour of ICPBs under the severe loading conditions experienced at bus stops and heavy-vehicle parking facilities.

Objectives Of the Study

- To evaluate the compressive and flexural strength characteristics of Interlocking Concrete Paver Blocks.
- To assess the rutting resistance of ICPBs under repeated wheel loading conditions.
- To compare the structural performance of ICPBs with conventional asphalt pavements.
- To evaluate maintenance efficiency through simulated repair operations.
- To examine the economic and environmental benefits associated with modular pavement construction.
- To recommend suitable applications of ICPBs for bus stops, parking areas, industrial pavements, and other heavy-duty urban facilities.

II. LITERATURE REVIEW

Interlocking Concrete Paver Blocks (ICPBs) have gained widespread acceptance as an alternative pavement system due to their superior structural performance, durability, and ease of maintenance. Several researchers have investigated their mechanical properties, load distribution behavior, and long-term performance under different traffic conditions.

Studies have shown that ICPBs exhibit excellent compressive strength ranging from 35 MPa to 55 MPa, making them suitable for heavy-duty pavements such as industrial yards, bus terminals, ports, airports, and parking facilities. Unlike conventional asphalt pavements, which primarily rely on material stiffness, ICPBs distribute applied wheel loads through mechanical interlocking between adjacent blocks. This interlocking mechanism reduces stress concentrations in the pavement structure and minimizes permanent deformation.

Previous investigations reported that the shape and laying pattern of paver blocks significantly influence pavement performance. Herringbone laying patterns provide the highest resistance against horizontal displacement because wheel loads are distributed in multiple directions. Rectangular blocks laid in stretcher bond patterns are comparatively less resistant to braking and turning forces. Proper joint filling with well-graded sand further improves interlocking efficiency and reduces block movement under repeated traffic loading.

III. MATERIALS AND METHODS

Materials

The study utilized Interlocking Concrete Paver Blocks (ICPBs) of size 200 mm × 100 mm × 60 mm, manufactured in accordance with IS 15658 standards [5]. The paver blocks were produced using Ordinary Portland Cement (OPC), fine aggregate, and coarse aggregate to achieve a target compressive strength of 40 MPa [3]. Crushed stone was used for the base and sub-base layers, compacted to achieve a California Bearing Ratio (CBR) of 30% to ensure adequate load distribution and rutting resistance [12]. Jointing sand was placed between the blocks to provide proper interlock and structural stability. Mechanical performance was evaluated using a Universal Testing Machine (UTM) for compressive and flexural strength tests, while a rutting machine was used to simulate repeated traffic loading [6]. The ICPB pavement was installed under simulated field conditions representing typical urban bus stops and parking areas subjected to dynamic and static loads.

3.1 Methods

The experimental program consisted of three phases: strength evaluation, rutting resistance, and maintenance performance. Compressive and flexural strengths of the Interlocking Concrete Paver Blocks (ICPBs) were determined in accordance with ASTM C39 and ASTM C78, respectively [5]. Rutting resistance was assessed using a wheel-tracking machine under repeated loading of up to 200,000 cycles, representing heavy traffic conditions at bus stops and parking areas [7]. Rut depth was measured periodically to evaluate pavement deformation. Maintenance performance was assessed by simulating localized repairs through block removal and reinstallation, with repair time and resource requirements recorded [11]. Statistical analysis was performed using ANOVA at a 5% significance level ($p < 0.05$) to compare the performance of ICPBs with conventional asphalt pavements [9]. All experimental data were analyzed using SPSS software for statistical validation.

Material	Specification
Cement	OPC 53 Grade
Fine Aggregate	River Sand (Zone II)
Coarse Aggregate	Crushed Granite (10 mm)
Water	Potable Water
Bedding Sand	Clean, Dry Sand
Base Course	Crushed Stone Aggregate
Subgrade CBR	30%

3.2 Experimental Programme

The experimental programme consisted of laboratory testing and simulated field evaluation to determine the structural performance of Interlocking Concrete Paver Blocks.

The investigation was carried out in four stages:

1. Compressive strength testing.
2. Flexural strength testing.
3. Wheel-tracking test for rutting resistance.
4. Maintenance simulation through block replacement.

Compressive strength was determined using a Universal Testing Machine in accordance with relevant testing standards after 28 days of curing. Flexural strength was measured using three-point loading arrangements. Rutting performance was evaluated using a wheel-tracking machine subjected to repeated loading up to 200,000 load cycles. Rut depth measurements were recorded periodically during testing.

Maintenance efficiency was assessed by intentionally removing damaged paver blocks and replacing them with new blocks under simulated field conditions. The total repair time, labour requirement, and disturbance to surrounding pavement were recorded for comparison with conventional asphalt pavement repair methods.

3.3 Statistical Analysis

Experimental results were statistically analysed using one-way Analysis of Variance (ANOVA) at a 95% confidence level ($p < 0.05$). The statistical analysis was performed using SPSS software to determine the significance of differences between ICPB and conventional asphalt pavement performance. Mean values, standard deviations, and coefficients of variation were also calculated to evaluate manufacturing consistency and repeatability of test results.

IV. RESULTS AND DISCUSSION

4.1 Compressive Strength

The compressive strength test results indicate that all paver blocks exceeded the minimum strength requirement recommended for heavy-duty pavements. The average compressive strength obtained after 28 days of curing was 42 MPa, demonstrating excellent structural capacity.

Concrete paver blocks manufactured using quality-controlled materials exhibited uniform strength characteristics, as indicated by the low variation between specimens. This consistency confirms the effectiveness of the manufacturing process and ensures reliable pavement performance under repeated traffic loading.

Table 2. Compressive and Flexural Strength

Manufacturer	Compressive Strength (MPa)	Flexural Strength (MPa)
Manufacturer 1	42.1	6.4
Manufacturer 2	41.8	6.5
Manufacturer 3	42.3	6.6
Average	42.07	6.50

The coefficient of variation was found to be less than 3%, indicating excellent manufacturing consistency.

4.2 Flexural Strength

Flexural strength represents the ability of concrete paver blocks to resist bending stresses generated by vehicle wheel loads. The average flexural strength obtained during testing was 6.5 MPa, which is adequate for heavy traffic conditions.

Higher flexural strength minimizes crack initiation and propagation, thereby improving the long-term durability of the pavement. The results demonstrate that the selected concrete mix possesses sufficient tensile capacity to withstand repeated loading without significant deterioration.

4.3 Rutting Resistance

Rutting is one of the most common failure modes observed in bus stops and parking areas because vehicles repeatedly brake, accelerate, and remain stationary for extended periods.

The wheel-tracking test revealed that the ICPB pavement exhibited a maximum rut depth of only 3 mm after 200,000 loading cycles, whereas conventional asphalt pavement developed approximately 15 mm rut depth under identical loading conditions.

Table 3. Rutting Performance

Pavement Type	Rut Depth (mm)	Loading Cycles
Interlocking Concrete Paver Blocks	3	200,000
Conventional Asphalt Pavement	15	200,000

The results clearly indicate that ICPBs provide nearly 80% lower permanent deformation compared with conventional asphalt pavements.

This improvement can be attributed to:

- Mechanical interlocking between adjacent blocks.
- Effective load transfer through the bedding sand.
- Reduced stress concentration on the subgrade.
- Higher stiffness of concrete compared with asphalt mixtures.

4.4 Load Distribution Behaviour

One of the primary advantages of Interlocking Concrete Paver Blocks is their ability to distribute wheel loads over a wider pavement area.

When a vehicle wheel applies pressure to the pavement surface, the load is transferred through adjacent blocks by means of friction and mechanical interlocking. This mechanism reduces localized stress concentrations and prevents excessive deformation in the underlying layers.

The bedding sand layer acts as a flexible cushion that accommodates minor irregularities while maintaining efficient load transfer. Strong edge restraints prevent lateral movement of blocks during braking and turning operations, thereby improving pavement stability.

4.5 Maintenance Performance

Maintenance efficiency represents one of the most significant advantages of modular pavement systems.

During the simulated maintenance operation, approximately 100 damaged paver blocks were removed and replaced within 30 minutes, whereas repairing an equivalent asphalt pavement required approximately 3–4 hours because of cutting, resurfacing, compaction, and cooling operations.

Table 4. Maintenance Comparison

Parameter	ICPB	Asphalt Pavement
Repair Time	30 minutes	3–4 hours
Traffic Disruption	Very Low	High
Material Reuse	Yes	No
Equipment Requirement	Minimal	Heavy Equipment
Cost of Repair	Low	High

The modular construction enables localized repairs without disturbing adjacent pavement sections, thereby reducing maintenance costs and minimizing inconvenience to road users.

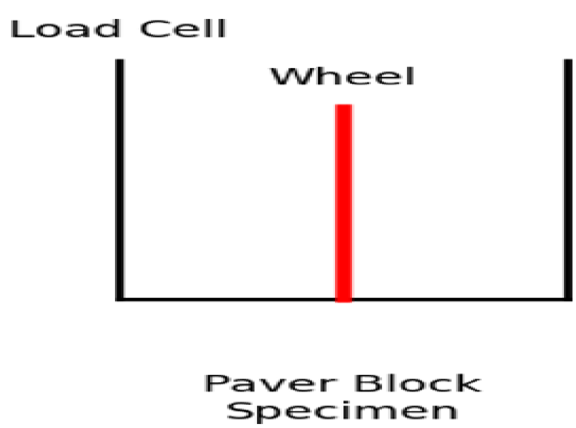

Fig1: The wheel-tracking machine setup for rutting Resistance testing in the lab

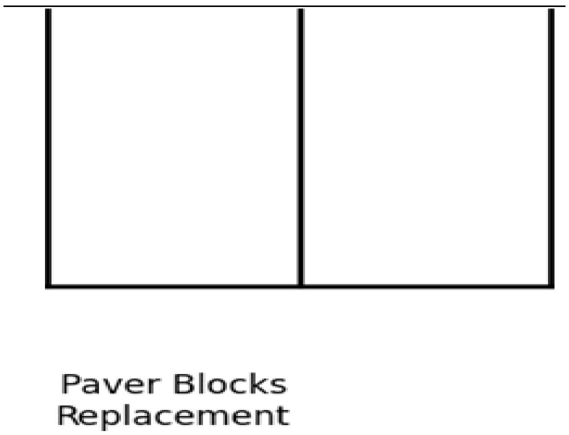

Fig 2: Maintenance and Repair Process of ICPBs

V. CONCLUSION

This study evaluated the structural and functional performance of Interlocking Concrete Paver Blocks for bus stops and parking areas subjected to heavy traffic loading. Laboratory investigations demonstrated that the paver blocks achieved an average compressive strength of 42 MPa and an average flexural strength of 6.5 MPa, confirming their suitability for heavy-duty pavement applications.

The wheel-tracking test indicated a maximum rut depth of only 3 mm after 200,000 loading cycles, which was significantly lower than that observed in conventional asphalt pavements. The superior rutting resistance is primarily attributed to the effective interlocking mechanism that distributes wheel loads uniformly across the pavement structure and reduces stress concentrations within the subgrade.

Maintenance evaluation further demonstrated that localized repairs can be completed within 30 minutes, considerably reducing traffic disruption, labour requirements, and maintenance costs. The modular nature of ICPBs also promotes material reuse, minimizes construction waste, and enhances environmental sustainability.

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