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Eco-Friendly Paver Block: Comparative Study by Composition Review

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Abstract

Eco-friendly paver tiles are manufactured using environmentally non-degradable construction wastes, adhering to the “Recycle, Reuse, Reduce” principle. This study investigates the reuse of construction waste as cost-effective engineering materials to foster sustainability, minimize environmental impact, and ensure long-term durability. By incorporating non-degradable materials like plastics and components of paver blocks, the research seeks to reduce concrete usage while improving architectural aesthetics, engineering functionality, and local market demand. Waste plastic and silica sand were evaluated for thermoplastic composites in floor tiles, assessed by water absorption and compressive strength tests. Key findings demonstrate that 100% recycled marble or porcelain aggregates enhance mortar’s mechanical and durability properties, while recycled coarse concrete aggregate replacements above 60% negatively affect strength and water absorption. Cement-concrete waste powders and alkali-activated construction and demolition wastes exhibit potential for reducing carbon footprints, promoting circular economies, and warrant further investigation into environmental and economic impacts. The inclusion of furnace slag (up to 40%) or glass powder (up to 30%) improves compressive and tensile strengths, affirming their eco-friendly applications.

Plastic waste, such as MPW and LDPE, shows promise in paver blocks, with compressive strengths supporting traffic scenarios using 10–50% plastic content. However, process optimization is required for viable end products. This study underscores the importance of resource recovery, reduced reliance on natural materials, and innovation in sustainable construction materials. Findings support greener development for low-load applications like walkways and streets, advancing environmental and economic sustainability in the construction sector. This study benefit to the new researcher to review the literature.

Keywords: *Non-degradable, Construction wastes, sustainability, strength, durability.*

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Introduction

The most pressing issue of today's world is global warming. Due to rapid urbanization and natural calamities, more Construction and Demolition Wastes (CDW), such as plastic waste, used concrete aggregates, and glass pieces, are deposed from municipal and industrial activities, which have affected the environment directly or indirectly (Olofinnade et al., 2021).

Reusing plastic waste and recycled concrete aggregates to manufacture construction materials will address the global waste management challenges and contribute to sustainability. In 2021, global plastic production reached 390 million tons, with only about 10-12% being recycled, leaving high amounts of waste in landfills and oceans (Goli et al., 2020).

Over time, CDW could be the major alternative to natural aggregate, where Robayo-Salazar et al. (2020) stated that 25-30% of global solid waste accumulates CDW, with over 3 billion tons generated annually. It is found that the compressive strength of Recycled concrete aggregate (RCA) is almost the same as that of normal concrete, while suitable adjustment in the mix design is to be redone in order to address higher water absorption (Pederneirasa et al., 2020). Moreover, using RCA contributes to reducing CO2 emission in cement production, which currently accounts for 8% of global CO2 emission (Iftikhar. et al., 2023).

Research conducted by Awoyera and Adesina (2020) demonstrates that reusing plastic waste in manufacturing paver blocks results in acceptable properties for low to medium-traffic areas, abrasion resistance, and enhanced strength and sustainability (Awoyera & Adesina, 2020). The introduction of plastic waste and RCA in engineering construction materials such as paver blocks fulfills the requirement of sustainable waste management and provides economic and environmental benefits. The reuse of construction and demolition wastes, like recycled concrete aggregates and plastic waste, provides a solution to the depletion of natural resources and environmental degradation (Wang, Chin, & Xia, 2019).

Every year, tons of plastic waste escapes into the oceans from coastal nations. hat is the equivalent of setting five garbage bags full of trash on every foot of coastline worldwide. Plastics often contain additives making them stronger, more flexible, and durable. But many of these additives can extend the life of products if they become litter, with some estimates ranging to at least 400 years to break down. (Parker, 2024). This is one of the main reasons for environmental pollution affecting nature, and the final consequence is global warming, the burning issue of today's world. The continuous increase in construction projects worldwide increases construction waste (CW). If not appropriately addressed, a significant amount of landfill construction waste can critically influence the economy and environment (Omer, et al., 2022)

Waste occurs within the lifecycle of buildings during the construction, modification, and demolition phases. Construction waste has become a serious environmental problem in many countries. Environmental Protection Agency of the USA estimated that approximately 136 million tons of building-related construction debris was generated in the US in 1996. In the US, construction and demolition (C&D) waste represents about one-third of the volume of materials in landfills. Stoke et al. reported that C&D waste took up about 65% of Hong Kong's landfill space at its peak in 1994–1995. Construction wastes and debris replace thirty-five percent of the space in Canada's landfills Government of Canada Publication). According to Ferguson et al., over 50% of waste in a typical UK landfill could be construction waste. Chen et al. (2022 and Esin and Cosgun (2007) reported that construction activity generates 20–30% of all waste deposited in Australian landfills.

Construction and Demolition Debris deposited in forests, streams, ravines, and empty lots causes erosion, pollutes wells, water tables, and surface waters, attracts pests, increases fire hazards, and detracts from the attractiveness of natural environments. (Esin & Cosgun, 2007)

With the world's rapid development process, there are also emerging environmental impacts because of these non-degradable construction wastes. Therefore, the main objective of this study is to address the global issue of reusing, reducing, and recycling construction waste to make eco-friendly construction materials.

The main scope of the study is to reuse recycled concrete aggregate and plastic waste as aggregate in sustainable green concrete paving blocks and check the feasibility of utilizing construction wastes as raw materials for concrete paving block. The goal is to convert non-degradable wastages into effective construction materials and enhance knowledge to obtain sustainable, durable, and cost-effective, eco-friendly concrete paving blocks. The objectives of this study were to review the literature on construction wastes, such as recycled concrete aggregate and plastic wastes, in a sustainable way for manufacturing paving blocks and to obtain the impact on the properties of the paving block while changing the different compositions.

Research Questions

How do the workability, compressive strength, and water absorption of paver blocks change with varying plastic content and particle size of sand?

What effects do Recycled Concrete Aggregate (RCA) and recycled glass have on paver blocks' mechanical properties and aesthetic appeal?

How do polypropylene fibers enhance paver blocks' tensile strength and crack resistance, and what are their overall benefits in construction applications?

How do different environmental conditions impact the durability and long-term performance of paver blocks made with MPB and recycled materials?

Methodology

The review analyzes and summarizes research papers on reusing construction and demolition waste (CDW) for manufacturing paving blocks. The process involved examining abstracts, methodologies (to determine whether the articles were experimental or reviews), and segment headings to derive an executive summary of each paper. Following a pretreatment and pre-reading strategy, relevant articles from 2017-2024 and an older background study from 2007 were included. The review emphasizes key details such as publication years, objectives, methodologies, citation counts, and findings to assess the potential of CDW in addressing global issues through sustainable paving block production. Most of the reviewed articles used experimental methods, and some were reviewed articles.

Results

The review results have been presented in a tabulated form (see Table 1). This section has focused on the summary of results based on every one of the studies, discussion based on the literature, and discussion based on

Table 1. Summary of the previous studies on recycling of waste concrete materials, plastics, and their properties.

Authors and publication years	Title	Objective	Methods	Findings	Sources of journal	Citations count
Nasr et al., (2020)	Properties of eco-friendly cement mortar contain recycled materials from different sources	To recycle the wastes of some of building materials such as marble, granite and porcelain tiles, and clay brick by using them as cement and aggregate replacement materials in [cement mortar]()	Experimental method	It shows that it is possible to produce eco-friendly mortar using 100% recycled marble or porcelain aggregate, which can significantly improve mechanical and durability properties compared to natural aggregate mortar.	Journal of Building And Construction	73
Wang Chain & Xia (2019)	Material characterization for sustainable concrete paving block	To study the property variations of sustainable concrete paving blocks incorporating different contents of construction wastes.	Experimental method	Recycled coarse concrete aggregate (RCCA) replacement over 80% leads to decreased strength and increased water absorption, so it should be limited to 60%.	Applied Sciences	33
Kaliyavaradhan, et al, (2020)	Valorization of waste powders from cement-concrete life cycle: A pathway to circular future	To review the origins, properties, and potential applications of waste powders from the cement-concrete life cycle to improve sustainability in construction while emphasizing the need for further research on their performance, environmental impacts, and economic benefits.	Review	The result shows that cement-concrete waste powders can be repurposed for construction applications to boost sustainability, but more research on performance, environmental impacts, and economic benefits is required before widespread use.	Journal of Cleaner Production	83
Goli, et al, (2020)	Application of Municipal Plastic Waste as a Manmade Neo-construction Material: Issues & Way forward	To review the engineering properties and issues related to using municipal plastic waste (MPW) as a neo-construction material, aiming to explore its potential for sustainable construction applications.	Review	It has resulted that MPW can boost sustainability in construction as a binder or filler. Yet, challenges like quality, composition, material compatibility, and process optimization require critical assessment for viable end-products.	Resources Conservation and Recycling	69
Iftikhar, et al, (2023)	Predicting compressive strength of eco-friendly plastic sand paver blocks using gene expression and artificial intelligence programming	To develop empirical models using gene expression programming (GEP) and multi-expression programming (MEP) to predict the compressive strength of plastic sand paver blocks (PSPB) made from plastic, sand, and fiber.	Experimental	The result indicated that MEP beats GEP in predicting PSPB strength, with sand grain size and fiber percentage being key factors. PSPB shows promise for eco-friendly and cost-effective construction.	Scientific Reports	22
Olofinnad, et al, (2021)	Solid waste management in developing countries: Reusing of steel slag aggregate in eco-friendly interlocking concrete paving blocks production	To investigate the utilization of crushed waste furnace steel slag as a replacement for natural sand in the production of concrete interlocking paving blocks for pedestrian and non-traffic applications.	Experimental	The findings indicate that replacing sand with up to 40% furnace steel slag boosts compressive strength by 15% and up to 20% replacement enhances tensile strength by 10%, showcasing furnace slag's potential for eco-friendly paving infrastructure.	Case Studies in Construction Materials	58

Jonbi & Fulazzaky, (2020)	Modeling the water absorption and compressive strength of geopolymer paving block: An empirical approach	To investigate the incorporation of finely ground waste glass (GP) with different fineness as a partial cement replacement in concrete and concrete paver blocks to enhance their properties and provide a waste management solution	Experimental	Incorporating up to 30% GP in concrete enhances compressive strength and durability while staying within shrinkage limits. This highlights its potential as a sustainable cement replacement and promotes a circular economy in construction.	Measurement	17
Robayo-Salazar, et al, (2022)	Reuse of powders and recycled aggregates from mixed construction and demolition Waste in alkali-activated materials and precast concrete units	Recycling of coarse and fine fractions and powder from construction and demolition waste (CDW) using alkaline activation technology (geo polymerization)	Experimental	The results of the physical-mechanical characterization validate CDW-based materials for construction. Mortar achieved 40.5 MPa compressive strengths, and concrete 36.9 MPa compressive strengths after 90 days at 25°C. Life cycle analysis shows mixed alkali-activated CDWs have a 44% lower carbon footprint than OPC-based materials, ensuring environmental sustainability.	Sustainability	23
Thiam, et al., (2021)	Mechanical properties of a mortar with melted plastic waste as the only binder: Influence of material composition and curing regime, and application in Bamako	To investigate the effect of curing conditions and granular material size on the mechanical properties (compressive and splitting tensile strengths) of a mortar with melted plastic waste (high-density polyethylene (HDPE) and low-density polyethylene (LDPE)) as the only binder (MPB: mortar with melted plastic waste binder).	Experimental	The results position this MPB material as a promising choice for interlocking pavers, offering a solution to manage plastic waste and reduce production costs.	Case Studies In Construction Materials	27
Chen et al.(2022)	Recycling thermoset plastic waste for manufacturing green cement mortar	The primary objective of this study is to explore the feasibility of recycling thermoset plastic waste as a sustainable alternative material for manufacturing green cement mortar	Experimental	The findings underscore the potential of thermoset plastic waste as a sustainable alternative in green cement mortar production, promoting circular economy principles and innovation in eco-friendly construction materials.	Cement and Concrete Composites	23
Attri, et al, (2022)	Sustainable precast concrete blocks incorporate recycled aggregate, stone crusher, and silica dust.	To study the effect of incorporating coarse RCA, SCD, and SD and their impact on engineering properties on paver block	Experimental	Results show increased workability by 2.6% at 45% coarse RCA but decreased by 4.6% and 10.2% at 100% SD and 100% SCD, respectively. Compressive strength decreased by 6% at 45% coarse RCA but increased by 2.8% and 3.8% at 100% SD and 100% SCD.	Journal of Cleaner Production	25
Tempa, et al, (2022)	An experimental study and sustainability assessment of plastic waste as a binding material for producing economical cement-less paver blocks	To introduce various types of PW as a binding material to substitute cement to produce cement-less paver blocks completely.	Experimental	Test results indicate low water absorption potential for the plastic paver block, with an average initial and final setting time of the binder at 19 and 24 minutes, respectively.	Engineering Science and Technology-An International Journal-Jestech	33

Sai, et al, (2021)	Influence of brick waste and brick waste fines as fine aggregate on the properties of paver blocks - Preliminary investigation	To investigate paver blocks for pedestrian traffic, they are produced using C and D brick waste aggregates to replace fine aggregates (M-Sand).	Experimental	The results obtained were satisfactory for applying the blocks in the streets with low movement and load.	Materials Today-Proceedings	14
Kumar, et al, (2022)	Sustainable Zero-Slump Concrete Containing Recycled Aggregates from Construction and Demolition Waste of a 63-Year-Old Demolished Building	The use of recycled concrete aggregate (RCA) from construction and demolition waste (CDW) in zero-slump concrete (ZSC) to produce M-40 grade paver blocks and properties was investigated to optimize its replacement percentage.	Experimental	As observed, mechanical and durability properties degrade with an increase in RCA content, and CDW can be viewed as a resource, not a waste, which can save natural resources and pave the way to sustainable development.	Journal of Materials in Civil Engineering	9
Mane et al.,(2019)	Use of plastic waste as a partial replacement of aggregate in paver blocks	To study the effects of the use of waste products on the resultant properties of concrete mix. This waste product is used as a replacement for coarse aggregate.	Experimental method	It is observed that the compressive strength for 2.5%, 3%, 4% replacement of plastic coarse aggregate is high and decreases at 10% replacement of plastic coarse aggregate.	International Research Journal of Engineering and Technology	5
Ohemeng et al. (2018)	Utilization of waste low-density polyethylene in strong concrete pavement block production	To investigate the feasibility of using waste low-density polyethylene as a partial replacement for sand in the production of concrete pavement blocks.	Experimental method	It is observed that the strengths of PCPBs decreased as the plastic content increased. Compressive strengths of 20N/mm2, 30N/mm2, and 40N/mm2, which are satisfactory for pedestrian walkways, light traffic, and heavy traffic situations, could be achieved if 10%—50% plastic content is used.	International Institute for Science, Technology and Education	29

Summary of the results

The findings collectively highlight innovative approaches for sustainable construction materials. Using 100% recycled marble or porcelain aggregates enhances mortar's mechanical and durability properties, while recycled coarse concrete aggregate (RCCA) replacements above 60% compromise strength and water absorption. Cement-concrete waste powders and mixed alkali-activated CDWs show potential for reducing carbon footprints and supporting circular economies, though further research on environmental and economic impacts is needed. Incorporating furnace slag (up to 40%) or glass powder (up to 30%) improves compressive and tensile strengths, demonstrating their viability for eco-friendly applications. Plastic waste, such as MPW and LDPE, offers promise in paver blocks and as a binder or filler, though challenges in material compatibility and process optimization must be addressed. Results show compressive strengths suitable for various traffic scenarios (20–40 N/mm²) with plastic content ranging from 10–50%. While RCA, SD, and SCD influence workability and strength, careful proportions optimize performance. The findings emphasize resource recovery, reduced reliance on natural materials, and paving the way for sustainable development, particularly in low-load applications like walkways and streets (see Table 1).

Discussion, conclusion, and recommendations

Overview of the Study

Global warming and environmental degradation are among the most pressing challenges of our time, largely driven by rapid urbanization and the accumulation of construction and demolition waste (CDW). This study focuses on the feasibility of recycling thermoset plastic waste and other CDW materials as sustainable alternatives in manufacturing green cement mortar and paving blocks. The study emphasizes the importance of reusing materials like recycled concrete aggregates (RCA), plastic waste, and glass, which collectively address global waste management challenges, reduce reliance on natural resources, and contribute to circular economy principles.

The research underscores the alarming levels of waste generation, with global plastic production reaching 390 million tons annually, yet only 10-12% being recycled. CDW accounts for 25-30% of global solid waste, with approximately 3 billion tons produced yearly. Innovative reuse strategies for such waste, including plastic and RCA, have demonstrated potential in creating eco-friendly construction materials with acceptable mechanical properties, durability, and cost-efficiency.

The study reviews methodologies, findings, and practical applications of recycled materials, highlighting their capacity to enhance sustainability in construction. It also addresses challenges like material compatibility, water absorption, and the need for optimized mix designs to ensure performance.

The research's ultimate goal is to develop sustainable, durable, and eco-friendly construction materials, reduce the environmental impact of non-degradable waste, and align construction practices with global sustainability goals. This study provides a pathway for future research and innovation in waste management and green building technologies.

Discussion based on literature

The results highlight four key objectives for sustainable construction, with the highest priority given to the use of plastic waste due to its potential to mitigate plastic pollution while offering cost-effective and durable construction materials. The reuse of construction and demolition waste (CDW) and recycling of building materials are closely followed, emphasizing the importance of reducing landfill use, conserving resources, and aligning with circular economy principles. The replacement of natural sand or aggregates holds a slightly lower priority but remains critical for reducing the depletion of natural resources. These objectives collectively address pressing environmental concerns, promote economic and practical feasibility through material reuse, and optimize resource utilization, aligning with global sustainability goals (see Figure 1).

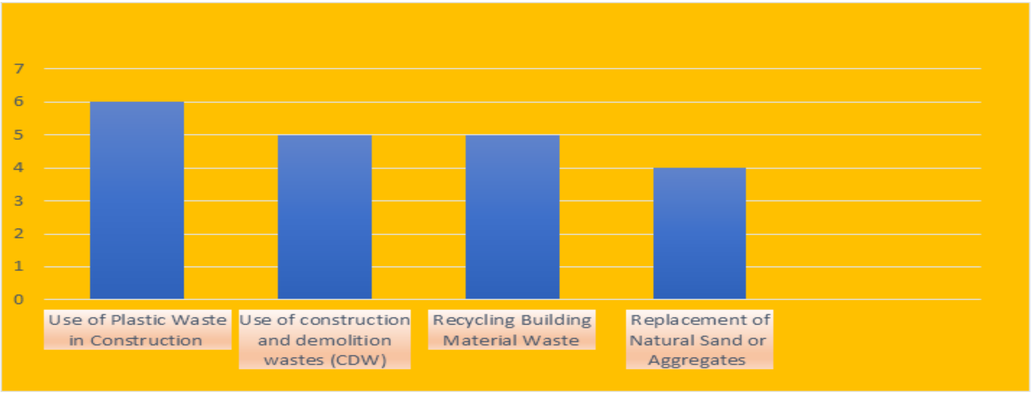

Figure 1. Objective focus analysis.

The results illustrate journal and citation counts with a Pareto curve overlay, highlighting the concentration of research influence across various journals. The highest citation counts are associated with the top few journals, indicating their dominance in disseminating impactful research. The steep rise in the Pareto curve reflects how a small subset of journals accounts for a majority of the citations while the remaining journals contribute comparatively less. This distribution underscores the importance of targeting high-impact journals for publishing primary research, as they provide greater visibility and citation potential. Conducting future research in areas covered by these top journals can ensure alignment with critical, high-impact fields and facilitate better academic and practical contributions. This focus can drive innovation and further sustainability in the research ecosystem (see Figure 2).

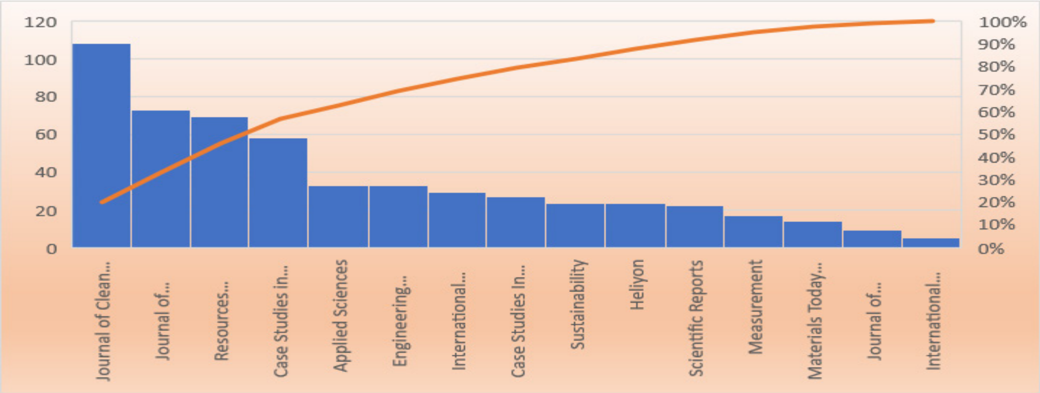

Figure 2. Journal and citation counts focus analysis.

The findings put the primary focus on sustainability and eco-friendliness, reflecting the demand for environmentally friendly construction solutions that reduce environmental impacts and promote green building practices. Improved mechanical and durability properties are the second most highlighted, ensuring sustainable alternatives maintain structural integrity. Limitations on replacement percentages underscore the need to adhere to specific thresholds to balance performance with material efficiency. The importance of circular economy and resource conservation is evident, highlighting the role of waste and recycled materials in conserving natural resources and minimizing waste. Application suitability for low-traffic areas points to the potential of sustainable materials for specific uses, such as walkways or light-load streets, aligning with their performance constraints. Overall, the data illustrates a balance between environmental sustainability and practical application, guiding the efficient use of materials while supporting sustainable development and construction standards (see Figure 3)

Figure 3. Findings focus analysis.

Discussion based on the research questions

Our discussion section highlights the research findings that connect with the literature of our study. Two of our main objectives were derived from four research questions. The whole discussion section analyzes the research findings related to the research questions

Research question 1

How do the workability, compressive strength, and water absorption of paver blocks change with varying plastic content and particle size of sand?

The result indicated that by reusing plastic as filler, the workability of concrete used to manufacture paver blocks increases in plastic as raw material to reduce friction between aggregate and cement mortar.

However, compressive strength decreases with more plastic, with an optimal performance noted at 2% plastic content. Furthermore, water absorption increases with the addition of MPW despite the fact that most polymers are hydrophobic The result is supported by the study of Rahul Mane et al. (2019), who found plastic waste to replace aggregate in paver blocks partially.

Research question 2

What effects do Recycled Concrete Aggregate (RCA) and recycled glass have on paver blocks' mechanical properties and aesthetic appeal?

The result highlighted that replacing natural aggregates with RCA minimizes about 45% of the properties of paver blocks, where an increase in RCA content decreases paver blocks' compressive strength and workability. Our result is supported by the study of Attri et al. (2022), who found sustainable precast concrete blocks incorporating recycled concrete aggregate, stone crusher, and silica dust.

Additionally, the inclusion of glasses (recycled) makes a better and shining appearance on the surface of the paver block, which gives an excellent aesthetic appearance while used in construction. Our result is supported by the study of Jonbi et al. (2020) who has studied about incorporation of finely ground waste glass with different fineness as a partial replacement in concrete and concrete paver blocks to enhance their properties and provide a waste management solution. (See table 1).

Research question 3

How do polypropylene fibers improve the paver tensile strength and crack resistance of paver blocks, and what are their broader benefits in construction applications?

The result shows that polypropylene fibers increase the paver block's tensile strength, improving mechanical properties. They also reduce cracks on the surface of the paver block while the curing process is done. The overall benefits consist of a 15% flexural strength increment with a 0.5% fiber content of paver blocks. The fiber also improves durability and leads to reduced water absorption. This study is supported by mostly reviewed articles based on the reuse of plastics in the construction of paver blocks (Itfikar et al., 2023) (see Table 1).

Research question 4.

How does different environmental conditions influence the durability and long-term performance of paver blocks made with MPB and recycled materials?

The results show that paver blocks, made from MPB, are durable under various environmental conditions. During the 12-month UV radiation and freeze-thaw cycles, blocks retain 90% of their compressive strength, while traditional blocks exhibit 15% strength loss. Our result is supported by Thiam et al.'s (2021) study in its background study (see Table 1)

Conclusion

The study focuses on the potential of reusing construction and demolition waste (CDW) and plastic waste in producing eco-friendly paver blocks, focusing on their engineering properties and the sustainability of the resulting materials. debris along with plastic waste, examining the engineering properties of the resulting eco-friendly paver blocks. The findings from the comprehensive review of various studies suggest that incorporating recycled materials like plastic, recycled concrete aggregates (RGA), and glass into paver blocks helps to improve structural performance and sustainability. It explores the impact of varying compositions on the performance and sustainability of the final product. For example, our study is a review article in which different experimental articles and review papers from different resources were examined. The results indicate that using recycled materials in paver blocks, such as plastic, recycled concrete aggregates (RCA), and glass, adds both performance and sustainability. 2% plastic content improves workability, while finer sand increases strength. While RCA may slightly reduce some of the strength properties, recycled glass adds aesthetic appeal, and adding polypropylene fibers enhances durability and reduces cracking. Notably, Mixed plastic-based paver blocks can retain up to 90% of their strength under environmental stress, compared to only a 15% strength loss in traditional blocks, making these eco-friendly options a better option for aesthetic, durable, and eco-friendly paver blocks both durable and visually appealing for sustainable construction. However, it is important to note that this study's findings rely on secondary data, which might raise concerns regarding the reliability of the results. More primary research is required to validate the findings and explore the practical applications of these materials in large-scale production. All the data sources were secondary data, so there is still a question of the reliability and validity of the results.

Recommendation

This review highlights reusing the construction and demolished waste (CDW) and plastic waste in engineering construction materials. From the study and review of these articles, we found that the reuse of the CDW and plastic wastes as raw materials in manufacturing paver blocks is conceptually eco-friendly. However, the concern is the use of somewhere; we find out that the melting of plastic is also used as a binder, which may contribute to environmental issues like global warming when manufacturing paving blocks, which is not suitable for the environment. It will directly play the role of catalyst for the increasing global warming. So, to address this issue, we suggest that more studies into using shredded plastic as a fine aggregate instead of melting it. This approach would be more eco-friendly and align nearer to reducing waste and maintaining sustainability. Reusing plastic waste as fine aggregates should be done by cracking it into smaller pieces, which will be directly eco-friendly and good for the environment.

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