iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VI **Month of publication:** June 2026

DOI: https://doi.org/10.22214/ijraset.2026.83850

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

Performance Evaluation of Concrete Paver Blocks with Partial Replacement of Fine Aggregate by Waste Foundry Sand

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Abstract: ***The construction industry is increasingly focusing on sustainable alternatives to natural construction materials due to rapid depletion of natural resources and rising environmental concerns. Waste Foundry Sand (WFS), generated as a by-product of metal casting industries, possesses physical characteristics similar to conventional fine aggregates and offers significant potential for utilization in concrete products. This study investigates the performance of M30 grade concrete paver blocks incorporating Waste Foundry Sand as a partial replacement of fine aggregate at replacement levels of 10%, 15%, 20%, 25% and 30%.***

The physical properties of Waste Foundry Sand and crushed sand were evaluated through specific gravity, fineness modulus, and water absorption tests. Concrete paver blocks were cast, cured for 28 days, and tested for compressive strength, water absorption, abrasion resistance, and flexural strength in accordance with relevant Indian Standards. The results demonstrated that the incorporation of Waste Foundry Sand significantly influences the mechanical and durability characteristics of paver blocks. Among the investigated mixes, the 10% WFS replacement level exhibited the best overall performance, achieving a compressive strength of 40.55 MPa, flexural strength of 3.26 MPa, water absorption of 5.31% and satisfactory abrasion resistance within the limits prescribed by IS 15658:2021. The study confirms that Waste Foundry Sand can be effectively utilized as a sustainable partial replacement of natural fine aggregate in concrete paver block production, contributing to environmental conservation, reduction in industrial waste disposal and economic benefits in construction practices.

Keywords: Waste Foundry Sand, Concrete Paver Blocks, Economic Paver Blocks, Utilization of Industrial Waste, Sustainable Construction, Compressive Strength, Water Absorption, Abrasion Resistance, Flexural Strength, Fine Aggregate Replacement, IS 15658:2021.

I. INTRODUCTION

Concrete paver blocks are extensively used in pavements, footpaths, parking areas, and other infrastructure works due to their strength, durability, and ease of maintenance. The growing demand for construction materials has increased the consumption of natural fine aggregates, leading to depletion of natural resources and environmental concerns.

Waste Foundry Sand (WFS), a by-product of the metal casting industry, is generated in large quantities and often disposed of as waste. Utilization of WFS as a partial replacement of fine aggregate in concrete paver blocks offers a sustainable solution for waste management while reducing the dependence on natural sand.

The present study investigates the performance of M30 grade concrete paver blocks incorporating different percentages of Waste Foundry Sand through compressive strength, water absorption, flexural strength and abrasion resistance tests. The objective is to evaluate its suitability as a sustainable alternative to conventional fine aggregate in paver block production.



Figure 1 : Materials used for preparation of M30 grade concrete paver blocks

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A. Motivation

The increasing depletion of natural fine aggregates and the growing accumulation of industrial waste have created significant environmental and economic challenges in the construction industry. Waste Foundry Sand (WFS), generated in large quantities by metal casting industries, is often disposed of in landfills, leading to environmental concerns and additional disposal costs. Utilization of WFS as a partial replacement of fine aggregate in concrete paver blocks offers a sustainable solution by reducing industrial waste disposal, conserving natural resources, and lowering material costs. The present study aims to evaluate the feasibility and performance of Waste Foundry Sand in concrete paver block production through a comprehensive experimental investigation.

B. Paper Organization

Section II presents the literature review related to the utilization of Waste Foundry Sand in concrete and paver block applications. Section III describes the problem statement, objectives, and scope of the study. Section IV details the materials, mix proportions, and experimental methodology adopted for the investigation. Section V presents the experimental observations and test results. Section VI discusses the comparative analysis and engineering interpretation of the obtained results. Section VII highlights the environmental and economic benefits of Waste Foundry Sand utilization. Finally, Section VIII presents the conclusions and recommendations derived from the study.

II. LITERATURE REVIEW

A. Utilization of Waste Foundry Sand in Concrete

Hossiney [7] investigated the utilization of Waste Foundry Sand (WFS) in brick manufacturing and reported that WFS can be successfully incorporated into construction materials without adversely affecting their engineering properties. The study highlighted the potential of WFS as an environmentally sustainable alternative to conventional fine aggregates.

B. Effect on Mechanical and Durability Properties

Aneke [10] investigated masonry bricks produced using scrap plastic waste and foundry sand and reported that foundry sand can contribute to the development of sustainable construction products with acceptable strength characteristics.

C. Sustainable Construction and Environmental Benefits

Almohana [11] highlighted the importance of incorporating industrial waste materials into concrete production to reduce environmental impacts and promote sustainable construction practices.

D. Research Gap

Previous studies have demonstrated the successful utilization of Waste Foundry Sand (WFS) in bricks, masonry units, and concrete applications, highlighting its environmental and economic benefits. However, limited research has been conducted on the use of WFS as a partial replacement of fine aggregate in M30 grade concrete paver blocks.

Further, studies evaluating the combined effects of WFS on compressive strength, flexural strength, water absorption, and abrasion resistance of paver blocks are limited. Therefore, the present study aims to investigate the performance of M30 grade concrete paver blocks containing different percentages of Waste Foundry Sand and determine the optimum replacement level.

III. PROBLEM STATEMENT

A. Problem Statement

The rapid growth of construction activities has resulted in excessive consumption of natural fine aggregates, leading to depletion of natural resources and environmental concerns. At the same time, large quantities of Waste Foundry Sand (WFS) generated by metal casting industries are disposed of in landfills, creating disposal and pollution-related problems.

The utilization of Waste Foundry Sand as a partial replacement of fine aggregate in concrete paver blocks offers a sustainable solution to both issues. However, the effect of WFS on the mechanical and durability properties of paver blocks requires systematic investigation to determine its suitability for practical applications.

Therefore, the present study focuses on evaluating the performance of M30 grade concrete paver blocks incorporating different percentages of Waste Foundry Sand and identifying the optimum replacement level based on strength, durability and economic considerations.

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B. Objectives

1) To assess the suitability of Waste Foundry Sand (WFS) as a partial replacement of fine aggregate in M30 grade concrete paver blocks.
2) To evaluate the mechanical and durability characteristics of paver blocks containing varying percentages of WFS through compressive strength, water absorption, flexural strength and abrasion resistance tests.
3) To determine the optimum percentage of WFS replacement for sustainable and economical paver block.

C. Scope of Study

The scope of the present investigation is limited to M30 grade concrete paver blocks prepared using Waste Foundry Sand as a partial replacement of fine aggregate. Replacement levels of 10%, 15%, 20%, 25% and 30% were considered. The study includes determination of physical properties of fine aggregates, preparation and curing of paver blocks, and evaluation of compressive strength, water absorption, flexural strength, and abrasion resistance. A comparative cost-benefit analysis was also carried out to assess the economic viability of using Waste Foundry Sand as a sustainable construction material.

IV. METHODOLOGY

A. Mix Preparation of WFS Blocks

Concrete paver blocks of dimensions 250 mm × 130 mm × 60 mm were prepared using M30 (1:0.75:1.5) grade concrete by partially replacing crushed sand with Waste Foundry Sand at replacement levels of 10%, 15%, 20%, 25% and 30%. The selected replacement levels were adopted to evaluate the influence of Waste Foundry Sand on the strength and durability characteristics of paver blocks over a wide range of replacement percentages. After casting, the specimens were demolded after 24 hours and cured in water for 28 days before testing.

B. Experimental Program of WFS Blocks

1) Compressive Strength Test
2) Water Absorption Test
3) Abrasion Resistance Test
4) Flexural Strength Test

V. OBSERVATIONS AND RESULTS

A. Physical Properties

Table No : 1 Physical Properties

Property	WFS	Crushed Sand
Specific Gravity	2.75	2.38
Fineness Modulus	3.018	2.602
Water Absorption	4.60 %	2.82 %

B. Compressive Strength

The 10% WFS replacement mix exhibited the highest compressive strength of 40.55 MPa, indicating optimum utilization of Waste Foundry Sand among the investigated replacement levels.

Table No : 2 Compressive Strength

WFS %	Strength (MPa)
10	40.55
15	36.93
20	38.58
25	38.75
30	37.59

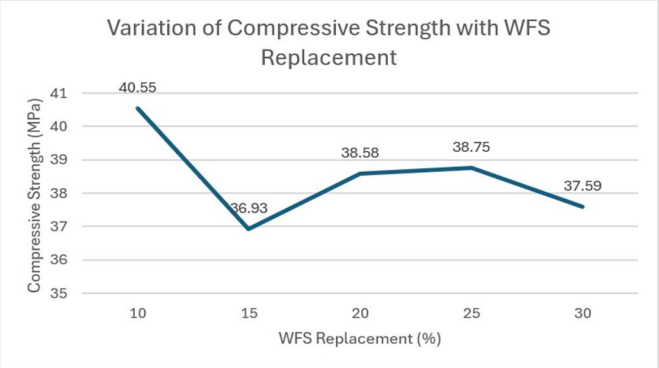


Figure 2 : Graph of Compressive Strength V/S WFS Replacement

C. Water Absorption

The water absorption values of all mixes were below the maximum limit of 6% specified in IS 15658:2021, indicating satisfactory durability performance.

Table No : 3 Water Absorption

WFS %	Water Absorption(%)
10	5.31
15	5.39
20	5.50
25	5.63
30	5.88

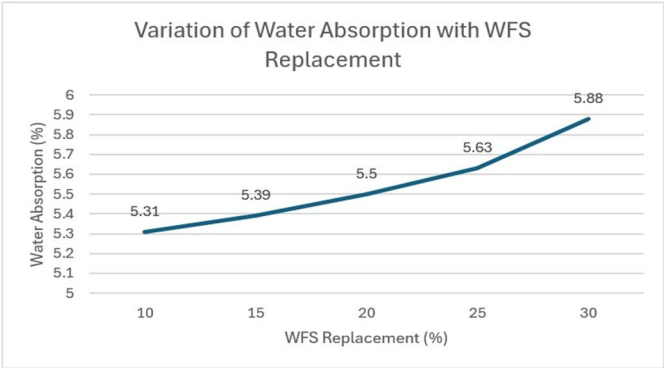


Figure 3 : Graph of Water AbsorptionV/S WFS Replacement

D. Flexural Strength (MPa)

The maximum flexural strength of 3.26 MPa was obtained at 10% WFS replacement, demonstrating better resistance to bending stresses.

Table No : 4 Flexural Strength (MPa)

WFS %	Flexural Strength (MPa)
10	3.26
15	3.20
20	3.19
25	3.16
30	3.11

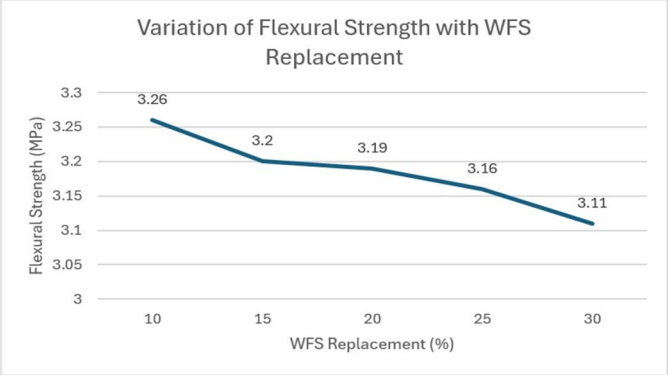


Figure 4 : Graph of Flexural Strength V/S WFS Replacement

E. Abrasion Resistance

The average wear value of 1.3224 mm satisfied the requirements of IS 15658:2021, confirming adequate resistance to surface wear and abrasion.

Table No : 5 Abrasion Resistance

Parameter	Value
Average Wear	1.322 mm
Maximum Wear	2.172 mm
IS Limit (Average)	3.5 mm
IS Limit (Individual)	4.0 mm

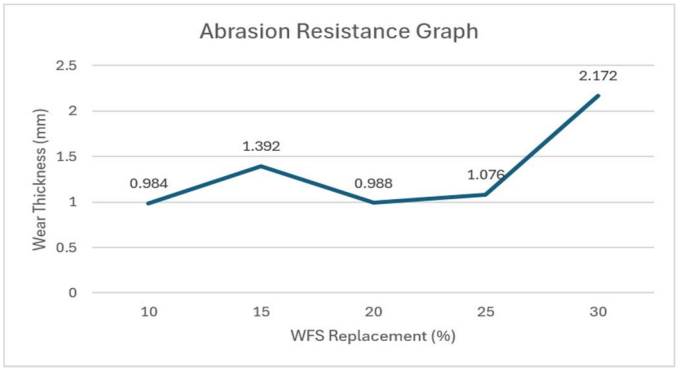


Figure 5 : Graph of Wear Thickness V/S WFS Replacement

VI. COMPARATIVE ANALYSIS AND ENGINEERING INTERPRETATION

A. Strength Performance

The highest compressive strength of 40.55 MPa was achieved at 10% WFS replacement, indicating optimum utilization of Waste Foundry Sand.

Compressive and flexural strengths decreased at higher replacement levels, suggesting that excessive WFS content adversely affects the mechanical performance of concrete paver blocks.

B. Durability Performance

Water absorption increased gradually with increasing WFS content due to the higher absorption characteristics of Waste Foundry Sand.

All mixes exhibited water absorption values below the 6% limit specified in IS 15658:2021, indicating satisfactory durability performance.

C. Abrasion Resistance

The average wear value of 1.322 mm was well within the limits specified by IS 15658:2021.

The abrasion resistance results confirm the suitability of WFS-based concrete paver blocks for pavement and pedestrian paving applications.

D. Cost Benefit Analysis

Waste Foundry Sand is available at a lower cost (₹300–500/tonne) compared to natural sand (₹700–1100/tonne). For the optimum replacement level of 10% WFS, the cost of fine aggregate can be reduced by approximately 5–6% compared to conventional paver blocks. In addition to the economic benefit, the utilization of Waste Foundry Sand reduces industrial waste disposal and conserves natural sand resources. Therefore, the incorporation of 10% WFS provides both economic and environmental advantages, making it a sustainable alternative for paver block production.

VII. ENVIRONMENTAL AND ECONOMIC BENEFITS

1) Reduction in landfill disposal
2) Conservation of natural sand
3) Reduction in environmental impact
4) Sustainable construction material
5) Lower production cost

VIII. DISCUSSION

1) The experimental studies with varying percentage of wfs as replacement of fine aggregate, suggests that wfs can be partially utilised in concrete paver blocks.
2) Physical property evaluation revealed that Waste Foundry Sand possesses higher specific gravity, fineness modulus and water absorption as compared to crushed sand.
3) The Compressive Strength of 40.55 MPa was achieved at 10% replacement, 36.93 MPa at 15%, 38.58 MPa at 20%, 38.75 MPa at 25% and 37.59 MPa at 30% of Waste Foundry Sand replacement. The maximum yield came for 40.55 MPa of 10% replacement.
4) The Flexural Strength of 3.26 MPa was observed for 10%, 3.20 MPa for 15%, 3.19 MPa for 20%, 3.16 MPa for 25% and 3.11 MPa for 30% replacement mix. The maximum yield came for 3.26 MPa of 10% replacement.
5) The Water Absorption Value of 5.31% was obtained for 10%, 5.39% for 15%, 5.50% for 20%, 5.63% for 25% and 5.88% for 30% replacement. All the values satisfied the requirements of IS 15658:2021.
6) Abrasion Resistance Test result values of 0.984 mm for 10%, 1.392 mm for 15%, 0.988 mm for 20%, 1.076 mm for 25% and 2.172 mm for 30% replacement confirmed satisfactory wear resistance and compliance with IS 15658:2021.

IX. CONCLUSION

On the basis of detailed investigation and studies and results obtained, it is concluded that

1) 10% Waste Foundry Sand replacement was identified as the optimum mix based on combined mechanical and durability performance.
2) Utilization of Waste Foundry Sand can be contributed to sustainable construction practices and can also reduces dependency on natural fine aggregate.
3) Waste Foundry Sand shall provide economic benefits through reduction in the material costs and shall provide solution for industrial waste disposal.
4) The present investigation recommends 10% Waste Foundry Sand replacement as the optimum proportion for M30 grade concrete paver block production.
5) Thus, Waste Foundry Sand can be successfully utilised as a partial replacement of aggregate in concrete paver block.

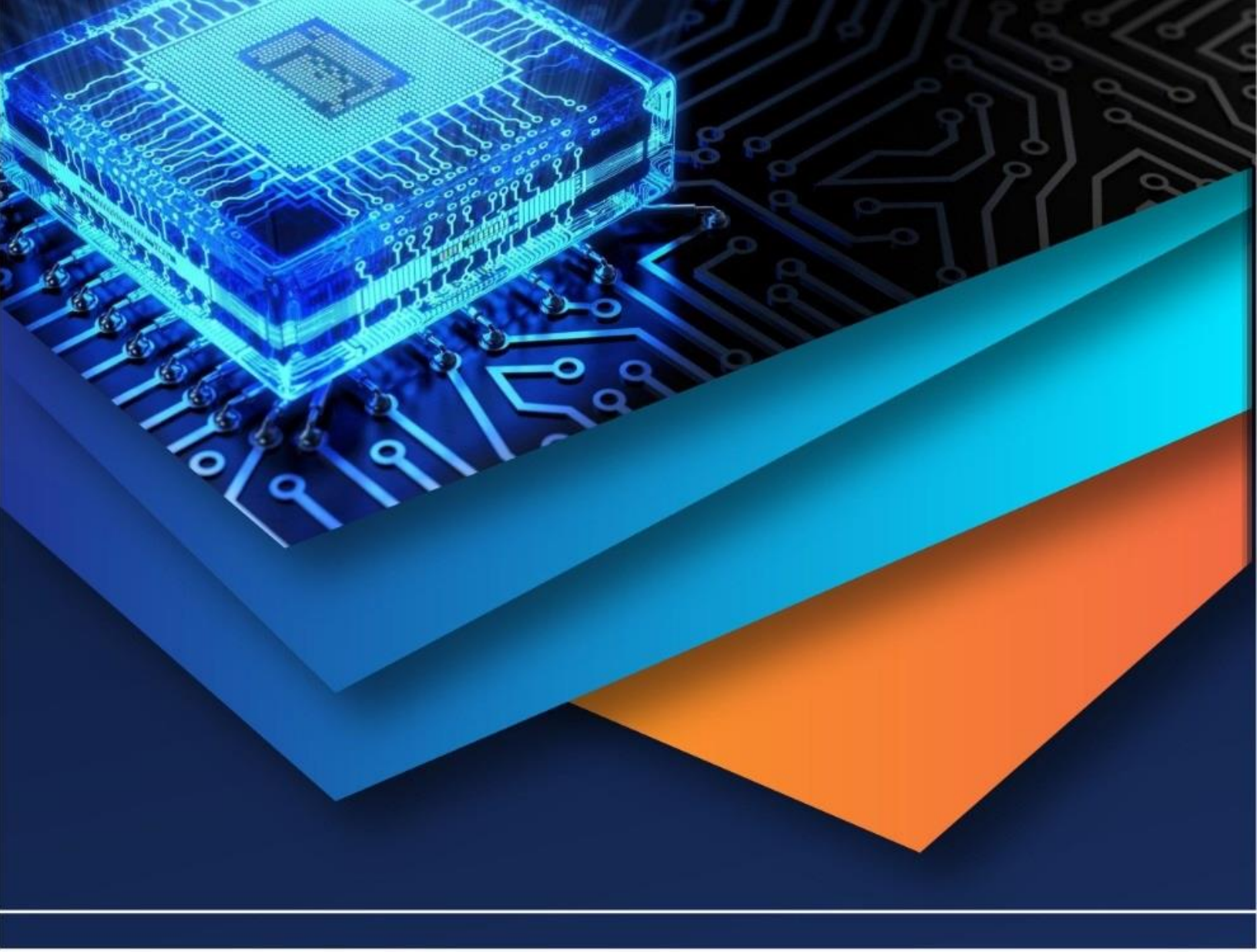
X. FUTURE SCOPE

1) Investigation of Waste Foundry Sand (WFS) performance at higher replacement levels using additional cementitious materials such as fly ash or GGBS for improved strength and durability.

2) Microstructural analysis (SEM/XRD) of concrete paver blocks to better understand bonding behaviour and pore structure modification due to WFS.
3) Long-term durability studies including freeze–thaw resistance, chemical attack, and fatigue performance under repeated loading.
4) Field performance evaluation of WFS-based paver blocks under real traffic conditions to assess service life and practical applicability.
5) Development of optimized mix design models for different grades of paver blocks incorporating industrial waste materials for sustainable construction applications.

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