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Transforming Waste into Value: The Role of Discarded Waste in Sustainable Paver Block Production

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Abstract

Concrete is the primary material used in building construction, but significant waste is generated during the demolition of structures. The increasing activities in the construction sector and manufacturing industries have led to a rise in waste production. This review paper explores the potential of utilizing Construction and Demolition (C&D) waste in the production of sustainable paver blocks, addressing the pressing environmental challenge of the estimated 12-14 million tonnes of construction waste generated annually in India. It emphasizes the effectiveness of using Demolished Concrete Aggregate (DCA) as a substitute for natural aggregates in interlocking paver blocks, which meet the required compressive and flexural strengths for medium-traffic applications. The paper also highlights the cost benefits of incorporating demolition waste, indicating that replacing up to 50% of natural aggregates can optimize performance in high-traffic areas. Additionally, the strategic application of C&D waste helps reduce landfill pressure while promoting sustainable construction practices. Various mix proportions are discussed to demonstrate their effectiveness. Furthermore, the review proposes a method for manufacturing paver blocks using C&D waste, cement, and fly ash, emphasizing their suitability for low-load-bearing applications, even with lower compressive strength than traditional blocks. Overall, the findings advocate for the reuse of C&D waste, significantly contributing to sustainable development and reducing the environmental impacts associated with construction activities.

Keywords: Concrete, Construction, Construction and Demolition (C&D), Sustainable, Paving Blocks, Waste

INTRODUCTION

The building industry has been compelled to investigate strategies that are sustainable as a result of the rising worries over the deterioration of the environment and the depletion of resources. There are many different kinds of waste materials that might be used in the creation of concrete paving blocks, which is one direction that shows promise. These waste components, which include trommel separated inert waste and construction and demolition (C&D) trash, provide a viable option for decreasing the negative effect that building has on the environment while simultaneously addressing the difficulty of waste disposal.

Just behind water in terms of consumption, concrete is the most widely used material in the world, accounting for three tonnes per year per person. As to the 12th five-year plan of India, it is anticipated that the demand for concrete would reach one billion tonnes by the year 2027 for the country. Cement, aggregates, water, and super plasticisers are the many components that make up concrete. Taking into consideration the fact that natural aggregates make up more than 70% percent

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of the total weight of concrete, the purpose of this study is to investigate inert waste and construction and demolition waste in order to determine the optimal percentage of these materials that may be used in the production of sustainable concrete paving concrete blocks.

For example, dirt, earth, slurry, boulders, concrete, and other similar materials are examples of inert waste. Inert waste is often acquired by bio-remediation and bio-mining of legacy trash. Inert waste is waste that cannot dissolve spontaneously, either biologically or chemically.

The term “legacy waste” refers to municipal solid waste (MSW) that has been collected and stored for a considerable amount of time (often 10 years) on some undeveloped area or at a landfill. It is common to see vast mountains of rubbish far beyond the boundaries of the city. Typically, they are stockpiles of rubbish that has been left behind.

According to the rules provided by the Central Pollution Control Board (CPCB) in the year 2019, the term “bio-mining” refers to the scientific process of excavating, treating, sorting, and making profitable use of garbage that has been handed down from generation to generation. The process of bio-mining is an ecologically benign method that may be used to extract recyclable materials and soil from legacy debris. These recyclable items include plastic, metal, paper, textiles, inert materials, construction and demolition waste materials, and other solid materials. It offers a dependable solution to complicated environmental problems and employs procedures that are beneficial to the environment for the sorting and segregation of materials for the purpose of future use, recycling, or filling low-lying regions.

Trommel plants are often used for the process of bio mining legacy garbage. Trommel segregation is a procedure that is commonly used in waste management. It is concerned with the separation of waste materials according to their size, which results in a consistent supply of various waste streams. As an example, materials used in the construction of buildings include glass, plaster, plasterboard, siding shingles, insulation, metal, wood, bricks, asphalt or cement concrete, and other materials.

Generally speaking, construction and demolition waste, which consists of a mixture of concrete, bricks, and other debris from construction projects, is dumped in a variety of open areas and bodies of water. This practice ought to be avoided. C&D waste, after undergoing the processes described below Figure 1, along with inert waste, can be utilised for other purposes, such as the production of concrete paving blocks, which can serve as a partial replacement for coarse aggregate and fine aggregates.

In the process of bio-mining legacy waste, the first and most important stage is segregation, as will be seen in the image above. This process entails separating legacy garbage into several categories, such as recyclable materials, inert materials, biodegradable materials, and non-biodegradable materials. Through the use of this procedure, the efficiency of subsequent biological treatment and resource recovery is improved in accordance with the categories listed in Figure 2.

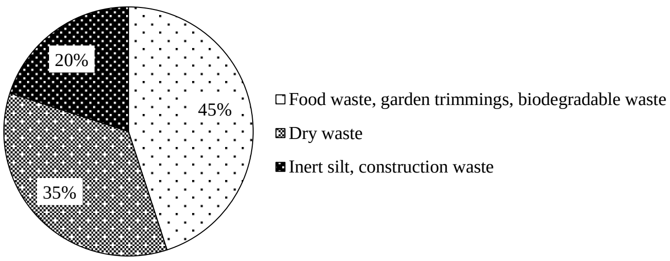

Figure 1. Municipal solid waste composition.
(Source: Circular Economy in Municipal Solid and Liquid Waste, MOHUA, GOI, Year-2021)

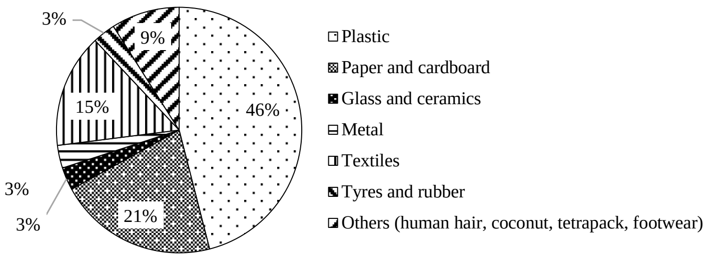

Figure 2. Dry waste composition in MSW.

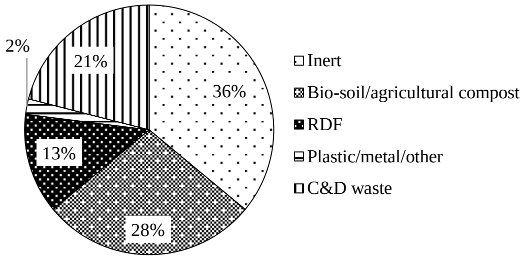

Figure 3. Approved data of Chhotaudepur Municipality.

A focused treatment is made possible by the separated garbage, which includes biodegradable waste that may be composted. For example, food waste, garden trimmings, and biodegradable waste make up roughly forty-five percent of the entire composition of municipal solid waste.

There are many different types of recyclable materials that are included in dry trash, which accounts for 35 percent of municipal solid waste (MSW). Here is a breakdown of the components that make up dry waste: Waste Made of Plastic (46 percent), Paper and Cardboard (21 percent), Glass and Ceramic (three percent), Metal (three percent), Textiles (15 percent), Tyres and Rubber (three percent), and Other Materials (nine percent), which includes human hair, Tetrapack, Coconut shells, and Footwear. It is possible to dispose of inert materials, which account for twenty percent of municipal solid waste (MSW), in a secure manner or to utilise them for land filling, road treatment, and other purposes.

Figure 3 shows material obtained from Trommel Segregation of Chottaudaepur Town Dumping Site Legacy Waste, Which Consist of Constrution and Demolition Waste (21%), Inert (36%), Plastic/Metal/Other (2%), RDF 13%, Bio-soil/Agricultural Compost (28%) etc.

ADVERSE EFFECTS OF C&D WASTE AND INERT WASTE

Construction and Demolition (C&D) waste, along with inert waste, creates multiple environmental, social, and economic challenges when not managed effectively. These wastes contribute to pollution of air, water, and soil due to dust, leachates, and hazardous materials like asbestos or lead. Overburdening landfills with C&D waste reduces available capacity for other types of waste, while leachate can contaminate groundwater and surrounding ecosystems. The generation of dust during demolition or transport of waste exacerbates air pollution, impacting both human health and climate through increased greenhouse gas emissions. Additionally, improper disposal often blocks drainage systems, increasing urban flooding risks.

Inert waste, including materials like bricks, concrete, and stones, is non-biodegradable and remains in the environment for long periods, occupying valuable land and reducing soil permeability. This disrupts natural water cycles and affects the productivity of land. Both C&D and inert waste reduce resource efficiency by necessitating the extraction of virgin materials, depleting natural reserves, and increasing environmental footprints. They also degrade the aesthetics of urban and rural areas, creating visual nuisances and negatively impacting local communities.

To mitigate these adverse effects, sustainable practices such as recycling, reuse of materials, and adoption of modern waste management technologies are critical. Segregation of waste at the source, establishing recycling plants, and promoting the use of recycled materials in construction can significantly reduce environmental impacts. Additionally, stringent regulations and enforcement can encourage responsible waste disposal and ensure efficient management, contributing to a more sustainable and resource-efficient future.

INTERLOCKING CONCRETE PAVER BLOCKS (ICPB)

Interlocking Concrete Paver Blocks (ICPB) are an essential part of India's urban infrastructure development, providing a durable and flexible solution for paving roads, walkways, parking areas, and public spaces. As cities continue to expand, the need for sustainable, cost-effective, and eco-friendly paving solutions has grown, and ICPB meet these demands effectively. Their modular design, durability, and ease of maintenance have made them a preferred choice for both urban and rural infrastructure projects across the country. ICPB can be categorized based on the materials used in their production, some common types include:

1. Concrete Paver Blocks
2. Fly Ash Paver Blocks
3. Recycled Material Paver Blocks
4. Rubber Paver Blocks
5. Plastic Paver Blocks

Interlocking Concrete Paver Blocks (ICPB) are popular in modern construction for various applications, including pavements, driveways, and walkways. The following are the advantages, disadvantages, properties, and manufacturing costs associated with different types of ICPB categorized based on the materials used in their production shown in Table 1.

Interlocking Concrete Paver Blocks offer a variety of options based on material type, each with distinct advantages and disadvantages. Understanding these factors is crucial for selecting the appropriate type for specific applications, ensuring both sustainability and performance in construction projects.

Innovative Sustainable Materials Being Used in Paving Blocks

The following are some innovative sustainable materials being used in paving blocks:

1. *Recycled plastic:* Paving blocks made from recycled plastic waste reduce landfill pressure and offer durability, flexibility, and weather resistance. These blocks are lightweight, require less maintenance, and help cut down on plastic waste [6, 7].
2. *Fly ash:* Often a by-product of coal-fired power plants, fly ash can replace a portion of cement in paver blocks, providing a strong, eco-friendly option that reduces the carbon footprint and conserves raw materials [8].
3. *Crushed glass:* Glass waste can be incorporated into paving blocks to create a textured, reflective surface. The addition of crushed glass enhances strength and aesthetics, offering a sustainable way to repurpose glass waste.
4. *Foundry sand:* This by-product of the metal-casting industry can replace traditional sand in paver blocks, helping to reduce waste while maintaining compressive strength and reducing the extraction of natural sand [9].
5. *Recycled rubber:* Old tires can be processed and integrated into paver blocks to enhance flexibility and shock absorption, making them ideal for areas with heavy traffic or playgrounds.

Table 1. Advantages, disadvantages, properties, and manufacturing costs associated with different types of ICPB categorized based on the materials used in their production.

ICPB categorized	Advantages	Disadvantages	Properties	Manufacturing cost
1. Concrete Paver Blocks [1, 2]	• High compressive strength and durability. • Available in various designs, colors, and patterns. • Easy to install and replace. • Resistant to weathering and environmental factors.	• Heavy, which can complicate installation. • Requires proper sub-base preparation. • Susceptible to cracking under heavy loads if not properly designed.	• *Compressive strength:* 25–50 MPa • *Water absorption:* 6–8% • *Flexural strength:* 3–5 MPa	Approximately ₹400–₹800 per square foot, depending on design and location.
2. Fly Ash Paver Blocks [3, 4]	• Eco-friendly, using waste material from power plants. • Lightweight compared to traditional concrete blocks. • Enhanced workability and lower water demand. • Good thermal insulation properties.	• Lower strength compared to traditional concrete blocks. • Can be susceptible to leaching if not properly manufactured. • May require special curing processes.	• *Compressive strength:* 20—35 MPa • *Water absorption:* 5–7% • *Flexural strength:* 2–4 MPa	Approximately ₹300–₹600 per square foot.
3. Recycled Material Paver Blocks [5]	• Promotes sustainability by recycling waste materials. • Reduces the demand for virgin aggregates. • Can have unique aesthetics due to varied materials.	• Variable quality and strength based on source materials. • May require more extensive testing and quality control. • Potentially limited availability depending on recycling facilities.	• *Compressive strength:* 15–30 MPa (varies widely) • *Water absorption:* 8–12% • *Flexural strength:* 2–4 MPa	Approximately ₹250–₹500 per square foot
4. Rubber Paver Blocks	• Excellent shock absorption and slip resistance. • Lightweight and easy to handle. • Durable and resistant to weathering and chemicals.	• Limited design options compared to concrete. • May have higher initial costs. • Can be susceptible to fading in color.	• *Compressive strength:* 20–30 MPa • *Water absorption:* 1–3% • *Flexural strength:* 1–2 MPa	Approximately ₹500–₹1,000 per square foot
5. Plastic Paver Blocks [6, 7]	• Made from recycled plastics, promoting sustainability. • Lightweight and easy to install. • Resistant to water, chemicals, and UV radiation.	• Lower load-bearing capacity compared to concrete. • Can be more expensive than traditional paver blocks. • May degrade over time with exposure to sunlight.	• *Compressive strength:* 15–25 MPa • *Water absorption:* 0–2% • *Flexural strength:* 2–3 MPa	Approximately ₹400–₹800 per square foot

6. *Rice husk ash:* As a by-product of the rice milling industry, rice husk ash is a renewable alternative to cement in paver blocks. It’s rich in silica, which improves durability and minimizes environmental impact.
7. *Coconut shells:* Crushed coconut shells can be mixed into concrete to make durable, eco-friendly paver blocks. This material is lightweight and resistant to extreme conditions, offering an innovative way to repurpose agricultural waste.

8. *Ceramic waste:* Used ceramic tiles and other ceramic waste can be crushed and used as a cement substitute, reducing the demand for new materials while enhancing block strength and durability.
9. *Construction and demolition waste:* Crushed concrete and masonry waste can be recycled into aggregate for paver blocks, significantly lowering the need for new raw materials and reducing landfill waste [10] [2].
10. *Kota stone chips:* Recycled from industrial stone waste, kota stone chips offer a durable, cost-effective alternative aggregate, enhancing compressive strength and reducing the environmental impact of paver block production [11].

These materials not only contribute to sustainability by reusing waste but also provide durable, economical, and innovative solutions for modern paving needs.

Characteristics for Utilization of Construction and Demolition Waste in Paver Block

Utilizing construction and demolition (C&D) waste in paver blocks brings multiple benefits and unique characteristics, including:

1. *Enhanced sustainability:* Reusing C&D waste reduces the demand for new raw materials, conserving natural resources and promoting circular economy practices in construction [10].
2. *Cost efficiency:* Incorporating recycled materials lowers production costs by reducing the need for primary aggregates and cement, making paver blocks more economical to manufacture.
3. *Waste reduction:* Recycling C&D waste minimizes landfill use and addresses disposal issues, helping to alleviate environmental impacts associated with construction debris.
4. *Compressive strength:* Properly processed C&D materials, such as crushed concrete or brick, can achieve compressive strengths comparable to or even exceeding those of traditional aggregates, suitable for footpaths, parking lots, and low-traffic roads.
5. *Durability and weather resistance:* Paver blocks with C&D aggregates often demonstrate resilience to weathering, abrasion, and temperature variations, making them well-suited for outdoor applications.
6. *Reduced water absorption:* Certain types of C&D waste, when processed, exhibit low water absorption, which improves the longevity and strength of paver blocks by reducing porosity.
7. *Low maintenance:* C&D paver blocks typically require minimal maintenance, as they can be replaced individually if damaged, reducing long-term repair costs and resources.
8. *Versatile application:* These paver blocks can be used in various settings, including sidewalks, driveways, parking lots, and garden paths, providing a practical solution for multiple construction needs.
9. *Energy savings:* Using recycled materials in paver blocks lowers the energy required for mining, processing, and transporting virgin materials, thereby reducing the overall carbon footprint.
10. *Potential for customization:* Different types of C&D waste (e.g., crushed concrete, bricks, tiles) can be mixed to achieve specific design and performance characteristics, offering tailored solutions for varied paving applications.

Utilizing C&D waste in paver blocks not only fosters sustainable construction practices but also delivers a robust and affordable paving material solution.

Challenges for Utilization of Construction and Demolition Waste in Paver Block

Utilizing construction and demolition (C&D) waste in paver blocks presents several challenges, including:

1. *Inconsistent material quality:* C&D waste varies widely in composition, and contaminants like wood, metals, and plastics can affect the quality and strength of paver blocks. Ensuring consistent quality requires thorough sorting and processing [10].
2. *Higher processing costs:* Additional steps, such as sorting, crushing, and cleaning C&D materials, increase processing costs, which can offset some of the savings from using recycled materials.

3. *Lack of standardization:* Currently, there are limited standards and guidelines for incorporating C&D waste into paver blocks, making it challenging to ensure uniform performance and regulatory compliance [10].
4. *Potential for lower strength and durability:* Some types of C&D aggregates, such as bricks or lightweight materials, may not match the strength or durability of traditional aggregates, limiting their applications in high-stress areas [10].
5. *Environmental contamination risks:* C&D waste can contain harmful substances like asbestos, lead, or other hazardous materials. Without proper testing and treatment, these contaminants pose environmental and health risks.
6. *Limited awareness and acceptance:* Construction industries and clients may be hesitant to adopt recycled paver blocks due to concerns about performance, durability, and aesthetics, slowing down market acceptance.
7. *Reduced workability:* Some C&D waste, when mixed with cement, can lead to reduced workability or increased water demand, which can complicate the casting and finishing of paver blocks.
8. *Increased water absorption:* Certain recycled aggregates have higher porosity, resulting in greater water absorption that can weaken paver blocks over time, particularly in freeze-thaw environments.
9. *Transportation and logistics costs:* Sourcing and transporting C&D waste to recycling facilities and construction sites can be expensive, particularly if recycling facilities are far from urban construction sites.
10. *Regulatory and permit challenges:* In many regions, recycling C&D waste requires permits and must meet local environmental regulations, which can create bureaucratic hurdles and discourage recycling efforts.

Despite these challenges, ongoing research and technological advancements aim to improve the feasibility of using C&D waste in paver blocks, potentially making it a more standardized and cost-effective solution in the future.

Properties of Construction and Demolition Waste in Paver Block

Incorporating construction and demolition (C&D) waste in paver blocks influences several properties, which are crucial for determining their suitability and performance in various applications:

1. *Compressive strength:* C&D aggregates like crushed concrete or masonry can provide good compressive strength, comparable to traditional aggregates, but results may vary depending on waste quality. Typically, C&D-based paver blocks are suitable for low to medium load-bearing applications.
2. *Density:* C&D waste-derived aggregates generally yield lower-density paver blocks, especially if lightweight materials like bricks or tiles are used. This can reduce the load on underlying structures and simplify installation.
3. *Durability:* Paver blocks with C&D waste can achieve adequate durability, though it may vary depending on the type of waste used. Proper processing can improve resistance to weathering and abrasion, making blocks suitable for outdoor use.
4. *Water absorption:* C&D aggregates often have higher porosity, leading to greater water absorption. This can be mitigated through treatments or specific mix designs, but paver blocks with C&D waste may still have higher water absorption than conventional blocks.
5. *Thermal insulation:* C&D-based paver blocks, especially those using lightweight materials, can provide better thermal insulation, which is beneficial for outdoor surfaces exposed to heat or for applications in warmer climates.
6. *Workability:* The irregular shapes and sizes of C&D aggregates can reduce workability, requiring adjustments in mix proportions and water content to achieve smooth casting and optimal strength.
7. *Shrinkage and cracking:* Higher water absorption in some C&D aggregates can increase shrinkage and potential for cracking in paver blocks. Controlling aggregate size and mix ratios helps mitigate this issue.

8. *Flexural strength:* C&D-based paver blocks may exhibit lower flexural strength due to irregular aggregate shapes, making them less suitable for applications requiring high flexural performance, like heavy-load areas.
9. *Environmental sustainability:* The use of C&D waste reduces the demand for virgin materials and diverts waste from landfills, making paver blocks with C&D materials a more sustainable choice [2].
10. *Cost efficiency:* Utilizing C&D waste can reduce raw material costs for paver blocks, although additional processing and sorting may increase overall production costs if not properly managed [2].
11. *Aesthetic variability:* C&D-based aggregates can create unique textures and colors in paver blocks, providing aesthetic variety that may be desirable for certain applications, such as landscaping or decorative walkways [2].

By adjusting mix designs and carefully selecting C&D materials, paver blocks with C&D waste can be customized to meet specific requirements, offering a sustainable, cost-effective alternative in construction.

REVIEW OF PREVIOUS STUDIES

The review of previous studies on the sustainable production of concrete paving blocks highlights the increasing importance of utilizing alternative materials and methods to enhance environmental sustainability in construction. Many studies have explored the incorporation of industrial by-products, such as fly ash, slag, and recycled aggregates, into concrete mixtures, demonstrating significant improvements in strength and durability while reducing reliance on natural resources. Researchers have also examined the benefits of using waste materials, such as plastic and rubber, which not only contribute to waste management but also enhance the mechanical properties of paving blocks. Furthermore, the studies emphasize the importance of optimizing mix designs to achieve the desired performance characteristics, including compressive strength, flexural strength, and water absorption. Life cycle assessments have been conducted to evaluate the environmental impacts of various materials and production processes, providing insights into the overall sustainability of concrete paving blocks. Overall, this review underscores the potential of innovative approaches in concrete production to foster sustainable development in the construction industry, paving the way for more eco-friendly infrastructure solutions.

Granite Chips

Goutam et al. (2019) Granite chips, a by-product from granite cutting, pose environmental and landfill challenges when improperly disposed. This study explores the integration of granite waste in building blocks as a substitute for traditional aggregates. Using granite waste not only conserves natural aggregates but also reduces environmental pollution from granite dumping. Given rising landfill costs and environmental awareness, using granite waste is a sustainable solution for construction. The study specifically investigates granite waste's effectiveness in concrete paving blocks, finding improved compressive strength at certain replacement levels (10% at 0.40 w/c ratio and 5% at 0.42 w/c ratio). Water penetration depth increased with replacement up to 15%, while abrasion loss was within permissible limits, suggesting that these concrete samples are suitable for paving applications. This approach offers a sustainable, eco-friendly use for granite waste in construction, particularly in concrete paver blocks [12].

Goutam et al. (2019) Interlocking Concrete Block Pavement has gained popularity in India for various applications, such as footpaths and parking areas, over the past decade. Given India's significant granite deposits, accounting for over 20% of the world's resources, the disposal of granite waste from factories poses environmental challenges. This experimental study evaluates the use of granite waste as a partial and full replacement for coarse aggregate in paver blocks at replacement levels of 25%, 50%, 75%, and 100%. Results indicate that the compressive strength peaked at 25% granite waste replacement, achieving 48.42 N/mm² at 28 days, surpassing the control mix (M45 grade) at 56 days with a strength of 49.86 N/mm². Additionally, the flexural strength reached 5.05 N/mm² at 28 days for the 25% replacement mix, outperforming natural aggregates. Abrasion resistance decreased to 0.402

mm at this level, while water absorption dropped to 2.13%, indicating potential for sustainable construction practices using granite waste [13].

Ceramic Tile Powder

Aswin et al. (2018) explored the use of ceramic waste as a partial replacement for cement in concrete production, aiming to reduce construction waste and environmental impact while lowering costs. By incorporating ceramic tile powder in varying percentages (10%, 20%, 30%, 40%, and 50%) to replace Ordinary Portland Cement (OPC), researchers evaluated its effects on the compressive strength of concrete cubes and paver blocks over 14 and 28 days. Findings indicate that substituting cement with ceramic tile powder enhances compressive strength up to a certain level: for concrete cubes, the optimum replacement is 30%, while for paver blocks, it is 40%. Replacements beyond these levels decrease strength, highlighting an ideal replacement percentage to achieve both strength and sustainability. This approach not only offers a way to recycle ceramic waste but also provides a practical alternative in construction, particularly in the field of civil engineering and materials science [14].

Gupta et al. (2021) investigated replacing Ordinary Portland Cement (OPC) with crushed ceramic tile powder in varying percentages (5%, 10%, 20%, 30%, 40%, and 50%) to improve the compressive strength and durability of paver blocks and concrete cubes. Through experimental testing, researchers assessed the suitability of ceramic tile waste in enhancing mortar strength. Results indicate that replacing cement with 10-20% ceramic tile powder improves mechanical strength due to pozzolanic reactions, although these reactions are weaker at early curing stages (7 and 14 days). The study suggests that ceramic waste tiles offer a viable alternative for cement replacement, presenting an effective solution for safe ceramic waste disposal and advancing sustainable practices in the construction industry. This approach not only leverages ceramic waste to enhance construction materials but also contributes positively to environmental management in civil engineering [15].

Foundry Sand

Dixit Patel et al. (2014) examined the use of used foundry sand as a partial replacement for PPC 53 grade cement in paver blocks, focusing on changes in compressive and flexural strength, water absorption, and cost. By substituting cement in varying proportions (10%, 20%, 30%, 40%, and 50%), researchers evaluated the performance of paver blocks over 7, 14, and 28 days. Results show that even with 50% cement replacement, a compressive strength of 23.48 N/mm² was achieved, suitable for applications like footpaths, parking areas, and street roads. Water absorption decreased with higher replacement levels, reaching 2% at 50% substitution. Additionally, the study found cost savings, with a 50% cement replacement lowering paver block costs by 20.13% compared to standard mixes. This research highlights used foundry sand as a viable, cost-effective material that contributes to sustainable development in the construction industry [9].

Kota Stone Chips

Vivek et al. (2016) explored using kota stone chips as a partial replacement for aggregates in rubber mold paver blocks, focusing on increasing compressive strength and reducing costs. Paver blocks are commonly used in outdoor applications due to their low maintenance, easy replacement, and eco-friendly potential. By incorporating industrial waste like kota stone chips, this research aims to reduce environmental impact and the cost of paver production. Experimental tests showed that a 40% replacement of aggregates with kota stone chips led to a 2.01% increase in compressive strength compared to standard mixes, with negligible changes in water absorption. Additionally, this substitution reduced the overall cost of rubber mold paver blocks by 2.90%. Incorporating kota stone waste not only addresses disposal issues but also conserves natural aggregates, making rubber mold paver blocks more sustainable and cost-effective for the construction industry [11].

Fly Ash

Hamza et al. (2024) Paver blocks (PB) are popular in construction for their durability and strength, used in high-traffic applications such as pavements and driveways. However, the cement used in PB production contributes to carbon emissions, raising costs and environmental concerns. To address this, the study explores partial replacement of cement with marble waste and fly ash, both industrial by-products. Three sample types (M1, M2, and M3) were tested with varying replacement percentages (5-30%). Results showed that M1-15, M2-20, and M3-20 mixes achieved optimal compressive and flexural strengths at different curing stages. ANOVA and Tukey tests indicated significant differences in flexural strength across curing times, with positive correlations among the mixes, highlighting marble waste and fly ash as viable alternatives in PB production [16].

Sachin et al. (2022) reviewed on concrete paver blocks are commonly used for durable, aesthetic surfaces, made with cement, aggregates, and water. To address natural resource depletion and rising industrial waste, sustainable construction practices are integrating waste materials like plastic, fly ash, and rice husk ash as replacements. Using these waste products in paver blocks offers a lightweight, cost-effective alternative to traditional cement blocks. These eco-friendly pavers meet design needs with various shapes and colours while conserving resources and reducing environmental impact. This approach promotes sustainable building and offers a green, resource-conscious solution for public and private infrastructure projects [17].

Cong Bang et al (2020) Concrete paver blocks are widely used in urban and commercial areas like shopping malls, parking lots, and footpaths. This study explores creating paver blocks by partially replacing cement with fly ash and adding various fibers, such as nylon, steel, coconut, glass, and polypropylene, to improve strength and durability. Fly ash not only boosts concrete's strength and cost-effectiveness but also reduces environmental impact by repurposing waste. Testing at 7, 14, and 28 days showed enhanced compressive strength with these additions. Using fly ash and fibers in paver blocks offers a sustainable, economical method, lowering both costs and carbon emissions [18].

Plastic Waste

Panimayam et al. (2017) addressed the challenges posed by rapid industrialization and urbanization, particularly the shortage of construction materials and the increase in waste products. It explores the reuse of waste plastics as a partial replacement for coarse aggregate in M20 concrete, which is commonly used in construction. Incremental additions of waste plastics (0% to 10%) were tested for their physical properties, and paver blocks were cast and tested for strength at 7, 14, and 28 days. The findings indicate that incorporating 4% waste plastics maintains compressive strength comparable to plain cement concrete, offering a cost-effective solution while reducing environmental impacts from waste disposal [19].

N Tamil Selvi et al. (2022) This study investigates the use of plastic and construction demolition waste in conventional concrete paver blocks, addressing India's significant waste generation issues, with 26,000 tonnes of plastic and only 5% of construction and demolition waste processed daily. The research evaluates the compressive strength, density, and water absorption of paver blocks made with these materials. Results indicate that while incorporating plastic waste leads to decreased compressive strength and increased density, it also reduces water absorption compared to conventional blocks. Specifically, the water absorption capacity decreases as the plastic content increases, although the strength of the blocks diminishes with higher plastic proportions [7].

Construction and Demolition (C&D) Waste

Brijpuria et al. (2021) India generates approximately 12-14 million tonnes of construction waste annually, with concrete and brick waste comprising a significant portion. This study investigates using recycled concrete waste for interlocking paver blocks by partially or fully replacing natural aggregates with Demolished Concrete Aggregate (DCA). Although DCA replacement can reduce compressive and flexural strength, tests indicate that paver blocks with 100% DCA meet Indian standards for medium-traffic applications. With a compressive strength above 40 MPa and flexural strength exceeding the 2.25 MPa requirement, DCA-based paver blocks are suitable for medium-traffic city streets, markets, and utility cuts, promoting a sustainable alternative in construction [10].

Contreras-Llanes et al. (2021) Construction and Demolition Waste (CDW) is a significant global waste stream, prompting interest in its reuse within the Circular Economy. They examined using recycled aggregates (RAs) from CDW to replace natural aggregates (NAs) in precast concrete products like kerbstones and paver blocks. Testing showed that RAs increased water absorption and porosity but reduced bulk density and compressive strength. However, all RA-based products met EN 1338 strength standards, with some exceeding reference tensile strength. Many RA compositions achieved class 1 flexural strength (EN 1340) and Class 4 abrasion resistance, meeting class 3 standards for high-traffic or pedestrian areas [20].

Singh Gaur (2022) examined experimental analyses of paver blocks made with demolition waste, showing that they perform well across tests for compressive strength, workability, flexural strength, water absorption, impact value, and crushing value. Studies reveal that using construction and demolition waste is cost-effective compared to traditional paver blocks. Most research suggests replacing up to 50% of natural aggregate with demolition waste for optimal performance, focusing mainly on M20, M25, and M35 concrete grades. These paver blocks are suitable for high-traffic streets when used with appropriately designed base and sub-base layers [2].

Vani et al. (2021) India faces challenges with limited reclamation sites and landfill space for construction and demolition (C&D) waste. A strategy to reduce, reuse, and recycle this waste is crucial, particularly through its use in paving blocks as a partial fine aggregate replacement. Different mix proportions (0%, 20%, 40%, 60%, and 80%) of C&D waste were tested, revealing that a 40-60% replacement maximizes compressive strength and reduces concrete costs by 3.28%. This approach conserves natural resources, decreases energy use, and lowers CO_2 emissions, supporting sustainable construction. The study emphasizes the effectiveness of utilizing C&D waste, particularly in manufacturing concrete paver blocks, to achieve sustainable development goals [21].

Kanchan Aachat B et al. (2022) There is growing global interest in addressing environmental issues caused by industrial waste, particularly from demolished structures. Utilizing these waste materials for manufacturing paver blocks supports sustainable development. In India, this technology has been implemented for constructing footpaths and parking areas, and is now widely used for creating green concrete paver blocks from demolition waste. Approximately 530 million tons of construction and demolition (C&D) waste is generated annually, yet only a small fraction is recycled. This study investigates the effects of fully replacing fine aggregate with demolition waste in M20 and M40 mix concrete paver blocks, which achieved 91% strength at 28 days. The findings suggest that these blocks are suitable for low-load-bearing pavements, offering a cost-effective and sustainable solution to reduce landfill waste [22].

Moorthi et al. (2023) discussed the issue of Construction and Demolition (C&D) waste, a significant portion of solid waste generated from building activities, which is often sent to landfills. This not only consumes valuable land but also poses environmental and health risks. The study proposes the development of sustainable paver blocks using C&D waste as a replacement for natural aggregates, incorporating cement and fly ash as binders. These paver blocks, sized 275 mm × 220 mm × 130 mm, show reduced costs and good heat resistance, making them suitable for applications such as gardens, pedestrian paths, and cycleways, despite having lower compressive strength than traditional concrete blocks [23].

Outcomes Based on Review of Previous Studies

1. Incorporating granite chips as aggregate substitutes can conserve natural resources and reduce pollution from granite waste [12].
2. Growing landfill costs and environmental concerns highlight the need for innovative waste management solutions like granite waste utilization [12].
3. The study found that granite concrete paving blocks showed enhanced compressive strength, with optimal results at 10% replacement for a w/c ratio of 0.40 and 5% for 0.42 [12].
4. Increased water penetration and acceptable abrasion loss (maximum 0.32 mm) suggest the feasibility of using granite waste in concrete paving applications [12].

5. Replacing 40% of aggregates with kota stone chips led to a 2.01% increase in compressive strength of rubber mould paver blocks [11].
6. The 40% replacement of aggregates with kota stone chips also reduced the cost of paver block production by 2.90%, making it a more economical option [11].
7. The M2-20 mix, which replaces 20% of cement with fly ash, achieved the highest compressive and flexural strength across various curing periods (7, 28, and 56 days), highlighting the potential for fly ash to enhance paver block durability while reducing cement usage [16].
8. These demolition waste-based paver blocks, particularly in M20, M25, and M35 concrete grades, are deemed suitable for high-traffic applications, provided they are laid on a properly designed base and sub-base, making them viable for sustainable urban infrastructure [2].

CASE STUDIES

Several case studies have been conducted to evaluate the effectiveness of industrial waste and construction and demolition waste in paving blocks. These studies highlight real-world applications and the practical implications of using industrial waste and construction and demolition waste in paving blocks.

Case Study 1: Utilization of Recycled Aggregates in Concrete Paving Blocks [5]

Introduction

The increasing focus on sustainability in the construction industry has spurred research into the use of recycled aggregates in concrete products. This study investigates the properties of concrete paving blocks incorporating various construction wastes, including recycled concrete coarse aggregate (RCCA), recycled concrete fine aggregate (RCFA), crushed glass (CG), crumb rubber (CR), and ground granulated blast furnace slag (GGBS).

Objectives

The primary aim of this study is to analyze how different waste materials affect the properties of concrete paving blocks. Specifically, it seeks to determine the optimal replacement levels of each recycled material to achieve desirable strength, durability, and water absorption characteristics while maintaining compliance with industry standards.

Methodology

Five types of waste materials were incorporated into the concrete paving blocks:

1. Recycled concrete coarse aggregate (RCCA)
2. Recycled concrete fine aggregate (RCFA)
3. Crushed glass (CG)
4. Crumb rubber (CR)
5. Ground granulated blast furnace slag (GGBS)

The paving blocks were tested for compressive strength, tensile splitting strength, water absorption, and abrasion resistance at various replacement levels.

Key Findings

1. *Recycled concrete coarse aggregate (RCCA)*
    a. Replacement of natural aggregates with RCCA led to a significant decrease in both compressive strength and tensile splitting strength.
    b. Increased water absorption was observed, with optimal replacement not exceeding 60% to meet standards.
    c. Abrasion resistance deteriorated at levels above 80% RCCA.
2. *Recycled concrete fine aggregate (RCFA)*
    a. Similar to RCCA, RCFA adversely affected compressive and tensile strengths, with higher percentages resulting in increased water absorption.
    b. Abrasion resistance remained largely unaffected, allowing for a maximum replacement of 20% to achieve desired performance.

3. *Crushed glass (CG)*
   a. Incorporating CG enhanced the strength and reduced water absorption in the paving blocks.
   b. The highest compressive strength and lowest water absorption occurred at a 20% replacement level, while tensile strength peaked at 40%.
   c. Abrasion resistance was optimal with 30% CG replacement.
4. *Crumb rubber (CR)*
   a. Increasing CR content resulted in a sharp decline in compressive and tensile strengths, alongside higher water absorption.
   b. Slip resistance was slightly reduced, leading to the conclusion that CR should not be used as a replacement for fine aggregates.
5. *Ground granulated blast furnace slag (GGBS)*
   a. GGBS replacement positively impacted the blocks' properties, particularly at 30% and 50% levels, enhancing compressive strength, tensile splitting strength, and abrasion resistance.
   b. A 70% GGBS replacement was detrimental to all tested properties, emphasizing the importance of not exceeding a 50% replacement level.

Conclusion

The study demonstrates the feasibility of using various recycled materials in concrete paving blocks, with careful consideration of replacement levels to optimize performance. The recommended levels are as follows:

1. *RCCA:* 0% to 60%
2. *RCFA:* 0% to 20%
3. *Crushed Glass:* 0% to 40%
4. *GGBS:* 0% to 50%

These findings provide valuable reference data for future research and practical applications in the sustainable construction industry, promoting the use of recycled materials in concrete paving blocks while ensuring compliance with standard performance requirements.

Case Study 2: Sustainable Use of Demolition Waste in Paver Block Production [22].

Background

The global construction industry is facing a significant challenge due to the environmental impact of industrial waste, particularly from demolished structures. As urbanization accelerates, so does the generation of construction and demolition (C&D) waste, with approximately 530 million tons produced annually. Despite this vast quantity, only a small fraction is recycled or reused. This case study examines the innovative use of demolition waste in manufacturing paver blocks, highlighting its potential for sustainable development in India.

Problem Statement

The improper disposal of C&D waste contributes to environmental degradation, with many materials ending up in landfills. Traditional paver block manufacturing relies heavily on natural aggregates, which exacerbates resource depletion and increases carbon footprints. As the demand for construction materials rises, finding alternatives that utilize waste materials becomes critical for sustainable urban development.

Methodology

This study conducted experimental investigations to evaluate the feasibility of replacing fine aggregate in concrete paver blocks with demolition waste. The research focused on two concrete mix designs: M20 and M40. The following steps were undertaken:

1. *Material collection:* Demolition waste was sourced from local construction sites, ensuring a representative sample of the types of waste produced.
2. *Mix design:* Concrete blocks were produced with varying proportions of demolition waste replacing fine aggregate, adhering to standard practices.

3. *Testing:* The paver blocks underwent various tests, including compressive strength tests to evaluate their performance compared to conventional blocks.
4. *Analysis:* Results were analyzed to determine the compressive strength and suitability of the paver blocks for low-load-bearing applications.

Findings

1. *Strength attainment:* The paver blocks made with 100% demolition waste achieved 91% compressive strength at 28 days. This marginal deterioration compared to conventional blocks indicates that demolition waste can effectively replace fine aggregate without significantly compromising structural integrity.
2. *Cost efficiency:* Utilizing demolition waste in paver block production can reduce material costs and promote the recycling of waste materials. This approach not only conserves natural resources but also lowers the overall environmental impact of construction activities.
3. *Sustainability:* The production of paver blocks from demolition waste contributes to sustainable construction practices. It mitigates the issues related to landfill disposal and promotes a circular economy where waste materials are repurposed.

Conclusion

The case study demonstrates that the use of demolition waste as a partial replacement for fine aggregate in paver block production is a viable and sustainable solution. The findings indicate that these paver blocks can be effectively used in low-load-bearing pavements, supporting the growing need for eco-friendly construction materials. As urbanization continues to rise, adopting such innovative practices can significantly reduce the environmental footprint of the construction industry and foster sustainable urban development in India. This approach not only addresses waste management challenges but also promotes a more responsible use of resources, aligning with global sustainability goals.

CONCLUSION

Several by-products have the potential to improve paver block qualities and boost performance in paving applications, according to a review of the literature on interlocking concrete paver block (ICPB) incorporating industrial wastes, such as fly ash, plastic waste, blast furnace slag, and particularly construction and demolition waste.

1. By partially replacing cement with marble waste and fly ash, the study demonstrates a viable method for lowering carbon emissions and material costs in paver block production, supporting sustainable practices without compromising performance.
2. Paver blocks constructed with up to 50% demolition waste as a replacement for natural aggregate meet the desired performance standards in compressive strength, workability, and durability, while also being more cost-effective than conventional concrete blocks.
3. Paver blocks made with recycled materials like Demolished Concrete Aggregate (DCA) meet or exceed medium-traffic standards, achieving compressive strength over 40 MPa and flexural strength above 2.25 MPa.
4. Using recycled aggregates can reduce paver block costs by up to 3.28% compared to conventional concrete.
5. Incorporating C&D waste in paver production conserves resources, reduces landfill waste, and lowers energy use and CO2 emissions, aiding sustainable development.
6. Although slightly lower in compressive strength, recycled material paver blocks are suitable for low-load-bearing applications like gardens and pedestrian paths, promoting eco-friendly construction.

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