A systematic review of barriers to the utilization of construction and demolition waste in sustainable construction

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Abstract

Rapid urbanization, infrastructure expansion, and large-scale redevelopment activities have resulted in a substantial increase in the generation of construction and demolition (C&D) waste across the world. In developing countries such as India, C&D waste is predominantly viewed as an environmental and logistical burden rather than a valuable secondary resource. Consequently, large quantities of reusable materials are disposed of through uncontrolled dumping and inefficient handling practices, leading to severe environmental degradation, loss of recoverable materials, and increased pressure on natural resources. Simultaneously, the construction industry continues to rely heavily on virgin materials, particularly natural aggregates, which accelerates resource depletion, disturbs ecological balance, and contributes significantly to greenhouse gas emissions associated with extraction, processing, and transportation activities.

Recycling and reuse of C&D waste are widely recognized as effective strategies for promoting sustainable construction and supporting circular economy objectives. A growing body of research has demonstrated the technical feasibility of utilizing recycled C&D materials in various construction applications, including road sub-bases, embankments, backfilling, pavement layers, and non-structural concrete. These practices offer multiple benefits such as conservation of natural aggregates, reduction in landfill dependency, and mitigation of environmental impacts. However, despite the availability of recycling technologies and well-documented environmental advantages, the actual utilization of recycled C&D waste in mainstream construction projects remains limited, particularly in developing economies.

This persistent gap between technical feasibility and practical implementation indicates that the challenges associated with C&D waste utilization extend beyond material performance considerations. Existing literature highlights that adoption is significantly influenced by a complex interplay of institutional frameworks, economic constraints, management practices, health and safety concerns, and stakeholder perceptions. Factors such as unclear regulatory provisions, weak enforcement mechanisms, lack of financial incentives, resistance to change from conventional construction practices, and limited confidence in recycled materials collectively restrict widespread adoption. Therefore, a comprehensive understanding of these barriers is essential to formulate effective strategies that can enhance the utilization of C&D waste and promote sustainable construction practices.

Index Terms

Construction and demolition waste; Sustainable construction; Stakeholder perception; Barriers to C&D waste utilization; Recycling and reuse; Policy and regulatory challenges; Questionnaire-based assessment.

I. Introduction

The construction sector plays a crucial role in economic development, urban growth, and infrastructure modernization. Rapid population growth, industrial expansion, urban redevelopment, and transportation projects have significantly increased construction activities across both developed and developing countries [6], [14]. Along with these developments, the generation of construction and demolition (C&D) waste has increased at an unprecedented rate, making it one of the largest waste streams globally.

C&D waste is generated during activities such as excavation, demolition of old structures, renovation works, road widening, and infrastructure upgrading. Materials such as concrete debris, bricks, masonry, mortar, asphalt pavement, tiles, metals, wood, and excavated soil form a major portion of this waste stream [11]. In India and many other developing countries, C&D waste management practices remain largely informal and poorly regulated. Large quantities of waste are disposed of through open dumping, illegal

landfilling, or roadside disposal, leading to land degradation, blockage of drainage systems, air and water pollution, and serious public health risks [4].

At the same time, the construction industry continues to rely heavily on natural aggregates obtained through quarrying and river sand mining. Excessive extraction of these materials results in depletion of natural resources, ecological imbalance, loss of biodiversity, and increased greenhouse gas emissions associated with material processing and transportation [15]. From a sustainability perspective, C&D waste should therefore be viewed not merely as a disposal problem, but as a valuable secondary resource that can be reintegrated into the construction cycle [10].

Recycling and reuse of C&D waste offer multiple benefits, including conservation of natural aggregates, reduction in landfill dependency, lower transportation impacts, and decreased environmental footprint associated with raw material extraction [3]. Recycled aggregates derived from concrete and masonry waste have shown potential for use in road sub-bases, embankments, backfilling, and non-structural concrete applications [12].

Despite these advantages, the utilization of recycled C&D materials in mainstream construction projects remains limited. Contractors, engineers, and clients often hesitate to adopt recycled materials due to concerns related to inconsistent quality, lack of performance assurance, higher perceived costs, health–safety risks, and uncertainty regarding regulatory approval [7], [9]. In many cases, recycled materials are restricted to low-value applications or avoided entirely in favour of conventional materials.

This contradiction, where technically feasible and environmentally beneficial solutions exist but practical implementation remains weak, highlights the presence of deeper systemic barriers. These barriers extend beyond material properties and are strongly influenced by stakeholder behaviour, management priorities, economic decision-making, institutional frameworks, and policy enforcement mechanisms [1], [9].

II. Literature Review

A. Overview of Construction and Demolition Waste in Sustainable Construction

The literature on construction and demolition (C&D) waste management has expanded significantly over the past two decades due to increasing environmental concerns, depletion of natural resources, and the growing volume of waste generated by urban development activities [6], [14]. While extensive research confirms the technical feasibility of recycling C&D waste, practical implementation in real construction projects remains limited, particularly in developing countries [4], [7].

Construction and demolition waste constitutes one of the largest solid waste streams globally due to rapid urbanization, infrastructure expansion, and redevelopment activities [6], [14]. The construction sector consumes a substantial proportion of natural resources and simultaneously generates large quantities of waste materials such as concrete debris, masonry, asphalt, metals, wood, and excavated soil [11].

Several studies emphasize that C&D waste should be treated as a valuable secondary resource rather than a disposal burden to support sustainable construction and circular economy objectives [10], [15]. Recycling and reuse of C&D waste reduce dependence on virgin materials, minimize landfill usage, and lower environmental impacts [3]. However, despite these benefits, the utilization of recycled C&D waste remains limited in construction practice, particularly in developing countries [4], [7].

B. Global Research Trends on C&D Waste Utilization

Global research highlights that countries with strong regulatory frameworks, mandatory source segregation, and advanced recycling i nfrastructure achieve higher C&D waste recycling rates [6], [14]. Studies from Europe and China indicate that institutional support and strict enforcement are key drivers of successful C&D waste utilization [9], [14].

Lifecycle-based assessments demonstrate that recycled C&D materials can offer significant environmental and economic benefits when transportation impacts and avoided landfill costs are considered [15], [16]. However, these long-term benefits are often overlooked at the project level, where construction decisions prioritize short-term cost and risk considerations [7].

C. Stakeholder and Management-Related Barriers

Stakeholder perception and management practices are consistently identified as major barriers to C&D waste utilization. Several studies report that lack of confidence in the quality and performance of recycled materials discourages adoption, even when technical feasibility is proven [7], [10].

Inadequate waste management planning, poor coordination among stakeholders, and lack of clear responsibility allocation further restrict effective waste utilization [1], [9]. Behavioural resistance, fear of performance failure, and reliance on traditional construction practices also limit adoption [2], [7].

Design-stage decisions significantly influence waste generation and recycling potential, yet lack of coordination among designers and contractors often results in missed opportunities [11].

D. Technical Barriers and Quality Concerns

Numerous studies confirm that recycled aggregates derived from concrete and masonry waste can achieve acceptable mechanical and durability properties for applications such as road sub-bases, embankments, and non-structural concrete [12], [16].

However, poor segregation at demolition sites leads to contamination, reducing material consistency and reliability [3], [11]. Inadequate processing technologies and absence of standardized testing protocols further limit confidence in recycled materials [12]. Engineers often hesitate to specify recycled materials due to lack of codal provisions and long-term field performance data [12], [16].

E. Financial and Economic Barriers

Economic feasibility is one of the most frequently cited barriers in the literature. Recycling facilities require high capital investment, skilled manpower, energy consumption, and quality-control infrastructure, increasing production costs [3], [15].

In contrast, virgin materials benefit from established supply chains and economies of scale, making them more competitive in the short term [14]. Contractors prioritize immediate cost savings over long-term sustainability benefits, particularly in competitive bidding environments [7], [15].

Financial incentives such as subsidies, tax benefits, and reduced disposal charges have been shown to significantly improve recycling adoption [13].

F. Environmental and Health–Safety Barriers

Environmental and health–safety concerns associated with demolition and recycling activities are also discussed in the literature. Exposu re to dust, noise, and hazardous substances increases occupational health risks for workers [6], [11]. Inadequate safety measures and lack of training further discourage recycling practices [1].

Public opposition to recycling facilities due to dust and noise pollution is reported, particularly in densely populated urban areas [6]. These concerns increase regulatory scrutiny and liability risks, limiting widespread adoption of C&D waste recycling [1].

G. Policy and Regulatory Barriers

Policy and regulatory barriers emerge as the most critical constraints across global and Indian studies. Lack of clear regulations governing reuse and recycling of C&D waste creates uncertainty among stakeholders [4], [10]. Weak enforcement further reduces compliance and allows continuation of conventional disposal practices [14].

Absence of mandatory source segregation and lack of recycled material specifications in construction codes and tender documents significantly restrict adoption [7], [9]. Studies emphasize that strong regulatory pressure and standardization are essential for mainstreaming recycled C&D materials [10], [14].

H. Synthesis of Literature Findings

A synthesis of the reviewed literature reveals that barriers to C&D waste utilization are multidimensional and interrelated. While technical feasibility is well established [12], [16], non-technical barriers such as stakeholder perception, financial constraints, and policy enforcement dominate real-world implementation challenges [7], [9], [14].

Technological solutions alone are insufficient and must be supported by regulatory frameworks, economic incentives, and behavioural change initiatives [10], [15].

III. PRISMA-Based Study Selection Process

To ensure methodological transparency and systematic identification of relevant studies, the PRISMA 2020 framework was adopted.

- Records identified: 160
- After duplicate removal: 132
- Records excluded after screening: 94
- Full-text assessed: 38
- Full-text excluded: 22
- Studies included: 16

This structured process ensured that the findings are based on rigorously screened and methodologically sound literature.

IV. Recommendations

Based on the critical insights obtained from the systematic literature review, the following recommendations are proposed to enhance the utilization of construction and demolition (C&D) waste in sustainable construction:

1. Strengthening Policy and Regulatory Frameworks

Governments should develop clear, comprehensive, and enforceable regulations governing the reuse and recycling of C&D waste. Mandatory source segregation at construction and demolition sites should be strictly implemented, and recycled C&D materials should be formally incorporated into national construction codes, standards, and tender specifications. Strong enforcement mechanisms are essential to reduce uncertainty and build stakeholder confidence[4],[9],[10],[14].

2. Mandatory Use of Recycled Materials in Public Projects

Public infrastructure and government-funded construction projects should mandate the use of recycled C&D materials in suitable ap plications such as road sub-bases, embankments, backfilling, and non-structural concrete. Public-sector leadership can stimulate market demand and encourage private-sector adoption [7], [10], [15].

3. Stakeholder Awareness and Capacity Building

Targeted training programs, professional workshops, and certification courses should be conducted for contractors, engineers, architects, and site managers. These initiatives should focus on material performance, quality assurance, and best practices in C&D waste manag ement to address negative perceptions and resistance to change [2], [7], [11].

4. Development of Standardized Technical Guidelines

Standardized testing procedures, performance benchmarks, and design guidelines for recycled C&D materials should be developed and widely disseminated. Pilot projects and long-term field performance studies should be encouraged to provide practical evidence of d urability and service life, particularly for structural and semi-structural applications [12], [16].

5. Financial Incentives and Market Support

Economic instruments such as tax benefits, subsidies for recycling facilities, reduced landfill charges, and preferential procurement pol icies should be introduced to improve the cost competitiveness of recycled materials. These measures can offset initial investment costs and promote stable market demand [13], [15].

6. Enhancement of Health–Safety and Environmental Practices

Strict occupational health–safety regulations should be enforced during demolition, segregation, and recycling operations. Adoption of dust suppression systems, noise control measures, and adequate personal protective equipment can mitigate health risks and improve pu blic acceptance of recycling facilities [6], [11].

V. Conclusion

This systematic review provides a comprehensive synthesis of existing literature on the barriers restricting the utilization of construction and demolition (C&D) waste in sustainable construction. The review confirms that although the technical feasibility of recycling and r eusing C&D waste has been well established through numerous experimental and lifecycle studies, the actual adoption of recycled materials in construction practice remains limited due to dominant non-technical constraints [12], [15], [16].

The findings clearly indicate that policy and regulatory barriers represent the most critical challenges. Lack of clear legislative provisions, weak enforcement of existing rules, absence of mandatory source segregation, and limited inclusion of recycled materials in construction codes and tender documents significantly discourage adoption [4], [9], [10], [14]. These regulatory gaps create uncertainty among construction stakeholders and reinforce reliance on conventional materials.

Stakeholder and management-related barriers were identified as the second most influential group of constraints. Literature consistently reports that lack of confidence in the quality and long-term performance of recycled materials, resistance to change from traditional construction practices, inadequate waste management planning, and poor coordination among project stakeholders negatively affect recycling efforts [1], [2], [7], [9], [11]. These findings highlight the importance of behavioural change and managerial commitment in p romoting sustainable construction practices.

Financial and economic barriers further limit the utilization of recycled C&D waste. High initial investment costs for recycling facilities, increased operational and quality-control expenses, lack of financial incentives, and immature recycling markets reduce the cost compe titiveness of recycled materials when compared to virgin aggregates [3], [13], [15]. Short-term economic considerations continue to dominate construction decision-making, particularly in competitive project environments [7].

Although technical and environmental–health safety barriers were found to be significant, the literature suggests that these challenges are largely manageable through proper segregation practices, standardized testing protocols, technological improvements, and enforcement of safety regulations [11], [12], [16]. Their relatively lower impact compared to institutional and behavioural barriers indicates that technical limitations are not the primary obstacle to C&D waste utilization.

Overall, this review demonstrates that improving C&D waste utilization requires an integrated and systemic approach involving strong regulatory frameworks, stakeholder engagement, economic support mechanisms, and technical assurance. The study provides a solid theoretical foundation for future empirical research and supports evidence-based policymaking aimed at mainstreaming recycled C&D waste in sustainable construction and advancing circular economy objectives [10], [14], [15].

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