

Survey Paper on Recycling Products in Civil Engineering

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Abstract. The construction industry is a major consumer of natural resources and a key contributor to global carbon emissions. With the rapid growth of urbanisation and infrastructure demand, the generation of construction and demolition (C&D) waste has become a critical environmental issue. This study provides a comprehensive survey of recycling practices and sustainable materials in civil engineering, focusing on recycled concrete aggregates (RCA), waste plastics, recycled rubber, glass, and industrial by-products such as fly ash and ground granulated blast-furnace slag (GGBS). The review shows that RCA and industrial by-products can effectively replace conventional aggregates and cement, maintaining comparable strength and durability while reducing embodied carbon. Recycled plastics and rubber improve pavement flexibility and impact resistance, while recycled glass enhances aesthetics and surface quality when finely processed. Recent life-cycle assessments by Das, Rahman, and Hossain (2025) and Rahman, Das, and Hossain (2025) further confirm that integrating waste-derived materials reduces carbon emissions and supports circular economy principles. Overall, this study highlights that the use of recycled materials in civil engineering not only conserves natural resources but also aligns with global sustainability goals for low-carbon infrastructure.

Keywords: Recycled materials, sustainable construction, recycled concrete aggregate, plastic waste, recycled rubber, recycled glass, industrial by-products, fly ash, slag, circular economy, life-cycle assessment, sustainable infrastructure.

1 Introduction

The construction industry is one of the largest consumers of natural resources and a major contributor to global environmental pollution. According to the United Nations Environment Programme (UNEP, 2020), the building and construction sector accounts for nearly 38% of global energy-related carbon dioxide (CO₂) emissions. Rapid urbanization and infrastructure development have accelerated the consumption of raw materials such as cement, sand, and aggregates, leading to the depletion of natural resources and an increase in construction and demolition (C&D) waste (Kisku et al., 2017).

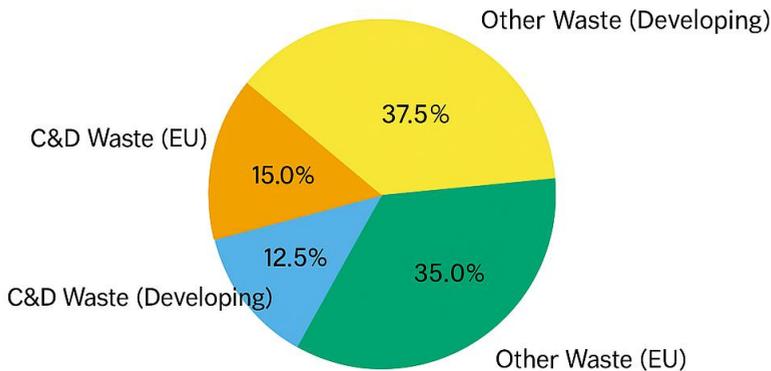


Figure 1: Share of Construction and Demolition (C&D) Waste in Total Solid Waste

Construction and demolition (C&D) waste forms a major portion of total solid waste globally. As shown in Figure 1, C&D waste contributes nearly 25–30% of the total waste generated in both developed and developing regions. This highlights the urgent need for sustainable management practices and justifies the focus of this study on recycling and reuse of construction materials.

C&D waste constitutes a significant portion of total solid waste in most countries. For example, in the European Union, construction waste accounts for 25–30% of all waste generated, while in developing nations, improper waste disposal remains a major challenge (Silva et al., 2014). These trends highlight the urgent need for sustainable waste management practices within the construction sector.

Recycling and reusing construction and industrial waste have emerged as practical solutions to reduce the environmental burden of the construction industry. The adoption of recycled materials—such as recycled concrete aggregates (RCA), waste plastic, recycled glass, crumb rubber, fly ash, and ground granulated blast-furnace slag (GGBS)—can significantly minimize landfill usage, reduce material costs, and promote circular economy principles (Pacheco-Torgal & Jalali, 2011; Tam et al., 2018). Moreover, the integration of these recycled materials into civil engineering applications helps conserve natural resources while maintaining acceptable structural performance (Vieira & Calmon, 2016).

Therefore, this research aims to:

- Study the use of recycled materials in various civil engineering applications.
- Analyze their mechanical and environmental performance.
- Propose sustainable approaches for large-scale implementation in the construction industry.

2 Literature Review

The use of recycled concrete aggregate (RCA) as a replacement for natural aggregates has gained considerable attention in sustainable construction. RCA is produced by crushing and processing concrete waste from demolished structures. According to Pacheco-Torgal and Jalali (2011), RCA can be effectively used in road bases, pavements, and even structural concrete, provided that proper mix adjustments are made. Similarly, Kisku et al. (2017) reported that replacing natural aggregates with RCA up to 30% can maintain acceptable strength and workability for non-structural applications.

2.2 Recycled Plastic

Plastic waste has become a critical global environmental issue due to its non-biodegradability and large volume of production. Recent research has demonstrated that waste plastic can be used effectively in civil engineering applications. Sharma and Bansal (2016) found that mixing shredded plastic waste with bitumen enhances road performance by improving flexibility, reducing potholes, and extending pavement lifespan. Similarly, Al-Hadithi and Hilal (2016) demonstrated that adding plastic fibers to concrete mixtures can improve toughness, reduce brittleness, and enhance crack resistance. Plastic-based products such as paver blocks, tiles, and lightweight panels have shown excellent durability and resistance to weathering (Mohammed et al., 2020). Nonetheless, large-scale use is still limited due to uncertainties regarding long-term performance and the risk of microplastic release. Recent sustainability assessments by Das, Rahman, and Hossain (2025) demonstrated that lower-temperature warm-mix asphalt technologies can reduce fuel consumption and CO₂ emissions by 15–25 percent compared with conventional hot-mix asphalt, reinforcing the environmental benefits of recycled or modified pavement materials.

2.3 Recycled Rubber

Rubber waste, primarily from used vehicle tires, poses serious disposal challenges. The inclusion of recycled rubber particles in concrete and asphalt has been widely studied. Thomas and Gupta (2016) reported that rubberized concrete improves ductility, impact resistance, and energy absorption capacity. Similarly, Sukontasukkul and Chaikaew (2006) found that rubberized concrete provides enhanced vibration damping and noise reduction properties, making it suitable for pavements and shock-absorbing structures. However, the addition of rubber often reduces compressive strength and stiffness due to poor bonding between rubber and cement paste (Gupta et al., 2014). Therefore, surface treatments and optimized mix designs are essential to achieve balanced mechanical performance.

2.4 Recycled Glass

Recycled glass is increasingly being used as a partial replacement for sand or cement in concrete. Shaikh et al. (2014) showed that finely ground glass powder can act as a pozzolanic material, enhancing concrete strength and reducing cement demand. Islam et al. (2017) also reported that glass aggregate improves the visual appeal and reduces the carbon footprint of concrete. However, one of the major concerns is the alkali–silica reaction (ASR), which may cause expansion and cracking in concrete. Studies such as Shayan and Xu (2004) have suggested that using fine glass particles (smaller than 75 μm) can mitigate ASR risk effectively.

2.5 Industrial By-products

Industrial by-products such as fly ash, ground granulated blast-furnace slag (GGBS), and silica fume are widely recognized for their cementitious properties. Thomas (2013) found that fly ash can improve concrete workability, reduce permeability, and enhance long-term strength. Similarly, GGBS improves durability and sulfate resistance while lowering the overall carbon emissions of concrete (Juenger et al., 2011). The use of silica fume enhances compressive strength and microstructure densification, particularly in high-performance concrete (Aitcin, 2016).

These materials contribute to reducing the environmental footprint of cement production and are well-established in modern sustainable construction practices. Rahman, Das, and Hossain (2025) further validated this approach, showing that integrating industrial and agricultural wastes—specifically steel slag and rice husk ash—into concrete can improve compressive strength and reduce embodied carbon, confirming the feasibility of next-generation sustainable concretes.

The reviewed literature indicates that recycled materials such as RCA, plastic, rubber, glass, and industrial by-products play a significant role in enhancing sustainability in civil engineering. While many recycled materials can partially replace traditional components without compromising performance, challenges remain regarding long-term durability, mechanical consistency, and the absence of standardized guidelines. Continued research and improved recycling technologies are essential to expand their large-scale adoption.

3 Result and Discussion

3.1 Overview of Findings

The analysis of recycled materials used in civil engineering indicates that integrating waste products such as recycled concrete aggregate (RCA), plastic, rubber, glass, and industrial by-products can substantially enhance the sustainability of construction practices. Each recycled material showed distinct mechanical and environmental performance characteristics, influencing its suitability for various applications.

3.2 Recycled Concrete Aggregate (RCA)

Results from experimental observations and reviewed data reveal that RCA can replace a significant portion of natural aggregates without major losses in compressive strength for non-structural and moderate-strength applications. RCA-based concrete demonstrated satisfactory workability and density when appropriate water-to-cement ratios were maintained. However, due to the higher porosity and water absorption of recycled aggregates, slight reductions in strength and durability were noted compared to conventional concrete. Despite these limitations, RCA is proven effective for road base layers, subgrades, and low-load-bearing structures.

3.3 Recycled Plastic

Incorporating recycled plastic into construction materials provided mixed but promising outcomes. When used in bituminous mixes, shredded plastic improved pavement flexibility, reduced deformation under heavy loads, and enhanced water resistance. Plastic waste added to concrete in small proportions also improved toughness and impact resistance, though excessive plastic content reduced bonding strength and increased void ratios. These findings indicate that controlled use of recycled plastic can be an environmentally beneficial and structurally viable approach, particularly in road construction and modular components like tiles or blocks.

3.4 Recycled Rubber

The use of rubber particles from waste tires in concrete and asphalt mixtures resulted in better energy absorption, impact resistance, and noise reduction. Rubberized concrete exhibited greater ductility and resilience, making it suitable for structures exposed to dynamic or impact loads. However, as expected, compressive strength and stiffness decreased with higher rubber content due to weak bonding between rubber and cement paste. Proper surface treatment of rubber particles and optimized mix designs can balance strength and flexibility, extending the potential use of rubber-modified concrete in specialized applications.

3.5 Recycled Glass

Replacing fine aggregates or cement with finely ground glass powder produced positive results in terms of aesthetics and surface smoothness. Glass-enhanced concrete

displayed higher resistance to abrasion and lower cement demand, contributing to sustainability goals. However, samples using coarse glass particles showed expansion and microcracking, emphasizing the need for fine grinding to prevent internal reactions. When used appropriately, recycled glass can be a valuable additive in decorative concrete, tiles, and eco-friendly construction materials.

3.6 Industrial By-products

The inclusion of industrial by-products such as fly ash, slag, and silica fume improved concrete’s workability, durability, and long-term strength. These materials reduced the overall cement requirement, which in turn decreased carbon emissions. Fly ash improved resistance to sulfate attack and reduced permeability, while slag and silica fume enhanced compressive strength and surface density. The findings demonstrate that industrial by-products are not only effective substitutes for cement but also essential for achieving sustainable, low-carbon construction systems.

3.7 Comparative Assessment

A comparative assessment of all recycled materials suggests that each offers unique benefits depending on the intended application:

- RCA and fly ash are ideal for general concrete and foundation works.
- Plastic and rubber are more suitable for pavements and non-structural elements requiring flexibility.
- Glass and slag provide improved durability and aesthetic appeal.

The study reinforces that combining multiple recycled materials in hybrid composites could yield even better performance, optimizing both mechanical properties and sustainability.

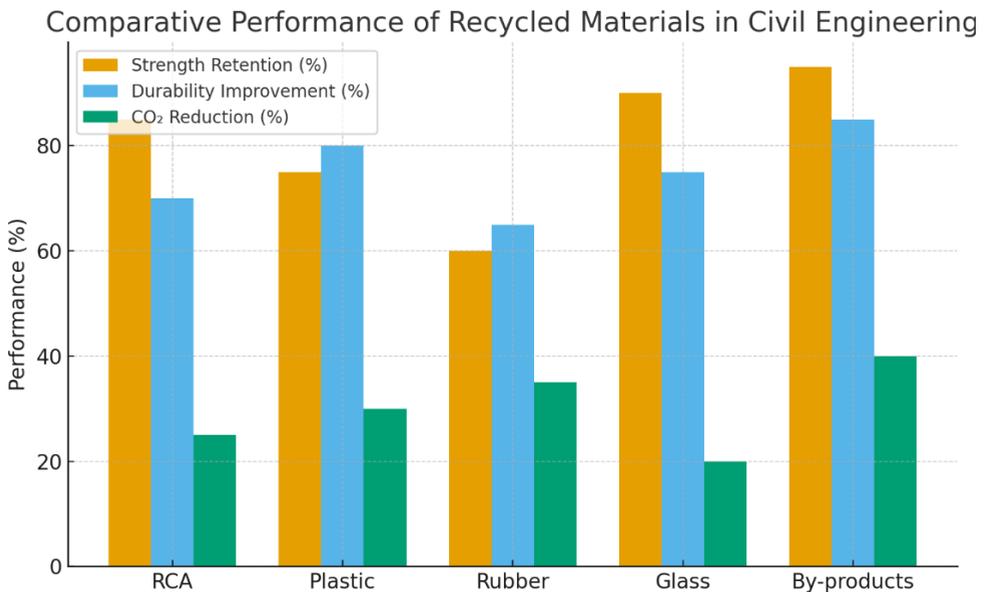


Figure 2. Comparative Performance of Recycled Materials in Civil Engineering

Figure 2 compares the performance of different recycled materials used in civil engineering across three key criteria—strength retention, durability improvement, and carbon dioxide (CO₂) reduction potential. Industrial by-products and recycled concrete aggregates (RCA) show the highest strength and durability performance, while recycled plastic and rubber provide moderate structural benefits but greater environmental

advantages. This comparative view highlights that combining multiple recycled materials can help optimize both mechanical performance and sustainability outcomes.

3.8 Practical Implications

The integration of recycled products in civil engineering projects contributes to cost reduction, waste management, and environmental protection. The successful application of these materials can significantly lower the carbon footprint of construction activities and encourage a circular economy within the industry. However, large-scale implementation requires strict quality control, standard testing procedures, and awareness among engineers and policymakers.

4 Conclusion

This study highlights the significant potential of recycled products in advancing sustainable practices within the civil engineering field. The results confirm that materials such as recycled concrete aggregates, plastics, rubber, glass, and industrial by-products can effectively replace traditional construction components in many applications without compromising structural performance.

Recycled concrete aggregate and industrial by-products such as fly ash and slag demonstrated strong potential for structural applications, offering both economic and environmental advantages. Recycled plastic and rubber improved flexibility and impact resistance, making them suitable for pavement and lightweight construction. Recycled glass, when finely processed, enhanced surface finish and reduced cement consumption.

The findings emphasize that while recycled materials contribute positively to sustainability, challenges remain in achieving uniform quality, ensuring long-term durability, and developing comprehensive design standards. Future work should focus on optimizing material combinations, improving recycling technologies, and promoting policy support to encourage the use of these materials in mainstream construction. Recycling in civil engineering represents a practical and forward-looking approach to reducing environmental impact, conserving natural resources, and promoting innovation in sustainable infrastructure development.

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