Clean Technologies and Environmental Policy (2026) 28:221
https://doi.org/10.1007/s10098-026-03565-x

REVIEW

From rubble to resource: overcoming challenges and drivers in concrete waste recycling for a sustainable circular economy in the built environment

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Received: 30 March 2025 / Accepted: 6 August 2026

Abstract
The construction industry often encounters significant environmental challenges, driven by rising waste management demands and its substantial contribution to carbon emissions. Concrete waste accounts for a significant share of global construction sector waste, underscoring the urgent need for effective resource recovery methods. Concrete waste recycling (CWR) is increasingly recognized as a circular-economy strategy to reduce waste and minimize environmental impact. However, despite its perceived advantages, widespread adoption remains stifled by systemic barriers. While previous studies have broadly addressed construction waste management, comprehensive reviews focusing specifically on CWR barriers and critical success factors (CSFs) remain limited. To address this gap, this study systematically reviews the barriers and CSFs influencing CWR implementation in the built environment. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach, 65 scholarly publications were retained for analysis. The review identified 30 barriers across six domains, with the most dominant being high investment costs, poor quality and limited applications of recycled concrete products, lack of comprehensive regulations, limited advanced recycling technologies, and insufficient recycling facilities. The CSFs for CWR implementation encompass legal and regulatory, economic and market, infrastructure and technology, and knowledge and education drivers. The study integrates these findings into a conceptual framework that defines CWR's systemic drivers, barriers, and stakeholders for effective implementation. It emphasizes that overcoming CWR barriers requires implementing relevant CSFs, supported by coordinated stakeholder action across the concrete recycling value chain. The findings provide practical insights for practitioners and policymakers to enhance CWR and achieve circular economy objectives in the built environment.

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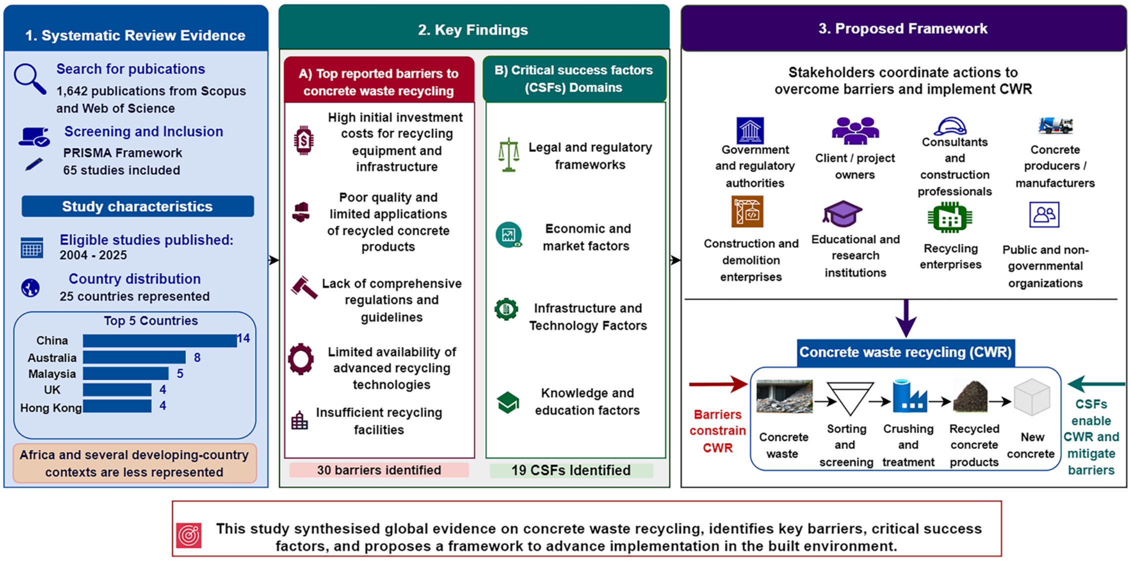
Published online: 18 August 2026

Graphical abstract



Keywords Concrete waste management · Concrete waste recycling · Circular economy · Barriers · Drivers · Construction industry

Introduction

The construction industry is a key driver of the global economy, contributing significantly to jobs, related industries, and national gross domestic product (GDP) (Hasan and Elmualim 2023). However, it is also one of the least sustainable sectors environmentally and a major source of carbon emissions. It is reported that the construction industry is responsible for a noteworthy share of global carbon emissions, estimated at around 33% across various studies (Song et al. 2023; Xiao et al. 2024). The industry faces several challenges, including excessive use of non-renewable resources due to rapid urbanization, energy-intensive production processes that result in high greenhouse gas emissions, and the generation of large amounts of construction and demolition waste (CDW) (Ding et al. 2023).

Globally, around 2.36 billion tons of CDW are generated each year, posing serious environmental risks due to solid waste build-up and greenhouse gas emissions (Hasan and Elmualim 2023; Zheng et al. 2017). Waste concrete can make up as much as 70% of this waste (Liu et al. 2023). This problem is especially pressing in areas with rapid construction growth and in those hit by natural disasters like earthquakes and severe weather (Villagrán-Zaccardi et al. 2022). Managing concrete waste effectively is therefore crucial, as it accounts for a large share of the industry's waste. Addressing this issue is both an environmental necessity and an economic opportunity, particularly as traditional disposal methods such as landfilling become less viable due to limited space and rising costs (Xuan et al. 2018).

In response, there is growing interest in the circular economy (CE) approach, which focuses on reducing waste and promoting closed-loop systems in the built environment. In concrete construction, higher-value CE strategies include reducing materials use and waste through improved specifications and designs, extending structural service life through repair and refurbishment, and the direct reuse and remanufacturing of concrete components to reduce demand for new materials and the associated environmental impacts (Marsh et al. 2022; Zhang et al. 2022; Oyewole et al. 2026). However, when concrete structures reach the end-of-use stage and direct reuse or life extension is no longer feasible, recycling becomes an important subsequent strategy for recovering materials and retaining them within the construction value chain (Marsh et al. 2022). Specifically, concrete waste recycling (CWR) involves collecting, sorting, and processing demolition waste to produce recycled aggregates for new concrete, thereby conserving natural resources, diverting waste from landfills, and lowering the environmental burden of construction waste disposal (Liu et al. 2020; Barbhuiya et al. 2024; Xiao et al. 2023).

Despite CWR's perceived benefits, recycling rates vary widely across regions, highlighting the need to understand the factors that shape recycling practices in various contexts (Iacovidou and Purnell 2016; Jin and Chen 2019). For instance, Al-Sharif et al. (2024) examined the CE for CWR in Jordan and reported that implementation levels remain low, with most concrete waste either disposed of in landfills or used as backfill material, and with limited recycling initiatives in place. Similarly, Grazia et al. (2022) conducted a critical review of concrete waste recovery rates across the European Union, highlighting significant variations among member states. While some nations have achieved considerable advancements, others continue to encounter various challenges. There is a lack of comprehensive evaluation of the economic, environmental, and technical barriers associated with different concrete waste management strategies (Xuan et al. 2018; Al-Otaibi 2024).

Additionally, many studies often combine CDW, overlooking the distinct characteristics of various waste streams (Villagrán-Zaccardi et al. 2022; Iacovidou and Purnell 2016). Marsh et al., (2022) assert that CE strategies are not “material-agnostic”; strategies suitable for concrete waste may not be appropriate for other types of construction and demolition waste. Therefore, understanding the obstacles to effective CWR implementation is essential for developing successful strategies.

This review examines the major barriers to CWR implementation in the construction industry and identifies the CSFs needed to overcome them. Specifically, it synthesizes technical, economic, regulatory, market and social factors that hinder CWR efforts. By identifying and analyzing these factors, this paper integrates them into a conceptual framework that links stakeholder roles, systemic drivers, and CWR barriers. Ultimately, this research aims to contribute to the discussion on CE and sustainable construction practices by guiding policymakers, industry professionals, and researchers on the necessary steps to advance CWR. It is worth noting that this review focuses specifically on concrete waste generated by demolished concrete structures.

Background of study and theoretical foundation

This section provides the conceptual background for the study by first discussing CE principles in the built environment, followed by CWR as a practical CE strategy. It then presents the theoretical perspectives that explain the adoption of CWR practices among construction stakeholders.

Circular economy (CE) principles

The CE concept has gained increasing attention in the construction sector as a response to resource depletion, waste generation, and environmental degradation associated with the conventional linear “take–make–dispose” model. CE promotes resource efficiency, waste prevention, material recovery, and value retention by slowing, closing, and narrowing material loops (Geissdoerfer et al. 2017). Earlier contributions by Stahel and Reday-Mulvey (1981) introduced the concept of a loop economy, outlining strategies to prevent waste, create jobs at the regional level, enhance resource efficiency, and reduce material use in industrial processes.

Several CE definitions emphasize similar principles. MacArthur (2013) described CE as a restorative and regenerative industrial system, while Kirchherr et al. (2017) defined it as a sustainable development model based on reduction, reuse, recycling, and recovery to enhance environmental, economic, and social outcomes. Similarly, Murray et al. (2017) conceptualized CE as an economic model in which resource flows are planned to support environmental quality, economic prosperity, and social equity. In the construction context, these definitions highlight the need to retain materials value through durable designs, repair, reuse, recovery, and recycling.

The foundational practices of CE are based on the 3R principles: reduction, reuse, and recycling (Kirchherr et al. 2017). These principles have been expanded into broader frameworks such as the 6R and 10R models, which include redesign, repair, refurbish, repurpose, remanufacture, recover, and rethink strategies (Berg et al. 2018; Potting et al. 2017). Within this framework, CWR represents a practical CE strategy for reducing waste, conserving natural aggregates, and closing material loops at the end of a concrete structure's life cycle.

Concrete waste recycling (CWR)

Concrete waste consists of by-products generated from the construction, demolition, renovation, and processing of concrete structures. It includes concrete sludge, demolished concrete, grinding residues, wet concrete, and fine concrete fragments (Ho et al. 2021; Marsh et al. 2022; Hasan and Elmualim 2023). Concrete waste is widely generated in rapidly urbanizing regions and in areas affected by coordinated attacks, earthquakes, or severe weather events (Villagrán-Zaccardi et al. 2022; Zabek et al. 2024). Conventional disposal through landfilling occupies valuable land, increases environmental contamination risks, and contributes to greenhouse gas emissions (Hasan and Elmualim 2023). At the same time, increasing demand for concrete has intensified pressure on high-quality natural aggregates, highlighting the need to recycle concrete waste into useful building materials (Xiao et al. 2023).

In these contexts, CWR is crucial for sustainable construction practices as it diverts waste from landfills and reduces reliance on natural resources (Villagrán-Zaccardi et al. 2022; Ram et al. 2019). Empirical evidence shows that CWR can reduce greenhouse gas emissions, landfill use, and material-related costs, while also generating economic benefits such as revenue, job creation, technological development, and increased demand for recycled materials (Tam 2008; Ram et al. 2019; Jin and Chen 2015; Al-Sharif et al. 2024; Zhang et al. 2019a).

CWR involves converting waste concrete into reusable materials such as recycled coarse aggregates (RCA), recycled fine aggregates (RFA), and recycled concrete powder (RCP) (Hasan and Elmualim 2023). These products can be reintroduced into concrete production, where recycled aggregates partially replace natural aggregates and recycled powder may replace cement in suitable proportions. The recycling process typically involves sorting, crushing, screening, and contaminant removal to separate steel reinforcement, impurities, and different particle sizes, thereby improving the quality of recycled products (Nitichote and Yodsudjai 2022).

Despite these processes, recycled concrete products are often limited by quality concerns. Recycled aggregates commonly contain adhered cement mortar, which increases water absorption and porosity, thereby reducing the mechanical and durability performance of new concrete (Poon et al. 2023). As a result, they are frequently restricted to lower-grade applications such as road construction, pavements, and drainage systems (Marsh et al. 2022).

To improve the performance and compatibility of recycled concrete aggregates, various treatment techniques have been developed to remove adhered mortar or cement paste. These include mechanical, thermal, chemical, microbial, carbonation, supplementary cementitious material-based, and chemical admixture treatments (Nežerka et al. 2023; Zhang 2024; Gebremariam et al. 2020; Varshney et al. 2023). Among these, carbonation-based conditioning has received increasing attention because it can enhance recycled material performance while contributing to carbon reduction (Tam et al. 2020; Moon and Choi 2019; Poon et al. 2023). Overall, CWR provides a pathway to close material loops, as illustrated in Fig. 1, but its broader implementation depends on overcoming technical, economic, regulatory, market, and behavioural barriers.

Theoretical background of the study

Pomponi and Moncaster (2017) highlight the interdisciplinary nature of CE in the construction industry, noting that circular construction research must consider governance, stakeholder behaviour, and socio-technical systems. Similarly, Oluleye et al. (2022) opine that CE adoption requires attention to both technological and social dimensions.

This review is informed by the Diffusion of Innovation theory and Attitude theory. The Diffusion of Innovation theory explains how new ideas, practices, and technologies spread within a social system (Rogers et al. 2014). It is relevant to CWR adoption because stakeholders such as contractors, policymakers, designers, clients, and communities may adopt recycling practices at different rates depending on perceived benefits, compatibility with existing practices, implementation complexity, and institutional support. The theory also highlights the role of social networks and peer influence in shaping adoption decisions (Corvellec et al. 2022).

Attitude theory explains how individual and collective attitudes influence behaviour (Adabre et al. 2023). Positive attitudes toward sustainability and environmental protection can motivate stakeholders to adopt concrete recycling practices, whereas negative attitudes or misconceptions about the quality of recycled materials can act as barriers.

Fig. 1 Closed-loop recycling process of concrete waste

Furthermore, social norms and peer behaviour can influence attitudes; for instance, if industry leaders advocate for concrete recycling, others are more likely to follow suit. Accordingly, this review is grounded in these theories, positing that addressing barriers to CWR through effective implementation measures and coordinated stakeholder action can facilitate CWR implementation and enhance the transition to a CE context.

Research methodology

This study employed a systematic literature review (SLR) guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to examine the barriers to CWR and the CSFs for effective implementation in construction projects. The SLR was considered appropriate because it provides a replicable and transparent research process for identifying relevant literature and future research gaps (Illankoon and Vithanage 2023). The review is guided by two research questions: (1) What are the major barriers to the practical implementation of CWR as identified in previous studies? (2) What strategies can support effective CWR implementation, and which key stakeholders are involved?

To identify pertinent studies within the scope of this review, Scopus and Web of Science search engines were selected due to their broad coverage of peer-reviewed literature. The updated search was conducted on 13 February 2025 and was limited to English-language peer-reviewed publications from 2000 onwards. The search utilized the following keywords: "barriers", "challenges", "problems", "success factors", "strategies", "solutions", "recycling", "concrete recycling", "concrete waste recycling", "concrete demolition waste", "concrete waste management", "construction and demolition waste", "CE" and "circular economy". Boolean operators were used: "OR" to link related terms and "AND" to connect different search concepts.

The search was applied to the title, abstract, and keywords fields where applicable. Eligible publications were peer-reviewed studies that examined concrete, construction, and demolition waste recycling, barriers, drivers, CSFs or implementation strategies within the CE framework.

The initial database search identified 1,642 records. After applying year and language filters, 553 records remained. Following duplicate removal, 530 documents were screened by title and abstract, resulting in 235 records for full-text assessment. Publications were excluded if they lacked author attribution, were inaccessible or were outside the review scope. A final set of 65 scholarly documents was retained for analysis, as illustrated in Fig. 2 (see Online Appendix A for the summary of included studies).

The selected publications were reviewed to extract study characteristics, CWR barriers, CSFs and stakeholders involved. Data on publication year, country, research focus, and document type were recorded. Barriers and CSFs were coded, thematically grouped based on similarity, and quantified according to the number of studies in which they were identified. This supported both qualitative synthesis and frequency-based mapping of key CWR implementation issues.

Results and discussion of review findings

This section presents the findings of the review. It begins with the characteristics of the identified publications, including their distribution by publication year and country/region. It then discusses the major barriers to CWR implementation, the recommended strategies to overcome them, and the key stakeholders that could support implementation. The section concludes by synthesizing these review findings into an integrated framework for advancing CWR implementation in the built environment.

Characteristics of identified publications

The distribution of eligible studies demonstrates that the included publications ranged from 2004 to 2025, as presented in Fig. 3. The earliest eligible paper was published in 2004, with publication activity remaining sporadic until 2016. Thereafter, research outputs increased steadily, with 2021 recording the highest number of publications (10 papers), followed by 2024. Studies published between 2020 and 2024 accounted for 32 papers, representing nearly half of the total reviewed publications. This indicates growing scholarly interest in construction waste recycling and CE practices. One eligible publication from 2025 was also included, reflecting continued attention to circularity in the construction sector.

The included studies were distributed across 25 countries, as shown in Fig. 4. China contributed the most studies (14), followed by Australia (8), Malaysia (5), and the United Kingdom (UK) and Hong Kong (4 each). Overall, the distribution indicates that research on CWR is geographically uneven, with stronger representation from parts of Asia, Europe, and Oceania, while African and several developing-country contexts are comparatively less represented.

Major barriers to CWR implementation

The barriers to CWR implementation identified in the reviewed studies were grouped into six categories: regulatory and policy, financial and economic, technical and technological, social and behavioural, market, and organizational and operational barriers (Fig. 5). The frequency values in

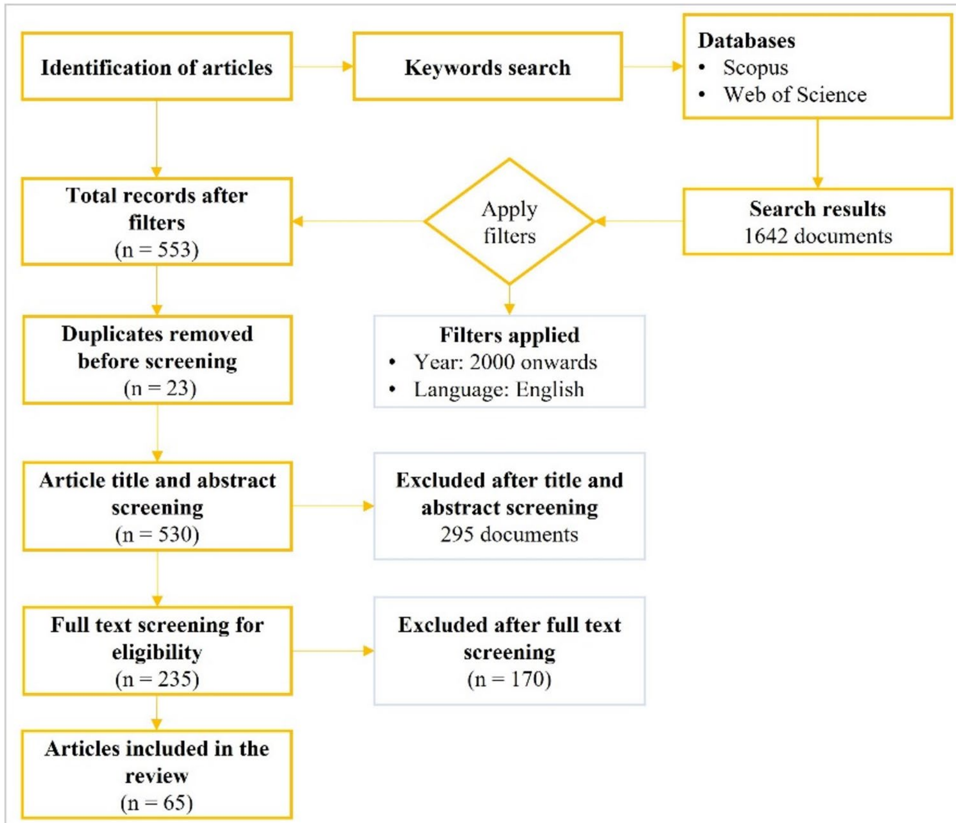


Fig. 2 Study selection process of relevant literature on concrete waste recycling (CWR) implementation

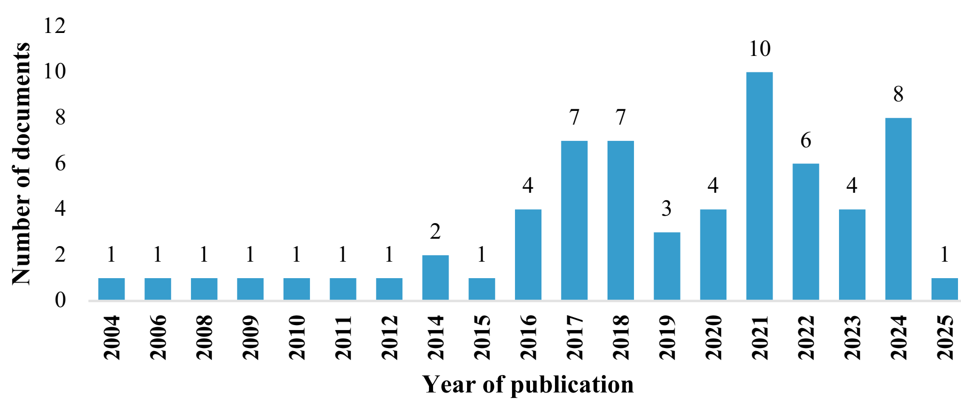


Fig. 3 Yearly distribution of identified CWR studies

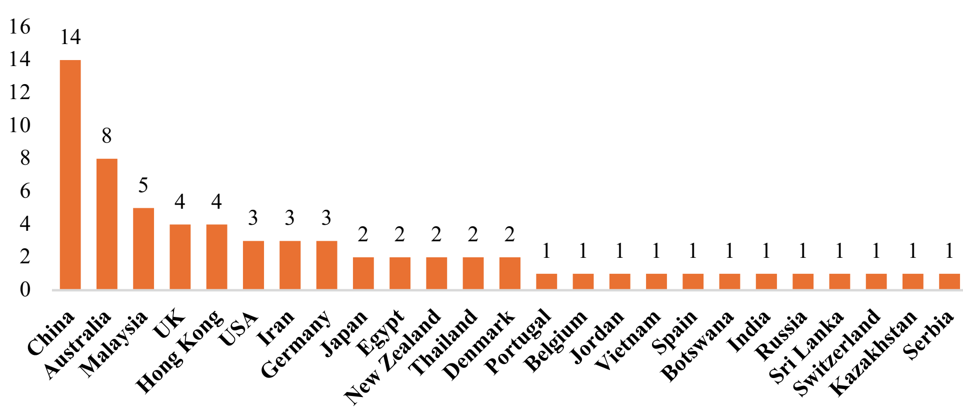


Fig. 4 Country distribution of identified CWR studies

Fig. 5 Major barriers to CWR implementation

Fig. 5 indicate the number of reviewed articles in which each barrier was reported, while the detailed mapping of the barriers, frequencies, and supporting references is provided in Online Appendix B.

At the individual barrier level, the top five reported barriers were high initial investment costs for recycling equipment and infrastructure (n = 14), poor quality and limited applications of recycled concrete products (n = 12), lack of comprehensive governmental regulations and guidelines (n = 10), limited availability of advanced recycling technologies (n = 10), and insufficient recycling facilities (n = 10). These dominant barriers indicate that a combination of financial burdens, product-quality concerns, weak regulatory support, technological limitations, and inadequate recycling infrastructure constrains CWR implementation.

Market-related barriers were among the most prominent groups identified. The most frequently reported issue was the poor quality and limited applications of recycled concrete products, followed by restricted markets and low demand, which discourage CWR investment and limit wider adoption of recycled concrete in construction projects (Chinda 2016; Zhang and Tan 2020; Broujeni et al. 2016; Akhtar and Sarmah 2018). Organizational and operational barriers were also prominent, particularly insufficient recycling facilities, lack of stakeholder cooperation, time constraints, restricted site space, and poor data management, which further limit the integration of CWR into construction and demolition workflows (Badraddin et al. 2021; Bao et al. 2020; Ma et al. 2020; Tam 2009).

Furthermore, technical and technological barriers were also emphasized. Limited availability of advanced technologies for demolition, sorting, recycling, and treatment processes affects recycling efficiency and product quality (Ram et al. 2019). In addition, impurities, adhered mortar, metals, and other embedded materials increase processing requirements and reinforce doubts about the suitability of recycled concrete products for higher-value applications (Villagrán-Zaccardi et al. 2022), while limited technical know-how further constrains effective implementation (Ding et al. 2023). These challenges are compounded by high investment costs for machinery and supporting infrastructure, operational and transportation expenses, and inadequate funding, making CWR financially unattractive, particularly when recycling costs are not supported by incentives or incorporated into project budgets (Ma et al. 2023; Nitichote and Yodsudjai 2022).

Social and behavioural, barriers further reflect the role of stakeholder perception in CWR adoption. Studies emphasized stakeholder resistance, preference for traditional practices, quality concerns about recycled concrete products, and limited awareness of CWR benefits as barriers to adoption (Hasan and Elmualim 2023; Senarathna and Perera 2021). Regulatory and policy barriers also limit implementation, as the lack of comprehensive government regulations and guidelines, limited governmental incentives and weak enforcement create uncertainty around acceptable recycling practices and reduce stakeholder confidence in recycled concrete products (Badraddin et al. 2021; Ram et al. 2019; Katerusha 2021).

In sum, based on the cumulative frequencies reported in Fig. 5, market-related, organizational/operational, technical/technological, and financial/economic barriers were the most frequently reported constraints to CWR implementation. Addressing these identified barriers requires coordinated policy, financial, technological, market, stakeholder, training and project-planning interventions.

Critical success factors (CSFs) for CWR implementation

Effective implementation of CWR necessitates a multifaceted approach to overcome the barriers identified in Sect. "Major barriers to CWR implementation". Based on the reviewed studies, 19 CSFs were identified and grouped into four domains: legal and regulatory frameworks, economic and market factors, infrastructure and technology factors, and knowledge and education factors (Fig. 6). The detailed mapping of the CSFs, frequencies, and supporting references is provided in Online Appendix C.

Legal and regulatory measures are central to creating confidence in CWR practices and recycled concrete products. Clear regulations, technical standards, quality certification systems, and enforcement mechanisms can reduce uncertainty regarding recycling processes, product performance,

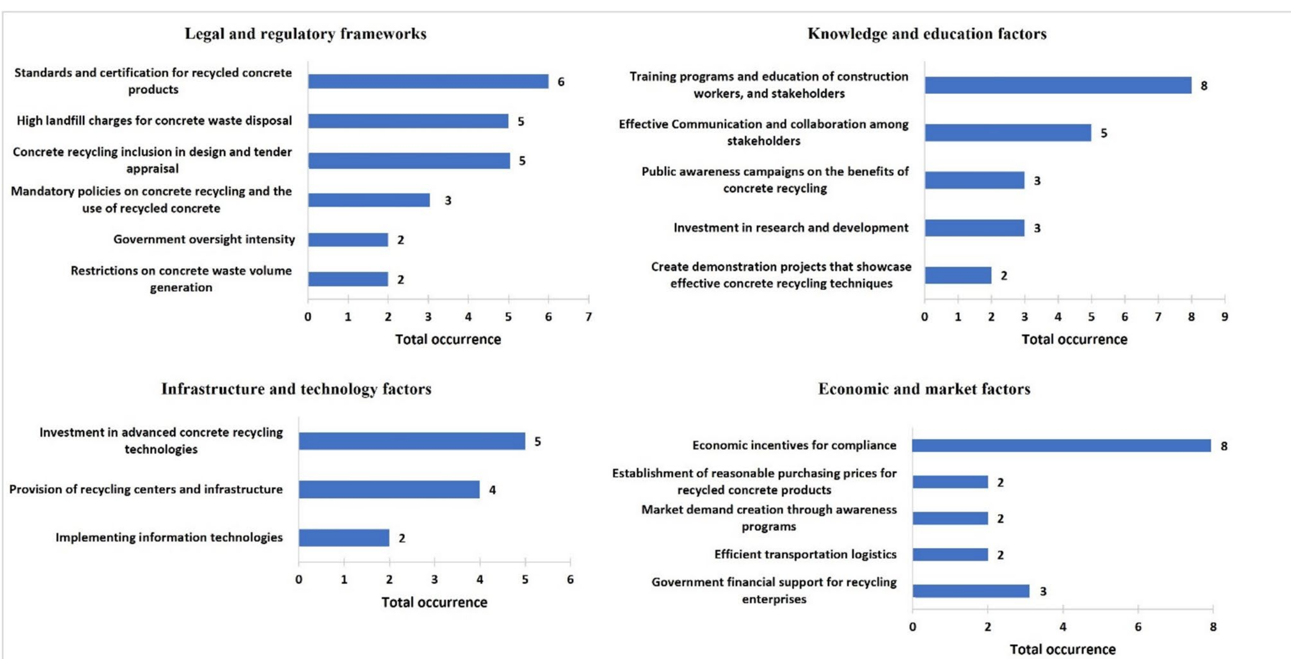


Fig. 6 Critical success factors for CWR implementation

and permissible applications (Marsh et al. 2022; Hasan and Elmualim 2023). Policy instruments such as recycling targets, landfill restrictions, minimum recycled-content requirements, public procurement criteria, and landfill taxes can also stimulate demand and discourage conventional disposal practices (Ajayi and Oyedele 2017; Al-Sharif et al. 2024). These measures need to be supported by government oversight, audits, inspections, and accountability mechanisms to ensure consistent implementation (Liu et al. 2020; Li et al. 2024).

Economic and market-related factors are equally important because CWR is often constrained by high investment and operational costs (Ding et al. 2023). Grants, subsidies, tax reduction, and other financial incentives can reduce the cost burden associated with recycling facilities, equipment, and technologies (Tam 2009; Ma et al. 2023). In addition, competitive pricing of recycled aggregates is needed to increase market demand, particularly when virgin aggregates remain cheaper or more readily available (Tam 2009; Bao et al. 2020; Liu et al. 2020). Strategically locating recycling centers near construction and demolition sites and optimizing transport logistics are also critical for reducing cost-related barriers and improving market viability (De Schepper et al. 2014; Luo et al. 2022). Achieving this requires collaboration among government, recycling enterprises, contractors, and suppliers to reduce processing, transportation, and quality-control costs (Liu et al. 2020).

Infrastructure and technology factors are required to improve recycling efficiency, product quality, and scalability. The provision of recycling centres and supporting infrastructure is particularly important because adequate facility availability improves access to recycling services and strengthens concrete waste recovery, especially in areas with high construction and demolition activity (Zhang et al. 2019b; Badraddin et al. 2022). Government support through land allocation for regional recycling hubs near construction clusters can address spatial constraints that limit recycling operations (Tam and Tam 2006; Oyejobi et al. 2024). In addition, investment in advanced recycling technologies can improve the consistency of recycled aggregates and reduce concerns about their performance (Jin et al. 2017). Information technologies, including Building Information Modelling (BIM), RFID-enabled material tracking, material passports, and AI-supported logistics platforms, can further support waste estimation, traceability, demolition planning, and recycling coordination (Keles et al. 2025; Guerra et al. 2020; Vahidi et al. 2024).

Knowledge and education factors are also required to address awareness gaps, stakeholder resistance, limited expertise and misconceptions about recycled concrete products. Targeted training for construction professionals can improve understanding of recycling techniques, quality control procedures, and the application of advanced materials in eco-efficient and sustainable design and construction (Hasan and Elmualim 2023). Public and industry awareness campaigns can also increase acceptance by communicating the environmental and economic benefits of CWR (Ram et al. 2019; Badraddin et al. 2022; Ding et al. 2023). In addition, collaborative platforms such as workshops, professional forums, certification databases, and knowledge-sharing networks can support capacity building and communication among stakeholders (Li et al. 2024; Bao et al. 2020). Continued research, pilot projects, and demonstration applications are also important for validating recycled concrete performance, refining standards, and building stakeholder confidence (Jin et al. 2017; Song et al. 2024).

Overall, the CSFs identified as shown in Fig. 6 indicate that CWR implementation depends on the alignment of policy, market, technology, infrastructure, and stakeholder capacity. Together, these factors provide the enabling conditions for overcoming implementation barriers and advancing CWR implementation.

A Conceptual framework for CWR implementation

Based on the review findings, this study developed a conceptual framework for advancing concrete waste recycling in the built environment (Fig. 7). The proposed framework is grounded in the understanding that CWR contributes to CE implementation by converting end-of-life concrete into reusable materials, such as recycled aggregates, for use in new concrete production, thereby supporting the transition from linear construction practices toward circular concrete waste management.

However, the review advocates that several barriers constrain CWR implementation. These include regulatory and policy limitations, high investment and operational costs, technical and technological constraints, weak market conditions, organizational and operational challenges, and social or behavioural resistance (Fig. 7). These barriers can reduce stakeholder confidence, limit the use of recycled concrete products, hinder market uptake, and prevent the adoption and implementation of recycling practices (Hasan and Elmualim 2023). Therefore, improving CWR implementation requires more than technical processing capacity; it requires coordinated interventions that address the institutional, economic, technological, market, and behavioural conditions across the concrete recycling value chain.

The proposed framework, therefore, positions the identified CSFs as drivers for mitigating these barriers and strengthening CWR implementation. Legal and regulatory drivers, such as standards, certification systems, procurement requirements, landfill restrictions, and enforcement mechanisms, can reduce regulatory uncertainty and improve confidence in recycled concrete products. Economic and market drivers, including financial incentives, competitive

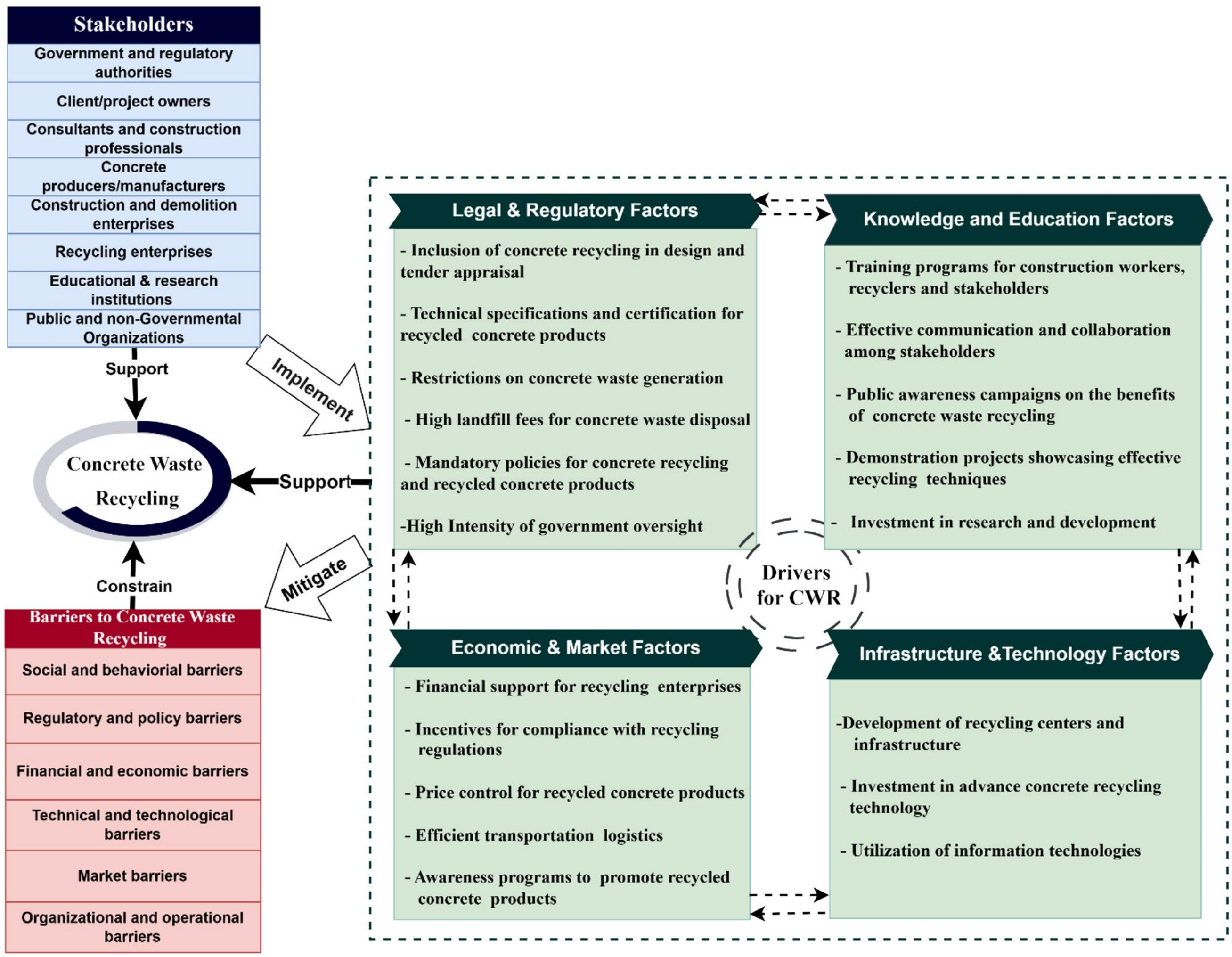


Fig. 7 Conceptual framework for CWR implementation. *Note*: Dashed lines indicate stakeholder collaboration

pricing, transportation logistics, and demand creation, can enhance the financial viability and market appeal of recycled concrete products. Infrastructure and technology drivers, such as recycling centres, advanced recycling technologies, and information technologies, can improve materials recovery, product quality, traceability, and operational efficiency. Knowledge and education drivers, including training, awareness campaigns, research, demonstration projects, and stakeholder collaboration, can address perceived knowledge gaps, misconceptions, and resistance to change.

The developed framework further highlights the stakeholder groups required for effective implementation. Government, regulatory, and waste management authorities can provide policy direction, standards, incentives, enforcement, landfill controls, waste collection systems, and industrywide recycling coordination (Wang et al. 2024). Construction and demolition enterprises can support implementation by segregating waste, practising selective demolition, planning recycling, and using recycled aggregates in suitable applications (Li et al. 2024). Clients and project owners can stimulate demand by incorporating recycled concrete products into project briefs, procurement decisions, and tender requirements, while consultants and built-environment professionals can support adoption through design specifications, material selection, and waste minimization strategies (Superti et al. 2021). Recycling enterprises process concrete waste into recycled aggregates and improve product quality through sorting, crushing, and waste treatment technologies, while concrete producers/manufacturers incorporate recycled aggregates into new concrete products that meet required performance and quality standards (Ram et al. 2019). Educational and research institutions can contribute by generating evidence on recycled concrete performance, developing innovative recycling technologies, and facilitating knowledge transfer through training programs and knowledge-sharing platforms (Ma et al. 2020). The public and non-governmental organizations can further support public awareness and implementation monitoring (Wang et al. 2024).

Overall, the proposed framework shows that effective CWR implementation requires applying relevant CSFs to mitigate implementation barriers, while supported by stakeholder responsibilities for coordinated action across the concrete recycling value chain. In practical terms, the framework can be used by policymakers, project clients, and industry practitioners to diagnose perceived implementation barriers, select relevant CSFs, assign responsibilities, and coordinate actions. For researchers, the framework provides a sound basis for further empirical testing, stakeholder validation and comparative studies across diverse construction contexts. In this way, the framework provides a practical, research-informed pathway for planning, implementing, monitoring, and advancing CWR implementation in the built environment.

Conclusions

This study highlights the growing importance of CWR as a resource recovery strategy to address concrete waste in the construction sector. Given the widespread use of concrete and its significant contribution to construction and demolition waste, sustainable resource recovery strategies such as CWR are essential for reducing landfill disposal, conserving resources, and supporting the transition to a circular economy. Responding to the limited availability of comprehensive reviews focused specifically on CWR barriers and CSFs, this study systematically reviewed literature published from 2000 onwards using the Scopus and Web of Science databases, following the PRISMA approach. A total of 65 relevant publications were retained for analysis, leading to the identification of 30 barriers and 19 CSFs for CWR implementation.

The findings reveal that CWR adoption is constrained by interconnected regulatory, financial, technical, market, organizational, and behavioural barriers. The dominant barriers include high initial investment costs for recycling equipment and infrastructure, poor quality and limited applications of recycled concrete products, lack of comprehensive government regulations and guidelines, limited availability of advanced recycling technologies, and insufficient recycling facilities. These barriers reduce confidence in recycled materials, limit investment in recycling systems, and hinder the integration of CWR into mainstream construction and demolition practices.

To address these challenges, the study identified legal and regulatory, economic and market, infrastructure and technology, and knowledge and education factors as CSFs for CWR implementation. The findings indicate that effective CWR implementation requires clear standards and certification systems, supportive policy instruments, financial incentives, competitive markets, strategically located recycling infrastructure, advanced recycling technologies, sustained training, wider awareness, and knowledge-sharing initiatives.

Furthermore, the study's novel contribution lies in its holistic framework for CWR implementation aimed at transitioning to a circular economy. The conceptual framework proposes that effective CSFs can effectively mitigate implementation barriers when aligned with stakeholder responsibilities and coordinating actions across the concrete recycling value chain. In addition, the comprehensive analysis of barriers and success factors specific to CWR implementation not only fills a critical gap in the existing literature but also equips policymakers, researchers, and stakeholders with actionable insights to drive effective CWR initiatives.

However, despite its significant contributions, this study has some perceived limitations. First, the review was limited to publications retrieved from Scopus and Web of Science databases, and only English-language publications from 2000 onwards were considered, which may have limited the temporal, geographic, and linguistic diversity of the evidence base. Second, the developed framework is literature-based, while the frequency analysis indicates how often barriers and CSFs for CWR implementation were identified in the reviewed studies, rather than their severity or causal influence.

Future research should empirically validate the proposed framework across different geographic, regulatory, and economic contexts. Longitudinal studies are also needed to assess the effects of policy instruments, technological innovations, and market-development strategies on CWR adoption. Greater attention should also be given to developing countries, where limited infrastructure, weak regulatory enforcement, and cost constraints may shape CWR adoption and implementation differently.

Ultimately, advancing CWR implementation requires coordinated policy, market, technological, educational and collaborative stakeholder-driven interventions to transform concrete waste into valuable resources and foster a resilient circular economy in the built environment.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10098-026-03565-x.

Acknowledgements The authors would like to express their sincere gratitude to the Department of Construction Management and Intelligence, The Hong Kong Polytechnic University, for providing funding for this research study through the full-time PhD research studentship scheme.

Author contribution Authors' Contribution Margaret D. Oyewole: Conceptualization, Data curation, Methodology, Writing—original draft, Writing, review & editing. Daniel W.M. Chan: Supervision, Funding acquisition, Writing, review & editing. Benjamin I. Oluleye: Writing, review & editing. Tunde Folorunso: Writing, review & editing.

Funding Open access funding provided by The Hong Kong Polytechnic University. Hong Kong Polytechnic University

Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors affirm that they have no known conflict of interest.

References

Adabre MA, Chan APC, Darko A et al (2023) Facilitating a transition to a circular economy in construction projects: intermediate theoretical models based on the theory of planned behaviour. Build Res Inf 51(1):85–104

Ajayi SO, Oyedele LO (2017) Policy imperatives for diverting construction waste from landfill: experts' recommendations for UK policy expansion. J Clean Prod 147:57–65

Akhtar A, Sarmah AK (2018) Construction and demolition waste generation and properties of recycled aggregate concrete: a global perspective. J Clean Prod 186:262–281

Al-Otaibi A (2024) Barriers and enablers for green concrete adoption: a scientometric aided literature review approach. Sustainability 16(12):5093

Al-Sharif M, Geldermans B, Rinke M (2024) From waste to wealth: A study of concrete recycling in Jordan. Frontiers in Sustainability 5.

Badraddin AK, Rahman RA, Almutairi S et al (2021) Main challenges to concrete recycling in practice. Sustainability. https://doi.org/10.3390/su131911077

Badraddin AK, Radzi AR, Almutairi S et al (2022) Critical success factors for concrete recycling in construction projects. Sustainability. https://doi.org/10.3390/su14053102

Bao Z, Lee WMW, Lu W (2020) Implementing on-site construction waste recycling in Hong Kong: barriers and facilitators. Sci Total Environ 747:141091

Barbhuiya S, Das BB, Adak D (2024) A comprehensive review on integrating sustainable practices and circular economy principles in concrete industry. J Environ Manage 370:122702

Berg A, Antikainen R, Hartikainen E et al (2018) Circular economy for sustainable development. Reports of the Finnish Environment Institute 26:2018

Broujeni BR, Omrani G, Naghavi R et al (2016) Construction and demolition waste management (Tehran case study). Eng Technol Appl Sci Res 6(6):1249–1252

Chinda T (2016) Investigation of factors affecting a construction waste recycling decision. Civ Eng Environ Syst 33(3):214–226

Corvellec H, Stowell AF, Johansson N (2022) Critiques of the circular economy. J Ind Ecol 26:421–432

De Schepper M, Van den Heede P, Van Driessche I et al (2014) Life cycle assessment of completely recyclable concrete. Materials (Basel) 7(8):6010–6027

Ding Z, Wang X, Zou PXW (2023) Barriers and countermeasures of construction and demolition waste recycling enterprises under circular economy. J Clean Prod 420:138235

Gebremariam AT, Di Maio F, Vahidi A et al (2020) Innovative technologies for recycling end-of-life concrete waste in the built environment. Resour Conserv Recycl 163:104911

Geissdoerfer M, Savaget P, Bocken NMP et al (2017) The circular economy – a new sustainability paradigm? J Clean Prod 143:757–768

Grazia MD, Trottier C, Dantas SRA et al (2022) Influence of recycled concrete aggregate type on rheological behaviour of mixtures proportioned using the equivalent volume method. Recent Prog Mater 4(3):1–1

Guerra BC, Leite F, Faust KM (2020) 4D-BIM to enhance construction waste reuse and recycle planning: case studies on concrete and drywall waste streams. Waste Manag 116:79–90

Hasan A, Elmualim A (2023) Entire concrete waste reuse model. Multi-functional concrete with recycled aggregates. Elsevier, pp 363–379

Ho HJ, Iizuka A, Shibata E (2021) Chemical recycling and use of various types of concrete waste: a review. J Clean Prod. https://doi.org/10.1016/j.jclepro.2020.124785

Iacovidou E, Purnell P (2016) Mining the physical infrastructure: opportunities, barriers and interventions in promoting structural components reuse. Sci Total Environ 557:791–807

Illankoon C, Vithanage SC (2023) Closing the loop in the construction industry: a systematic literature review on the development of circular economy. J Build Eng 76:107362

Jin R, Chen Q (2015) Investigation of concrete recycling in the U.S. construction industry. Procedia Eng 118:894–901

Jin R, Chen Q (2019) Overview of concrete recycling legislation and practice in the united states. J Construct Eng Manag 145(4):05019004

Jin R, Li B, Zhou T et al (2017) An empirical study of perceptions towards construction and demolition waste recycling and reuse in China. Resour Conserv Recycl 126:86–98

Katerusha D (2021) Barriers to the use of recycled concrete from the perspective of executing companies and possible solution approaches - case study Germany and Switzerland. Resour Policy. https://doi.org/10.1016/j.resourpol.2021.102212

Keles C, Cruz Rios F, Hoque S (2025) Digital technologies and circular economy in the construction sector: a review of lifecycle applications, integrations, potential, and limitations. Buildings 15(4):553

Kirchherr J, Reike D, Hekkert M (2017) Conceptualizing the circular economy: an analysis of 114 definitions. Resour Conserv Recycl 127:221–232

Li Y, Li M, Liu C et al (2024) Exploring critical success factors for recycled concrete utilization in China. Environ Eng Manag J 23(9):1799–1812

Liu J, Teng Y, Wang D et al (2020) System dynamic analysis of construction waste recycling industry chain in China. Environ Sci Pollut Res 27(30):37260–37277

Liu S, Rong P, Zhang C et al (2023) Preparation and carbonation hardening of low calcium CO_2 sequestration materials from waste concrete powder and calcium carbide slag. Cem Concr Compos 141:105151

Luo W, Liu S, Hu Y et al (2022) Sustainable reuse of excavated soil and recycled concrete aggregate in manufacturing concrete blocks. Constr Build Mater. https://doi.org/10.1016/j.conbuildmat.2022.127917

Ma M, Tam VWY, Le KN, Li W (2020) Challenges in current construction and demolition waste recycling: a China study. Waste Manag 118:610–625

Ma M, Tam VWY, Le KN et al (2023) Analysing the impacts of key factors on the price of recycled concrete: a system dynamics model. J Build Eng 80:108123
MacArthur E (2013) Towards the circular economy. J Ind Ecol 2(1):23–44
Marsh ATM, Velenturf APM, Bernal SA (2022) Circular economy strategies for concrete: implementation and integration. J Clean Prod 362:132486
Moon EJ, Choi YC (2019) Carbon dioxide fixation via accelerated carbonation of cement-based materials: potential for construction materials applications. Constr Build Mater 199:676–687
Murray A, Skene K, Haynes K (2017) The circular economy: an interdisciplinary exploration of the concept and application in a global context. J Bus Ethics 140(3):369–380
Nežerka V, Holeček P, Somr M et al (2023) On the possibility of using bacteria for recycling finest fractions of concrete waste: a critical review. Rev Environ Sci Biotechnol 22(2):427–450
Nitichote K, Yodsudjai W (2022) Recycled aggregates production through economic perspectives. Int J Sustain Construct Eng Technol 16(5):257–263
Oluleye BI, Chan DWM, Saka AB et al (2022) Circular economy research on building construction and demolition waste: a review of current trends and future research directions. J Clean Prod 357:131927
Oyejobi D, Firoozi A, Fernandez DB et al (2024) Integrating circular economy principles into concrete technology: Enhancing sustainability through industrial waste utilization. Results Eng 24:102846
Oyewole MD, Chan DWM, Seidu S et al (2026) Circular concrete reuse as a higher-value process to achieving decarbonization in the construction sector: a systematic review. Waste Manage Res. https://doi.org/10.1177/0734242X261437544 (in press)
Pomponi F, Moncaster A (2017) Circular economy for the built environment: a research framework. J Clean Prod 143:710–718
Poon CS, Shen P, Jiang Y, Ma Z, Xuan D (2023) Total recycling of concrete waste using accelerated carbonation: a review. Cem Concr Res 173:107284
Potting J, Hekkert MP, Worrell E et al (2017) Circular economy: measuring innovation in the product chain. Planbureau voor de Leefomgeving (2544).
Ram VG, Prajapati R, Poulose MK (2019) Challenges and prospects of demolition waste recycling in India. Indian Concr J 93(9):75–83
Rogers EM, Singhal A, Quinlan MM (2014) Diffusion of innovations. An integrated approach to communication theory and research. Routledge, pp 432–448
Senarathna D, Perera B (2021) Managing concrete wastes by implementing contemporary construction practices in Sri Lanka. Proceedings The 9th World Construction Symposium. Ceylon Institute of Builders 413–421.
Song Y, Park M, Joo J (2023) Study on the calculation method of carbon emissions in the construction industry: targeting small river maintenance projects in Korea. Water 15(20):3608
Song W, Hou G, Yang L et al (2024) Evolutionary game analysis for promoting the realization of construction waste recycling and resource utilization: based on a multi-agent collaboration perspective. Buildings 14(8):2368
Stahel WR, Reday-Mulvey G (1981) Jobs for tomorrow: the potential for substituting manpower for energy. Vantage Press
Superti V, Houmani C, Hansmann R et al (2021) Strategies for a circular economy in the construction and demolition sector: identifying the factors affecting the recommendation of recycled concrete. Sustainability. https://doi.org/10.3390/su13084113
Tam VWY (2008) Economic comparison of concrete recycling: a case study approach. Resour Conserv Recycl 52(5):821–828
Tam VWY (2009) Comparing the implementation of concrete recycling in the Australian and Japanese construction industries. J Clean Prod 17(7):688–702
Tam VWY, Tam CM (2006) Evaluations of existing waste recycling methods: a Hong Kong study. Build Environ 41(12):1649–1660
Tam VWY, Butera A, Le KN, Li W (2020) Utilising CO_2 technologies for recycled aggregate concrete: a critical review. Constr Build Mater 250:118903
Vahidi A, Gebremariam AT, Di Maio F et al (2024) RFID-based material passport system in a recycled concrete circular chain. J Clean Prod. https://doi.org/10.1016/j.jclepro.2024.140973
Varshney H, Ahmad Khan R, Khaleel Khan I (2023) Quality improvement techniques for recycled aggregates concrete incorporating fibers and *Bacillus* species bacteria—a review. Mater Today Proc. https://doi.org/10.1016/j.matpr.2023.03.223
Villagrán-Zaccardi YA, Marsh ATM, Sosa ME et al (2022) Complete re-utilization of waste concretes–valorisation pathways and research needs. Resour Conserv Recycl 177:105955
Wang Y, Liu Y, Wang T et al (2024) Evolutionary game and simulation analysis of construction waste recycling from the perspective of stakeholders. PLoS ONE 19(8):e0307652
Xiao J, Zhang H, Tang Y et al (2023) Principles for waste concrete recycling and basic problems of recycled concrete. Chin Sci Bull 68(5):510–523
Xiao W, Fu X, Song W et al (2024) Complex network analysis of embodied carbon emission transfer in China's construction industry. Front Environ Sci 12:1409539
Xuan D, Poon CS, Zheng W (2018) Management and sustainable utilization of processing wastes from ready-mixed concrete plants in construction: a review. Resour Conserv Recycl 136:238–247
Zabek M, Jegen P, Kreiss L (2024) Introducing a novel concept for an integrated demolition waste recycling center and the establishment of a stakeholder network: a case study from Germany. Sustainability. https://doi.org/10.3390/su16103916
Zhang D (2024) CO_2 utilization for concrete production: commercial deployment and pathways to net-zero emissions. Sci Total Environ 931:172753
Zhang Y, Tan W (2020) Demolition waste recycling in China: new evidence from a demolition project for highway development. Waste Manag Res 38(6):696–702
Zhang C, Hu M, Dong L et al (2019a) Eco-efficiency assessment of technological innovations in high-grade concrete recycling. Resour Conserv Recycl 149:649–663
Zhang LW, Sojobi AO, Kodur VKR et al (2019b) Effective utilization and recycling of mixed recycled aggregates for a greener environment. J Clean Prod 236:117600
Zhang C, Hu M, Di Maio F et al (2022) An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. Sci Total Environ 803:149892
Zheng L, Wu H, Zhang H et al (2017) Characterizing the generation and flows of construction and demolition waste in China. Constr Build Mater 136:405–413