Utilization of Concrete Cube Waste as a Sustainable Material for Pavement Pavers

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Abstract — This research investigates the potential of using waste generated from discarded or broken concrete cubes, typically produced during construction quality control tests, as an alternative material in the manufacturing of pavement pavers. The study evaluates mechanical properties, durability, cost-effectiveness, and environmental impacts of using this recycled material compared to conventional aggregates. Results suggest that concrete cube waste can be successfully incorporated into paver production without compromising performance, offering a sustainable solution that supports a circular economy within the construction industry.

Keywords: Concrete Cube Waste, Pavement Pavers, Sustainability, Recycling, Construction Waste, Environmental Impact, Concrete Recycling

I. INTRODUCTION

Concrete is the backbone of modern infrastructure, yet its production is associated with significant environmental burdens due to the depletion of natural resources and high energy usage. Construction activities also generate substantial waste, including unused or tested concrete cubes. Typically discarded after compressive strength testing, these cubes represent a viable source of recycled aggregate. Recycling concrete cube waste to produce pavement pavers offers a multifaceted solution to pressing issues of waste management, sustainability, and material cost. This paper explores the viability of using such waste, emphasizing its mechanical performance, economic and environmental implications. In the context of rapid urbanization and infrastructural growth, the construction industry is both a key driver of development and a major contributor to environmental degradation. One of the critical challenges it faces is the effective management of construction waste, particularly concrete debris generated from quality control testing processes. Among the byproducts of such testing are concrete cubes, routinely cast and crushed to determine compressive strength. These tested cubes are often discarded as waste, contributing to the mounting burden of construction and demolition (C&D) waste in landfills. The pressing global need for sustainable development and responsible resource management has paved the way for innovative approaches to waste recycling. This research paper explores one such sustainable strategy—repurposing concrete cube waste as a raw material in the production of pavement pavers. The concept not only addresses environmental concerns by reducing the consumption of natural aggregates such as river sand and gravel but also promotes circular economy principles within the construction sector. The potential benefits of using concrete cube waste extend beyond ecological gains. From a technical perspective, the recycled aggregates derived from these cubes possess high initial quality due to controlled manufacturing conditions. Their reuse in paver production could enhance mechanical performance, reduce material costs, and lower the overall carbon footprint of construction projects. Moreover, this method supports India's mission for sustainable urban development and aligns with global efforts toward green construction practices.

This study delves into the feasibility of replacing conventional aggregates with crushed concrete cube waste in varying proportions, examining the resulting pavers for critical parameters such as compressive strength, water absorption, abrasion resistance, durability, and density. Through comprehensive laboratory testing and analysis, the paper aims to demonstrate that concrete cube waste, often viewed as valueless debris, can be transformed into a functional, eco-friendly building material. This innovation contributes to sustainable engineering solutions and offers a replicable model for waste management in civil construction.

Benefits of Using Concrete Cube Waste:
- Reduces demand for natural aggregates (e.g., sand, gravel)
- Aids in concrete waste management
- Enhances durability and mechanical performance
- Lowers production costs
- Reduces overall carbon footprint

II. OBJECTIVES OF THE STUDY

1) To investigate the properties of concrete cube waste and its suitability in pavement paver manufacturing.
2) To evaluate mechanical characteristics like compressive strength, durability, and water absorption of pavers using recycled concrete cube waste.
3) To assess the environmental benefits of using concrete cube waste in comparison to traditional paver materials.
4) To analyze the cost-effectiveness of incorporating recycled concrete in large-scale production.

III. LITERATURE REVIEW

1) Several studies have examined the reuse of construction and demolition waste in concrete applications. According to Poon et al. (2004), recycled aggregates can be effectively used in concrete with minimal loss in performance. Tam et al. (2009) demonstrated that recycled concrete aggregate (RCA) is suitable for non-structural elements such as pavers and road bases.
2) Silva et al. (2014) analyzed the long-term durability of recycled aggregate concrete and found it satisfactory for pavement applications under certain curing conditions. Similarly, Limbachiya (2009) emphasized that the mechanical properties of RCA improve with proper processing and grading. These findings support the hypothesis that concrete cube waste, a form of high-quality RCA, can be used effectively in paver manufacturing.
3) Attri et al. (2021) investigated the impact of replacing natural coarse aggregates (NCA) and river sand (RS) with RCA in concrete paver blocks. The study found that up to 45% NCA and 40% RS could be replaced with RCA without significantly affecting the mechanical and durability properties of the paver blocks.
4) Gifty et al. (2019) demonstrated the viability of using construction and demolition (C&D) waste as a replacement for natural aggregates in paver blocks. Their findings indicated satisfactory strength properties, supporting the potential of RCA in sustainable construction.
5) Anusha et al. (2022) explored the incorporation of waste plastics and sugarcane bagasse ash (SCBA) in paver block production. The research revealed that using up to 40% SCBA, along with waste plastics, maintained compressive strength comparable to conventional paver blocks, promoting the utilization of waste materials in construction.
6) Sundaramurthy et al. (2022) evaluated the performance of precast cement concrete paver blocks incorporating fly ash and polypropylene fibers. The results indicated improved mechanical properties and durability, showcasing the benefits of using industrial by-products.
7) Kazi et al. (2021) focused on the reuse of plastic waste in paver blocks by partially replacing cement with non-recyclable plastic waste. The study highlighted cost reduction in paver blocks and addressed plastic waste management issues.
8) R.A. et al. (2023) investigated the use of plastic waste and M-sand in road paver blocks, showing that paver blocks produced with plastic waste achieved satisfactory compressive strength and ultrasonic pulse velocity, indicating their suitability for load-bearing applications.

IV. MATERIALS AND METHODS:

A. *Collection of Concrete Cube Waste*

Concrete cubes were collected post-testing from construction sites and civil engineering laboratories. The cubes were crushed using a jaw crusher into aggregate sizes of 0–5 mm and 5–10 mm.

B. *Preparation of Pavement Pavers*

Three mix designs were prepared:

- Mix A (Control): Traditional aggregates only.
- Mix B: 50% replacement with concrete cube waste.
- Mix C: 100% replacement with concrete cube waste.

C. *Materials used:*

- OPC 43-grade cement
- Natural sand
- Crushed cube aggregates
- Water
- No admixtures

D. *Testing Procedures*

The following tests were conducted as per IS 15658:

1) Compressive Strength (IS 516)
2) Water Absorption
3) Abrasion Resistance (IS 1237)
4) Freeze-Thaw Durability
5) Density

V. RESULTS AND ANALYSIS: -

A. *Test Results Summary*

Test Type	Mix A (Control)	Mix B (50% CCA)	Mix C (100% CCA)
Compressive Strength (N/mm^2) @ 28 days	34.3	32.5	30.2
Water Absorption (%)	5.2	5.5	6.0
Abrasion Loss (g)	20.0	20.2	22.5
Freeze-Thaw Weight Loss (%)	1.3	1.6	1.8
Density (kg/m^3)	2385	2353	2296

B. *Analysis: -*

- Compressive Strength: Minor reduction in strength observed with increased CCA, still within acceptable limits for pedestrian pavers (>25 MPa)
- Water Absorption: Slightly higher in Mix C, indicating increased porosity. Needs additional surface sealing for water-sensitive applications.
- Abrasion Resistance: Slight increase in wear, but results remain within IS standards for footpaths
- Durability: Marginally reduced, but Mix B showed excellent freeze-thaw resistance.
- Density: A minor reduction in density was observed, potentially lowering material weight and easing handling.

VI. ENVIRONMENTAL & ECONOMICAL CONSIDERATIONS: -

- Environmental Impact: Replacing virgin aggregates with recycled materials reduces quarrying, carbon emissions, and landfill waste.
- Cost Analysis: Estimated 15–20% cost savings in raw material procurement by using cube waste, with potential for higher savings on a larger scale.

VII. CONCLUSION: -

The research indicates that concrete cube waste can be effectively utilized in the production of pavement pavers without significant compromise in quality. The 50% replacement mix offers the best balance between performance and sustainability.

A. Key Conclusions:

– Concrete cube waste is a viable, eco-friendly material for paver production.
– Mechanical properties remain within permissible limits.
– Offers cost and environmental benefits in the long run.
– Supports the circular economy and reduces construction waste.

B. Future Scope:

Further studies may explore long-term performance in field conditions and develop optimized mix designs with admixtures or supplementary cementitious materials.

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